NUTRITION AND FOOD SAFETY IN PUBLIC HEALTH

Edited by
JANA BABJAKOVÁ
STANISLAV SEKRETÁR

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Reviewers
Prof. Ľudmila Ševčíková, MD, PhD
Prof. Ľubomír Valík, Ing., PhD

Proofreaders
Janka Bábelová, Ing., PhD
Anna Cibulková Ing.

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Authors

Jana Babjaková, MD, PhD, MPH
Institute of Hygiene
Faculty of Medicine in Bratislava, Comenius University in Bratislava

Assoc. prof. Stanislav Sekretár, Ing., PhD
Institute of Hygiene
Faculty of Medicine in Bratislava, Comenius University in Bratislava

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FOOD SAFETY

PREFACE

Why is this topic part of your MPH study? Everyone needs to eat. We are what we eat and what we do. Someone who is educated in the field of public health should have at least a basic knowledge about nutrition based on valuable supporting scientific evidence (EBN- evidence based nutrition) and be able to advise others regarding individual needs.

Nutrition belongs among the most important environmental factors that affect our overall health status. Research has provided evidence that diets rich in nutrient dense foods can help prevent diseases. To understand nutrition and to make anything out of it can be more difficult than it seems at first sight. Nutrition topics and advice are often controversial because the science is complicated and the final evidence can be sometimes rather inconsistent.

Many diseases have long latent periods; they may result from cumulative exposure during many years. Different potential determinants may act alone or in combination and there are different interactions among them. Multiple causes of majority of diseases potentially include not only diet, but also genetic, occupational, psychosocial factors, together with level of physical activity, behavioural characteristics, and many other influences.

We must also consider that it is very difficult to correctly analyse and interpret the results of scientific studies in a definitive manner. The collective body of research on the topic has been hampered by the lack of consistency in the methods used. Prior knowledge of nutrition science might be reviewed under new evidence in the future and what now belongs or does not belong to evidence-based medicine may be revised after a couple of years.

If we try to find something in common in primary prevention by healthy diet, different points of consensus are well-known and long-lasting in general for healthy population (not suffering from different kinds of diseases like allergies, sensitivities, intolerances and other serious diseases, or providing excessive vigorous physical activity). Diverse dietary guidelines and recommendations promote diets that are abundant in beneficial foods with more protective nutrients. They all recommend quite simple, basic general principles of good diets as a part of healthy lifestyle – maintaining appropriate calories balance during each stage of life (childhood, adolescence, adulthood, pregnancy and breastfeeding, and older age) – usually it means lower calories intake (eating less), consuming lots of vegetables instead of other higher energy-dense and lower nutritional-dense items (foods higher in calories and containing fewer nutrients), in a pleasant atmosphere, avoiding "junk food" (such as soft drinks, candies), reducing sedentary life style – be more active and do plenty of exercise (moving more to prevent and/or reduce overweight and obesity), managing stress and getting more sleep. What should we specifically eat to be healthy? The keys to good nutrition are balance, variety and moderation. Increased attention in dietary research and guidance has been focused on the whole dietary patterns rather than particular nutrients. Our diet should be mainly plant-based consisting of simple whole foods, it means particularly high consumption of a variety

of colourful vegetables, fruits (preferably freshly produced), approprate intake of whole grains, legumes, nuts and seeds, also containing more sea items, and different herbs. There are different recommendations regarding to amount of milk and dairy products and meats (definitely less red meat and omit processed meat). Generally, we should decrease amount of saturated fat, try to avoid trans-fat, limit simple sugars and refined saccharides, reduce salt, mostly by restricting highly processed foods as much as possible. In addition, moderation of portions can lead to better health. A big problem in our diets includes enormous amount of calorie intake, much higher than we need with our predominantly sedentary life style. Total calorie restriction in our diet is recommended for the majority of our population in this part of world.

As humans we have a very similar genetic makeup, however, there are significant interpersonal differences among us, and the specific dietary advice can vary from person to person. Most likely, development of individual personalized medicine and personalized nutrition in the future could give the answer to many questions, though a great number of related ethical, economical, and other issues and consequences must be taken into account.

It is important for individuals to try to change their behaviours and it is also important for policymakers to help alleviate food insecurity, help create healthier food environments, and take other steps to promote healthy eating and physical activity.

The second chapter of this textbook provides a comprehensive overview of what we know about food safety hazards and control measures. We have to recognize that microbiological and chemical hazards can enter the food supply at any point in the system along the pathway from the farm through processing, transport, storage, and retail sale. Four basic food safety principles (Clean, Separate, Cook, and Chill) work together to reduce the risk of food-borne illnesses. All who share responsibility for food safety should participate in continuous learning, and place first priority on protecting the safety of food every day. That will be good for the food system – and for the consumers it serves.

NUTRITION

Jana Babjaková
Institute of Hygiene, Faculty of Medicine, Comenius University in Bratislava

1 INTRODUCTION TO HUMAN NUTRITION

Nutrition plays an essential role in maintaining health.

Human nutrition is a complex, multifaceted scientific domain indicating how substances in foods provide essential nourishment for the maintenance of life. Good nutrition is the key element of human well-being; even before birth and throughout infancy good nutrition allows brain functioning to evolve without impairment and the immune system to develop more robustly.

Malnutrition, in all its forms, including **undernutrition, micronutrient deficiencies, overweight and obesity,** not only affects people's health and well-being by impacting negatively on human physical and cognitive development, compromising the immune system, increasing susceptibility to communicable and non-communicable diseases, restricting the attainment of human potential and reducing productivity, but also poses a high burden in the form of negative social and economic consequences to individuals, families, communities, and states.

Many of those who are under- or overweight are also micronutrient-deficient**.** Whereas in the past the burden of overnutrition was highest in developed or rich countries, the burden is now spreading to and increasing in poor or developing countries. This trend is now referred to as **the double burden of disease**. There is a complex interplay between poverty, food and nutrition insecurity, malnutrition and infection that becomes a downward spiral, with infection adding to the metabolic demands for nutrition, while reducing the capacity to work and earn the money required to address the infection, which further reduces dietary intake. Thus a **vicious cycle** continues. These complex interactions spiral throughout the life course, from infants to children, to young women having babies to babies. All this is exacerbated by basic and underlying causes, such as inequality, poverty, conflicts, and natural disasters. Despite these enormous challenges, there have been improvements in some countries, but these have been largely offset by setbacks elsewhere. It was estimated that, during the last decade of the twentieth century, 826 million people were undernourished – 792 million in developing countries and 34 million in developed countries. In

developing countries, more than 199 million children under the age of 5 years suffer from acute or chronic protein and energy deficiencies. An estimated 3.5–5 billion people are iron deficient, 2.2 billion iodine deficient, and 140–250 million vitamin A deficient. This has led to several global initiatives and commitments, spearheaded by a number of the United Nations organizations, to reduce global undernutrition, food insecurity, hunger, starvation, and micronutrient deficiencies. Some progress has been made in reducing these numbers, but the problems are far from solved.

For young children, good nutrition status averts death and equips the body to grow and develop to its full potential. **Over the course of the human lifespan**, it leads to more effective learning at school, better-nourished mothers who give birth to better-nourished children and adults who are more likely to be productive and earn higher wages. In their middle age, it gives people metabolisms that are better prepared to ward off the diseases associated with changes in diet and physical activity. Without good nutrition, people's lives and livelihoods are built on quicksand.

We have known for many years that certain foods promote good health. However, the latest nutritional science shows that there is not a single "healthy diet." Instead, there are many patterns of eating around the world that sustain good health. A healthy eating pattern also includes enough energy (calories) to fuel the body, but not so much as to cause weight gain.

Over the course of evolution, human beings (and their primate predecessors) adapted progressively to a wide range of **naturally occurring foods**, but the types of foods and the mix of nutrients (in terms of carbohydrates, fats and proteins) remained relatively constant throughout the ages. Food supply was often precarious, and starvation frequent.

Earlier populations had no choice; they only consumed foods that were produced **locally**. Their availability was often extremely **seasonal.** This resulted in diets that were highly variable across the globe; for example, in some Arctic climates, almost no carbohydrates, fruits, or vegetables were consumed, and diets consisted mainly of fat and protein from animal sources. In other regions, populations subsisted on primarily vegetarian diets with the large majority of calories from carbohydrate sources. The fact that humans could survive and reproduce with such **varied dietary patterns** is a testimony to the adaptability of human biology. Yet, disease rates and overall mortality varied dramatically among these various populations, and formal studies of these relationships provided early clues about the importance of diet in human health and disease.

In the last few decades, enormous changes have occurred in the diets of most populations. These changes were due to a combination of increased wealth of some groups, new processing and preservation technologies, and greatly expanded transportation infrastructures. Collectively, these changes have allowed foods to be transported across and among continents and to be available virtually the whole year (globalisation).

At first, these changes globally were described as the "**westernization"** of diets because of increases in meat, dairy products, and processed foods. However, many of the more recent changes are not necessarily toward the diets of western countries, but instead emphasize refined starches, sugar and sugary beverages, and partially hydrogenated vegetable fats. These patterns, which have been described as **"industrial diets"**, are usually the cheapest source of calories, and they have permeated poor populations of both rural and urban countries around the world.

The recent changes in diets, along with changes in physical activity and tobacco use, have profoundly affected rates of disease, sometimes positively but often adversely. On the one hand, we have seen declines in rates of **coronary heart disease** (CHD) in many western countries thanks to positive diet changings (e.g. Finland - North Karelia

Project). On the other hand, e.g. in Japan, formerly a country with very low rates of colon cancer, rates of this **malignancy** have increased greatly and now have surpassed those of the United States.

Most importantly, at present an **epidemic of obesity and diabetes** has affected almost all the world's populations. The majority of deaths due to coronary heart disease, stroke, diabetes, some kinds of cancer, and other non-communicable diseases **are largely preventable by healthy diets in combination with regular physical activity, stress relieving, proper sleeping pattern**, **and avoidance of tobacco and alternative tobacco products use.**

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2 TYPES OF STUDIES IN NUTRITION

Modern nutritional research is aiming at health promotion and disease prevention and on performance improvement. It is generally believed but very difficult to prove that **diet plays a role as a risk factor** of various diseases.

Many different research designs are available for investigating nutrition-related questions. Each one has **strengths and weaknesses**. The traditional methods of nutritionists (a basic biochemistry, animal experiments, small human metabolic studies) form the basis of dietary recommendations and contribute substantially, but do not address directly the relation between diet and occurrence of major diseases of our civilization. Methods using cell cultures can have high throughput and illuminate detailed cellular and molecular relationships, but integrating such findings with the biology of intact humans is problematic. Experiments on animals are often used for nutrition-related research and can help as a method to study detailed pathways. However, it is recognized that physiology and pathophysiology in animal models only approximates that in humans.

Research studies involving human subjects require prior **approval from an ethics committee**. One universal rule is **"informed consent"**. This safeguard is designed to protect the rights of subjects. The purpose of the study must be explained as well as any potential hazards. This must be done in a way that the person is able to understand it properly. Subjects must be free to refuse to participate without feeling pressured and must be free to withdraw from the study at any time without penalty.

The study of chronic disease in humans has required epidemiologic approaches.

According to study design it is possible to use both types of studies – **observational studies** (ecological = population-based study, cross-sectional study, case-control study, cohort study - prospective, longitudinal, panel studies) and **experimental studies** (= interventional studies with possibility of establishing causality).

While the formal study of diet and health is only a few decades old, the importance of diet to maintain health was already known to the ancient Greeks. As Hippocrates said: "If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health."

The first population-based studies collecting information on nutrition were conducted in the 20th century. Diet and physical activity are one of the most difficult exposures to assess in observational research and are plagued by considerable measurement error.

Over the past couple of decades, a large number of **observational studies** have attempted to elucidate the role of diet in health and disease.

Initially, investigations compared dietary intakes and disease rates among populations in various countries, which were termed **ecological studies**. These analyses highlighted the large differences in disease rates worldwide and provided many hypotheses; however, such studies are limited as many other factors besides diet vary across cultures and the data are inherently aggregated. The next generation of studies was primarily **case-control investigations**, which mainly examined dietary factors retrospectively in relation to risk of cancer and other diseases. Unfortunately,

case-control studies of diet are generally problematic since participants are asked to remember their diet prior to a particular time in the past, and individuals are asked to recall their diet prior to the date of their diagnosis. Now, **large prospective studies** of many thousands of persons are beginning to provide data based on both biochemical indicators of diet and dietary questionnaires that have been rigorously validated. Prospective studies are less subject to biases resulting from the retrospective reporting of dietary intakes or the effects of disease on biochemical indicators. For example, it is possible to determine that diet plays an important role in coronary heart disease prevention with trans fats, saturated fats, and a high glycaemic index promoting heart disease and a diet high in fibre, fish oil, and polyunsaturated fats decreasing the risk.

Migrant studies can evaluate environmental factors as one of the major contributors to most chronic diseases, independent of the genetic background of the population. Cancer rates change dramatically in populations migrating from countries of sparse nutrition to those of more affluence. Though other environmental factors probably play an important role, the influence of dietary changes is likely.

Measuring dietary intake in large populations remains a challenge. In an attempt to reduce the misclassification inherent in diet assessment, **measurement error correction models** have been developed but are seldom used. **Biomarkers of nutrient intake** represent the optimal standard for calibration of questionnaire-based diet assessment methods, but these biomarkers are not widely available.

Recent advances in molecular biology have yet to contribute substantially to dietary recommendations, but in the future these approaches may provide useful intermediary endpoints, allow **the study of gene-diet interactions**, and enhance our understanding of the mechanisms by which dietary factors influence disease.

Randomized dietary interventional studies have used different approaches for ensuring that subjects comply with the intervention diet when testing their relationships with health outcomes. For example, **randomized controlled trials** (RCTs), such as Prevencion con Dieta Mediterranean (PREDIMED), coached participants to follow a dietary pattern and provided them with key foods (e.g. olive oil or nuts) to facilitate adherence. In contrast, **feeding studies** (another form of interventional study), such as those conducted in the DASH (Dietary Approaches to Stop Hypertension) and the Optimal Macronutrient Intake Trial for Heart Health (OmniHeart), provided all food to be consumed to each participant. These study designs across randomized trials and feeding studies provide strong evidence for the benefits and risks of particular dietary patterns because a prescribed intervention allows a relatively precise definition of dietary exposures, and randomization helps ensure that any potential confounding variables are randomly distributed between study arms. However, some trials are necessarily restricted to testing a dietary pattern's effect on an intermediate outcome or a surrogate endpoint, such as blood lipids, because of the complexities involved in maintaining dietary compliance over long study duration. Additionally, the feeding trials fail to represent what happens in real world situations. Observational cohort studies provide an important evidentiary complement to RCTs because they enable the study of hard endpoints for disease in addition to intermediate outcomes and often provide a wider range of exposures for study.

Research methods are constantly evolving and being improved. A recent development is the use of **systematic reviews and meta-analyses**. In a systematic review, the literature is reviewed using search engines according to strict criteria. In meta-analyses, the reviewers assume that findings from the different studies are quantitatively poolable.

As there is an enormous amount of money tied up in the results of research studies, there is some evidence of a conflict of interest in studies that potentially affect profit of

the research funder, most typically in industry funding. Unfortunately some studies are example of how the outcome of sponsored research invariably favours the sponsor's interests.

One of possible solutions to this problem is **to create a sufficient pool of research funds, independent of the food industry, to support needed research.**

The interpretation of positive or inverse associations (or the lack of associations) in epidemiological studies has always to receive considerable attention.

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3 MEASURING OF FOOD INTAKE

There is no ideal tool to measure **a person's nutritional status** accurately. It is necessary to look at several different measurements in order to assess a person's nutritional status. This process is known as the A, B, C, D of nutritional assessment:

- Anthropometry
- Biochemical and haematological variables
- Clinical and physical assessment
- Dietary intake

Nutritional epidemiology provides data about the diet-disease relationships that is transformed by Public Health Nutrition into the practise of prevention. The specific contributions of nutritional epidemiology include dietary assessment, description of nutritional exposure and statistical modelling of the diet-disease relationship. In all these areas, substantial progress has been made over the last years.

Food consumption data may be collected at the national, household or the individual level. **There is no ideal method for assessing dietary intake.**

Information on food intake can be obtained directly or indirectly.

Indirect measurements of food intake make use of information on the availability of food at national, regional, or household levels to estimate food intakes, rather than using information obtained directly from individuals who consume the food. Indirect methods are most useful at the population and household levels for determining the amount and types of foods.

Information on food intake can be obtained directly from consumers in a number of different ways.

Direct measures are usually used to obtain food intake data from individuals.

Measuring the food intake in free-living individuals is a complex task and is very difficult (because of existence of inter and intra-individual variation, complexity of composition of foods, cultural relationships with foods, multiple foods, complex and heterogeneous intake, etc.).

The procedure for measuring food and nutrient intake usually involves five steps:

1. obtaining a report of all food consumed by each individual,
2. identifying these foods in sufficient detail to choose an appropriate item in the food tables,
3. quantifying the portion sizes,
4. measuring or estimating the frequency with which each food is eaten,
5. calculating nutrient intake from food tables.

All measurements of food intake are subject to sources of error.

The dietary assessment method used depends on the purpose of the study. The existence of error means that it is always important to be aware of and, whenever possible, to assess the nature and magnitude of the error.

The primary aim is to collect a true record of habitual food and nutrient intake of an individual or group of individuals.

The dietary assessment has not only clinical but also strong public health reason (to evaluate the adequacy and safety of the food that people eat at national or community

levels and to identify the need for or to evaluate nutrition-based intervention programs) and also reason for research (to study the interrelationships between food intake and physiological function or disease conditions under controlled conditions, or in field conditions).

I. Methods for measuring intake on specified days:
e.g. Menu records, weighed records, recalled intake – repeated 24-hour recall, seven-day food diary.

II. Methods for measuring intake over the longer term:
e.g. Food frequency questionnaires, diet histories.

Duplicate diet
It has the highest accuracy, so it can provide very accurate data on nutrients consumed, but it is a very expensive method and has higher burden than other methods. Subject prepares, weighs and keeps a duplicate portion of every item consumed, and the nutrient content is analysed in a lab.

Weighed records
Weighed records can provide accurate data on types and amounts of foods consumed. A subject weighs each item prior to consumption and keeps a record of all foods and drinks consumed, as well as any leftovers.

24-hour dietary recall
It relies on a short-term memory of subjects. A trained interviewer asks the subject to recall and describe every item of food consumed. The interview is usually conducted face to face, but may also be conducted by telephone. In some situations, the recall is self-administered by the subject, but this approach may not yield sufficiently reliable data. It should be repeated at least twice during one week, and once during a weekend to achieve more objective data.

Food frequency questionnaire (FFQ)
FFQ, sometimes referred to as a "list-based diet history", belongs to widely used methods, because it is cheap and quick and it is the primary dietary data collection instrument. FFQ contains the list of foods and the subject is asked to indicate a typical frequency of consumption often over the last 6 months to a year. FFQs are generally self-administered but may also be interviewer-administered. The number or types of food items may vary, as well as the number and types of frequency categories. FFQs may be unquantified, semi-quantified or completely quantified.

Diet record method, diary method
It includes a detailed listing of all foods consumed on one or more days, and it is supposed to be recorded by participants at the time the food is eaten.

Six main groups of **innovative technologies** were identified: Personal Digital Assistant, Mobile-phone, Interactive computer, Web, Camera and tape-recorder and Scan and sensor–based technologies.

Compared with the conventional food records, Personal Digital Assistant and mobile phone devices seem to improve the recording through the possibility for "real-time" recording at eating events, but their validity to estimate individual dietary intakes is still low to moderate.

Digital photography

Much interest is also directed towards the technique of taking and analysing photographs of all meals ingested, which might improve the dietary assessment in terms of precision. When using this method, of food selection and leftovers are quickly captured. These images are later compared with images of standard portions of food using computer software. Digital photography can remove the need for recall (and estimation) and can be comparable to weighed records. Images can be taken at the point of consumption either by a researcher (e.g. Digital Photo Method) or by a subject (e.g. Remote Food Photograph Method) and then converted to portion weights by trained analysts. A related method called the Remote Food Photography Method (RFPM) relies on smartphones to estimate food intake in near real-time in free-living conditions.

This is a popular method mostly among younger generation and can be used as a memory aid, but still has some shortcomings (e.g. not clear cooking methods, brand names/fortification, leftovers).

Combined methods

Different types of dietary assessment methods may be combined to improve accuracy and facilitate interpretation of the dietary data. Methods may also be combined for practical reasons.

Four possible **sources of error** occur to some degree with all dietary methods, but can be minimized by careful study design and execution:

- sampling bias
- response bias
- inappropriate coding of foods
- use of food composition tables in place of chemical analysis

Assessing the validity of dietary recalls and food records for estimating usual intakes involves 3 issues:

1. reporting accuracy – agreement between items observed and items recalled (70-80%)
2. accuracy in nutrient calculation – representativeness of food composition database, coding procedures, calculation software; it may be assessed by comparing calculated nutrient intake with chemical analysis of food composites
3. accuracy of assessing usual intake – to compare the results of one method designed to measure same things, or compare the calculated intakes of individual nutrients with biochemical indicators (urinary nitrogen – indicator of protein intake). A novel approach of detecting and using biomarkers for estimating specific dietary intakes and the relation to end points has been proposed in connection with the recently developed technology of metabolomics.

The need for standardisation of food tables with the prime aim to link these food tables with a highly standardised and comparable nutrient database is well acknowledged in Europe.

Efforts have also been undertaken in recent years to extend existing nutrient databases towards bioactive compounds in addition to nutrients (carotenoids, flavonoids, phenols, phytoestrogens etc).

Statistical modelling of the dietary data and the diet-disease relationships can refer to complex programmes that convert quantitative short-term measurements into habitual intakes of individuals and correct for the errors in the estimates of the diet-disease relationships by taking data from validation studies with biomarkers into account.

For dietary data, substitution modelling should be preferred over simple adding modelling. More attention should also be put on the investigation of non-linear relationships.

Most of the new technologies in dietary assessment were seen to have overlapping methodological features with the conventional methods predominantly used for nutritional epidemiology.

The most appropriate method to be used will depend on several factors: nutrient or food of interest, individual or group intakes, population to be studied, time frame, and budget. Validation should always be performed.

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4 NUTRITIONAL VALUE OF FOOD AND NUTRITIONAL QUALITY OF FOOD

The foods we consume contain **thousands of specific chemicals**, some known and well quantified, some poorly distinguished and others that are presently unrecognised and now immeasurable.

People eat food, not nutrients; however, it is the combination and amounts of nutrients in foods that determine health. In foods, in the gut during absorption, digestion, fermentation in the blood during transport, and in cells during metabolism, nutrients interact with each other.

The most important categories of nutrients are **proteins, carbohydrates, fats, vitamins, minerals, and trace elements**.

They belong to:

1**. macronutrients** (carbohydrates, proteins, fats) - daily intake of macronutrients ranges in tens up to hundreds of grams (represent 80 – 90% of a dry part of food);

2. micronutrients (vitamins, minerals, trace elements) - their daily intake is in milligrams or micrograms.

Nutritional value (i.e. energy and biological value) of food are quantitative and qualitative nutritional demands of the human body.

Nutrients satisfy the basic body needs as:

- growth – formation of new body cells and tissues and their repair, development,
- chemical regulation of metabolic functions,
- energy for muscle contraction,
- conduction of nerve impulses,
- reproduction.

The chemicals that comprise our food can be divided into groups, which are not mutually exclusive:

1. Essential nutrients
2. Major energy sources
3. Additives
4. Agricultural chemical contaminants
5. Microbial toxin contamination
6. Inorganic contaminants
7. Chemicals formed in the cooking or processing of food
8. Natural toxins
9. Other natural compounds

Food as a basic life-support material supplies the body with certain essential chemicals that enable to do its work and build body cells and tissues. The list of nutrients essential or otherwise useful to human physiology is long, complex, and probably still incomplete, nowadays it includes more than 40 distinct substances (Table 1). They must be obtained from food sources, because the body does not produce them or produces them in amounts too small to maintain growth and health.

Their dietary or metabolically-induced deficiency causes recognizable symptoms that disappear when the nutrients are replaced.

Table 1 *Essential dietary components (Source: Ševčíková et al., 2011)*

1. Energy sources	Carbohydrate, Fat, Protein
2. Essential amino acids	Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, Valine, Histidine
3. Essential fatty acids	Linoleic, Linolenic, Arachidonic, Eicosapentaenoic Acid
4. Vitamins	
Water-soluble	Ascorbic Acid (C), Thiamine (B_1), Riboflavin (B_2), Pantothenic Acid (B_3), Pyridoxine (B_6), Folacin, Niacin (PP), Biotin (H), Cobalamin (B_{12})
Fat-soluble	Vitamin A, Vitamin D, Vitamin E, Vitamin K
5. Minerals	
Major minerals [g]	Calcium, Chlorine, Magnesium, Sodium, Phosphorus, Potassium, Sulphur
Trace elements [μg]	Iron, Iodine, Zinc, Copper, Manganese, Chromium, Cobalt, Selenium, Molybdenum, Fluorine
6. Fibre	
7. Water	

The term **nutrient density** for foods/beverages has been used loosely to promote the Dietary Guidelines. The 2010 Dietary Guidelines for Americans defined '*all vegetables, fruits, whole grains, fat-free or low-fat milk and milk products, seafood, lean meats and poultry, eggs, beans and peas (legumes), and nuts and seeds that are prepared without added solid fats, added sugars, and sodium*' as nutrient dense. Guidelines further state that nutrient-dense foods and beverages **provide vitamins, minerals and other substances that may have positive health effects with relatively few (kilo) calories or kilojoules.** The definition states nutrients and other beneficial **substances have not been 'diluted' by the addition of energy** from added solid fats, added sugars or by the solid fats naturally present in the food. However, the Dietary Guidelines Advisory Committee and other scientists have failed to clearly define 'nutrient density' or to provide criteria or indices that specify cut-offs for foods that are nutrient dense. Today, 'nutrient density' is a ubiquitous term used in the scientific literature, policy documents, marketing strategies, and consumer messaging. However, the term remains ambiguous without a definitive or universal definition.

4.1 Proteins

Protein is the major structural component of all cells in the body. Thus an adequate supply of dietary protein is essential to maintain cellular integrity and function, and for keeping the health.

The most important aspect of a protein from a nutritional point of view is its amino acid composition, but the protein's structure may also influence its digestibility. Some proteins, such as keratin, are highly insoluble in water and hence are resistant to digestion, while highly glycosylated proteins, such as the intestinal mucins, are resistant to attack by the proteolytic enzymes of the intestine. Protein has a unique structural unit, **the amino acid**, which is made up of the three elements – carbon, hydrogen, oxygen – that make up also carbohydrates and fats. Nevertheless, amino acids and their proteins have an additional important element – nitrogen – as the base (alkaline) ($-NH_2$) portion of their structure. Although there are hundreds of amino acids in nature, only 20 of these commonly appear in proteins.

Essential amino acids: Nine of the amino acids are vital (Table 1).

The remaining (non-essential) group can be synthesized in the human body.

Diet almost always contains a mixture of different proteins.

Complete proteins are those that contain all the essential amino acids (meat, egg, milk, and dairy products). **Incomplete proteins** that are deficient in the essential amino acids are mostly of plant origin (grains, legumes, nuts, and seeds).

Functions of proteins: the primary function is the growth, development and maintenance of body cells, tissue and organs (basis of muscles, bones, skin, nails, mucosa, antibodies); in detoxication processes as components of enzymes; in transportation of nutrients; specific function in nutrition of the brain and nervous system, they help to keep nitrogen balance in the organism.

Some amino acids perform important physiological and metabolic roles (e.g. tryptophan is a precursor of niacin and of neurotransmitter serotonin, prolin is an essential component of collagen, glutamine is essential for maintenance of acid-base balance in the kidney), contribute to the body´s overall energy metabolism; may be used for gluconeogenesis.

Factors influencing protein requirements are: tissue growth (includes age, body size and general physical status); diet (includes nature of protein in the diet and its ratio or pattern of amino acid structure); presence of any disease (usually increase protein intake).

Current Slovak recommendations 2014 are in Tables 10, 12, 14. For protein, the recommendations are given both as population ranges expressed as was expressed as a percentage of total energy intake (protein E %). Different dietary guidelines usually suggest around 10-20 E%, it means it should be at least 10% of the daily calories, but not more than 20 E% from protein, according to the Institute of Medicine (IOM) of the U.S. National Academy of Sciences, daily caloric intake should range from 10 to 35 E%.

A recommended intake can be also in g/kg body weight (bw) per day.

Recommended daily allowances (RDAs) for dietary protein in most countries are 0.8–1 g/kg of body weight per day. According to the Institute of Medicine (Food and Nutrition Board) RDA for both men and women is 0.80 g of good quality protein/kg body weight/d and is based on careful analyses of available nitrogen balance studies. That is about 60–80 g for a man and 55–80 g for a woman. For girls and boys between 15–18 years of age with increased physical activity it is recommended around 1.15 g of proteins/kg/day, and 1.2 g of proteins/kg/day, respectively.

Increased protein intake is indicated also during pregnancy and lactation, and vigorous physical activity. RDAs are based on the minimum protein intake needed to prevent the loss of lean body mass, so an average adult may need generally more than 60–70 grams of protein per day.

Proteins in both the diet and body are more complex and variable than the other energy sources, carbohydrates and fats.

Isolated protein deficiency is rare in adults but may be observed in children mostly in developing countries. This deficiency in protein consumption may result in serious forms of protein malnutrition such as marasmus and kwashiorkor. However, most people eat more protein than is recommended by the RDAs.

Dietary protein quality is determined by its:

1) digestibility (the proportion of dietary protein that is absorbed),

2) amino acid composition (the higher the similarity in amino acid composition between a dietary protein and the average body protein, the higher is the quality of the protein),

3) any unique unavailability of specific amino acids.

Plant proteins have a lower digestibility in comparison with animal proteins and also the amino acid composition of plant proteins is less similar to human body protein. There is a problem of limiting amino acid – grains are usually low in lysine, beans are low in methionine. As a result, the quality of plant proteins is generally lower than that of animal proteins, so it is recommended to combine different sources of plant proteins to achieve a higher protein quality (protein complementation).

Protein turnover refers to the continuous synthesis (remake) and degradation of body proteins. This overall process of protein degradation or breakdown plays many essential roles in functioning of organisms (including cell growth, adaptation to different physiological conditions, elimination of abnormal or damaged proteins, and normal functioning of the immune system). Even in the steady state, body proteins constantly undergo breakdown and resynthesis. When growth is occurring, not only is there a net deposition of protein, but the rates of both synthesis and breakdown are increased.

Protein balance refers to the difference between how much protein goes into the body and how much protein goes out of the body. Protein balance essentially is **nitrogen balance;** it refers to the difference between nitrogen intake and excretion. There is tendency in adults to keep nitrogen balance (balance between synthesis and catalysis of proteins in the body). Requirements for infants and children vary according to their age and growth pattern and nitrogen balance should be positive.

There remains uncertainty about quantitative aspects of amino acid nutrition, especially in healthy adults, but there is now a consensus that the current international requirement estimates for adults are far too low. This has potentially important implications for the evaluation of dietary protein quality and for the planning, now and in the future, of food protein supplies for population groups. There are also incohesive recommendations for healthy adults undertaking resistance or endurance exercise about requirements of higher dietary protein intake (some professional organizations recommend for athletes to take from 1.2 to 1.7 grams/kg of body weight per day). On the other hand, since health food stores are selling and promoting the ingestion of large amount of different amino acid supplements, it is important that the safe upper limit of amino acid requirements is determined. Nevertheless, the recommended protein intakes can generally be met through diet alone, without the use of protein or amino acid supplements. Protein intakes above 20% of total energy intake can be achieved usually only by a very high consumption of animal proteins (meats, eggs and milk or dairy products).

4.2 Carbohydrates

Carbohydrates are derived primarily from plant-based foods. The name carbohydrate comes from its chemical nature. It is composed of carbon, hydrogen, and oxygen molecules, but this definition is not universal for all carbohydrates.

Carbohydrates are **the primary energy source** for most people in the world. This makes carbohydrate quality a critical issue, since those who consume too few calories need nutrient-dense carbohydrate sources so that every calorie counts; and those who consume too many calories also need high-quality carbohydrates since they cannot afford to waste calories on less nutritious sources. Carbohydrates vary tremendously in structure and physiological function, and much of the recent carbohydrate research has focused on these differences and their impact on chronic diseases such as diabetes and heart disease.

The major classes of carbohydrates include:

•**monosaccharides** (simple sugars),

•**disaccharides** (simple sugars),

•**oligosaccharides,**

•**polysaccharides** (complex carbohydrates).

According to the FAO/WHO the term "sugars" refers collectively to monosaccharides, disaccharides, and sugar alcohols.

Simple carbohydrates consist of single and double sugar units that are easily digested and provide quick energy.

Complex carbohydrates provide energy more slowly and prevent large fluctuations in blood glucose levels.

Monosaccharides. In human metabolism, all types of sugar are converted into **glucose**.

After eating food with carbohydrates, glucose enters the blood, raising blood sugar (glucose) levels. When blood glucose levels rise, beta cells in the pancreas release insulin. Insulin is a hormone that makes our cells absorb blood sugar for energy or storage. As the cells absorb the blood sugar, blood sugar levels start to drop.

Fructose (found in fruits), **and galactose** (found in milk products) are found naturally. Simple carbohydrates are also found in processed and refined sugars (candies, carbonated sweet beverages - soda, and syrups). Many other simple sugars consumed today are "hidden" in different kinds of processed foods that are not usually seen as sweets (1 tablespoon of ketchup contains around 4 grams = around 1 teaspoon of free sugars, a single can of sugar-sweetened soda contains up to 40 grams = around 10 teaspoons of free sugars). Refined sugars (white sugar, white flour, and white rice) provide calories, but they lack vitamins, minerals, and fibres. Such simple sugars are often called "empty calories" and can lead to an increase in total calories and weight gain if they are taken in excess. **Added sugars** are sugars and syrups that are added to foods during processing or preparation (white table sugar, brown sugar, corn syrup, high fructose corn syrup – HFCS, molasses, honey, pancake syrups, fruit-juice concentrates, and dextrose). The major sources of these sugars include soft drinks, fruit beverages, candy, and sugar-sweetened grain-based dessert items. Most of these food items have also lower micronutrient densities than foods and beverages with naturally occurring sugars.

Disaccharides *c*onsist of two monosaccharides covalently linked by a glycosidic bond. The major dietary disaccharides include sucrose (glucose + fructose) and lactose (glucose + galactose). **Sucrose** occurs naturally in plants, but most often is consumed as an extract of sugar cane or sugar beet. Sucrose is widely used as a sweetener and preservative. The only source of **lactose** is milk and other dairy products. **Maltose and trehalose**, both disaccharides of glucose, are also present in small amounts. Maltose is found in wheat and barley, and is a product of starch hydrolysis. Trehalose is found in yeast products, mushrooms, and crustacean seafood.

Sugar alcohols. Also commonly referred to **as polyols**, sugar alcohols are derived from the hydrogenation of mono- and disaccharides, and **include sorbitol, mannitol, xylitol, isomalt, lactitol, maltitol, and erythritol**. Polyols are not as easily digested as other sugars, so they produce a lower glycaemic response and a reduced caloric value. Additionally, sugar alcohols are less cariogenic than other carbohydrates.

Carbohydrates with three to nine degrees of polymerization (i.e. three to nine monosaccharide units) are classified as **oligosaccharides**. Some oligosaccharides occur naturally in plants: **stachyose and raffinose** in soybeans and other legumes and **fructooligosaccharides** in fruits, vegetables, and grains (e.g. wheat, rye, onions, bananas). However, because of their usefulness as food ingredients and their possible health benefits, an increasing number of oligosaccharides are now synthesized from sugars or obtained through extraction and/or partial hydrolysis of longer-chain

plant polysaccharides (inulin extracted from chicory root). Being fairly resistant to digestion in the small intestine, oligosaccharides display physiological effects similar to fibre, and some appear to promote the growth of beneficial colonic microflora.

Polysaccharides have a high degree of polymerization, ranging from 10 sugar units to several thousands**.** Polysaccharides may act as food stores in plants in the form of starch, or food stores in humans and other animals in the form of glycogen. Polysaccharides also have structural roles in the plant cell wall in the form of cellulose or pectin, and the tough outer skeleton of insects in the form of chitin. Polysaccharides can be subdivided into **starch and non-starch polysaccharides.**

Starch is a source of carbohydrate made up of many chains of single sugar units and it is the primary storage form of carbohydrate in plants, but is found primarily in grains and grain products (e.g. cereals, corn, flour, and rice) and in some root vegetables (e.g. potatoes and beets) and legumes. Dextrins are intermediate products in the breakdown of starch. While most starch is digested and absorbed in the small intestine, a small portion escapes digestive enzymes and passes into the colon, where it may be fermented by the gut microbiota. **Resistant starch** (RS) is indigestible even after prolonged incubation with amylase. In cereals, RS represents 0.4% to 2% of the dry matter; in potatoes, it is 1% to 3.5%; and in legumes, it is 3.5% to 5.7%. There are four types of resistant starch, which either occur naturally or are a consequence of food processing. Because RS1 and RS2 occur naturally in plants, they are considered dietary fibre by some. RS3 and RS4 are both formed during food processing and do not occur naturally. The end products of the fermentation of the RS in the colon are short-chain fatty acids (e.g. acetate, butyrate, and propionate), carbon dioxide, hydrogen, and methane.

Non-starch polysaccharides also escape digestion and absorption in the small intestine and are fermented in the colon. However, their resistance to digestion is not due to physical or structural barriers to digestive enzymes, but rather to the lack of enzymes capable of breaking the glycosidic bonds between the monomeric units. As a result of their indigestibility, non-starch polysaccharides are considered **dietary fibre** and include **cellulose, hemicelluloses** (e.g.glucans), **gums, and mucilages, and pectins.**

Dietary fibre can be divided into 2 groups according to water solubility:

a) **the soluble** (viscous fibre) includes pectin and hydrocolloids
b) **the insoluble** (non-viscous fibre) includes cellulose and hemicellulose.

Fibre describes a chemically diverse group of non-digestible carbohydrates so it is not broken down by the endogenous digestive enzymes and will reach the colon mostly intact and there it is digested by bacteria. Certain insoluble fibres such as cellulose are not fermented at all.

Fibre is usually present in the food naturally, but sometimes there is extra fibre added to the food (fibre obtained from food raw material by physical, enzymatic, or chemical means and synthetic carbohydrate polymers).

This complex carbohydrate affects the digestion and absorption of foods in ways that are beneficial to good health. By modifying the rate and site of nutrient absorption, and by increasing faecal mass and delivering fermentation products to the circulation, the various components of the dietary fibre complex can modify human metabolism to a degree, which is of major significance for health. Dietary fibre contributes to the maintenance of normal bowel function, and epidemiological evidence suggests that high intakes are associated with reduced incidences of various dyslipidaemias, with type 2 diabetes and coronary heart disease, and with several abnormalities of the metabolic syndrome, which predisposes to these major pathologies. Proper fibre intake is associated with a reduced risk of colorectal cancer. The quantity of fibre consumed by the populations of prosperous industrialized societies was quite low. The adequate intake (AI) for healthy individuals older than 1 year was estimated to be 14 g/1000 kcal/

day, which equates to about 38 g/day for a male adult and 25 g/day for a female in their mid-life. The recommended intake for total fibre for adults over 50 years of age is set at 30 grams for men and 21 grams for women, due to decreased food consumption.

According to Scientific Advisory Committee on Nutrition the definition of dietary fibre should be broadened, it includes resistant starch and oligosaccharides.

Glycogen is stored in relatively small amounts in the liver and muscle tissues and helps sustain normal blood sugar levels during fasting periods.

Glycaemic carbohydrates (sugars and starches) are digested and absorbed in the small intestine, thereby increasing blood glucose for metabolism by tissues, whereas **non-glycaemic carbohydrates** (oligosaccharides, resistant starches, and non-digestible polysaccharides – fiber) remain undigested and pass into the colon where they can be fermented.

For total carbohydrates the population range is usually around 50–60 E%, Slovak current recommendations from 2014 are in Tables 10, 12, 14. According to the Institute of Medicine (IOM, 2002) adults should get 45 – 65 E% from carbohydrates. According to the new Nordic Nutrition Recommendations (NNC, 2012) and European Food Safety Authority (EFSA, 2010) 45–60 E%, as a consequence of the ranges for other macronutrients and also in line with studies on dietary patterns and health outcomes. RDA for carbohydrate is set at 130 g/d for adults and children based on the average minimum amount of glucose utilized by the brain.

The amount of carbohydrates also relates to fat metabolism and prevents the breaking down of fats and proteins for energy, which results in excessive production of toxic metabolic by-products. Regarding the heart activity, the glycogen in cardiac muscle is an important emergency source of contractile energy and a constant amount of carbohydrate is necessary for the proper functioning of the central nervous system.

Change in blood glucose over time is called the "**glycaemic response**." Carbohydrate-containing foods differ in their ability to raise blood glucose levels. A number of factors can influence the glycaemic response to foods, including the nature of the carbohydrate consumed, the rate of digestion and absorption, the rate of clearance from the bloodstream, and the presence of other food components (e.g. fibre, fat, and protein). In an effort to better understand how different foods impact the glycaemic response was proposed the use of the **glycaemic index** (GI) as a relative indicator of blood glucose response to the carbohydrate contained in a particular food. The GI is determined by comparing the blood glucose response (area under the curve) of a test food containing a specified amount of available carbohydrate to a standard food containing the same amount of carbohydrate. Some food carbohydrates increase the blood glucose level more than others do (Table 2). Foods that have a high GI cause a more pronounced increase in blood glucose, spikes, whereas foods with a lower GI cause a rather shallow increase in blood glucose. Many of these foods can have different glycaemic responses due to differing factors, including variety of the grain used and cooking conditions. Typically, high-GI foods would include items with easily digested starches (e.g. refined grains and potatoes), free glucose, or large amounts of disaccharides rapidly hydrolysed to glucose. Alternatively, low-GI foods (e.g. unprocessed grains, non-starchy fruits, and vegetables) would contain more slowly digested or higher fibre content. Low-GI foods may also be high in fat, which slows carbohydrate digestion and absorption. Not only food can differ, even the same person can vary in their glycaemic response from day to day.

The glycaemic load (GL) of a serving of food can be calculated as its carbohydrate content measured in grams (g) multiplied by the food's GI and divided by 100. The glycaemic load of food is a number that estimates how much the food will raise a person's blood glucose level after eating it. One unit of glycaemic load approximates the effect of

consuming one gram of glucose. Glycaemic index and glycaemic load offer information about how foods affect blood sugar and insulin. The lower a food's glycaemic index or glycaemic load, the less it affects blood sugar and insulin levels. The list of glycaemic index and glycaemic load for some common foods is shown in Table 2.

Carbohydrates have been assigned an energy value of **4 kcal/g (17 kJ/g)**. The actual caloric values of carbohydrates can vary from practically zero in the case of some fibres (e.g. gums and cellulose) to 4.2 kcal/g for most digestible starches.

Table 2 *Glycaemic index and glycaemic load (modified http://www.health.harvard.edu/newsweek/Glycaemic_index_and_glycaemic_load_for_100_foods.htm)*

FOOD	Glycaemic index (glucose = 100)	Serving size (grams)	Glycaemic load/ serving
BAKERY PRODUCTS AND BREADS			
Banana cake, made with sugar	47	60	14
Banana cake, made without sugar	55	60	12
Sponge cake, plain	46	63	17
Apple muffin, made with sugar	44	60	13
Apple muffin, made without sugar	48	60	9
Waffles, Aunt Jemima (Quaker Oats)	76	35	10
Bagel, white, frozen	72	70	25
Baguette, white, plain	95	30	15
Kaiser roll	73	30	12
Rye-kernel, pumpernickel bread	56	30	7
White wheat flour bread	71	30	10
Whole wheat bread, average	71	30	9
Pita bread, white	68	30	10
Corn tortilla	52	50	12
BEVERAGES			
Coca Cola, average	63	250 mL	16
Apple juice, unsweetened, average	44	250 mL	30
Orange juice, unsweetened	50	250 mL	12
Tomato juice, canned	38	250 mL	4
BREAKFAST CEREALS AND RELATED PRODUCTS			
Muesli, average	66	30	16
Oatmeal, average	55	250	13
Instant oatmeal, average	83	250	30
Puffed wheat, average	80	30	17
GRAINS			
Pearled barley, average	28	150	12
Sweet corn on the cob, average	60	150	20
Couscous, average	65	150	9
Quinoa	53	150	13

FOOD	Glycaemic index (glucose = 100)	Serving size (grams)	Glycaemic load/ serving
White rice, average	89	150	43
Quick cooking white basmati	67	150	28
Brown rice, average	50	150	16
Bulgur, average	48	150	12
DAIRY PRODUCTS AND ALTERNATIVES			
Ice cream, regular	57	50	6
Milk, full fat	41	250mL	5
Milk, skim	32	250 mL	4
Reduced-fat yogurt with fruit, average	33	200	11
FRUITS			
Apple, average	39	120	6
Banana, ripe	62	120	16
Grapefruit	25	120	3
Grapes, average	59	120	11
Orange, average	40	120	4
Peach, average	42	120	5
Peach, canned in light syrup	40	120	5
Prunes, pitted	29	60	10
Raisins	64	60	28
Watermelon	72	120	4
BEANS AND NUTS			
Baked beans, average	40	150	6
Chickpeas, average	10	150	3
Navy beans, average	31	150	9
Lentils, average	29	150	5
Soy beans, average	15	150	1
Cashews, salted	27	50	3
Peanuts, average	7	50	0
PASTA and NOODLES			
Macaroni, average	47	180	23
Spaghetti, white, boiled 20 min, average	58	180	26
Spaghetti, wholemeal, boiled, average	42	180	17
SNACK FOODS			
Microwave popcorn, plain, average	55	20	6
Potato chips, average	51	50	12
VEGETABLES			
Green peas, average	51	80	4
Carrots, average	35	80	2
Boiled white potato, average	82	150	21
Sweet potato, average	70	150	22

According to the last WHO recommendations, based on analysis of the latest scientific evidence, **limiting intake of free sugars should be less than 10% of total energy** as a part of the healthy diet (equivalent to 50 g or around 12 level teaspoons). A further **reduction to below than 5% of total energy is suggested for additional health benefits (**equivalent to around 25 grams = 6 teaspoons) of sugar per day for an adult of normal Body Mass Index (BMI). The suggested limits on intake of sugars in the draft guideline apply to all monosaccharides (such as glucose, fructose) and disaccharides (such as sucrose or table sugar) that are added to food by the manufacturer, the cook or the consumer, as well as sugars that are naturally present in honey, syrups, fruit juices and fruit concentrates. The WHO guideline does not refer to the sugars in fresh fruits and vegetables, and sugars naturally present in milk. Adults who consume less sugar have lower body weight and increasing the amount of sugars in the diet is associated with weight gain. In addition, research shows that children with the highest intake of sugar-sweetened drinks are more likely to be overweight or obese than children with a low intake of sugar-sweetened drinks.

Strong evidence shows that higher consumption of added sugars, especially sugar-sweetened beverages, increases also the risk for type 2 diabetes among adults and this relationship is not fully explained by body weight. The recommendation is further supported by evidence showing higher rates of dental caries when the intake of free sugars is above 10% of total energy intake. There is moderate evidence from prospective cohort studies indicating that higher intake of added sugars, especially in the form of sugar-sweetened beverages, is consistently associated with increased risk for hypertension, stroke, and CHD in adults. Worldwide intake of free sugars varies by age, setting, and country. In Europe, intake in adults ranges from about 7–8% of total energy intake in countries like Hungary and Norway, to 16–17% in countries like Spain and the United Kingdom. Intake is much higher among children, ranging from about 12% in countries like Denmark, Slovenia, and Sweden, to nearly 25% in Portugal. There are also rural/urban differences. In rural communities in South Africa intake is 7.5%, while in the urban population it is 10.3%.

Fruit, vegetables, brown rice, enriched whole-grain breads, whole grain cereals, rolled oats, beans, legumes, and sweet potatoes are good examples of more healthy carbohydrate foods.

4.3 Fats/Lipids

Lipid has long been recognized as an important dietary component. The term lipid is sometimes used as a synonym for fats- fats are a subgroup of lipids.

Fat is a critical source and storage of metabolic energy, providing 9 calories per gram. It is a substrate for the synthesis of metabolically active compounds and a regulator of gene expression, and serves as a carrier for other nutrients such as the fat-soluble vitamins A, D, E, and K and vitamin precursors. The roles of essential fatty acids and their products in the achievement and maintenance of optimal health are further elucidated through research. Depending on type, amount in the diet and other factors, fat can have more positive or negative health effects on individuals.

Dietary lipids that are essential for our lives consist of **triacylglycerols, phospholipids, and sterols.**

I. triacylglycerols are quantitatively the most important; they take up approximately 95% of our daily fat consumption. They are composed of glycerol and attached 3 fatty acids. Triacylglycerols, also referred to as triacylglycerols, are an essential nutrient, which supplies the highest density of energy, protects against low temperatures and damages of

the vital organs. They are helping with the transmission of nerve impulses, production of metabolic precursors, and formation of cell membrane structure and transport of other molecules such as protein. Because of the hydrophobic nature of lipids, dietary fat is handled differently than protein or carbohydrate with respect to digestion and absorption. Dietary fats are broken down throughout the gastrointestinal system. A unique group of enzymes and cofactors allows this process to proceed in an efficient manner.

Fatty acids (FA) differ in three major characteristics:

1. **the length of chain** (majority of FA in our diet have 16 or 18 carbon atoms)
2. **the presence and number of double bond**s (saturation/degree of unsaturation)
3. **the point of saturation** (where a double bond is located)
   Saturated fatty acids have no double bonds, unsaturated fatty acids have at least one double bond – monounsaturated fatty acids have just one double bond, whereas polyunsaturated fatty acids have at least two double bonds.

- **SFA - Saturated fats** are composed mainly of saturated fatty acids from animal sources. Foods that are rich in saturated fatty acids are: meat such as beef, pork, lamb, and poultry skin; whole milk as well as other dairy foods such as butter, cheese, some yogurt, and ice cream; and from plant origin there are two representatives: coconut oil, and palm oil. Triacylglycerols containing mostly saturated fatty acids are chemically more stable and they are less prone to oxidation, which negatively impacts on the properties of the fat or oil.
- **MUFA - Monounsaturated food fats** - Oleic acid, the major monounsaturated fatty acid in the body, is derived mainly from the diet. Fats with a high amount of MUFA are liquids or soft products – olive, canola, and peanut oils.
- **PUFA - Polyunsaturated food fats** - omega-3 polyunsaturated fatty acids result in eicosanoids that have vasodilator properties whereas omega-6 polyunsaturated fatty acids result in eicosanoids that have vasoconstrictor properties. The main n-3 fatty acid in our diet is linolenic acid, which is used to make certain prostaglandins and the fatty acids – eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) called fish oil fatty acids and it is possible to find them in fatty fish like salmon, mackerel, herring, and trout. PUFA are also present in most nuts, especially walnuts, pine nuts, pecans, and Brazil nuts, seeds (sesame).

The more unsaturated the fatty acids that are attached, the lower is the melting point. Triacylglycerols composed of unsaturated fatty acids are geometric isomers of fatty acids resulting from differences in the conformation (spatial orientation) of the double bond(s). Studies have shown that by replacement of saturated fat with polyunsaturated fat it is possible to get a reduction in heart disease risk (but evidently other diet factors, genes, lifestyle habits like smoking, exercise, and stress, sleeping habits also play a role).

The presence of a **cis relative to a trans** double bond results in a greater bend or kink in the acyl chain. Double bonds in dietary fats occur most commonly in the cis configuration. Trans fatty acids, more commonly called **trans fats,** occur naturally through microbial metabolism in ruminants (in beef fat and dairy fat, in small amounts), and are made artificially by heating liquid vegetable oils in the presence of hydrogen gas and a catalyst, a process called hydrogenation. Trans fats are a by-product of the chemical reaction that turns liquid vegetable oil into solid margarine or shortening and that prevents liquid vegetable oils from turning rancid. Partially hydrogenating of vegetable oils makes them more stable and less likely to spoil. It also converts the oil into a solid, which makes transportation easier. Partially hydrogenated oils can also withstand repeated heating without breaking down, making them ideal for frying fast foods. Trans fats are found in vegetable shortenings, some margarines, crackers, cookies, snack foods, and other foods made with or fried in partially hydrogenated

oils. They boost LDL as much as saturated fats do and also lower protective HDL, rev up inflammation, and increase the tendency for blood clots to form inside blood vessels. Trans fats are contributing to the epidemic of cardiovascular disease in developing nations around the world. It is recommended to eat them as little as possible or eliminate them from the diet totally.

Fat has twice as many calories as proteins or carbohydrates and eating too much fat will put on kilograms.

Daily requirements of fat depend on age, gender, health status, energy expenditure, and other factors. Current Slovak recommendations 2014 are in Tables 10, 12, 14.

The general recommendations are 70–112 g daily for a man and 65–97 g, 30.0–32.3 E% daily for a woman. Ratio of fatty acids SFA: MUFA: PUFA in food should be 1: 1: 1. The recommendations of daily food intake from fat increased from previously recommended to 20–35% (IOM) in some countries. According to the NNR a population range for total fat intake has been adjusted to 25–40 E%. Dietary recommendations for omega-3 fatty acids are 1.6 g/day for men and 1.1 g/day for women, whereas omega-6 fatty acids recommendations are 17 g/day for men and 12 g/day for women (IOM).

According to the WHO guidelines, the traditional target is to restrict the intake of saturated fatty acids to less than 10% of daily energy intake and less than 7% for high-risk groups.

NNR in 2012 recommend intake for cis monounsaturated fatty acids 10–20 E% (increased when comparing with the year 2004- 10–15 E%), cis polyunsaturated fatty acids should be 5–10 E%, including at least 1 E% as omega-3 fatty acids, trans fatty acids intake should be kept as low as possible.

Essential fatty acids are long-chained unsaturated fatty acids that cannot be manufactured by the body. Humans must obtain the essential fatty acids from dietary sources. Linoleic, linolenic, arachidonic and eicosapentaenoic are the only fatty acids known to be essential and serve important functions of the body: they strengthen capillary and cell membrane structure, which helps prevent and increase skin and membrane permeability, they combine with cholesterol for its transport in the blood; they prolong blood clotting time and increase fibrinolytic activity and they help to form prostaglandins.

II. Phospholipids are composed of two fatty acids esterified to a glycerol molecule and one polar head group attached via a phosphate linkage; serve as the structural components of cellular membranes and lipoprotein particles. They are present in small quantities in almost all plant and animal foods. However, they can be added into food artificially during food manufacturing as emulsifiers.

III. Sterols. Cholesterol belongs to a family of substances called steroids (sterols) and is a precursor to all steroid hormones. A derivative of cholesterol in the skin, 7-dehydrocholesterol, is irradiated by sunlight's ultraviolet rays to produce vitamin D. It is essential in the formation of bile acids and it is an essential component of cell membrane, too. The highest cholesterol content is found in shrimp and egg yolk. The relation between dietary cholesterol and blood cholesterol is very complicated and determined also by genetics via differences in relative cholesterol absorption (varies from 30 to 80% among humans). In people that are very efficient at taking up increased cholesterol intake it is more likely to be translated into an increase in cholesterolaemia. There are recommended limits in cholesterol daily intake to less than 300 milligrams for most people according to several guidelines. The Dietary Guidelines for Americans (DGAC) 2010 recommended that cholesterol intake be limited to no more than 300 mg/day, but new 2015 DGAC did not bring forward this recommendation because available evidence shows no appreciable relationship between consumption of dietary

cholesterol and serum cholesterol, consistent with the conclusions of the American Heart Association and American College of Cardiology (AHA/ACC).

Phytosterols. The most common dietary phytosterols are -sitosterol, campesterol, and stigmasterol. In contrast to cholesterol, phytosterols are poorly absorbed and levels in plasma tend to be low. Because of their ability to displace cholesterol from intestinal micelles, phytosterols can reduce the absorption efficiency of cholesterol, lowering circulating LDL levels.

Prostaglandins is a group of naturally occurring long-chain fatty acids having many tissue activities including maintaining smooth muscle tone and platelet aggregation.

Chain length of fatty acids is important in their absorption because the medium and short chain fatty acids are more soluble in water.

Lipoproteins are packages of fat wrapped in water-soluble proteins. All the lipoproteins are closely associated with lipid disorders related to cardiovascular diseases.

These plasma lipoproteins contain triacylglycerols, cholesterol, fatty acids, phospholipids (any of a class of fat-related substances that contain phosphorus, fatty acids and a nitrogenous base), and traces of fat-soluble vitamins and steroid hormones. The higher the protein ratio, the higher is the density: Chylomicrons have the lowest density and are mostly triacylglycerols (90%) with a small amount of protein, delivering diet fat to liver cells;

Very low-density lipoproteins (**VLDL**) are hepatically derived particles that mediate the transport of fat from the liver to peripheral tissue;

Intermediate low-density lipoproteins **(ILDL)** continue the delivery of endogenous triacylglycerols to tissue cells;

Low density lipoproteins **(LDL)** deliver cholesterol to the peripheral tissue cells;

Lipoprotein(a) [Lp(a)] contains an LDL-like particle and a single copy of apo(a) covalently bound to apoB on the LDL-like particle. Blood Lp(a) concentrations are highly heritable and affected by the apo(a) gene (LPA) located on chromosome 6q26-27, although the precise function of Lp(a) remains to be established, high blood Lp(a) concentrations are associated with increased coronary heart disease and stroke risk.

High-density lipoproteins **(HDL)** are derived from the liver and intestine, the primary role of HDL particles is to participate in "reverse cholesterol transport" by shuttling cholesterol from the peripheral tissues to the liver for excretion, metabolism, or storage. HDL is a heterogeneous group of particles that differ in both the apolipoprotein composition and size.

It may be more effective to focus on qualitative fat consumption – notably, decreased saturated fat and increased unsaturated fat – combined with recommendations to restrict energy intakes.

Future well-controlled clinical trials are necessary to elucidate clearly the effects of qualitative fatty acid intake in relation to disease risk of non-communicable diseases.

4.4 Minerals and Trace Elements

1. Minerals are inorganic elements widely distributed in nature. They have vital and varied roles in metabolism with many of metabolic functions, building, activating, regulating, transmitting, and controlling.

Minerals are classified as **major minerals** required in relatively large quantities, which make up 60% to 80% of all the inorganic material in the body and include calcium, magnesium, sodium, potassium, phosphorus, sulphur, and chlorine. Summary of major minerals (required intake over 100 mg/day) is presented in Table 3.

2. **Trace elements** are essential elements, which required intake is under 100 mg/day. Essential trace elements include iron, iodine, zinc, copper, manganese, chromium, cobalt, selenium, molybdenum and fluorine (Table 4).

Current Slovak Recommendations from 2014 are in Tables 10–15.

Table 3 *Characteristics of minerals (Source: Ševčíková et al., 2011)*

Mineral	RDA (adult)	Physiological Functions	Deficiency Diseases/Overload Disorders	Food Sources
Calcium (Ca)	800– 1,500 mg	Bone mineralization, muscle contraction	Tetany /Calcium deposits in soft tissues	Dairy products, fortified soy and rice milk, fish bones
Phosphorus (P)	1,000–1,500 mg	Builds bones and teeth	Bone diseases /renal insufficiency	Meat, fish, eggs, legumes and dairy products; whole wheat, rice
Magnesium (Mg)	300–450 mg	Bone mineralization, active in more than 300 chemical reactions in the body (coenzyme)	Tremor, spasm, /Diarrhoea, decreased calcium absorption	Whole grains, meat, milk, nuts, green vegetables, legumes
Sodium (Na)	1,100– 3,000 mg	Maintains body's fluid balance; important for nerve function and muscle contraction; controls heart's rhythm	Fluid-electrolyte and acid-base balance disorders	Salt – naturally in many foods and is added to many prepared foods
Potassium (K)	1,800– 5,600 mg	Helps nerves and muscles function; regulates heart's rhythm; regulates bodily fluids	Fluid-electrolyte and acid-base balance disorders	Potatoes, dried fruits, bananas, legumes, raw vegetables, mushrooms; lean meat, milk and fish
Chlorine (Cl)	1,700– 5,000 mg	Major anion in extracellular fluid	Hypochloremic alkalosis	Salt (NaCl)
Sulphur (S)	Diet with adequate proteins	Essential constituent of proteins, enzyme activity, energy metabolism	Malnutrition symptoms /Cystinuria	Meat, egg, dairy products

Table 4 *Characteristics of trace elements (Source: Ševčíková et al., 2011)*

Element	RDA (adult)	Physiological Functions	Deficiency Diseases / Overload Disorders	Food Sources
Iron (Fe)	10–28 mg	Haemoglobin synthesis, oxygen transport, cell oxidation, enzymes	Anaemia hypochromic /haemosiderosis, heart disease, liver cirrhosis	Meat, egg, legumes, tofu, leafy greens, cereals
Iodine (I_2)	150–300 µg	Thyroid hormones; regulation of cell metabolism	Endemic goiter, cretinism, during pregnancy foetal development disorders, hypothyroidism / hyperthyroidism	Saltwater fish, shellfish, sea kelp and iodized salt
Zinc (Zn)	10–16 mg	Essential coenzyme, growth, immunity, wound healing, taste, sperm production, antioxidant	Hypogonadism, test and smell impairment / Immune suppression, nausea, metallic taste, copper deficiency	Oysters, meat, milk, poultry, fish, grain

Element	RDA (adult)	Physiological Functions	Deficiency Diseases / Overload Disorders	Food Sources
Copper (Cu)	1.5–2.5 mg	In enzyme systems with iron, maintains connective tissue and blood vessels; may play a role in cancer prevention	Hypocupremia – nephrosis /Wilsons disease (excess storage)	Meat, shellfish, whole-grain products, legumes and dried fruits
Manganese (Mn)	2.5–5 mg	Enzymes component, reproductive processes, essential for normal brain function and bone development	With protein-energy malnutrition /Inhalation toxicity	Tea, green vegetables, whole grain, legumes, oats, rice
Chromium (Cr)	60–180 µg	Glucose and fat metabolism		Whole grains and molasses, legumes
Cobalt (Co)		Constituent of vit. B_{12},	As B_{12} deficiency	Liver, meat, milk
Selenium (Se)	50–70 µg	Antioxidant, constituent of enzyme, immunity, possible cancer prevention, viral infections	Low content in soil, malnutrition /Brittle hair and nails, irritability, garlic breath, fatigue, nausea	Whole grains from selenium-rich soils, poultry, meat, dairy products
Molybdenum (Mo)	150–500 µg	Constituent of oxidase enzymes		Whole grain, milk, legumes
Fluorine (F)	1.5–4 mg	Promotes bone and tooth formation; prevents tooth decay	Dental caries, osteoporosis /fluorosis	Seafood, tea, coffee, soybeans, sodium fluoride is added to water

4.5 Vitamins

Vitamins are a chemically disparate group of compounds with a variety of functions in the body. What they have in common is that they are organic compounds that are required for the maintenance of normal health and metabolic integrity. Three key characteristics of these non-calorigenic food substances are evident: they are not "burned" to yield energy, they are vital to life, often not a single substance but a group of related substances turned out to have the particular metabolic activity.

Vitamins are grouped according to their solubility in either fat or water.

The fat-soluble vitamins – A, D, E, and K – are closely associated with lipids, they are absorbed from the intestinal tract by bile acids, may be stored in the liver or adipose tissue, excessive intake can cause hypervitaminosis, it may become toxic. There is no need to consume them as often as water-soluble vitamins, although adequate amounts are needed. These vitamins are not excreted as easily as water-soluble vitamins. Their functions are more related to structural activities (Table 5).

The water-soluble vitamins – B complex and C (Table 6) – have fewer problems in absorption and transport, cannot be stored except in the "tissue saturation" sense, are excreted mainly by urine, their blood level depends on the actual intake. The body needs water-soluble vitamins in frequent, small doses. These vitamins are not as likely as fat-soluble vitamins to reach toxic levels. But niacin, vitamin B6, folate, choline, and vitamin C have upper consumption limits. Vitamin B6 at high levels over a long period of time has been shown to cause irreversible nerve damage. A balanced diet usually provides enough of these vitamins. They function more as coenzyme factors in cell metabolism.

Table 5 *Characteristics of fat-soluble vitamins – adults (including pregnancy and lactation) (Source: Ševčíková et al., 2011, http://www.webmd.com/vitamins-and-supplements/tc/vitamins-their-functions-and-sources-topic-overview), Intakes (DRIs): Recommended Dietary Allowances and Adequate Intakes, Vitamins, Food and Nutrition Board, Institute of Medicine, National Academies, 2011)*

Vitamin	RDA (adult)	Physiological Functions	Deficiency Diseases/ Overload Disorders	Food Sources
A Beta-carotene (carotenoids) retinol	700–1300 µg/d	Production of rhodopsin, healthy immune barriers and epithelial tissue, growth, reproduction, bone and red blood cell formation, vision antioxidant, possible cancer prevention	night blindness, xerophthalmia, keratomalacia; /Hypervitaminosis liver toxicity, dry rough skin and cracked lips, irritability, headache, birth defects	Vitamin A from animal sources (retinol): fortified milk, cheese, cream, butter, eggs, liver Beta-carotene (from plant sources): leafy, dark green vegs; orange vegs (carrots, sweet potatoes)
D Ergocalciferol, cholecalciferol	10-15 µg/d	Calcium metabolism, bone mineralization, cancer prevention	Rickets, Osteomalacia, osteoporosis, osteogenesis imperfecta, fractures /Hypervitaminosis: heart, liver, kidney toxicity, hypercalcaemia*	Fortified milk, fatty fish, sunlight on skin
E Tocopherols, tocotrienols	15–19 mg/d	Antioxidant, haemopoesis, anticoagulant, protection from heart disease, possible cancer prevention	Deficiency is very rare; mild haemolytic anaemia in newborn infants, impaired fat absorption /Possible increase in heart disease, excess bleeding	Polyunsaturated plant oils (soybean, corn, cottonseed, safflower); leafy green vegetables; wheat germ; whole-grain products; liver; egg yolks; nuts and seeds
K Phylloquinone, menaquinones	12–20 µg/d 90-120 µg/d (+)	Bone mineralization, blood clotting	Bleeding diathesis /Interaction with blood thinners	Green leafy vegetables, synthesized by intestinal bacteria

*RDA: recommended dietary allowance * is used for conditions of CVD, diabetes, obesity, muscle weakness, multiple sclerosis, rheumatoid arthritis, chronic obstructive pulmonary disease (COPD), asthma, bronchitis, premenstrual syndrome, vitiligo, scleroderma, psoriasis, lupus vulgaris, tooth and gum disease, boosting the immune system, preventing autoimmune diseases; asterisk (+)*

Table 6 *Characteristics of water-soluble vitamins – adults (Source: Ševčíková et al., 2011, http://www.webmd.com/vitamins-and-supplements/tc/vitamins-their-functions-and-sources-topic-overview, Intakes (DRIs): Recommended Dietary Allowances and Adequate Intakes, Vitamins, Food and Nutrition Board, Institute of Medicine, National Academies, 2011)*

Vitamin	RDA (adult)	Physiological Functions	Deficiency Diseases/ Overload Disorders	Food Sources
C Ascorbic Acid	75–120 mg/d	Antioxidant, immunity, antiviral in test-tubes, cancer prevention, increases iron absorption	Scurvy /Pro-oxidant, excess iron absorption, diarrhoea	Fruits and vegetables, especially peppers and citrus fruits
B_1 Thiamine	1.1–1.4 mg/d	Carbohydrate metabolism, Energy metabolism, mood, nervous system, muscles and heart	Beriberi, Wernicke-Korsakoff syndrome / Drowsiness or muscle relaxation with large doses	Pork, whole-grain or enriched breads and cereals, legumes, nuts and seeds
B_2 Riboflavin	1.1–1.6 mg/d	Part of an enzyme needed for energy metabolism; important for normal vision and skin health	Ariboflavinosis, cheilosis, glossitis, skin disorders	Milk and dairy products, leafy green vegetables; whole-grain, enriched breads and cereals liver, oysters
PP, B_3 Niacin Nicotinic acid	14–23 mg/d	Important for nervous system, digestive system, and healthy skin, energy metabolism, lowers LDL cholesterol and triacylglycerols, raises HDL cholesterol	Pellagra, anorexia / Itching, skin flushing, liver toxicity, insulin resistance	Poultry, red meat, fish, legumes, peanut butter, nuts, vegetables (especially mushrooms, asparagus, and leafy green vegetables)
B_5 Pantothenic acid	8–10 mg/d	Coenzyme A, general metabolism	Paraesthesia / Diarrhoea; possibly nausea and heart burn	Widespread in foods, e.g. liver, egg, milk
B_6 Pyridoxine	1.3–2.0 mg/d	Protein metabolism, immunity, neurotransmitter synthesis (e.g. serotonin and dopamine), treats peripheral neuropathy	Anaemia, peripheral neurological disorders / neuropathy	Meat, liver, fish, poultry, eggs, potatoes, fortified cereals, peanuts, soybeans, leafy vegetables
B_7 Biotin	30–35 µg/d (+)	General metabolism	Dermatitis, enteritis	in foods; also produced in intestinal tract by bacteria
B_9 Folic Acid Folate	400-600 µg/d	General metabolism, prevents neural tube defects and other birth defects, part of an enzyme needed for making DNA and new cells, especially red blood cells, lowers homocysteine, possible cancer prevention	Deficiency during pregnancy is associated with birth defects - neural tube defects /May mask symptoms of vitamin B_{12} deficiency; other effects, nerve damage	Leafy greens, legumes, oranges, broccoli, cauliflower, peanuts
B_{12} Cobalamin	2–2.6 µg/d	Cell division, amino acid metabolism, nervous system, mental function	Megaloblastic anaemia (pernicious anaemia), neurological disturbance	Fish, shellfish, meat, liver, milk

The content of vitamins in fresh dietary sources is reduced during processing that should be considered (Table 7.).

Table 7 *Losses of vitamins by food processing (Source: Ševčíková et al., 2011)*

Vitamin	Losses by processing [%]	Vitamins destruction by			
		Light	Temperature	Oxygen	Leach out
A	10–30	+	+	+	–
D	–	–	–	–	–
E	50	+	–	+	–
K	–	–	–	–	–
C	50–55	+	+	+	+
B_1	25–45	+	+	+	+
B_2	20–50	+	+	–	+
B_3	25–50	–	+	–	+
B_6	30–60	+	–	–	+
B_{12}	> 10	–	300°C	–	+
Folic acid	50–90	–	250°C	–	+
Niacin	10–20	–	–	–	+
Biotin	0–70	–	230°C	–	+

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5 ENERGY NEEDS, ENERGY BALANCE, PHYSICAL ACTIVITY

Humans and other mammals constantly need to expend energy to perform physical work; to maintain body temperature and concentration gradients; and to transport, synthesize, degrade, and replace small and large molecules that make up body tissue. This energy is generated by the oxidation of various organic substances.

5.1 Energy Metabolism

Energy is available in four basic forms for life processes: chemical, electrical, mechanical, and thermal.

Metabolism is changing of chemical energy in food into electrical energy of brain and nerve activity, mechanical energy of muscle contraction, thermal energy of body temperature control, and other forms of chemical energy in the body.

There are two types of **metabolic reactions**, which constantly occur:

- **anabolism (substances are synthesized and energy is stored),**
- **catabolism (substances are broken down and energy is released).**

The chemical free energy of food is the only form of energy humans can use to maintain the structural and biochemical integrity of the body. Energy is that force (power) which enables the body to carry out its life-sustaining or metabolic activities. It is expended by the body to maintain electrochemical gradients, transport molecules, support biosynthetic processes, produce the mechanical work required for respiration and blood circulation, and generate muscle contraction. Most of these biological processes cannot directly harness energy from the oxidation of energy-containing substrates (primarily carbohydrate and fat from food and body energy stores). Instead, the resulting energy from the oxidation of metabolic fuels is captured by adenosine triphosphate (ATP) in the form of high-energy bonds. ATP is the major energy carrier to body sites and releases the energy required for chemical and mechanical work. Use of that energy results in the production of heat, carbon dioxide, and water, which are all eliminated from the body.

The energy provided by foods is measured in **kilocalories (kcal) or joules (J).**

This is the amount of heat required to raise the temperature of 1 kg of water by 1° C.

1 kcal equals 4.184 kilojoules (kJ); 1 megajoule (MJ) equals 239 kcal.

The total amount of energy in a food is referred to as **gross energy** and it can be calculated by burning the food in a special device (bomb calorimeter) and measuring how much heat is liberated. However, not all the energy that is consumed in the form of macronutrients actually enters the body, a small portion leaves the body undigested (excrements). The absorbed proportion (digestibility) is a constant value for each of these macronutrients (98% –carbohydrates, 95% – fats, 92% – proteins). The amount of energy that is absorbed is **digestible energy.** M**etabolisable energy** is the energy that is available for the body to use after taking into account the loss of dietary energy (by stools and urine).

5.2 Energy Balance

There are several components of **energy balance:**

1. Energy intake

Energy intake is defined as the caloric or energy content of food as provided by the major sources of dietary energy:

- carbohydrate (16.8 kJ/g)
- protein (16.8 kJ/g)
- fat (37.8 kJ/g)
- alcohol (29.4 kJ/g)

These numbers are referred to as the so-called Atwater factors (i.e. metabolisable energy for carbohydrate is 4 calories/gram, 9 calories/gram of fat and 4 calories/gram of protein).

There are several factors that can influence food intake:

- factors in the digestive system
- factors in the central nervous system, mostly the hypothalamus
- circulating factors (provide a link between the digestive system and the central nervous system)
- signals from the periphery (e.g. insulin, leptin, adiponectin, etc.)
- non-physiological, external factors (psychological factors, environmental factors, physical characteristics of food as taste, texture, colour, temperature, and presentation, cultural influences in the environment, such as time of day, social factors, peer influence, and cultural preferences)

2. Energy storage

The energy that is consumed in the form of food or drinks can either be stored in the body in the form of fat (adipose tissue, the major energy store), glycogen (short-term energy/carbohydrate reserves, in the liver, and the muscles), or protein (body tissue rarely used by the body for energy except in severe cases of starvation and other wasting conditions) or be used by the body to fuel energy-requiring events.

3. Energy expenditure

The food consumed is oxidized or combusted in the presence of oxygen to release carbon dioxide, water, and heat.

The energy that is consumed in the form of food is required by the body for metabolic, cellular, and mechanical work such as breathing, heartbeat, and muscular work, all of which require energy and result in heat production. Total energy needs are based on **basal and non-basal requirements.**

The **basal metabolic rate (BMR)** is the energy expended by the body to maintain basic physiological functions (e.g., heartbeat, muscle contraction and function, and respiration). BMR is the minimum level of energy expended by the body to sustain life in the awake state. It can be measured after a 12-hour fasting while the subject is resting physically and mentally, and maintained in a thermoneutral, quiet environment. BMR is slightly elevated above the metabolic rate during sleep, because energy expenditure increases above basal levels owing to the energy cost of arousal. The energy cost associated with meal ingestion is primarily influenced by the composition of the food that is consumed, and is also relatively stable within individuals over time. BMR is influenced by many factors. The best indicator of BMR is body composition especially lean body mass. Growth is also important (during growing periods BMR is increasing from 15% to 20%). Fever can increase the BMR by about 7% for each 0.83°C. Cold climate causes BMR rise in response to lower temperatures.

Non-basal requirement for energy includes food intake and physical exercise. The **thermic effect of a meal** usually constitutes approximately 10% of the caloric content of the meal that is consumed. The third source of energy expenditure in the body is the increase in metabolic rate that occurs during **physical activity**, which includes exercise as well as all forms of physical activity. Physical activity energy expenditure (or the thermic effect of exercise) is the term frequently used to describe the increase in metabolic rate that is caused by use of skeletal muscles for any type of physical movement. Physical activity energy expenditure is the most variable component of daily energy expenditure and can vary greatly within and between individuals owing to the volitional and variable nature of physical activity patterns.

Total energy requirements: The energy demands of basal metabolism and the effect of food and of physical activity make up a total energy requirement (Table 10, 12 and 14).

Energy regulation is the process by which energy intake and energy expenditure are balanced.

Energy balance is the accounting for the energy consumed in foods, losses in excreta, heat produced, and retention or secretion of organic compounds.

E intake – E faeces – E urine – E combustible gas – E expenditure = E retention or E secretion

Energy balance is regulated by a complex set of neuroendocrine feedback mechanisms. Changes in energy intake or in EE trigger metabolic and behavioural responses aimed at restoring energy balance.

The average adult human consumes close to 1,000,000 calories (4,000 MJ) per year. Despite this huge energy intake, most healthy individuals are able to strike a remarkable balance between how much energy is consumed and how much energy is expended, thus resulting in a state of energy balance in the body. This **accurate balance** between energy intake and energy expenditure is an example of homeostatic control and results in maintenance of body weight and body energy stores. This regulation of energy balance is achieved over the long term despite large fluctuations in both energy intake and energy expenditure within and between days.

Energy balance is a state where energy intake is equivalent to energy expenditure. Energy balance is attained when energy intake equals total energy expenditure (TEE) and body stores are stable.

An individual is said to be in **positive energy balance** when energy intake exceeds TEE (and consequently body energy stores increase).

Negative energy balance occurs when energy intake is less than TEE and body energy stores decrease. Perturbations to this homeostatic model affect body weight regulation. Net energy deficit results in weight loss and underweight. Imbalance in the energy equation, when daily intake of calories is greater than energy expended (a net energy surplus), leads to weight gain and obesity.

Overnutrition: Occurs when energy intake exceeds energy expenditure and results in excess body fat accumulation. Several levels of overnutrition are defined in adults using the body mass index (BMI, weight in kilograms divided by height in meters squared, kg/m^2).

- Overweight BMI = 25–29.9 kg/m^2
- Class I Obesity BMI = 30–34.9 kg/m^2
- Class II Obesity BMI = 35–39.9 kg/m^2
- Class III Obesity BMI ≥ 40.0 kg/m^2

In children, BMI changes with development; BMI definitions of overweight and obesity at different ages are now available.

Undernutrition: Occurs when energy intake is less than TEE over a considerable period of time resulting in clinically significant weight loss. In adults, undernutrition is classified using BMI.

- BMI of 18.5–24.9 is considered normal
- BMI of 17–18.49 is mild undernutrition
- BMI of 16–16.99 is moderate undernutrition
- BMI < 16 is severe undernutrition.

In children, undernutrition is classified using the weight-for-height (or length) index and height-for-age index with reference values derived from the World Health Organization data.

Wasting is defined as a low weight for height, with < −1SD (i.e. −1 Z-score) being mild, < −2 SDs being moderate, and < −3 SDs being severely wasted relative to the National Center for Health Statistics and the World Health Organization International Growth Reference.

Similarly, **stunting** is associated with a low height for age with < −1 SD being mild, < −2 SDs being moderate, and < −3 SDs of the reference values being severely stunted.

Methods for measuring energy expenditure (EE) include direct calorimetry, indirect calorimetry, and non-calorimetric methods.

Direct calorimetry is the measurement of the heat emitted from the body over a given period.

Indirect calorimetry estimates heat production indirectly by measuring oxygen consumption (VO_2), CO_2 production (VCO_2), and the respiratory quotient (RQ), which is equal to the ratio of the VCO_2 to VO_2.

Other methods to assess EE applicable to field conditions include heart rate (HR) monitoring and doubly labeled water method (DLW).

5.3 Physical Activity

The energy expended for physical activity (PA) varies greatly among individuals as well as from day to day. In sedentary individuals, about two thirds of total energy expenditure goes to sustain basal metabolism over 24 hours (the BEE), while one-third is used for physical activity. In very active individuals, 24-hour total energy expenditure can rise to twice as much as basal energy expenditure.

Some physical activity is better than none. However, more physical activity has more benefits for health.

Physical activity affects many health conditions, and the specific amounts and types of activity that benefit each condition vary. Both endurance and resistance are beneficial.

I. Aerobic Activity (an endurance activity or cardio activity)

In this kind of physical activity the body's large muscles move in a rhythmic manner for a sustained period of time (brisk walking, running, cycling, jumping rope, and swimming).

Aerobic physical activity has three components:

1. **Intensity**, or how hard a person works to do the activity. The intensities most often examined are moderate intensity (equivalent in effort to brisk walking) and vigorous intensity (equivalent in effort to running or jogging);
2. **Frequency**, or how often a person does aerobic activity;

3. **Duration**, or how long a person does an activity in any one session.

Although these components make up a physical activity profile, research has shown that the total amount of physical activity is more important for achieving health benefits than is any one component (frequency, intensity, or duration).

II. Muscle-Strengthening Activity (resistance training and lifting weights)

This kind of activity, causes the body's muscles to work or hold against an applied force or weight. These activities often involve relatively heavy objects, such as weights, which are lifted multiple times to train various muscle groups. Muscle-strengthening activity can also be done by using elastic bands or body weight for resistance (climbing a tree or doing push-ups).

Muscle-strengthening activity also has three components:

1. **Intensity**, or how much weight or force is used relative to how much a person is able to lift;
2. **Frequency**, or how often a person does muscle-strengthening activity;
3. **Repetitions**, or how many times a person lifts a weight (analogous to duration for aerobic activity).

III. Bone-Strengthening Activity

This kind of activity (weight-bearing or weight-loading activity) produces a force on the bones that promotes bone growth and strength. This force is commonly produced by impact with the ground. Examples of bone-strengthening activity include jumping jacks, running, brisk walking, and weight-lifting exercises. Bone-strengthening activities can also be aerobic and muscle strengthening.

Cardiorespiratory fitness is defined as ability of the cardiovascular and respiratory systems to supply oxygen to the working muscles during sustained hard dynamic exercise.

Cardiorespiratory fitness is normally evaluated by measuring maximal oxygen uptake (VO_2max) during a progressive graded exercise test on a treadmill or bicycle ergometer. **Muscular strength** is defined as the maximum force or tension that can be generated by a muscle and is measured by determining how much weight an individual can lift in a certain movement or by how much force or torque an individual can exert during an isometric (no movement) or isokinetic (constant velocity) contraction.

Overload is the physical stress placed on the body when physical activity is greater in amount or intensity than usual. The body's structures and functions respond and adapt to these stresses. For example, aerobic physical activity places a stress on the cardiorespiratory system and muscles, requiring the lungs to move more air and the heart to pump more blood and deliver it to the working muscles. This increase in demand increases the efficiency and capacity of the lungs, heart, circulatory system, and exercising muscles. In the same way, muscle-strengthening and bone-strengthening activities overload muscles and bones, making them stronger.

Progression is closely tied to overload. Once a person reaches a certain fitness level, he or she progresses to higher levels of physical activity by continued overload and adaptation. Small, progressive changes in overload help the body adapt to the additional stresses while minimizing the risk of injury.

Specificity means that the benefits of physical activity are specific to the body systems that are doing the work. For example, aerobic physical activity largely benefits the body's cardiovascular system.

According to the research, there are plenty of **general benefits** connected with providing of physical activity:

- Regular physical activity reduces the risk of many adverse health outcomes.
- For most health outcomes, additional benefits occur as the amount of physical activity increases through higher intensity, greater frequency, and/or longer duration.
- Most health benefits occur with at least 150 minutes a week of moderate intensity physical activity, such as brisk walking. Additional benefits occur with more physical activity.
- Both aerobic and muscle-strengthening physical activities are beneficial.
- Health benefits occur for children and adolescents, young and middle-aged adults, older adults, and those in every studied racial and ethnic group.
- The health benefits of physical activity occur for people with disabilities.
- The benefits of physical activity far outweigh the possibility of adverse outcomes.

Physical exercise (PE) is a form of physical activity that is planned, structured, repetitive, and performed with the goal of improving health or fitness**.**

Physical exercise can improve overall health and fitness and help to prevent many adverse health outcomes.

The benefits of physical activity occur in generally healthy people, in people at risk of developing chronic diseases, and in people with current chronic conditions or disabilities and include decreasing the risk of different non-communicable diseases (reduce risk of cardiovascular disease, type 2 diabetes and metabolic syndrome, some cancers) and increase the chances of living longer.

Many large observational studies have demonstrated a reduced risk of incident dementia and reduced progression of cognitive decline among older adults who regularly exercise.

Regular physical activity can produce long-term health benefits. Most health benefits occur with at least 150 minutes (2 hours and 30 minutes) a week of moderate intensity physical activity, such as brisk walking. For most health outcomes, additional benefits occur as the amount of physical activity increases through higher intensity, greater frequency, and/or longer duration.

Children and adolescents strongly benefit from the following:

- Improved cardiorespiratory and muscular fitness
- Improved bone health
- Improved cardiovascular and metabolic health biomarkers
- Favourable body composition

Moderate evidence:

- Reduced symptoms of depression

The beneficial effects of increasing physical activity are mostly about overload, progression, and specificity.

Children and adolescents should be provided with facilities and opportunities to take part in daily programmes of enjoyable exercise so that physical activity may develop into a lifetime habit. Regular physical activity in children and adolescents promotes health and fitness.

Compared to those who are inactive physically active youth have higher levels of cardiorespiratory fitness and stronger muscles. In addition, they typically have lower body fatness. Their bones are stronger, and they may have reduced symptoms of anxiety and depression.

Youth can achieve substantial health benefits by doing moderate- and vigorous-intensity physical activity for periods of time that add up to 60 minutes (1 hour) or more each day. This activity should include aerobic activity as well as age-appropriate muscle- and bone-strengthening activities.

Key Guidelines for Children and Adolescents

Children and adolescents should do 60 minutes (1 hour) or more of physical activity daily.

- Aerobic: Most of the 60 or more minutes a day should be either moderate- or vigorous-intensity aerobic physical activity, and should include vigorous-intensity physical activity at least 3 days a week.
- Muscle-strengthening: As part of their 60 or more minutes of daily physical activity, children and adolescents should include muscle-strengthening physical activity on at least 3 days of the week.
- Bone-strengthening: As part of their 60 or more minutes of daily physical activity, children and adolescents should include bone-strengthening physical activity at least 3 days of the week.

Adults and older adults have strong evidence of the following benefits:

- Lower risk of early death
- Lower risk of coronary heart disease
- Lower risk of stroke
- Lower risk of high blood pressure
- Lower risk of adverse blood lipid profile
- Lower risk of type 2 diabetes
- Lower risk of metabolic syndrome
- Lower risk of colon cancer
- Lower risk of breast cancer
- Prevention of weight gain
- Weight loss, particularly when combined with reduced calorie intake
- Improved cardiorespiratory and muscular fitness
- Prevention of falls
- Reduced depression
- Better cognitive function (for older adults)

Moderate to strong evidence:

- Better functional health (for older adults)
- Reduced abdominal obesity

Moderate evidence

- Lower risk of hip fracture
- Lower risk of lung cancer
- Lower risk of endometrial cancer
- Weight maintenance after weight loss
- Increased bone density
- Improved sleep quality

Adults should be encouraged to increase habitual activity gradually, aiming to carry out every day at work and during recreational time at least 30 minutes of physical activity of moderate intensity, e.g. brisk walking and stair climbing. More strenuous activities (e.g. slow jogging, cycling, field and court games and swimming) could provide additional benefits. The health benefits of physical activity far outweigh the risks of getting hurt. The US Federal Physical Guidelines and many studies show that

150 minutes per week of moderate intensity physical activity is required to achieve these health benefits**.** Adults gain additional and more extensive health and fitness benefits with even more physical activity. Muscle-strengthening activities also provide health benefits and are an important part of an adult's overall physical activity plan. According to the last available studies, adults with better muscle strength have a 20% lower risk of mortality (33% lower risk of cancer specific mortality) than adults with low muscle strength.

Key Guidelines for Adults

- All adults should avoid inactivity. Some physical activity is better than none, and adults who participate in any amount of physical activity gain some health benefits.
- For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week.
- For additional and more extensive health benefits, adults should increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity. Additional health benefits are gained by engaging in physical activity beyond this amount.
- Adults should also do muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on two or more days a week, as these activities provide additional health benefits.

Pedometers and similar equipment can be a motivation tool for people wanting to increase their physical activity to achieve daily limit approximately 10,000 steps/8km. The use of a pedometer is associated with significant increases in physical activity and significant decreases in body mass index and blood pressure.

Key Guidelines for Older Adults

- When older adults cannot do 150 minutes of moderate-intensity aerobic activity a week because of chronic conditions, they should be as physically active as their abilities and conditions allow.
- Older adults should do exercises that maintain or improve balance if they are at risk of falling.
- Older adults should determine their level of effort for physical activity relative to their level of fitness.
- Older adults with chronic conditions should understand whether and how their conditions affect their ability to do regular physical activity safely.

Physical Activity Level (PAL), the Physical Activity Index.

The level of physical activity is commonly described as the ratio of total to basal daily energy expenditure (TEE/BEE) - PAL. Describing physical activity habits in terms of PAL is not entirely satisfactory because the increments above basal needs in energy expenditure, brought

about by most physical activities where body weight is supported against gravity (e.g., walking, but not cycling on a stationary cycle ergometer), are directly proportional to body weight, whereas BEE is more nearly proportional to body weight.

It is important to encourage people to participate in physical activities that are appropriate for their age, that are enjoyable, and that offer variety.

Researchers from the EPIC study (European Prospective Investigation into Cancer and Nutrition) found that an increase in physical activity reduced the risk of mortality, particularly when comparing inactive people with those that were moderately inactive. They concluded that these findings provide evidence that even a small increase in the amount of PA by the most inactive members of society should be encouraged. It has the potential to improve greatly public health-related outcomes.

According to other studies, rigorous physical activity may be a key to boosting longevity.

Physical inactivity is a fast-growing public health problem and contributes to a variety of chronic diseases and health complications, including obesity, diabetes, and cancer. In addition to improving a patient's overall health, increasing physical activity has proven effective in the treatment and prevention of chronic diseases. Even with all the benefits of physical activity levels of inactivity are alarming.

Physical inactivity is the fourth leading cause of death worldwide. Although evidence for the benefits of physical activity for health has been available since the 1950s, promotion to improve the health of populations has lagged in relation to the available evidence and has only recently developed an identifiable infrastructure, including efforts in planning, policy, leadership and advocacy, workforce training and development, and monitoring and surveillance. The reasons for this late start are myriad, multifactorial, and complex. This infrastructure should continue to be formed, intersectoral approaches are essential to advance, and advocacy remains a key pillar. Although there is a need to build global capacity based on the present foundations, a systems approach that focuses on populations and the complex interactions among the correlates of physical inactivity, rather than solely a behavioural science approach focusing on individuals, is the way forward to increase physical activity worldwide. **Physically inactive doctors and health care professionals are less likely to provide exercise counselling to patients and provide less credible role models for the adoption of healthy behaviours.**

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6 HEALTHY DIET

Diet should satisfies the nutritional needs, i.e. covers the physiological requirements for normal metabolic functions and growth, and supports overall good health and contributes to a reduced risk of diet-associated diseases.

The ideal diet should provide energy and essential nutrients within optimal ranges from foods that are available, affordable, and palatable.

Nowadays in developed societies, there is characteristic excessive intake of energy, presence of enormous quantities of processed and refined food loaded with sugars, fat, salt, and artificial additives in diet.

General recommendations suggest consumption of **nutrient-dense, energy balanced diet**. Whole-foods approach to healthy eating (basic foods that are naturally lower in calories and packed with nutrients) seems to be better than consuming mostly processed foods.

The recommendations derive from an assessment of the evidence on chronic diseases, but should be used in combination with the recommended dietary allowances of the country to achieve an optimal and highly desirable pattern for the maintenance of good health.

The guidelines for individuals differ somewhat from the population goals, which need to be more stringent in order to achieve the goals for the individuals**.** Given our present understanding of food-health relationships, it seems likely that a large variety of foods can be combined in varying amounts to provide a healthy diet.

Increased attention in dietary research and guidance has been focused **on dietary patterns** rather than worrying about single nutrients or food groups, because dietary components are consumed in combination and correlated with one another. Different dietary patterns can bring health benefits. There is currently a large body of evidence directly supporting the importance of specific food patterns or dietary patterns in maintaining good health. This evidence might facilitate the formulation of food-based dietary guidelines and recommendations for nutrient intakes. Common characteristics of dietary patterns associated with positive health outcomes include higher intake of vegetables, fruits, whole grains, fish/seafood, non-fat dairy, legumes and nuts, lower consumption of red, processed meat, low intake of refined grains, sugar-sweetened foods and beverages, alcohol, and reducing salt.

The Mediterranean diet or whole food plant-based diet (the regimen emphasizing vegetables, fruits, whole grains, legumes, nuts, fish and olive oil, containing variety of unprocessed plant foods, rich in fibre and micronutrients with anti-oxidatory and anti-inflammatory potential, low in meat, sugar and salt) has been consistently linked with health benefits, including reduced mortality and reduced risk of chronic diseases.

According to the results from current studies, it seems that there are benefits of adherence to these types of diets for promoting health and longevity. Greater adherence to the Mediterranean diet was associated with longer telomeres. Telomere length variability may be partially explained by lifestyle practices; as accelerated telomere

attrition may underlie many chronic diseases, identifying modifiable factors that affect telomere dynamics is important.

But there are differences among Mediterranean countries and therefore it is important to evaluate the adherence of a population to the Mediterranean diet pattern. Diet indexes attempt to make a global evaluation of the quality of the diet based on a traditional Mediterranean reference pattern, described as *a priori*, general and qualitative. The Mediterranean diet indexes summarise the diet by means of a single score that results from a function of different components, such as food, food groups or a combination of foods and nutrients.

The old diet advice from previous decades ("fat is always bad") was probably incorrect. But the new oversimplification — "fat isn't bad, carbs are bad" — seems also incorrect. Some fats (polyunsaturated) are essential and some are more harmful (trans and saturated), and some carbs are rather harmful (sugar) and some look more helpful (fibre).

The high-carb diet rich in sugar and refined grains increases the risk of obesity, diabetes and heart disease, but on the other hand, according to the last available epidemiological studies it is suggested that encouraging population to eat more meat and full-fat dairy is not such good advice and it has no basis in science.

Higher diet quality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults, whereas opposite food patterns, rich in animal foods and poor in plant-based foods, typically called **western or westernized diets** are associated with higher risks.

It is interesting to search what the places called **"Blue Zones"** have in common (i.e. Okinawa, Sardinia, Loma Linda, Icaria, Nicoya). Their diets are quite diverse (vary from Italy and Greece to California, Costa Rica, and Japan) but their inhabitants live longer and healthier lives (fewer cases of heart disease, cancers, diabetes, dementia...). Among the lifestyle habits that are common to those populations are: a wise diet-high consumption of fruit, wild plants, vegetables, legumes and low consumption of meat (mostly pork – but only 5 times per month), never overeating (usually stop eating when their stomach is 80% full), high levels of daily physical activity (gardening, walking), social engagement, no alcohol consumption or moderate drinking, no smoking, positive attitude and enriching their days with periods of calm, enjoying the sun, nature and family surroundings.

6.1 Guidelines for Healthy Diet - the Pyramid/the Plate

Dietary guidelines are published in different countries. **The goals of these are to prevent nutrient deficiencies and to reduce the risk of chronic diseases**. Various nutrition guides are published by medical and governmental institutions **to educate the public on what they should eat to promote health.** Several sets of dietary guidelines include quantitative recommendations that focus on nutrients. They are usually intended for health professionals who in turn translate them into practical advice for the public. Other sets of dietary guidelines are based entirely on foods rather than nutrients; these are known as food-based dietary guidelines.

Nutrition facts labels are also mandatory in some countries to allow consumers to choose between foods based on the components relevant to health. It is difficult to determine a precise indispensable intake of individual foods that can, when combined with other foods, provide a nutritionally adequate diet under all conditions. Guidelines most likely can be harmonized following a unified approach to defining them, but there must be room to accommodate **nutritional individuality; a one-size-fits-all approach should not be too strictly and rigidly applied.**

History of one of the most important Food Guides from USDA started in 1916 with "Food for Young Children" and "How to Select Food" guidance, that was based on "protective foods", followed in the 1940s with A Guide to Good Eating (Basic Seven).

Figure 1 *Food Guide Pyramid 1992. (Source: USDA, 2014)*

Figure 2 *MyPyramid Food Guidance System 2005. (Source: USDA, 2014)*

In 1992, recommendations were expressed in a well-known **The Food Guide Pyramid** (Figure 1), which emphasizes foods from the five food groups shown in the sections of the pyramid. Each of these groups provides required nutrients for good health. For everyday living, the simplest and most practical plan is to follow those same guidelines, selecting from the various food groups the type and amount of food recommended.

All around the world there is a similar kind of **Pyramids adjusted for local conditions and habits**.

Levels for nutrients are established according to age, sex, developmental stage, body size, levels of physical activity, safe and adequate range.

In 2005, the **MyPyramid** (Figure 2) Food Guidance System was introduced along with updating of Food Guide Pyramid food patterns for the 2005 Dietary Guidelines for Americans, including daily amounts of food at 12 calorie levels. It continued "pyramid" concept, based on consumer research, but simplified illustration. The system added a band for oils and the concept of physical activity, illustration could be used to describe concepts of variety, moderation, and proportion.

In 2011, a so-called **MyPlate** (Figure 3) was introduced along with updating of USDA food patterns for the 2010 Dietary Guidelines for Americans. It has a different shape to help grab consumers' attention with a new visual cue. Its icon serves as a reminder for healthy eating, and is not intended to provide specific messages. Its visual is linked to food and is a familiar mealtime symbol in consumers' minds, as identified through testing. The term "My" continues the personalization approach from MyPyramid.

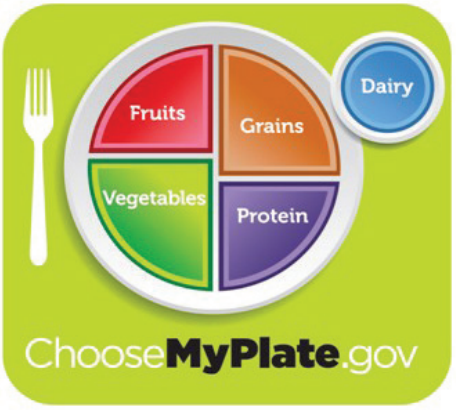

Figure 3 *MyPlate (Source: USDA, 2014)*

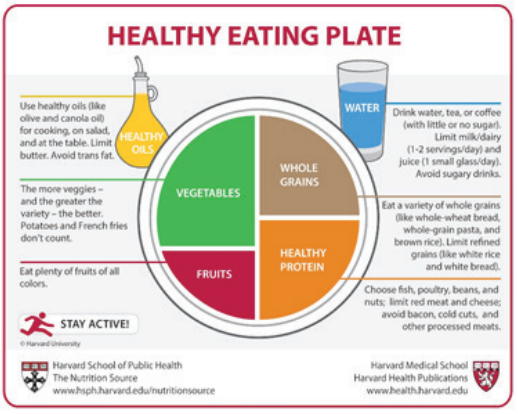

Figure 4 *Healthy eating plate. (Source: http://www.hsph.harvard.edu/nutritionsource/healthy-eating-plate-vs-usda-my-plate/2014)*

The U.S. Department of Health and Human Services (HHS) and the U.S. Department of Agriculture (USDA) have jointly published the Dietary Guidelines every 5 years since 1980. The Dietary Guidelines encourage individuals to eat a healthful diet — one that focuses on foods and beverages that help achieve and maintain a healthy weight, promote health, and prevent disease.

The Healthy Eating Plate (Figure 4), created by nutrition experts at the Harvard School of Public Health and Harvard Medical School, points consumers to the healthiest choices in the major food groups. The Healthy Eating Plate is based exclusively on the best available science and was not subjected to political or commercial pressures from food industry lobbyists. The red figure running across the Healthy Eating Plate's placemat is a reminder that staying active is also important in weight control. The main message of the Healthy Eating Plate is to focus on diet quality.

- The type of carbohydrate in the diet is more important than the amount of carbohydrate in the diet, because some sources of carbohydrate — like vegetables (other than potatoes), fruits, whole grains, and beans — are healthier than others.
- The Healthy Eating Plate also advises consumers to avoid sugary beverages, a major source of calories — usually with little nutritional value — in the diet.
- The Healthy Eating Plate encourages consumers to use healthy oils, and it does not set a maximum on the percentage of calories people should get each day from healthy sources of fat. In this way, the Healthy Eating Plate recommends the opposite of the low-fat message promoted for decades by the USDA.

6.2 Recommended Dietary Allowances and Dietary Reference Intakes

Recommended dietary allowances (RDAs) were established by the Food and Nutrition Board of the National Academy of Sciences. These numerical values provide nutrition guidance to health professionals and to the general public. **RDAs are defined as the levels of intake of essential nutrients that are judged to be adequate to meet the known needs of practically all healthy persons.**

In addition to providing information for labels on food, RDAs are used for many other purposes. Institutions use the RDAs to plan healthful diets for schools, prisons,

hospitals, and nursing homes. Industry uses them to develop new food products. Policy makers use them to evaluate and improve food supplies to meet national needs, and health workers use them to provide nutrition education.

Since 1941, when the first **RDAs** were published, they have been updated 10 times in USA. The most recent revision was in 1989 when RDAs were determined for protein, 11 vitamins, and 7 minerals. RDAs were set for different age groups, for men and women, and for pregnant and nursing mothers. The board also established Estimated Safe and Adequate Daily Dietary Intakes (ESADDIs) for 7 nutrients where available data were insufficient to set an RDA. New research was showing the importance of higher intakes of some nutrients for promoting health (preventing chronic disease) and performance; there was tremendous growth in food fortification and the use of dietary supplements; and the existing RDAs did not adequately distinguish guidelines for groups and populations from those for individuals.

The United Kingdom adopted the term dietary reference value (DRV), the EU introduced the term population reference intake (PRI), mostly in the USA and Canada the term dietary reference intake (DRI) was introduced, and Australia and New Zealand now use the term nutrient intake value (NIV). All are precisely equivalent to the original concept of the RDA, a term that many countries prefer to continue to use.

The Board replaced and expanded the RDAs with **Dietary Reference Intakes (DRIs)** to provide recommended nutrient intakes for use in a variety of settings. The dietary reference intake was introduced in 1997 in order to broaden the existing guidelines (RDAs).

It is a system of nutrition recommendations from the Institute of Medicine (IOM) of the U.S. National Academy of Sciences and it provides several different types of reference value.

The DRIs are a set of four reference values as follows:

- **Estimated Average Requirement (EAR)** is the amount of a nutrient that is estimated to meet the requirement of half of all healthy individuals in the population.
- **Recommended Dietary Allowance (RDA)** is the average daily dietary intake of a nutrient that is sufficient to meet the requirement of nearly all (97–98%) healthy persons. RDAs represent the mean requirement plus 2 SDs (Standard Deviation).
- **Adequate Intake (AI)** for a nutrient is similar to the ESADDI and is only established when an RDA cannot be determined. Therefore, a nutrient either has an RDA or an AI. The AI is based on observed intakes of the nutrient by a group of healthy persons.
- **Tolerable Upper Intake Level (UL)** is the highest daily intake of a nutrient that is likely to pose no risks of toxicity for almost all individuals. As intake increases above the UL, the potential risk of adverse effects may increase.

RDAs are published for professionals as well as for public. The RDAs (Figure 5) are modified according to expanding knowledge of nutrition and have become a guideline for proper nutrition for the health-conscious individuals. Each of these reference values distinguishes between gender and different life stages. RDAs, AIs and ULs are dietary guidelines for individuals, whereas EARs provide guidelines for groups and populations. In addition, factors that might modify these guidelines, such as bioavailability of nutrients from different sources, nutrient-nutrient and nutrient-drug interactions, and intakes from food fortificants and supplements, are incorporated into the guidelines in much greater detail than previously.

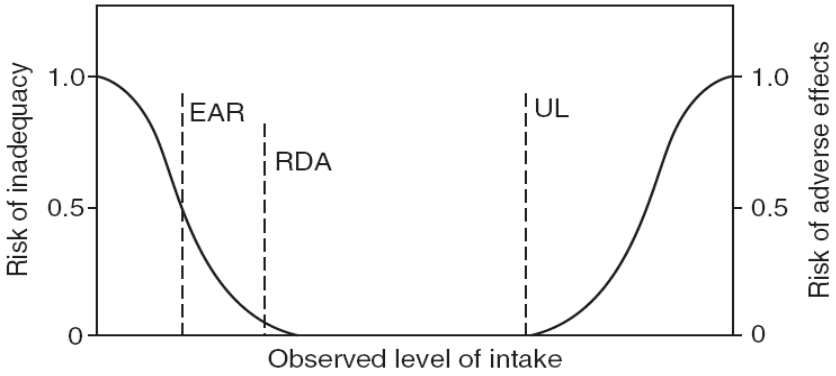

Figure 5 *Dietary reference intakes (Source: Ševčíková et al., 2011, Nestle, 2008)*

The World Health Organization (WHO) has taken a rather different approach, defining population safe ranges of intake. "**Normative requirement**" is now used to describe the population mean normative requirement (which would allow the maintenance of, or a desirable, body store or reserve); "**maximum**" to refer to the upper limit of safe ranges of population mean intakes; and "**basal**" for the lower such limit, below which clinically detectable signs of inadequacy would be expected to appear. These WHO requirements are revised in groups of nutrients at different times.

Recommended nutrient intakes (RNIs) are customarily defined as the intake of energy and specific nutrients necessary to satisfy the requirements of a group of healthy individuals. This nutrient-based approach has served well to advance science, but has not always fostered the establishment of nutritional and dietary priorities consistent with broad public health interests at national and international levels.

Food-based dietary guidelines (FBDGs) address health concerns related to dietary insufficiency, excess, or imbalance with a broader perspective, considering the totality of the effects of a given dietary pattern. They are more closely linked to the diet-health relationships of relevance to the particular country or region of interest. In addition, they take into account the customary dietary pattern, the foods available, and the factors that determine the consumption of foods. They consider the ecologic setting, the socioeconomic and cultural factors, and the biologic and physical environment that affects the health and nutrition of a given population or community. Finally, they are easy to understand and accessible for all members of a population.

The Joint Food and Agriculture Organization (FAO)/World Health Organization (WHO) consultation on preparation and use of Food-Based Dietary Guidelines has indicated the need to consider the following nine **key factors in developing national FBDGs**:

- Scientific evidence concerning diet-health relationships
- The prevalence of diet-related public health problems
- Food consumption patterns of the population
- Nutritional requirements
- The potential food supply
- The composition of foods, including consideration of food preparation practices
- The bioavailability of nutrients supplied by the mixed local diet
- Sociocultural factors that relate to food choices and accessibility
- Food costs

RDAs valid in Slovakia are in Tables 10–15.

6.3 General Recommendations

Common recommendations for healthy diet are as follows and they offer important messages about diet quality, not just quantity:

- Fill half of your plate with vegetables and fruits. The more colour, and the more variety, the better.
- Save a quarter of your plate for whole grains. The less processed the whole grains, the better. But grains are not essential for good health.
- Pick a healthy source of protein to fill one quarter of your plate: some protein sources (fish, chicken, beans, nuts) are healthier than others (red meat and processed meat).
- Enjoy healthy fats like olive, avocado, nuts for making the salads, and at the table. Limit butter, and avoid unhealthy trans fats.
- Drink water, coffee, or tea (which are also low-calorie and have health benefits). Limit milk and dairy products to one to two servings per day and limit juice. Skip sugary drinks.
- Staying active is half of the secret to weight control. The other half is eating a healthy diet with modest portions that meet your calorie needs.

To be more specific:

- **Carbohydrates intake**: to consume fibre-rich fruits, vegetables, increase intake of starches and other complex carbohydrates by eating more daily servings of a combination of whole grains and legumes. Consume foods and beverages with very little added sugars or caloric sweeteners.
- **Fat intake:** limiting intake of fats and oils high in saturated (consumption less than 7–10 % of calories from saturated fatty acids), and avoiding trans-fatty acid consumption (meat should be lean, preferably poultry; milk and dairy products preferably low-fat), majority of fats should come from sources of polyunsaturated and monounsaturated fatty acids (such as fish, nuts, seeds and vegetable oils).
- Maintain **protein intake** at moderate level (e.g. about 1 g/kg body weight for adults).
- Try **to eat every day five or more servings/portions of vegetables and fruits** (One adult portion of fruit or vegetables is 80g, is equal to a half cup or cup for most fresh or cooked vegetables = three heaped tablespoons of cooked vegetables; one medium piece of fresh fruit (one apple, banana), or 2-3 smaller (two kiwi fruit, three apricots), dry fruits = 30g (one tablespoon of mixed fruit, two figs, three prunes); or a combination of vegetables and fruits, especially green and yellow vegetables and citrus fruits; one 150ml glass of unsweetened 100% fruit or vegetable juice can count as a portion.
- **Do not drink alcoholic beverages,** alcohol is a carcinogen. If it is not possible to avoid alcohol consumption totally, limit the doses. Moderate alcohol consumption is defined as having up to 2 drinks per day for men, but only up to 1 drink per day for women (the equivalent of less than 30 g of pure alcohol daily for men, half for women). This definition is referring to the amount consumed on any single day and is not intended as an average over several days. The Dietary Guidelines also state that it is not recommended that anyone begins drinking or drinks more frequently on the basis of potential health benefits because moderate alcohol intake is also associated with increased risk of breast cancer, violence, drowning, and injuries from falls and motor vehicle crashes. Pregnant women should totally avoid alcoholic beverages.
- **Limit total daily intake of salt to 6 g or less** (approximately 1 tsp of salt, total maximum recommended limit of sodium for adults should be less than

2300 mg/ day). Limit the use of salt in cooking and avoid adding it to food at the table. Salty, highly processed food, salt-preserved, and salt-pickled foods should be consumed sparingly. At the same time, consume potassium-rich foods, such as fruits and vegetables.

- Maintain adequate **calcium intake**.
- **Avoid taking dietary supplements in excess** of the recommended dietary allowance. A single daily dose of multiple vitamin-mineral supplements containing 100% of the recommended dietary allowance is not known to be harmful or beneficial. However, vitamin-mineral supplements that exceed the recommended dietary allowance and other supplements (such as protein powders, single amino acids, fibre, and lecithin) do not only have health benefits for the population, but their use may be detrimental to health. The desirable way for the general public is to obtain recommended levels of nutrients by eating a variety of foods.
- Maintain an **optimal intake of fluoride,** particularly during the years of primary and secondary tooth formation and growth.
- **Maintain body weight**: in a healthy range, balance calories from foods and beverages with calories expended.
- Also according to the recommendations of the American Heart Association, World Cancer Research Fund, and American Institute for Cancer Research a diet that consists mostly of **unprocessed plant foods**, with emphasis on a wide range of whole grains, legumes, and non-starchy vegetables and fruits should be preferable. Healthy diet is low in energy density, which may protect against weight gain and associated metabolic diseases.
- Limiting or better **avoiding consumption of sugary drinks, energy rich foods, including "fast foods", red and processed meats** – it can improve health and reduce the risk of chronic disease.

6.4 Diet Quality Scores, Eating Indexes

Predefined **diet quality scores** are valuable tools to assess nutritional habits of individuals and populations. They reflect a more comprehensive picture of diet than individual food or nutrient intakes and provide a more holistic approach to study the relationship between diet and health. **Healthy diet indicator (HDI)** was originally developed in 1997, reflecting the 1990 dietary recommendations of the WHO for the prevention of chronic diseases. Being based on international guidelines, it is often used in cross-cultural settings.

Table 8 *Healthy diet indicator (HDI), (Source: Stefler, 2014)*

Components of the HDI scores	0 Point	0–10 Points	10 Points
SFAs, energy %	>15	10–15	0–10
n3-PUFAs, energy %	>3	0–1 or 2–3	1–2
n6-PUFAs, energy %	>13	0–5 or 8–13	5–8
Trans fatty acids, energy %	>2	1–2	<1
Mono and disaccharides, energy %	>30	10–30	0–10
Protein, energy %	>25	0–10 or 15–25	10–15
Cholesterol, mg/day	>400	300–400	0–300
Fruits/vegetables, g/day	0	0–400	>400
NSP, g/day	0	0–20	>20

Abbreviations: energy %, percentage of daily alcohol-free energy intake; HDI, healthy diet indicator; NSP, non-starch polysaccharides; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

Examples of dietary quality scores include: the **Healthy Eating Index (HEI)-2005 and 2010**, the **Alternate HEI (AHEI)** and updated **AHEI-2010**, the **Recommended Food Score (RFS),** the **Dietary Approaches to Stop Hypertension (DASH) Score**, the **Mediterranean Diet Score (MDS),** and the **Alternate Mediterranean Diet Score (aMed).**

The **Healthy Eating Index (HEI)** (Table 9) is **a measure of diet quality** that assesses conformance to federal dietary guidance. USDA's primary use of the HEI is to monitor the diet quality of the U.S. population and the low-income subpopulation. For this purpose, the Centre for Nutrition Policy and Promotion (CNPP) uses the data collected via 24-hour recalls of dietary intake in national surveys. The HEI is also used to examine relationships between diet and health-related outcomes and between diet cost and diet quality, to determine the effectiveness of nutrition intervention programmes, and to assess the quality of food assistance packages, menus, and the US food supply. The HEI is a scoring metric that can be applied to any defined set of foods, such as previously collected dietary data, a defined menu, or a market basket. The original HEI was created by CNPP in 1995. It was revised in 2006 by a federal working group, led by CNPP with members from the National Cancer Institute and the USDA Food and Nutrition Service, to reflect the 2005 Dietary Guidelines for Americans, and updated in 2012 to reflect the 2010 Dietary Guidelines for Americans. A score of 100 meant following the federal recommendations to the last dot and comma, while a score of 0 meant totally ignoring them.

Harvard School of Public Health researchers created **an Alternate Healthy Eating Index** and they did appear to correlate more closely with better health in both sexes. Men with high scores (those whose diets most closely followed the Healthy Eating Pyramid guidelines) were 20 per cent less likely to have developed a major chronic disease than those with low scores. Women with high scores lowered their overall risk by 11 per cent. Men whose diets most closely followed the Healthy Eating Pyramid lowered their risk of cardiovascular disease by almost 40 per cent; women with high scores lowered their risk by almost 30 per cent.

These findings suggest that closer adherence to the 2005 Dietary Guidelines may lower risk of major chronic disease. However, the AHEI-2010, which included additional dietary information, was more strongly associated with chronic disease risk, particularly CHD and diabetes.

The **Eating Choices Index (ECI)** score includes four components as follows:

1. consumption of breakfast
2. consumption of two portions of fruit per day
3. type of milk consumed
4. type of bread consumed

Each component provides a score from 1 to 5.

ECI scores correlate with nutrient profiles consistent with a healthy diet.

ECI provides a simple method to rank diet healthiness in large observational studies.

Table 9 *The Healthy Eating Index (HEI), (Source: http://epi.grants.cancer.gov/hei/developing.html, 2014)*

Component	Max. points	Standard for max. score/ per 1,000 kcal	Standard for min. score of zero
Adequacy:			
Total Fruit 2	5	≥0.8 cup equiv.	No Fruit
Whole Fruit 3	5	≥0.4 cup equiv.	No Whole Fruit
Total Vegetables 4	5	≥1.1 cup equiv.	No Vegetables
Greens and Beans 4	5	≥0.2 cup equiv.	No Green Vegs, Beans, Peas
Whole Grains	10	≥1.5 oz equiv	No Whole Grains
Dairy 5	10	≥1.3 cup equiv.	No Dairy
Total Protein Foods 6	5	≥2.5 oz equiv	No Protein Foods
Seafood and Plant Proteins 6,7	5	≥0.8 oz equiv.	No Seafood or Plant Proteins
Fatty Acids 8	10	(PUFAs+MUFAs)/SFAs >2.5	(PUFAs + MUFAs)/SFAs <1.2
Moderation:			
Refined Grains	10	≤1.8 oz equiv. per 1,000 kcal	≥4.3 oz equiv. per 1,000 kcal
Sodium	10	≤1.1 gram per 1,000 kcal	≥2.0 grams per 1,000 kcal
Empty Calories 9	20	≤19% of energy	≥50% of energy

1. Intakes between the minimum and maximum standards are scored proportionately
2. Includes fruit juice.
3. Includes all forms except juice.
4. Includes any beans and peas not counted as Total Protein Foods.
5. Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.
6. Beans and peas are included here (and not with vegetables) when the Total Protein Foods standard is otherwise not met.
7. Includes seafood, nuts, seeds, soy products (other than beverages) as well as beans and peas counted as Total Protein Foods.
8. Ratio of poly- and monounsaturated fatty acids to saturated fatty acids.
9. Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is >13 grams/1000 kcal.

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7 SPECIAL NUTRITIONAL NEEDS

The RDAs also accept special nutritional needs in some population groups such as pregnant and lactating women, children and adolescents, elderly people, physically active persons, or sportsmen.

7.1 Nutrition of Pregnant and Lactating Women

The foetal origin of adult disease (Barker hypothesis) suggests that adverse environments in foetal life and early childhood can increase risk of disease in adult life, e.g. malnutrition during gestation induces programming in the pancreatic beta cells, muscle, liver, adipose tissues, and neuroendocrine axis. Poor prenatal environment and a too rich postnatal environment lead to a poor ability to adapt, which increases the risk of obesity, glucose intolerance and coronary heart disease later in life. According to epidemiological studies, it seems that the perinatal environment can predispose human offspring to develop obesity and type 2 diabetes. Maternal malnutrition, obesity, diabetes, different stressors (psychological and pharmacological) could promote obesity and diabetes, while early-onset exercise can ameliorate these issues, especially in genetically predisposed offspring.

The need for most nutrients is increased during pregnancy to meet the high demands of both the growing foetus and the mother who herself goes through a period of growth to carry the child and prepare for lactation. Pregnant and lactating women have a higher need for energy and some vitamins and minerals. Foetal growth during pregnancy and milk secretion during lactation are nutrient-requiring processes. In well-nourished women, normal physiologic and metabolic adjustments in nutrient utilization probably provide the additional nutrients needed for foetal growth and milk secretion. In poorly nourished women, the additional demand for nutrients during these processes may lead to maternal and or foetal nutrient deficiencies.

The daily nutrient requirements of the lactating woman are higher than requirements during pregnancy. The higher recommended intakes are based primarily on the amounts secreted in milk. RDAs assume that the mother secretes about 500 kcal/day in milk, including about 5% as protein, more than 50% as fat, and 38% as lactose (IOM). This falls to 400 kcal/day in the second 6 months. The recommended intake of most micronutrients is also increased to cover the amounts secreted in milk. The only nutrient that is needed in lower amounts during lactation is iron, except for women who need to synthesize large amounts of blood to replace major blood losses during delivery.

7.2 Nutrition of Infants and Youth

The normal infant experiences a three -fold increase in weight and a two-fold increase in length during the first year of life, and also experiences dramatic developmental changes in organ function and body composition. These rapid rates of growth

and development are superimposed on relatively high maintenance needs incident to the higher metabolic and nutrient turnover rates of infants vs. adults. The first 2 years of a child's life are vital as optimal nutrition during this period reduces the risk of dying and of developing NCDs. It also fosters better development and healthy growth and development overall. Advice on a healthy diet for infants and children is similar to that for adults but these elements are also important according to the WHO recommendations.

- Infants should be breastfed exclusively for the first 6 months of life. **Breastfeeding** for the first 6 months of age best supports healthy growth and development.
- Breastfeeding is recommended for 12 months and thereafter at the discretion of the mother. Mother´s milk as the only one absolutely ideal "food" provides the correct balance of nutrients, enzymes, immunoglobulin, hormones, anti-infective and anti-inflammatory substances, and growth factors for the infant. Breastfeeding is especially effective in developing countries where access to sanitized water is limited.
- From 6 months of age, breast milk should be complemented with a variety of adequate, safe and nutrient-dense complementary foods.
- Children over the age of two should follow a **balanced diet** as defined by the Dietetic Associations or individual countries' health ministries. Children who do not follow a balanced diet are at risk for lifetime healthcare problems such as obesity, high blood pressure, cardiovascular diseases, and diabetes or undernourishment deficiency diseases.
- Salt and sugars should not be added to complementary foods.

Optimal nutrition is necessary for growth, development, metabolism, health, and well-being of children and adolescents. Early nutrition has a powerful effect on cognitive development and growth, particularly in the first 2–3 years.

It is important to develop healthy eating habits in childhood and adolescence, help with healthy food choices, and raise a healthy eater by setting a good example and practising positive habits and following food safety rules.

Recommended dietary allowances for children and adolescents are presented in Tables 14 and 15.

In developed countries children and adolescents are more likely to eat pre-packaged foods, high in sugar and fat, rather than more nutritious alternatives, which lead to obesity. With many countries now seeing a rapid rise in obesity among infants and children, the WHO in May 2014 set up the Commission on Childhood Obesity. The Commission will draw up a report for 2015 specifying which approaches and actions are likely to be most effective in different contexts around the world.

In developing countries, malnutrition still remains a big problem; effects of undernourishment can last a lifetime including blindness, stunted growth, disability, and death. Diarrhoeal diseases are consequences of sanitation deficiencies, and contaminated food. Globally, 161 million under-five-year-olds were estimated to be stunted in 2013. The global trend in stunting prevalence and numbers affected is decreasing. Between 2000 and 2013, stunting prevalence declined from 33% to 25% (numbers declined from 199 million to 161 million). In 2013, about half of all stunted children lived in Asia and over one third in Africa. Globally, 51 million under-five-year-olds were wasted and 17 million were severely wasted in 2013, wasting prevalence in 2013 was estimated at almost 8% and nearly a third of that was for severe wasting, totalling 3%. Alongside undernutrition, a 'double burden' of malnutrition is emerging with rates of obesity and related chronic diseases associated with urbanisation, aging populations, technological development and globalisation of food supplies and industry. Children are increasingly exposed to high-fat,

high-sugar, high-salt, energy-dense, micronutrient-poor foods which tend to be cheaper than healthy foods. There is a general imbalance in energy intake compared to physical activity levels, which is driving the obesity epidemic.

The number of overweight children increased all around the world. Globally, more than 42 million under-five-year-olds were overweight in 2013, up from 32 million in 2000. It is estimated that at least 35 million overweight children are living in developing countries and approximately 8 million in developed countries.

Adolescence is an important period during which major biological, social, physiological, and cognitive changes take place. Adolescents have special nutritional needs as a result of rapid growth (lean body mass, fat mass, bone mineralization) and maturational changes associated with the onset of puberty. Dietary surveys show that most adolescents do not meet age and gender nutrient recommendations and have inadequate dietary intake of calcium, iron, and zinc, thiamine, riboflavin, and vitamins A, C, D. Despite their poor dietary intakes, the only clinical nutrient deficiency commonly seen among adolescents is iron-deficiency anaemia**.** To accommodate rapid gains, calcium requirements are higher for adolescents than for children or adults.

7.3 Nutrition in Older Adults

Older adults are a diverse and extremely heterogeneous population group. Aging is a uniquely individual process that is influenced by an accumulation of life events. Differentiation between chronologic age and senescence must be taken into account. Some 70-year-old persons are fit and less "aged" from a cellular and functional standpoint than are some 40-year olds as a result of a variety of genetic, health status, and lifestyle characteristics. However, functional declines naturally occur with advancing age. Elderly people are often categorized by chronological age, with stratification so that the cohort of 65- to 74-year-olds is referred to as the "young old," 75- to 84-year-olds as "old," and those 85 years and older as the "oldest old."

The average age and the proportion of the population, which is older increase every year: according to the last available data from the WHO around the world the number of people aged 60 years and over was estimated at 600 million in 2000, a figure that is expected to rise to 1.2 billion by 2025 and 2 billion by 2050. Many of the physiological changes associated with aging can be slowed down to some extent by eating a healthy diet and taking physical exercise, and many of the chronic diseases prevalent in older adults are either preventable or modifiable with healthy lifestyle habits. Thus, older adults can experience successful aging that allows them to achieve physical, social, and mental well-being over the life course and to participate in society.

Aging is associated with a physiological anorexia; as shown by NHANES III data, energy intakes between ages 25 and 70 years can decline by as much as 1000 to 1200 kcal/day for men and 600 to 800 kcal/day for women. By age 80, 1 in 10 men consumed less than 890 kcal/day whereas 1 in 10 women consumed less than 750 kcal/day (This decrease in appetite is influenced by multiple physiological changes. Much of the intake decrease in early old age is an appropriate response to decreased energy needs due to reduced physical activity and loss of lean body mass.

Other physiological changes associated with aging promote anorexia as follows:

- **Early satiety** develops with age, related to gastrointestinal changes (delayed gastric emptying and altered gastric distension) and gastric hormone changes; and increased cytokine activity.

- Senses of **taste** and **smell** tend to decline in later years. These changes in taste and smell may decrease one's appetite for foods to such an extent that the diet becomes unbalanced.
- **Vision** generally becomes poorer with age. As a result, shopping, cooking, and eating may become more difficult. These problems may result in decreased meal preparation.
- **Less saliva** may be produced with aging and foods are more difficult to swallow.
- **The loss of teeth** makes it difficult to eat and chew foods properly. This often leads to eating softer foods, which restricts food intake and can lead to an unbalanced diet.
- **Muscular tone** and coordination often decreases with aging. This may make swallowing difficult and causes food to move slower through the intestine. Older adults are primary targets for laxative advertisements. A well-balanced diet with a variety of foods, adequate fibre, fluids, and physical activity often help to combat constipation.
- A decrease in the amount of **acid in the stomach gastric juice** may occur with aging. This causes decreased digestion and a feeling of indigestion. Older adults may be tempted to take baking soda, which can further decrease the stomach acid content. **A decrease in the amount of digestive enzymes** may decrease tolerance of milk or high fat foods.
- A **decrease in strength and energy** may occur with increasing age. As a result, food purchasing, carrying heavy groceries, choosing from a wide variety of foods and preparing meals may become difficult.
- **Body composition changes** with age and the decline in lean body mass leads to decreased strength and mobility, poor balance and an increased frequency of falls. Conserving muscle mass in old age is therefore a strategy for preserving strength, and is of great significance in maintaining physical activity, retarding insulin resistance, and ensuring normal immune function, too. Preventing age-related decline in cognitive functions and maintaining good eye health into older age are both major challenges.

The importance of good nutrition among older people for the maintenance of health has long been advocated, and evidence-based dietary recommendations for older people have been published by the WHO. However, for a variety of functional, physiological, psychological, and social reasons older people are nutritionally vulnerable and frequently consume diets that are poor in both quality and quantity. This vulnerability often results in macronutrient and micronutrient undernutrition. Improving the diet of older people may be able to delay the initiation, or slow the progression, of cognitive decline.

The single most important clinical aspect leading to diagnosis of malnutrition is weight change and especially unintentional weight loss. More recently developed, the Mini Nutritional Assessment represents the most widely accepted and validated nutritional assessment tool for older people, regardless of setting, with clearly defined thresholds. Its aims are to evaluate the risk of malnutrition without the need for specialized personnel. **Malnutrition** is a dynamic phenomenon that starts when nutritional intakes are insufficient to match requirements. Most commonly, malnutrition is used to refer to inadequate intakes of energy and protein, but the same reasoning can be applied to other nutrients (e.g. specific lipids such as longchain polyunsaturated fatty acids, vitamins, and micronutrients).

The prevalence of **obesity** decreases in extreme old age, but remains a common problem in the elderly. Aging is accompanied by an increase in fat mass and a decrease

in lean mass. There are several explanations of increased fat mass: reduced physical activity and energy expenditure, reduced growth hormone secretion, diminished sex hormones, and decreased resting metabolic rate due to reduction of lean mass. Moreover, fat mass distribution changes with aging: there is an increased central distribution of fat (intra-hepatic and intra-abdominal), which is associated with insulin resistance and non-insulin-dependent diabetes mellitus. For the population as a whole, overweight and obesity are associated with increase in all-cause mortality, as well as morbidity related to diseases for which overweight and obesity are risk factors (such as hypertension, dyslipidaemia, diabetes, coronary heart disease, stroke, osteoarthritis, sleep apnoea, and some cancers).

Sarcopenia has been defined as the loss of muscle mass and strength that occurs with advancing age. It is a complex, multifactorial process facilitated by a combination of voluntary and involuntary factors. These include the aging process over the life course, less than optimal diet in older age, sedentary lifestyle, chronic diseases, and some drug treatments.

Hydration Disorders. With aging, there is a decline in total body water. Elderly people are more susceptible to dehydration than younger people for many reasons. Simple interventions such as regularly offering fluids to elderly people have been shown to significantly decrease the frequency with which dehydration develops**.**

To prevent above-mentioned complications in the elderly is a challenge facing developed and developing countries alike. Promoting healthy aging must become a major policy initiative globally.

Recommended dietary allowances for older people are presented in Tables 10–13.

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8 ALTERNATIVE NUTRITION

Alternative ways of nutrition recommend other types of nutrition than recommended in guidelines. They can have scientific background and health benefits, but some do not respect principles of evidence-based medicine.

The most widely used diet worldwide is a vegetarian diet, which we take as an example.

Vegetarian diet

If it is balanced, it has positive effects in disease prevention, but it assumes deep knowledge to prevent nutrient deficiency. Vegetarians usually have healthier attitudes overall; many vegetarians avoid tobacco, use alcohol in moderation, if at all, and are more physically active than other adults. When researchers take into account all the effects of a total health-conscious lifestyle on disease development, the evidence still often weighs in favour of vegetarian eating patterns.

Vegetarianism is the practice of abstaining from the consumption of meat (red meat, poultry, seafood and the flesh of any other animal), and may also include abstention from animal by-products. Many millions of people have become vegetarians, replacing meats as a main item of protein with legumes, grains, and vegetables. It is therefore needed to achieve the necessary balance of essential amino acids. According to the American Dietetic Association, vegetarian diets that are appropriately planned and monitored are healthful and nutritionally adequate, and may provide health benefits in disease prevention and treatment.

Vegetarians tend to have higher fibre intakes than omnivores. The high fibre and low fat content of vegetarian foods are beneficial, and can result in decreased energy intake. Dietary protein may be used for energy, thus negatively affecting protein status. High intakes of grains containing anti-nutrients can decrease intestinal absorption of iron, calcium, and zinc. The most common deficiencies include vitamins B12 and D, calcium, iron, zinc, iodine, riboflavin, and essential fatty acids. Strict vegetarians acquire also very little carnitine in their diets.

Both lacto-ovo-vegetarians and meat eaters can generally rely on their diets **during critical times of life** (particularly pregnant women, infants, children, adolescents, and the elderly). Vegetarians have to be careful also to get enough kcal generally, but especially pregnant women and children. **During pregnancy**, nutrient needs for vegetarians are the same as for non-vegetarians except for a higher recommendation for iron intake. Analysis of available studies suggests that pregnant vegetarians consume lower levels of protein, vitamin B_{12}, calcium, and zinc, but no evidence indicates detrimental outcomes for mother or foetus. Vegetarian diets can be planned in order to meet the needs for all nutrients, with special attention to vitamin B_{12}, vitamin D, calcium, iron, and zinc. Women - lacto-ovo-vegetarians who consume also some animal products usually get enough proteins and other essential nutrients for a successful pregnancy, but occasionally uses of supplements are recommended to take in order to cover their extra nutritional needs.

Children and adolescents have a variety of motivations for following a vegetarian diet. Some are members of vegetarian families. Others cite an assortment of reasons, including health, animal welfare, and environmental concerns. There are numerous health benefits for adults following a vegetarian diet, including a lower body mass index (BMI), reduced risk of cardiovascular disease, lower blood pressure and lower rates of hypertension, reduced risk of type 2 diabetes, and a lower risk for prostate and colorectal cancers. Less is known about benefits for vegetarian children. Vegetarian children do tend to be leaner than nonvegetarian children are. Positive food patterns of vegetarian adolescents include greater consumption of fruits, vegetables, nuts, and legumes and lower consumption of sweets, fast food, and salty snack foods. In addition, diets of vegetarian children and adolescents tend to be lower in cholesterol, saturated fat, and total fat and higher in fibre than diets of nonvegetarians are. Key nutrients for vegetarian children and adolescents include protein, iron, zinc, calcium, vitamin D, vitamin B12, and omega-3 fatty acids. In the nonvegetarian diet, these nutrients are frequently largely obtained from animal products, so questions have been raised about their adequacy in vegetarian or vegan diets.

The meals of vegetarians follow a variety of patterns. This concerns the following types of vegetarians:

Vegans who rely only on plant foods.

Fruitarians who eat only fresh and dried fruits, nuts, some vegetables, seeds, honey, and sometimes olive oil.

Lacto-vegetarians, as the only allowed animal protein comes from milk, cheese and other dairy products.

Ovo-vegetarians who use eggs as their only source of animal protein.

Lacto-ovo-vegetarians, a food plan consisting of plant food plus diary products and eggs.

Pescetarians (Quasi-vegetarians) whose diet excludes beef, pork, poultry, includes mosty plant foods, fish, dairy products and eggs.

Semi-vegetarian (Flexitarians) whose diets consist largely of vegetarian foods, but may include fish or poultry, or sometimes other meats, on an infrequent basis.

"Far" vegetarians who eat mostly vegetarian diet, occasionally eat meat, but exclude red meat.

To find much more different advice is possible in the USDA National Agriculture Library's Vegetarian Nutrition Resource List.

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Table 10 *Recommended Dietary Allowances for Adults/Females (9th Revision) – Basic Table (Source: Kajaba et al., 2015)*

Nutritional factor		Working females 19–34y			Females 19–51y		Working females 35–62y			Not working females	
		Light work	Medium work	Hard work	Pregnant until 2nd trimester	Breast feeding	Light work	Medium work	Hard work	65 (63) – 79y	80y + more
Energy	kJ	9200	10300	11300	10900	12100	8800	9600	10900	8200	7700
	kcal	2200	2450	2700	2600	2900	2100	2300	2600	1950	1850
Proteins	g	58	63	70	80	80	57	60	68	56	55
Fats	g	75	85	92	87	97	72	80	90	68	65
PUFA n-6 (linoleic ac.)	g	6.3	7.0	7.7	7.6	8.2	6.0	6.5	7.3	5.5	5.3
PUFA n-3: ALA (alfa-linolenic ac.)	g	1.0	1.1	1.3	1.4	1.5	0.9	1.0	1.2	0.8	0.7
DHA + EPA	mg	350	350	350	400	350	350	350	350	350	350
PUFA n-3 together	g	1.4	1.5	1.7	1.8	1.9	1.3	1.4	1.6	1.2	1.1
Cholesterol	mg	300	350	350	450	400	300	300	350	300	300
Carbohydrates	g	324	358	398	375	427	306	335	380	279	262
Calcium	mg	1000	1100	1200	1400	1600	1000	1100	1200	1200	1200
Iron	mg	15	17	18	30	22	15	16	17	14	10
Vitamin A	µg	800	900	950	1100	1300	800	850	900	800	800
Vitamin B_1	mg	1.1	1.3	1.4	1.4	1.5	1.1	1.2	1.3	1.,0	1.0
Vitamin B_2	mg	1.3	1.5	1.7	1.6	1.7	1.3	1.4	1.5	1.2	1.2
Vitamin C	mg	100	110	120	120	150	95	100	110	100	100
Vitamin E	mg	15	16	17	16	19	14	15	16	14	14
Proteins	E %	10.5	10.3	10.4	12.3	11.0	10.8	10.4	10.5	11.5	11.8
Fats	E %	30.7	31.2	30.7	30.1	30.1	30.9	31.3	31.2	31.4	31.6
Carbohydrates	E %	58.8	58.5	58.9	57.6	58.9	58.3	58.3	58.3	57.1	56.6

Table 11 *Recommended Dietary Allowances for Adults/Females (9th Revision) – Additional Table (Source: Kajaba et al., 2015)*

Nutritional factor		Working females 19–34y			Females 19–51y		Working females 35–62y			Not working females	
		Light work	Medium work	Hard work	Pregnant until 2nd trimester	Light work	Medium work	Hard work	Pregnant until 2nd trimester	Light work	Medium work
Fibre	g	24	26	27	26	28	24	25	26	22	20
Magnesium	mg	300	320	350	350	330	300	300	320	300	300
Phosphorus	mg	700	800	800	900	1000	700	800	800	700	700
Zinc	mg	8	10	11	11	12	8	9	10	7	7
Copper	µg	1000	1200	1400	1100	1300	900	1000	1200	900	900
Chromium	µg	100	130	150	150	180	80	100	130	75	70
Selenium	µg	50	50	55	65	70	50	50	55	50	50
Iodine	µg	150	150	150	250	250	150	150	150	150	150
Vitamin B_6	mg	1.3	1.5	1.6	1.9	1.9	1.2	1.4	1.5	1.2	1.2
Vitamin PP (niacin)	mg	13	15	16	18	17	13	15	15	13	13
Pantothenic Ac.	mg	5	7	7	6	7	5	6	6	5	5
Folacin	µg	400	400	400	600	500	400	400	400	400	400
Vitamin B_{12}	µg	2.4	2.4	2.5	2.6	2.8	2.4	2.4	2.4	2.4	2.4
Vitamin D_3	µg	15	15	17.5	20	20	15	15	17.5	20	20
β-carotene	mg	90	90	95	100	100	90	90	90	90	90
Vitamin K	µg	5	6	7	8	10	4	5	6	5	5

Table 12 *Recommended Dietary Allowances for Adults/Males (9th Revision) – Basic Table (Source: Kajaba et al., 2015)*

Nutritional factor		Working males 19–34y			Working males 35–62y			Not working males	
		Light work	Medium work	Hard work	Light work	Medium work	Hard work	65(63)–79y	80y+more
Energy	kJ	11000	11700	13400	10000	11300	12500	9200	8200
kcal		2550	2800	3200	2400	2700	2950	2150	1950
Proteins	g	70	75	80	67	72	78	62	60
Fats	g	85	95	112	80	92	100	75	70
PUFA n-6 (linoleic ac.)	g	7.3	8.0	9.2	6.9	7.7	8.5	6.2	5.6
PUFA n-3: ALA (alfa-linolenic ac.)	g	1.2	1.4	1.7	1.1	1.3	1.5	1.0	0.8
DHA + EPA	mg	350	350	350	350	350	350	350	350
PUFA n-3 together	g	1.6	1.8	2.1	1.5	1.7	1.9	1.4	1.2
Cholesterol	mg	300	350	400	300	300	350	300	300
Carbohydrates	g	377	415	468	353	397	435	307	270
Calcium	mg	1000	1200	1300	1000	1100	1200	1200	1200
Iron	mg	10	11	12	9	10	11	10	10
Vitamin A	µg	1000	1000	1000	1000	1000	1000	1000	1000
Vitamin B_1	mg	1.2	1.3	1.4	1.2	1.3	1.3	1.1	1.1
Vitamin B_2	mg	1.4	1.5	1.6	1.4	1.5	1.5	1.2	1.2
Vitamin C	mg	100	120	130	100	110	120	100	100
Vitamin E	mg	15	16	18	14	15	17	15	15
Proteins	E %	10.9	10.3	10.0	11.2	10.6	10.6	11.5	12.3
Fats	E %	30.0	30.5	31.5	30.0	30.6	30.5	31.4	32.3
Carbohydrates	E %	59.1	59.2	58.5	58.8	58.8	58.9	57.1	55.4

Table 13 *Recommended Dietary Allowances for Adults/Males (9th Revision) – Additional Table (Source: Kajaba et al., 2015)*

Nutritional factor		Working males 19–34y			Working males 35–62y			Not working males	
		Light work	Medium work	Hard work	Light work	Medium work	Hard work	Light work	Medium work
Fibre	g	26	30	32	25	28	30	24	22
Magnesium	mg	400	400	420	410	410	420	420	420
Phosphorus	mg	700	700	700	700	700	700	700	700
Zinc	mg	10	14	16	10	12	14	10	10
Copper	µg	1400	1600	1800	1200	1400	1600	1200	1200
Chromium	µg	40	40	40	35	130	150	100	100
Selenium	µg	70	70	85	65	65	75	65	65
Iodine	µg	160	160	180	150	150	160	150	150
Vitamin B_6	mg	1.5	1.7	1.9	1.3	1.5	1.8	1.5	1.4
Vitamin PP (niacin)	mg	17	19	22	16	17	19	15	14
Pantothenic Ac.	mg	7	8	8	6	7	7	6	6
Folacin	µg	400	400	400	400	400	400	400	400
Vitamin B_{12}	µg	2.6	2.6	2.7	2.5	2.5	2.6	2.5	2.5
Vitamin D_3	µg	15	15	17,5	15	15	17.5	20	20
β-carotene	mg	120	120	130	120	120	125	110	110
Vitamin K	µg	6	7	8	5	6	7	6	6

Table 14 *Recommended Dietary Allowances for Children and Youth (9th Revision) – Basic Table (Source: Kajaba et al., 2015)*

Nutritional factor	Infants months		Children toddler/ preschool years		Schoolchildren years			Adolescents boys years		Adolescents girls years	
					7–10	11–14		15–18		15–18	
	0–6	7–12	1–3	4–6		boys	girls	studying	physically more active	studying	physically more active
Energy kcal/kg	95	90	90	80	72	60	55	50	58	42	53
kJ/day	2300	3100	5000	6900	8800	10700	10300	12600	15500	10000	12100
kcal/day	550	750	1200	1650	2100	2550	2450	3000	3700	2400	2900
Proteins g	12	16	25	35	53	64	62	75	90	60	70
Physical Activity (PAL)	1.4	1.4	1.4	1,5	1.6	1.7	1.8	1.7	2.1	1.65	2.0
Fats g	29	36	48	63	78	87	82	100	125	82	97
PUFA n-6 (linoleic ac.)* g	2.5	3.0	3.4	4,6	5.9	7.2	6.9	8.7	10.4	6,8	8.2
PUFA n-3**: ALA (alfa-lino lenic ac.) g	0,3	0,4	0.4	0.7	1.0	1.3	1.3	1.7	1.9	1.2	1.6
DHA mg	100	100	250	250	250	250	250	250	250	250	250
PUFA n-3 together g	0.4	0.5	0.7	1.0	1.3	1.6	1.6	2.0	2.2	1.5	1.9
Cholesterol mg	270	250	250	250	300	350	400	400	450	350	400
Carbohydrates g	60	91	167	236	297	378	367	450	554	354	437
Calcium mg	300	400	600	700	900	1200	1300	1300	1500	1200	1400
Iron mg	7	10	8	9	10	12	16	12	15	15	18
Vitamin A µg	500	600	600	700	800	1000	1000	1100	1300	900	1100
Vitamin B_1 mg	0.3	0.4	0.6	0.8	1.0	1.3	1.2	1.3	1.5	1.1	1.3
Vitamin B_2 mg	0.4	0.5	0.7	0.9	1.1	1.5	1.3	1.5	1.7	1.2	1.5
Vitamin C mg	50	55	60	70	80	90	100	100	130	90	120
Vitamin E mg	4	5	6	8	10	13	14	15	18	14	17
Proteins E %	8.7	8.5	8.3	8.5	10.1	10.0	10.1	10.0	9.7	10.0	9.7
Fats E %	47.5	43.2	36.0	34.4	33.4	30.7	30.1	30.0	30.4	30.7	30.1
Carbohydrates E %	43.8	48.3	55.7	57.1	56.5	59.3	59.8	60.0	59.9	59.3	60.2

In 0–6-month-old children average weight is 6.4 kg (+ 1SD **6.9** *kg) in 7–12-month-old children average weight is 5 kg (+ 1SD* **10.3** *kg)*

+ average weight x + 1SD kg % E from n-6: for 0–6-month-old 4%, for 7–12-month-old 3.5%, for 1–3-year-old 3% for the others 2.5 %*

*** % E from n-3: for all physiological groups 0.5 %*

Table 15 *Recommended Dietary Allowances for Children and Youth (9th Revision) – Additional Table (Source: Kajaba et al., 2015)*

Nutritional factor	Infants months		Children toddler/ preschool years		Schoolchildren years			Adolescents boys years		Adolescents girls years	
						11–14		15–18		15–18	
	0–6	7–12	1–3	4–6	7–10	boys	girls	studying	physically more active	studying	physically more active
Fibre g	1*	3	10	14	17	20	18	22	25	18	22
Magnesium mg	30	60	80	120	200	300	330	400	430	350	380
Phosphorus mg	200	300	400	500	800	1000	1100	1200	1400	1100	1300
Zinc mg	2	3	4	5	7	10	10	12	15	9	12
Copper µg	200	500	600	800	1000	1200	1300	900	950	850	900
Chromium µg	5	10	20	20	25	30	35	35	45	30	40
Selenium µg	10	15	20	25	35	40	45	60	70	55	65
Iodine µg	60	70	90	100	120	130	140	150	150	150	150
Vitamin B_6 mg	0.2	0.4	0.6	0.8	1.2	1.4	1.6	1.8	2.0	1.7	1.9
Vitamin PP (niacin) mg	3	5	8	10	12	14	15	16	18	14	16
Pantothenic Ac. mg	2	3	4	4	5	6	6	6	7	5	6
Folacin µg	70	80	150	200	250	300	350	400	470	400	450
Vitamin B_{12} µg	0.4	0.8	1.0	1.5	1.8	2.5	3,0	3.0	3.5	2.5	3.0
Vitamin D_3 µg	10	10	15	15	15	15	20	20	25	17.5	20
β-carotene mg	0.4	0.7	1.0	1.5	2.0	2.5	3.0	3.5	5.0	3,0	4.0
Vitamin K µg	4	10	15	20	30	40	50	70	80	60	70

** 4–6-month-old children*

9 DISEASES RELATED TO DIET AND THEIR PREVENTION, EATING DISORDERS

The nutritional quality and quantity of foods eaten, and therefore nutritional status, are major modifiable factors in promoting health and well-being, in preventing diseases, and in treating some diseases.

It is now widely accepted that **our nutritional status influences our health** and risk for both infectious and non-communicable diseases**.**

9.1 Diseases Related to Diet and their Prevention

In developed countries excessive intakes of macronutrients (overnutrition) and suboptimal intakes of micronutrients (hidden hunger), mainly because of low fruit and vegetable consumption, lead to obesity and related non-communicable diseases (NCDs).

Developing countries are suffering from a double burden of disease because of the persistence of undernutrition and related deficiency and infectious diseases (including human immunodeficiency virus/acquired immunodeficiency syndrome HIV/AIDS), and the emergence of NCDs as a result of the nutrition transition. It explains the vicious cycle of poverty and undernutrition and how this is related to underdevelopment and increased risk for NCDs in the developing world.

Chronic diseases may well originate in childhood and nutrition during these early periods may have long-lasting consequences. Tissues may be particularly susceptible to the influence of nutrients during periods of growth, the effect of diet may be cumulative, and the long-term impact may only translate into disease decades later. There is a need to examine diets at various times in life and with long follow-up, especially for studies of cancer.

Malnutrition

Malnutrition in developing countries affects individuals throughout the life course: from birth to infancy and childhood, through adolescence into adulthood, and into old age. Malnutrition affects, therefore, critical periods of growth and mental development, maturation, active reproductive as well as economical productive phases.

- 161 million children under 5 are stunted (low height-for-age). Stunting is irreversible, and has severe consequences for health and development.
- 2 billion people – around 1/3 of the developing world population – suffer from vitamin or mineral (micronutrient) deficiencies.
- 42 million children under 5 are overweight. More than 500 million adults are obese.
- Malnutrition (hunger, micronutrient deficiencies and obesity) costs an estimated $2.8-3.5 trillion, or 4-5% of global GDP. That is $400-500 per person.

- 99 million children under 5 are underweight (low weight-for-age) with severe consequences for health and the development of individuals and society.
- Micronutrient deficiencies lead to poor growth and ill health, including blindness, brain damage, and early death.
- Unhealthy diet and lack of exercise account for almost 10% of global disease and disability burden.
- 200 million fewer people are undernourished today than 20 years ago, but 805 million people still go to bed hungry every day – that is 1 in 9 people.

Non-communicable diseases (NCDs)

The type of diet prevailing in the developed countries is characterized by an excess of energy-dense foods, rich in fat and free sugars, but a deficiency of complex carbohydrate foods (the main source of dietary fibre). Research and practice have demonstrated close and consistent relationships between the establishment of this type of diet and the emergence of a range of different diseases.

The complex chain of events where behavioural and lifestyle factors influence the development of the biological risk factors for NCDs, emphasizes the need for a multisectorial approach in which all factors in the chain are targeted throughout the life course.

CVD (Cardiovascular disease), Coronary heart disease (CHD). Lipids and lipoproteins play a key role in the development of coronary heart disease. Epidemiological studies carried out in middle-aged men provide clear evidence that the risk of coronary heart disease is increased by major factors: high serum total cholesterol, high blood pressure, obesity, and cigarette smoking. The presence of several risk factors, simultaneously, increases the risk for the disease. A variety of different dietary patterns to manage lipids and lipoproteins provide options to target specific CHD risk factors. A recommendation to maintain normal BMI, a diet high in complex carbohydrates, low intake of industrially synthesized TFAs (trans fats) and SFA (saturated fatty acids), law salt intake, minimizing of the alcohol intake is important for preventing the disease. There is strong and consistent evidence in support of the association between intake of polyunsaturated fatty acids (PUFAs) and an improvement in blood lipids, particularly when PUFAs replace SFAs and TFAs in the diet.

The acceptable macronutrient distribution range (AMDR) for carbohydrate (45 – 65 % of energy) promotes achieving nutrient adequacy and attaining a healthy lipid and lipoprotein profile. Minimally processed plant sources of carbohydrate, such as whole grains, legumes, fruits, and vegetables, are an integral part of the dietary recommendations to reduce CVD risk. Some bioactive compounds, found in small quantities in plant-based foods, may exhibit antioxidant, antithrombotic, and/or anti-inflammatory properties. Higher-protein diets (22– 34% of energy), both isocaloric and calorie - restricted, have demonstrated favourable effects on body composition and CVD risk factors. Further intervention studies are needed to investigate the safety, efficacy, and feasibility of long-term adherence to high-protein/low - carbohydrate diets.

Obesity. Prevalence rates of obesity have escalated worldwide over the past 3 decades, both in developed and developing countries**.** As it has a multifactorial origin, from a public health point of view, the challenge is to modify, first of all, the populations' environment with increasing of the physical activity and providing an adequate diet. Dietary composition is a key factor in total energy intake with energy-dense foods providing less satiety than foods with a low energy density; this can encourage passive overconsumption.

Non-insulin-dependent diabetes mellitus. Approximately 80% of patients are obese and therefore the most rational approach to preventing this disease is to prevent

obesity. Physical activity not only improves glucose tolerance by reducing overweight, but also acts independently by having a beneficial effect on insulin metabolism. Many individuals with type 2 diabetes have also dyslipidaemia and hypertension, so decreasing intakes of saturated fat, cholesterol, and sodium should also be a priority. Several meta-analyses and reviews have concluded that Mediterranean-style diets, low-glycemic-index (GI) or low-glycemic-load (GL) diets, and low-carbohydrate, high-protein diets may be more effective (or just as effective) for improving components of the insulin resistance syndrome as traditional low- fat, high-carbohydrate diets. On the other hand the GI or GL values of a food do not meaningfully improve carbohydrate selection, and it is suggested that consumers ultimately focus on caloric intake, caloric density, and fiber content.

High blood pressure and cerebrovascular diseases. The risk of both coronary heart disease and stroke increases as blood pressure rises. There is a fivefold difference in CHD and a tenfold difference in risk of stroke over a range of diastolic blood pressure of 40 mmHg (5.33 kPa). A high body mass index (Body Mass Index = weight in kg/height in m^2) and high alcohol intake have strong, independent effects on blood pressure. Salt intake has a significant negative effect on the rise of blood pressure. Several studies suggest lower blood pressures among vegetarians than non-vegetarians.

Cancer. Cancer is a general term that represents more than 100 diseases, each with their own aetiology. The probability of suffering from cancer is extremely high. Cancer risk is influenced by both genetic and environmental factors, including dietary habits. Evidence continues to mount that dietary habits can significantly influence one's cancer risk and/or tumor behaviour. Some epidemiologists estimate that 30–40% of cancers in men and up to 60% of cancers in women are attributable to diet. Overweight (BMI > 25 kg/m^2) and obesity (BMI > 30 kg/m^2) are associated with increased risk for many, but not all, common cancers. So one of the most important ways to reduce overall cancer risk is to maintain a healthy weight throughout life. Studies indicate that increased consumption of fruits, vegetables, and whole grains is associated with reduced cancer risk. Therefore, it is recommended eating mostly foods of plant origin (at least five portions/servings = 400–600 g) of a variety of vegetables and fruits every day; eating whole grains and/or pulses (legumes); and limiting refined starchy foods. Alcohol consumption has been associated with an increased risk for some cancers. The responses to food and/or food components, which may be inhibitory or stimulatory, depending on the specific bioactive food component, are mediated through one and likely multiple, biological mechanisms. The identification and elucidation of the specific molecular sites of action for food components are critical for identifying those who will benefit maximally or be placed at risk from a particular dietary change. Until this information is available, it remains prudent to eat a variety of foods and to maintain a healthy weight through appropriate caloric intake and regular exercise.

Cancers of the oral cavity, pharynx, larynx, and oesophagus. In developed countries, the results of studies indicate that drinking alcoholic beverages is causally related to cancers of mouth, pharynx, oesophagus, and upper part of the larynx. There are also positive associations between oesophageal cancer and several dietary factors, including low intakes of green vegetables, fresh fruits, animal proteins, vitamins A and C, riboflavin, nicotinic acid, magnesium, calcium, zinc and molybdenum, high intakes of pickles, and mouldy foods containing N-nitroso compounds.

Stomach cancer. A high incidence of stomach cancer is found in Japan and other parts of Asia and in South America, but not in North America and Western Europe where the rates are low and still decreasing. These diseases are associated also with diets comprising large amounts of smoked and salt-preserved foods (which may contain precursors of nitrosamines). Total, red and processed meat intakes are associated with

an increased risk of gastric noncardia cancer, especially in *H. pylori* antibody-positive subjects. Although there is no clear association between fruit/vegetables and risk of gastric cancer, there is an evidence of a lower risk of GC with higher plasma levels of micronutrient such as vitamin C and carotenoids.

Colorectal cancer. Diets low in fibre-containing foods and high in fat increase the risk of colon cancer. Several studies also demonstrate positive associations between the risk for colorectal (primarily colon) cancer and dietary fat (saturated rather than unsaturated fatty acids), protective effect of fibre and dairy products.

Female breast cancer. Correlation studies provide evidence of a direct association between breast cancer mortality and the intake of high kJ diet and specific sources of dietary fats (e.g. milk and beef).

Endometrial cancer. Specific dietary factors, other than obesity, have not been identified for this disease.

Prostate cancer. Analyses show positive correlations between mortality from prostate cancer and total intake of food, excessive amount of milk and dairy products in diet.

Evidence indicates that a diet low in saturated fats, trans-fats, high in plant foods (especially green and yellow vegetables and citrus fruits), and low in alcohol, salt-pickled, smoked, and salt-preserved foods is consistent with a low risk of many of the current major cancers (cancer of the colon, prostate, breast, stomach, and oesophagus).

Osteoporosis. Advances in understanding of the roles of nutrient requirements for bone health in older populations have been achieved over the last decade. Calcium needs have been established as more critical than other single nutrients as determined by several meta-analyses of randomized controlled trials. Several other nutrients, including phosphorus, vitamin D, vitamin K, and protein, remain important for bone health and the prevention or delay of osteoporosis and fragility fractures. Healthy diets providing balanced intakes of all nutrients continue to be the preferred way to promote bone health of older adults along with other healthy lifestyles, such as participating in routine physical activities, not smoking, and consuming only moderate amounts of alcohol per day, if any. Physical activity helps maintain muscle mass, equilibrium/balance, and the general overall health of organ systems.

Dental caries. Dental caries is a very common health problem affecting a large proportion of people. There is a direct relationship between the quantity and a sucrose consumption and development of caries (very little incidence of caries, when the sugar consumption is below 10 kg/person yearly and steep increase may occur from 15 kg upwards).

Gastrointestinal disorders. Specific disease states for which nutrition has a profound role in medical and/or surgical management include diseases that affect the esophagus (eosinophilic esophagitis and gastroesophageal reflux disease), the small intestine (celiac disease, inflammatory bowel disease, and intestinal failure), and the pancreas (acute and chronic pancreatitis). In some cases, nutrition may have a role in the pathogenesis and treatment of disease (eosinophilic esophagitis, gastroesophageal reflux disease, celiac disease, and Crohn's disease), and in others nutritional issues arise as a result of the disease (Crohn ' s disease, celiac disease, intestinal failure, and pancreatitis).

Chronic kidney disease (CKD). The kidneys play a key role in maintaining fluid and electrolyte homeostasis, in excretion of metabolic waste products, and in the regulation of various hormonal and metabolic pathways. Even a slight reduction in renal function may therefore have metabolic and nutritional consequences.

Eye diseases. There is biological plausibility for a relationship between certain nutrients and certain eye diseases. Nutrition can have a strong impact on eye diseases

such as **cataract, age -related macular degeneration (AMD), and retinitis pigmentosa (RP),** which together account for 60% of blindness worldwide. High dietary intake of vitamins C and E, starting early in life, may prevent the incidence of age -related nuclear cataracts as well as AMD.

Lutein and zeaxanthin intake may protect against nuclear and posterior subcapsular cataract (PSC), while vitamins B 1, B 2, B 3, and folate may protect against nuclear and cortical cataract.

The immune system provides the body with a major defence against environmental assaults, particularly invasion by microorganisms and spontaneously arising neoplasms. A variety of chemicals commonly found in the workplace and widely distributed in the environment has induced changes in the immune system. Immunosuppression may be associated with severe infection and cancer whereas immunopotentiation may be associated with allergic or autoimmune diseases. Nutrition, through its modulation of specific and non-specific immune responses, is a critical determinant of optimum immune function. Both severe and moderate nutritional deprivations are associated with impaired immune responses and malnutrition is the most frequent cause of immunodeficiency throughout the world. It is very important that correction of nutritional deficiencies improves the immune function and so enhances the body's defence against environmental loads.

A **food allergy (FA)** is an allergic reaction to a particular food. Many different foods can cause allergic reactions. Most commonly they are triggered by certain nuts, peanuts, shellfish, fish, milk, eggs, wheat, and soybeans. Additives such as monosodium glutamate, metabisulphite, and tartrazine can cause allergy. Allergic reactions to foods may be severe and sometimes include an anaphylactic reaction. FA are most common among children whose parents have food allergies, allergic rhinitis, or allergic asthma. Food allergens are sometimes also blamed for such disorders as hyperactivity in children, chronic fatigue, arthritis.

Food intolerance differs from a food allergy in that it does not involve the immune system. Instead, it involves a reaction in the digestive tract that results in digestive upset.

The most important general recommendations about healthy lifestyle/diet are as follows:

- Staying lean and physically active throughout adult life has major health benefits.
- Diets low in the percentage of energy from fat have not been associated with lower risks of heart disease, cancer, or better long-term weight control. Fat intake (%E): SFA <7%; TFA <1%; 6–10% of PUFAs (n -6: 5 –8%, n -3: 1–2%); MUFAs ≈15–30% is recommended.
- Avoiding industrially produced transfat, keeping saturated fat low, and emphasizing unsaturated fats will minimize risks for heart disease and type 2 diabetes.
- High intake of fruits and vegetables help to prevent risks for cardiovascular disease- 400 –500g/day is recommended to reduce the risk of CHD, stroke and high blood pressure.
- Consuming grains in their original high fibre/whole grain form is likely to reduce risk for type 2 diabetes and heart disease.
- Consumption of sugary beverages increases risk for type 2 diabetes and probably heart disease.
- Various components found in red and processed meat products increase risk for developing type 2 diabetes.
- Restrict daily salt (sodium chloride) intake to less than 5 g/day; minimize other forms of sodium consumption through food additives and preservatives, such as

monosodium glutamate (MSG); 1.7 g of sodium per day is beneficial in reducing blood pressure and is not associated with adverse effects.
- Regular fish consumption, as consumed on a weekly basis - consumption of fish and other marine foods should provide over 200mg/day of DHA and EPA.
- High consumption of alcohol have many adverse health and social consequences, and intakes as low as one drink per day or less are associated with greater risks for breast cancer.

9.2 Eating Disorders

Eating disorders are characterised by an abnormal attitude towards food that causes someone to change their eating habits and behaviour. A person with an eating disorder may focus excessively on their weight and shape, leading them to make unhealthy choices about food with damaging results to their health.

Eating disorders can affect persons of all shapes and sizes. Eating disorders range from severe caloric restriction to severe overeating - from extremes in underweight, across the spectrum of normal weight up to the extremes of obesity, underlying nutritional, psychological, and medical effects of eating disorders can be found.

Eating disorders include:
- **pica syndrome,**
- **rumination disorder,**
- **avoidant/restrictive food intake disorder (ARFID),**
- **anorexia nervosa (AN),**
- **bulimia nervosa (BN),**
- **binge eating disorder (BED),**
- **feeding and eating conditions not elsewhere classified (FEC-NEC; atypical anorexia, subthreshold BN, purging disorder, and night eating syndrome)**.

Pica syndrome involves:
1. persistent eating of non-nutritive, non-food substances over a period of at least 1 month
2. eating is inappropriate to the developmental level of the individual
3. eating is not part of a culturally sanctioned practice
4. if the eating behaviour occurs in the context of another mental disorder, it is sufficiently severe to warrant independent clinical attention.

Rumination disorder is described as repeated regurgitation of food over a period of at least 1 month. The regurgitated food may be re-chewed, re-swallowed, or spit out.

ARFID consists of an eating or feeding disturbance in which there is a persistent failure to meet expected nutritional and/or energy needs associated with at least one of the following features:

1. significant weight loss or disturbance in growth curves in growing children
2. significant nutritional deficiency
3. dependence on enteral feeding
4. marked interference with psychosocial functioning.

The hallmark of **BED** is eating large amounts of food, accompanied by a loss of control. Additionally, at least three of the following five signs must be present during binge-eating episodes:

1. eating more rapidly than normal
2. eating until uncomfortably full
3. eating when not physically hungry
4. eating alone due to embarrassment
5. feeling disgusted, depressed, or markedly guilty after an episode.

Anorexia Nervosa

The first core feature is a refusal to maintain a minimally normal body weight for age and height. For adolescents and children, lack of weight gain, rather than active weight loss, would also be an appropriate measure. The second criterion describes an intense fear of gaining weight or persistent behavior that prevents weight gain. The third requires a distortion in the way that body weight and shape are viewed or a "persistent lack of recognition of the seriousness of the low body weight". Amenorrhea lasting >3 months has been a diagnostic criterion in the past. However, women on hormonal birth control, girls who have not reached menarche, and men are not able to apply this criterion.

The restricting type is classified by the strict use of caloric restriction and excessive exercise as a means of controlling their weight.

The binge eating/purging subtype describes those who engage in binge eating or inappropriate compensatory measures, such as vomiting or misuse of laxatives, diuretics, or enemas.

Almost every physical system is negatively impacted by AN and it is considered the deadliest psychiatric disorder.

Bulimia Nervosa

The core features of BN are binge eating and the subsequent use of inappropriate compensatory behaviors (occur at least once/week for at least 3 months). These behaviors are used in an attempt to attain a low body weight or prevent weight gain. Inappropriate compensatory behaviors consist of various forms of purging, restricting, and excessive exercise. Purging behaviors most often consist of vomiting and laxative abuse. Most persons with BN have a BMI in the healthy weight range, with some in the overweight and obese ranges.

There are many forms of disordered eating that are serious and cause psychological and physical distress but that do not fit the diagnostic criteria.

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10 FUNCTIONAL FOODS WITH POTENTIAL HEALTH BENEFIT

"**Functional foods**" **(FF) are foods and food components that provide health benefits beyond basic nutrition.**

"Functional foods" lack any standard definition despite their worldwide promotion and growth as a category of food.

FF are whole or modified foods that contain bioactive food components. Usually we recognise two groups of functional foods:

1. **Conventional fresh whole foods**, unprocessed, and unrefined. These are the simplest and most cost-effective forms of healthful functional foods that may be found in various grains, vegetables, fruits, seeds, nuts, milks, eggs, and fish.

2. Artificially produced foods - In characterizing this broad range of functional foods, the American Dietetic Association (ADA) describes these as including "**conventional foods**" (e.g. probiotic yogurts), "**modified foods**" that have been fortified or enriched (e.g. calcium fortified orange juice), "**medical foods**" that aid in the dietary management of a disease (e.g. diabetic beverage formulations), and "**foods for special dietary use**" sold at the retail level (e.g. gluten-free cookies).

It is the position of the Academy of Nutrition and Dietetics to recognize that although all foods provide some level of physiological function, **the term functional foods is defined as whole foods along with fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective levels based on significant standards of evidence.**

Selected "functional foods" with potential bioactive ingredient they contain are shown in Table 16. However, a lot of different nutritious foods can support health in some ways.

Table 16 *Examples of some "functional foods" and potential bioactive ingredients they contain (Source: Modern Nutrition in Health and Disease, 2014)*

Suspected health–promoting functional food	Potential bioactive ingredient	Suspected health–promoting functional food	Potential bioactive ingredient
Bluberries	*Polyphenols*	**Nuts**	*Flavonoids*
Tomatoes	*Lycopene*	**Fish**	*n-3 fatty acids*
Mushrooms	*Beta-glucans*	**Soy**	*Genistein, dadzein, equol*
Broccoli	*Sulphoraphane*	**Oats and other grains**	*Fiber, glucan, flavonois*
Garlic	*Allyl sulphur*	**Green tea**	*Catechins*

The links between several "functional foods" and health continue to mount. However, a clear understanding of the impacts of dietary exposure on the health of individuals is still

evolving. "Functional foods" must be considered in the context of the other constituents of the diet as well as the consumer's genetics and environmental exposures.

"Functional foods" do more than simply provide nutrients because they assist in maintaining health and thereby reducing the risk of disease. These foods represent a continuum of items that contain ingredients or natural constituents in conventional, fortified, enriched, and enhanced foods. The FDA (the Food and Drug Administration) does not officially recognize the term "functional food". Nevertheless, the FDA does regulate these foods according to whether it is considered a conventional food, a food additive, a dietary supplement, a medical food, or a food for special dietary use.

Both effect **biomarkers**, which predict a change in the true molecular targets (effect biomarker), and susceptibility biomarkers, which identify nutrient-nutrient and nutrient-gene interactions, will be needed to evaluate functional foods and nutraceuticals (nutrient with a drug-like action) adequately.

Oxidative stress can cause oxidative damage to large biomolecules such as proteins, DNA, and lipids, resulting in an increased risk for cancer and CVD. To prevent or slow down the oxidative stress induced by free radicals, sufficient amounts of antioxidants need to be consumed.

Although there are many thousands of compounds in the plant kingdom, only a handful are present in significant amounts in the diet of most humans. Over the last 20 years, there has been an enormous and growing interest in this class of compounds, which have also been referred to as **polyphenols, phytonutrients, non-nutrients, protective factors, dietary bioactives, and phytochemicals**.

A large body of evidence has reported that numerous **bioactive compounds** reduce CHD risk through a variety of mechanisms, many of which are non-lipid related. Bioactive compounds, found in small quantities in plant-based foods, may exhibit antioxidant, antithrombotic, and/or anti-inflammatory properties. Some compounds may also protect against several forms of cancer.

Phytochemicals are defined as bioactive non-nutrient plant compounds in fruit, vegetables, grains, and other plant foods, which have been linked to reducing the risk of major chronic diseases. Phytochemicals are classified into **phenolics, carotenoids, alkaloids, nitrogen-containing compounds, and organosulphur compounds.** The additive and synergistic effects of phytochemicals in fruit, vegetables, and whole grains are responsible for their potent antioxidant and anticancer activities. The benefit of a diet rich in fruit, vegetables, and whole grains is attributed to the complex mixture of phytochemicals present in these and other whole foods.

Phenolic compounds in our diet may provide health benefits associated with reduced risk for chronic diseases. Among fruits rich in these compounds there belongs apple, red grape, strawberry, pineapple, banana, peach, lemon, orange, pear, and grapefruit. Among the most common vegetables, the highest total phenolic content is found in broccoli, spinach, yellow onion, red pepper, carrot, cabbage, potato, lettuce, celery, and cucumber.

Data from experimental and clinical studies suggest that **polyphenols**, **particularly flavonoid** rich foods, can reduce CHD risk by improving endothelial function and decreasing blood pressure. Nonextractable polyphenols, a major part of dietary polyphenols, probably have a significant physiological impact within the large intestine, affecting microflora development and intestinal antioxidant status by producing metabolites that can be absorbed through the mucosa.

Flavonoids are found in a wide variety of plant-based foods and beverages. More than 4 000 distinct flavonoids have been identified. In plants, they protect against stress and excess ultraviolet light exposure. They also are responsible for the colour of most fruits and flowers, and also contribute to the taste sensation of foods such as red wine, tea, coffee, and chocolate, as well as fruits. Intake varies widely between

individuals but is typically several hundred milligrams per day. The pathways of absorption are quite well understood and the amount absorbed and excreted for many flavonoids has been documented. For many flavonoids, a substantial percentage of the dose is absorbed, but is also rapidly metabolized and excreted within 24 hours. Some flavonoids such as **proanthocyanidins and anthocyanins** are poorly absorbed intact, but their catabolites are very efficiently absorbed after microbial biotransformation. Flavonoids are chemical antioxidants, but work in vivo primarily by indirect antioxidant mechanisms, such as inhibition of oxidative enzymes and induction of antioxidant defences. Certain flavonoids modulate **sugar metabolism, blood pressure, LDL cholesterol, and platelet function.** Together, these mechanisms possibly **reduce the risk type 2 diabetes and inflammatory diseases**, as supported by human interventional and epidemiological studies.

There is now a substantial body of evidence, both in vivo and mechanistic in vitro, to show that flavonoids affect risk factors for **cardiovascular disease**. One of the important indicators of cardiovascular risk is endothelial function and this biomarker is disrupted by factors such as a high-fat diet. Improvement of endothelial function is seen in vivo in volunteers from red wine, tea and cocoa, and by pure epicatechin. Epicatechin, and especially its metabolite – **methylepicatechin**, inhibits NADPH oxidase (nicotinamide adenine dinucleotide phosphate-oxidase), inhibits arginase, and modulates nitric oxide concentration in endothelial cells. There is also evidence from interventional studies that certain flavonoids, such as **grape seed extract**, can affect markers of diabetes risk in type 2 diabetic patients and **pycnogenol** (aflavonoid-rich pine bark extract) can improve metabolic markers in diabetic patients, although not all epidemiological studies show an effect of flavonoids at reducing diabetes risk. There are some epidemiological studies but the evidence for reduction in the risk of cancer is ambiguous. Effect of flavonoids on neurodegenerative diseases is an area of much interest, but there is only limited data at the current time. Chronic inflammation is associated with obesity, arthritis, Crohn's disease, and ulcerative colitis, and may be influenced by diet, including flavonoids with anti-inflammatory effects.

Carotenoids are nature's most widespread pigments with yellow, orange, and red colours, and have also received substantial attention because of both their provitamin and antioxidant roles. **Lycopene and βcarotene** are examples of acyclized and cyclized carotenoids, respectively. Carotenoids are especially powerful against singlet oxygen generated from lipid peroxidation or radiation. **Astaxanthin, zeaxanthin, and lutien** are excellent lipid-soluble antioxidants that scavenge free radicals, especially in a lipid-soluble environment. Carotenoids at sufficient concentrations can prevent lipid oxidation and related oxidative stress.

Dietary modification by increasing the consumption of a wide variety of fruit, vegetables and whole grains daily is a practical strategy for consumers to optimize their health and reduce the risk for chronic diseases. Phytochemical extracts from fruit and vegetables have strong antioxidant and antiproliferative activities, and the major part of total antioxidant activity is from the **combination of phytochemicals**. **The additive and synergistic effects of phytochemicals in fruit and vegetables are responsible for their potent antioxidant and anticancer activities.**

The development and testing of functional foods is a new exciting area. These foods may help to improve or restore nutritional status in many people. However, much more should be known about suitable biomarkers to test their efficacy, variability in human response to specific food products, safety, consumer understanding, and how their health messages must be formulated, labelled, and communicated.

It is necessary to emphasize that additional research is needed to concentrate on the precise role of foods and their components on health.

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11 SYSTEMS BIOLOGY APPROACHES TO NUTRITION (OMICS), NUTRIGENOMICS

Not all individuals should be expected to respond identically to bioactive food components because of genetic and environmental factors.

The "omics" of nutrition can be used to identify responders and non-responders.

Nutrition requires an understanding of disciplines such as physiology, cell biology, chemistry, biochemistry, and molecular biology among others.

The tools of systems biology can be applied to settings relevant to nutrition with the goal of better understanding the breadth and depth of the impact that changing nutrient status has on physiology and chronic disease risk.

The ultimate goal of systems biology is to generate a predictive model of the system. Most researchers work with only one type of data, but the ideal is to use all types of data simultaneously.

While traditional nutrition research has dealt with providing nutrients to nourish populations, **it nowadays focuses on improving health of individuals through diet.**

On the one hand, nutrients can alter the expression or function of a gene (including epigenetic modifications). On the other hand, genetic polymorphisms can alter the response to a nutrient.

As a consequence, the disciplines "nutrigenetics" and "nutrigenomics" have evolved.

Nutrigenetics asks the question how individual genetic disposition, manifesting as single nucleotide polymorphisms, copy-number polymorphisms and epigenetic phenomena, affects susceptibility to diet.

Nutrigenomics addresses the inverse relationship that is how diet influences gene transcription, protein expression and metabolism. This latter approach also includes the study of how genetic variations influence food intake and eating behaviours.

A major methodological challenge and first pre-requisite of nutrigenomics is integrating **genomics** (gene analysis), **transcriptomics** (gene expression analysis), **proteomics** (protein expression analysis) and **metabonomics** (metabolite profiling) to define a "healthy" **phenotype**.

Genome ➡ Transcriptome ➡ Proteome ➡ Metabolome ➡ Phenotype

Although genetics can play a major role in the variable responses to nutrient intakes, it is also important to consider other factors such as age, sex, physical activity, smoking, and nutritional status.

The science of nutrigenomics seeks to improve human health by understanding how dietary constituents interact with the genome, and how individual genetic heterogeneity affects these interactions. Nutrigenomics is a branch of nutritional genomics and is the study of the effects of foods and food constituents on gene expression. This complex field is further complicated by the growing recognition that nutrition, in addition to acutely affecting gene regulation, can influence epigenetic processes and thereby induce persistent changes in transcriptional regulation and associated phenotype.

The long-term deliverable of nutrigenomics is personalised nutrition for maintenance of individual health and prevention of disease.

Epigenetic dysregulation, long recognized as playing a role in cancer and various developmental syndromes, is increasingly being investigated as a potential factor in the aetiology of a wide range of human diseases. Given that epigenetic mechanisms are most susceptible to environmental perturbation when they are undergoing developmental changes, nutritional influences on epigenetic processes must be considered in a developmental perspective. Accordingly, a major goal of nutritional epigenetics is to understand the extent to which human nutrition affects developmental epigenetics to cause persistent changes in disease susceptibility. The field of nutritional epigenetics faces extraordinary challenges: diverse nutritional exposures have the potential to influence epigenetic regulation in myriad genomic regions, potentially in a tissue-specific and cell-type-specific fashion. But this field also promises extraordinary opportunities to improve human health. Short-term nutrition interventions targeted to critical ontogenic periods could potentially optimize developmental epigenetics, conferring lifelong health benefits and the promise of nutritional therapies designed to correct pathogenic epigenetic dysregulation. Such ambitious goals will become reality only if we can improve dramatically our understanding of how diet affects the establishment and maintenance of epigenetic mechanisms, and how epigenetic dysregulation contributes to human disease.

Nutrigenomics (or nutritional genomics) refers to the application of high-throughput "omics" technologies, together with systems biology and bioinformatics tools, to understand **how nutrients interact with the flow of genetic information to affect various health outcomes.**

Genomics is the study of the genomes of organisms including influences of DNA sequence variation on biology and the impact of modifying DNA and histones on influencing gene transcription and DNA function – epigenomics, e.g. production of the universal methyl donor S-adenosylmethionine, so it has been proposed that dietary inadequacy may have a global influence on DNA methylation. However, the evidence for this diet-induced regulatory paradigm is not yet secure and despite the fact that recent advances in human genomics have uncovered extensive variations in genes affecting nutrient metabolism, their full impact on nutrient requirements remains to be elucidated.

Transcriptomics is the study of transcripts from the genome including messenger RNA and non-coding RNA such as micro RNA. For some nutrients that are known to have a direct

impact on gene transcription through the activation of a nuclear receptor (e.g. vitamin D and VDR, vitamin A and the retinoic acid receptor bioactive lipids and the peroxisome proliferator-activated receptor, [PPAR]), transcriptomics is a primary endpoint for understanding the impact of the nutrient on biology.

Proteomics is the study of proteins in a biological system including their level, location, physical properties, post -translational modifications, structures, and functions. The proteome refers to all of the proteins expressed and functional in a system. Unfortunately, the methods to assess the proteome cannot

measure the entire proteasome simultaneously. Experiments usually measure one or more subproteomes, proteins within subcellular or specific tissues, or proteins with specific physical properties.

Metabolomics is the study of the unique chemicals (metabolites) that are produced as a result of cellular processes, e.g. lipids, metabolites of intermediary metabolites. Evaluating the metabolome gives a snapshot of the physiology of a cell or organism by simultaneously measuring the levels of metabolites within a biological space. As the goal of genomics is to study all of our genes, the goal of metabolomics is to profile the entire complement of the small molecules that are involved in processes from signalling to transcription, from building proteins, to creating and shuttling energy.

Ionomics is the study of the mineral nutrient and trace element composition of an organism. Mineral elements are involved at all levels of biological regulation, e.g. in transcription factors (zinc), in enzymes (zinc, iron, copper, calcium), and in establishing electrochemical gradients in cells (calcium, sodium, potassium). It is also well established that direct and indirect interactions exist between mineral elements that can affect biology. Alterations in the ionome reflect changes in critical biological functions.

The Omics disciplines applied in the context of nutrition and health have the potential to deliver biomarkers for health and comfort, reveal early indicators for disease disposition, assist in differentiating dietary responders from non-responders, and, last but not least, discover bioactive, beneficial food components.

With an increasing understanding of gene-nutrient interactions, **personalised nutrition** may become a potential resource of diet optimisation, at least in at-risk populations. Research in this area is paving the way for personalized nutrition where dietary advice can ultimately be tailored to an individual's unique genetic profile in order **to improve on the current one-size-fits-all approach** to dietary guidance. However a high variety of foods in a balanced diet seems to be the best way to optimal nutrient supply without risking excessive intakes of single components. **Nevertheless, further extensive research in the form of genotype-specific nutritional interventional studies are needed to elucidate individual response to diet.**

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12 PUBLIC HEALTH NUTRITION

Public health nutrition (PHN) **as a discipline and as a field of practice is of immense importance to human health and the societies in which we live.** As a discipline draws heavily on related fields, such **as health promotion and public health.** PHN practice is often similar to and draws on the principles and practice of health promotion – the process of enabling people to increase control over and to improve their health. PHN is also the art and science of promoting population health status via sustainable improvements in the food and nutrition system. Based on public health principles, it is a set of comprehensive and collaborative activities, ecological in perspective and inter-sectoral in scope, including environmental, educational, economic, technical and legislative measures.

Main aims are:

•Improving health and wellbeing in the population
•Preventing nutrition related disease and minimising its consequences
•Prolonging valued life through good nutrition
•Reducing inequalities in health

The defining features of a health promotion approach include actions that are:

- implemented across the **whole population,** not just those at risk of specific diseases;
- directed towards **improving people's ability to control the factors** that determine their health;
- part of a process involving a **mix of strategies** from a number of stakeholders which aim to improve health;
- focus on **the prevention of disease and enhancement of health** for all through tackling the social determinants of health.

Public health nutrition programs can be supply driven or demand driven.

In **the supply-driven option**, the government takes the decision centrally to alter some properties of foods the most common approach being mandatory food fortification.

In **demand-driven approaches**, efforts are made to create a demand for a new food-purchasing pattern through a nutrition communication process.

The term '**public nutrition**' was defined in 1997 by Rogers and Schlossman as "a new field encompassing the range of factors known to influence nutrition in populations, including diet and health, social, cultural and behavioural factors; and the economic and political context." Like public health, public nutrition would focus on problem-solving in a real-world setting, making its definition an applied field of study whose success is measured in terms of effectiveness in improving nutrition situations. According to Hughes and Somerset, "Public health nutrition is the art and science of promoting population health status via sustainable improvements in the food and nutrition system. Based on public health principles, it is a set of comprehensive and collaborative activities, ecological in perspective and inter-sectoral in scope, including environmental,

educational, economic, technical, and legislative measures". Later in 1998, the Nutrition Society (UK) added that "PHN focuses on the promotion of good health through nutrition and the primary prevention of diet-related illness in the population and the emphasis is on the maintenance of wellness in the whole population."

A working group for the European Master's Programme for PHN offered a shorter definition: "PHN focuses on the promotion of good health through nutrition and physical activity and the prevention of related illness in the population."

Johnson (2001) wrote that "PHN practice includes an array of services and activities to assure conditions in which people can achieve and maintain nutritional health, including surveillance and monitoring nutrition-related health status and risk factors, community or population based assessment, programme planning and evaluation, leadership in community/population interventions that collaborate across disciplines, programmes and agencies, and leadership in addressing the access and quality issues." A popular definition from Beaudry and Delisle (2005, Canada) states that "Public Nutrition applies the population health strategy to the resolution of nutrition problems. Its fundamental goal is to fulfil the human right to adequate food and nutrition. It is in the interest of the public, involves participation of the public, and calls for partnership with relevant sectors beyond health."

The most recent is a definition from the World Public Health Nutrition Association (2007) as "**the promotion and maintenance of nutrition-related health and well-being of populations through the organised efforts and informed choices of society."**

PHN practice can best be defined by the nature of the work or core functions and by an understanding of the competencies required to perform this work. PHN practice is primarily about problem - solving – developing interventions in the population that address the socio - cultural, economic, environmental and individual determinants of suboptimal nutrition.

The nutrition challenges for the twenty-first century emphasize that the focus should be on prevention of nutrition-related diseases to minimize their serious economic and social consequences.

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13 OVERVIEW OF IMPORTANT CURRENT DOCUMENTS

1. WHO/FAO. UNDERSTANDING THE CODEX ALIMENTARIUS

CODEX ALIMENTARIUS - international food standards - is about safe, good food for everyone - everywhere. Codex standards are based on the best available science assisted by independent international risk assessment bodies or ad-hoc consultations organized by the FAO and WHO. Biotechnology, pesticides, food additives, and contaminants are some of the issues discussed in Codex meetings. While Third edition, 2006, Rome being recommendations for voluntary application by members, Codex standards serve in many cases as a basis for national legislation. Codex members cover 99% of the world's population. More and more developing countries are taking an active part in the Codex process. The first session of the Codex Alimentarius Commission was held in Rome from 25 June to 3 July 1963.

The booklet "Understanding Codex" was first published in 1999 to foster a wider understanding of the evolving food code and of the activities carried out by the Codex Alimentarius Commission – the body responsible for compiling the standards, codes of practice, guidelines, and recommendations that constitute the Codex Alimentarius. The Codex Alimentarius, or the food code, has become the global reference point for consumers, food producers and processors, national food control agencies, and the international food trade. The code has had an enormous impact on the thinking of food producers and processors as well as on the awareness of the end users – the consumers. Its influence extends to every continent, and its contribution to the protection of public health and fair practices in the food trade is immeasurable.

2. Key points from GLOBAL NUTRITION REPORT. Action and accountability

1. **People with good nutrition are a key to sustainable development**.
- Malnutrition affects nearly every country in the world.
- More nutrition indicators need to be embedded within the Sustainable Development Goal accountability framework.

2. We need to commit to **improving nutrition faster** and build this goal into the Sustainable Development Goal targets for 2030.
- The 2030 Sustainable Development Goal targets should be more ambitious than simple extensions of the 2025 World Health Assembly targets. A new consensus about what is possible needs to be established.

3. The world is currently not on course to meet the global nutrition targets set by the World Health Assembly, but **many countries are making good progress** in the target indicators.
- More high-quality case studies are needed to understand why progress has or has not been made.

4. **Dealing with different, overlapping forms of malnutrition** is the "new normal."
- Nutrition resources and expertise need to be better aligned toward the evolving nature of malnutrition.

5. We need to **extend coverage of nutrition-specific programmes** to more people who need them.
- More attention needs to be given to coverage data - an important way of assessing presence on the ground where it counts.

6. **A greater share of investments to improve the underlying determinants of nutrition** should be designed to have a larger impact on nutritional outcomes.
- We need to keep tracking the proportion of nutrition resources to these approaches.
- We must also provide more guidance on how to design and implement these approaches to improve their effectiveness and reach.

7. **More must be done to hold donors, countries, and agencies** accountable for meeting their commitments to improve nutrition.
- Stakeholders should work to develop, pilot, and evaluate new accountability mechanisms.
- Civil society efforts to increase accountability need support.
- We need to develop targets or norms for spending on nutrition.

8. **Tracking spending on nutrition is currently challenging**, making it difficult to hold responsible parties accountable.
- Efforts to track financial resources need to be intensified — for all nutrition stakeholders.

9. **Nutrition needs a data revolution**.
- Of the many information gaps, the ones that most need to be filled are those that constrain priority action and impede accountability.

10. **National nutrition champions** need to be recognized, supported, and expanded in number.
- We must fill frontline vacancies, support nutrition leadership programmes, and design country-led research programmes.

The challenge of improving nutritional status is a quintessentially 21st-century endeavour. It is a challenge that resonates the world over: nearly every country in the world experiences a level of malnutrition that constitutes a serious public health risk. Between 2 and 3 billion people are malnourished — they experience some form of undernutrition, are overweight or obese, or have some sort of micronutrient deficiency. The faces of poor nutrition are many: from children living under famine conditions that appear to be made of skin and bone, to adults who have trouble breathing owing to obesity, to infants who do not live to see their first birthday as a result of a combination of poor diets, poor infant feeding practices, and exposure to infectious disease. It is a challenge that requires effective action across a number of sectors and areas (food, health, social welfare, education, water, sanitation, and women) and across a number of actors (government, civil society, business, research, and international development partners). Strong alliances for action are much more effective than silver bullets, and the multiple causes of malnutrition often represent multiple opportunities to improve nutrition in a sustainable way.

Lastly, **poor nutrition is a challenge** that casts a long shadow: its consequences flow throughout the life cycle and cascade down the generations affecting everyone — especially children, adolescent girls, and women — and **include mortality, infection, cognitive impairment, lower work productivity, early onset and higher risk of non-communicable diseases (NCDs), stigma, and depression.**

3. ROME DECLARATION ON NUTRITION, 2014

One of the latest conference outcome documents that came from the Second International Conference on Nutrition, Rome, 19–21 November 2014, **organised by the Food and Agriculture Organisation of the United Nations (FAO) and World Health Organisation (WHO):**

"Welcoming the participation of Heads of State and Government and other high-level guests,

1. We, Ministers and Representatives of the Members of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), assembled at the Second International Conference on Nutrition in Rome from 19 to 21 November 2014, jointly organized by FAO and WHO, to address the multiple challenges of malnutrition in all its forms and identify opportunities for tackling them in the next decades.
2. Reaffirming the commitments made at the first International Conference on Nutrition in 1992, and the World Food Summits in 1996 and 2002 and the World Summit on Food Security in 2009, as well as in relevant international targets and action plans, including the WHO 2025 Global Nutrition Targets and the WHO Global Action Plan for the Prevention and Control of Non-communicable Diseases 2013–2020.
3. Reaffirming **the right of everyone to have access to safe, sufficient, and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger** consistent with the International Covenant on Economic, Social and Cultural Rights and other relevant United Nations instruments.

Multiple challenges of malnutrition to inclusive and sustainable development and to health

4. Acknowledge that **malnutrition, in all its forms,** including undernutrition, micronutrient deficiencies, overweight and obesity, not only affects people's health and well-being by impacting negatively on human physical and cognitive development, compromising the immune system, increasing susceptibility to communicable and non-communicable diseases, restricting the attainment of human potential and reducing productivity, but also poses a high burden in the form of negative social and economic consequences to individuals, families, communities and States.
5. Recognize that the **root causes of and factors** leading to malnutrition are complex and multidimensional:
   a. poverty, underdevelopment and low socio-economic status are major contributors to malnutrition in both rural and urban areas;
   b. the lack of access at all times to sufficient food, which is adequate both in quantity and quality which conforms with the beliefs, culture, traditions, dietary habits and preferences of individuals in accordance with national and international laws and obligations;
   c. malnutrition is often aggravated by poor infant and young child feeding and care practices, poor sanitation and hygiene, lack of access to education, quality health systems and safe drinking water, food-borne infections and parasitic infestations, ingestion of harmful levels of contaminants due to unsafe food from production to consumption;
   d. epidemics, such as of the Ebola virus disease, pose tremendous challenges to food security and nutrition.

6. Acknowledge that **different forms of malnutrition** co-exist within most countries; while dietary risk affects all socio-economic groups, large inequalities exist in nutritional status, exposure to risk and adequacy of dietary energy and nutrient intake, between and within countries.
7. Recognize that **some socioeconomic and environmental changes** can have an impact on dietary and physical activity patterns, leading to higher susceptibility to obesity and non-communicable diseases through increasing sedentary lifestyles and consumption of food that is high in fat, especially saturated and trans-fats, sugars, and salt/sodium.
8. Recognize **the need to address the impacts of climate change and other environmental factors** on food security and nutrition, in particular on the quantity, quality and diversity of food produced, taking appropriate action to tackle negative effects.
9. Recognize that **conflict and post conflict situations, humanitarian emergencies and protracted crises**, including, inter alia, droughts, floods and desertification as well as pandemics, hinder food security and nutrition.
10. Acknowledge that **current food systems are being increasingly challenged** to provide adequate, safe, diversified and nutrient rich food for all that contribute to healthy diets due to, inter alia, constraints posed by resource scarcity and environmental degradation, as well as by unsustainable production and consumption patterns, food losses and waste, and unbalanced distribution.
11. Acknowledge that **trade is a key element** in achieving food security and nutrition and that trade policies are to be conducive to fostering food security and nutrition for all, through a fair and market-oriented world trade system, and reaffirm the need to refrain from unilateral measures not in accordance with international law, including the Charter of the United Nations, and which endanger food security and nutrition, as stated in the 1996 Rome Declaration.
12. Note with profound concern that, notwithstanding significant achievements in many countries, recent decades have seen modest and uneven progress in **reducing malnutrition** and estimated figures show that:
    a) the prevalence of undernourishment has moderately declined, but absolute numbers remain unacceptably high with an estimated 805 million people suffering chronically from hunger in 2012–2014;
    b) chronic malnutrition as measured by stunting has declined, but in 2013 still affected 161 million children under five years of age, while acute malnutrition (wasting) affected 51 million children under five years of age;
    c) undernutrition was the main underlying cause of death in children under five, causing 45% of all child deaths in the world in 2013;
    d) over two billion people suffer from micronutrient deficiencies, in particular vitamin A, iodine, iron and zinc, among others;
    e) overweight and obesity among both children and adults have been increasing rapidly in all regions, with 42 million children under five years of age affected by overweight in 2013 and over 500 million adults affected by obesity in 2010;
    f) dietary risk factors, together with inadequate physical activity, account for almost 10% of the global burden of disease and disability.

A common vision for global action to end all forms of malnutrition

13. **We reaffirm that:**
    a) the elimination of malnutrition in all its forms is an imperative for health, ethical, political, social and economic reasons, paying particular attention to

the special needs of children, women, the elderly, persons with disabilities, other vulnerable groups as well as people in humanitarian emergencies;

b) nutrition policies should promote a diversified, balanced and healthy diet at all stages of life. In particular, special attention should be given to the first 1,000 days, from the start of pregnancy to two years of age, pregnant and lactating women, women of reproductive age, and adolescent girls, by promoting and supporting adequate care and feeding practices, including exclusive breast feeding during the first six months, and continued breastfeeding until two years of age and beyond with appropriate complementary feeding. Healthy diets should be fostered in preschools, schools, public institutions, at the workplace and at home, as well as healthy eating by families;

c) coordinated action among different actors, across all relevant sectors at international, regional, national and community levels, needs to be supported through cross-cutting and coherent policies, programmes and initiatives, including social protection, to address the multiple burdens of malnutrition and to promote sustainable food systems;

d) food should not be used as an instrument for political or economic pressure;

e) excessive volatility of prices of food and agricultural commodities can negatively impact food security and nutrition, and needs to be better monitored and addressed for the challenges it poses;

f) improvements in diet and nutrition require relevant legislative frameworks for food safety and quality, including for the proper use of agrochemicals, by promoting participation in the activities of the Codex Alimentarius Commission for the development of international standards for food safety and quality, as well as for improving information for consumers, while avoiding inappropriate marketing and publicity of foods and non-alcoholic beverages to children, as recommended by resolution WHA63.14;

g) nutrition data and indicators, as well as the capacity of, and support to all countries, especially developing countries, for data collection and analysis, need to be improved in order to contribute to more effective nutrition surveillance, policy making and accountability;

h) empowerment of consumers is necessary through improved and evidence-based health and nutrition information and education to make informed choices regarding consumption of food products for healthy dietary practices;

i) national health systems should integrate nutrition while providing access for all to integrated health services through a continuum of care approach, including health promotion and disease prevention, treatment and rehabilitation, and contribute to reducing inequalities through addressing specific nutrition-related needs and vulnerabilities of different population groups;

j) nutrition and other related policies should pay special attention to women and empower women and girls, thereby contributing to women's full and equal access to social protection and resources, including, inter alia, income, land, water, finance, education, training, science and technology, and health services, thus promoting food security and health.

14. **We recognize that:**

a) international cooperation and Official Development Assistance for nutrition should support and complement national nutrition strategies, policies and programmes, and surveillance initiatives, as appropriate;

b) the progressive realization of the right to adequate food in the context of national food security is fostered through sustainable, equitable, accessible in all cases, and resilient and diverse food systems;
c) collective action is instrumental to improve nutrition, requiring collaboration between governments, the private sector, civil society and communities;
d) non-discriminatory and secure access and utilization of resources in accordance with international law are important for food security and nutrition;
e) food and agriculture systems, including crops, livestock, forestry, fisheries and aquaculture, need to be addressed comprehensively through coordinated public policies, taking into account the resources, investment, environment, people, institutions and processes with which food is produced, processed, stored, distributed, prepared and consumed;
f) family farmers and small holders, notably women farmers, play an important role in reducing malnutrition and should be supported by integrated and multisectoral public policies, as appropriate, that raise their productive capacity and incomes and strengthen their resilience;
g) wars, occupations, terrorism, civil disturbances and natural disasters, disease outbreaks and epidemics, as well as human rights violations and inappropriate socio-economic policies, have resulted in tens of millions of refugees, displaced persons, war affected non-combatant civilian populations and migrants, who are among the most nutritionally vulnerable groups. Resources for rehabilitating and caring for these groups are often extremely inadequate and nutritional deficiencies are common. All responsible parties should cooperate to ensure the safe and timely passage and distribution of food and medical supplies to those in need, which conforms with the beliefs, culture, traditions, dietary habits and preferences of individuals, in accordance with national legislation and international law and obligations and the Charter of the United Nations;
h) responsible investment in agriculture, including small holders and family farming and in food systems, is essential for overcoming malnutrition;
i) governments should protect consumers, especially children, from inappropriate marketing and publicity of food;
j) nutrition improvement requires healthy, balanced, diversified diets, including traditional diets where appropriate, meeting nutrient requirements of all age groups, and all groups with special nutrition needs, while avoiding the excessive intake of saturated fat, sugars and salt/sodium, and virtually eliminating trans-fat, among others;
k) food systems should provide year-round access to foods that cover people's nutrient needs and promote healthy dietary practices;
l) food systems need to contribute to preventing and addressing infectious diseases, including zoonotic diseases, and tackling antimicrobial resistance;
m) food systems, including all components of production, processing and distribution should be sustainable, resilient and efficient in providing more diverse foods in an equitable manner, with due attention to assessing environmental and health impacts;
n) food losses and waste throughout the food chain should be reduced in order to contribute to food security, nutrition, and sustainable development;
o) the United Nations system, including the Committee on World Food Security, and international and regional financial institutions should work

more effectively together in order to support national and regional efforts, as appropriate, and enhance international cooperation and development assistance to accelerate progress in addressing malnutrition;

p) EXPO MILANO 2015, dedicated to "feeding the planet, energy for life", among other relevant events and fora, will provide an opportunity to stress the importance of food security and nutrition, raise public awareness, foster debate, and give visibility to the ICN2 outcomes.

Commitment to action

15. **We commit to:**

a) eradicate hunger and prevent all forms of malnutrition worldwide, particularly undernourishment, stunting, wasting, underweight and overweight in children under five years of age; and anaemia in women and children among other micronutrient deficiencies; as well as reverse the rising trends in overweight and obesity and reduce the burden of diet-related non-communicable diseases in all age groups;

b) increase investments for effective interventions and actions to improve people's diets and nutrition, including in emergency situations;

c) enhance sustainable food systems by developing coherent public policies from production to consumption and across relevant sectors to provide year-round access to food that meets people's nutrition needs and promote safe and diversified healthy diets;

d) raise the profile of nutrition within relevant national strategies, policies, actions plans and programmes, and align national resources accordingly;

e) improve nutrition by strengthening human and institutional capacities to address all forms of malnutrition through, inter alia, relevant scientific and socio-economic research and development, innovation and transfer of appropriate technologies on mutually agreed terms and conditions;

f) strengthen and facilitate contributions and action by all stakeholders to improve nutrition and promote collaboration within and across countries, including North-South cooperation, as well as South-South and triangular cooperation;

g) develop policies, programmes and initiatives for ensuring healthy diets throughout the life course, starting from the early stages of life to adulthood, including of people with special nutritional needs, before and during pregnancy, in particular during the first 1,000 days, promoting, protecting and supporting exclusive breastfeeding during the first six months and continued breastfeeding until two years of age and beyond with appropriate complementary feeding, healthy eating by families, and at school during childhood, as well as other specialized feeding;

h) empower people and create an enabling environment for making informed choices about food products for healthy dietary practices and appropriate infant and young child feeding practices through improved health and nutrition information and education;

ch) implement the commitments of this Declaration through the Framework for Action which will also contribute to ensuring accountability and monitoring progress in global nutrition targets;

i) give due consideration to integrating the vision and commitments of this Declaration into the post-2015 development agenda process including a possible related global goal.

16. We call on FAO and WHO, in collaboration with other United Nations agencies, funds and programmes, as well as other international organizations, to support national governments, upon request, in developing, strengthening, and implementing their policies, programmes, and plans to address the multiple challenges of malnutrition.

17. We recommend to the United Nations General Assembly to endorse the Rome Declaration on Nutrition, as well as the Framework for Action, which provides a set of voluntary policy options and strategies for use by governments, as appropriate, and to consider declaring a Decade of Action on Nutrition from 2016 to 2025 within existing structures and available resources.

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FOOD SAFETY

Stanislav Sekretár
Institute of Hygiene, Faculty of Medicine, Comenius University in Bratislava

14 INTRODUCTION

The term *food safety* has no universally accepted definition. In fact, it is sometimes used, wrongly, in relation to defects in food commodities that are much more to do with food quality than with safety. For example, microbial spoilage of food may make it unattractive, or even inedible, but if neither the microorganisms concerned, nor the by-products of their growth and metabolism have any adverse effect on health, then it is not strictly a food safety issue, but one of acceptability.

Food safety is a scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness. Food safety can be defined as the assurance that food will not cause harm to the consumer, when it is prepared and/or eaten according to its intended use. This definition covers a broad range of topics, from basic domestic and personal hygiene, to highly complex technical procedures designed to remove contaminants from sophisticated processed foods and ingredients.

Contaminated food is one of the most widespread public health problems of the contemporary world and causes considerable morbidity and mortality. Food poisoning can be very serious in vulnerable groups such as the elderly, infants, young children, pregnant women, and immunocompromised individuals. There are more than 250 food-borne diseases registered today. Food safety programmes are focusing on the farm-to-table approach as an effective means of reducing food-borne hazards. These hazards may emerge from microbiological, chemical, or physical contamination of food. Health significance of these hazards is estimated through risk assessment method, and thus hazards are regulated, controlled, and kept under surveillance. The practice of food safety can be distilled down to three basic operations:

- Protection of the food supply from harmful contamination.
- Prevention of the development and spread of harmful contamination.
- Effective removal of contamination and contaminants.

Most food safety procedures fall into one, or more than one, of these categories. For example, good hygiene practice is concerned with the protection of food against contamination, effective temperature control is designed to prevent the development (growth) and spread of contamination, and pasteurisation or disinfection are the measure to remove biological contaminants.

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15 FOOD SAFETY HAZARDS

A *food safety hazard* can be defined as any biological, physical or chemical agent present in food that has the potential to cause harm to the consumer, either by causing illness or injury. The term *contaminant* covers harmful substances or microorganisms that are not intentionally added to food. Contaminants may enter the food accidentally during growth, cultivation, or preparation, accumulate in food during storage, form in the food through the interaction of chemical components, or may be concentrated from the natural components of the food. There are three main types of hazard: biological, such as pathogenic bacteria, chemical, such as a toxin produced during processing, or a physical object, like a stone or piece of metal. In other words, hazards are the factors that food safety practice seeks to protect against, contain, and eliminate from foods.

15.1 Biological Hazards

Biological agents of concern to public health include pathogenic strains of bacteria, viruses, helminths, protozoa and algae, and certain toxic products they may produce. Technically, biological hazards may include also larger organisms, such as insects and rodents. However, these rarely present a direct threat to health. It is microorganisms and certain food-borne parasites that are of most concern as food safety hazards. Food-borne infections are caused when microorganisms are ingested, and these can multiply in the human body. Intoxications result when microbial or naturally occurring toxins are consumed in contaminated foods. Microorganisms or toxins may be introduced directly from infected food animals or from workers, other foods, or the environment during the preparation or processing of food. Poisonous substances may also be produced by the growth of bacteria and moulds in food. Pathogenic organisms of public health importance, which may be transmitted through contaminated food, are as follows:

- Bacteria (spore-forming): *Clostridium botulinum, Clostridium perfringens, Bacillus cereus*
- Bacteria (nonspore-forming): *Brucella abortis, Brucella suis, Campylobacter spp., Pathogenic Escherichia coli, Listeria monocytogenes, Salmonella spp., Shigella (S. dysenteriae), Staphylococcus aureus, Streptococcus pyogenes, Vibrio cholera, Vibrio parahaemolyticus, Vibrio vulnificus, Yersinia enterocolytica*
- Viruses: hepatitis A and E, Norwalk virus group, rotavirus
- Protozoa and parasites: *Cryptosporidium parvum, Diphyllabothrium, Entamoeba histolytica, Giardia lamblia, Ascaris lumbricoides, Taenia solium, Taenia saginata, Trichinella spiralis*

A significant number of bacterial species can be classified as food safety hazards. Some of these, such as *Salmonella* and *Listeria monocytogenes*, are very well known and familiar to consumers, whereas others are much less common and less well understood. With the improvement of standards of personal hygiene, basic sanitation, vaccination, food control and increasing application of technologies (e.g. pasteurization), many food-

borne diseases either have been eliminated or considerably reduced (e.g. poliomyelitis, cholera, brucellosis, typhoid and paratyphoid fevers, bovine TB). Nevertheless, most countries are experiencing a great increase in several other foodborne diseases.

15.1.1 Bacterial Food Safety Hazards

Bacteria fall into one of two categories according to the mechanism by which they cause illness:

- *Infection.* Most food-borne bacterial pathogens cause illness by multiplying in the gut after ingestion of contaminated food. They may then provoke symptoms by invading the cells lining the intestine, or in some cases, invading other parts of the body and causing more serious illnesses. *Salmonella, Campylobacter* and *E. coli O157* are all examples of bacteria that cause infective food poisoning. This type of food poisoning is usually characterised by a delay, or incubation time, of at least 8–12 hours (sometimes much longer) before symptoms develop. This category also includes some bacteria that produce symptoms by multiplying in the gut and producing toxins, rather than by actively invading the tissues. An example of this type is *Clostridium perfringens*, a food-poisoning bacterium usually associated with cooked meat products.
- *Intoxication.* There are a few food-borne pathogenic bacteria that produce illness not by infection, but by intoxication. These organisms are able to grow in certain foods under favourable conditions and produce toxins as a by-product of growth. The toxin is thus pre-formed in the food before ingestion and in some cases toxin may still be present even after all the bacterial cells have been destroyed by cooking. *Bacillus cereus* and *Staphylococcus aureus* are the examples of bacteria able to cause intoxication, but the most important and potentially serious cause of intoxication is *Clostridium botulinum*. Intoxications usually have much shorter incubations times than infections, because the toxins are pre-formed in the food.

15.1.2 Viruses

Viral gastroenteritis is very common worldwide. There are a number of viruses that are capable of causing food-borne infections, although in most cases, other forms of transmission are more common. Perhaps the best known are noroviruses and hepatitis A, which have been responsible for a number of serious food-borne disease outbreaks, often as a result of poor personal hygiene by infected food handlers. 'New' viruses may also pose a threat to food safety. For example, highly pathogenic avian influenza viruses primarily affect birds, but in some cases may be transmitted to humans and cause serious disease. So far, there is no direct evidence that this transmission can be food-borne, but these viruses are a source of great concern to the poultry industry and there is still much to learn about them.

15.1.3 Parasites

A wide range of intestinal parasites can be transmitted to humans via contaminated foods, although for most, faecal–oral, or water-borne transmission is more common. These organisms are much more prevalent in developing countries with poor sanitation, but the increasingly global nature of the food supply chain may increase their importance in the developed world. Currently, protozoan parasites are the most important, but other types also need to be considered as food safety hazards.

15.1.4 Protozoans

The protozoan parasites that can cause food-borne illness in humans include several well-known species, such as *Entamoeba histolytica*, the cause of amoebic dysentery, and *Cryptosporidium parvum*. However, in recent years, some unfamiliar species have emerged as threats to food safety, especially as contaminants in imported produce. An example is *Cyclospora cayetanensis*, the cause of several outbreaks of gastroenteritis in the USA associated with imported fruit.

15.1.5 Other Types of Parasite

Other types of food-borne parasite include nematode worms, such as *Trichinella spiralis* and the anisakid worms found in fish, and cestodes (tapeworms), such as *Taenia solium*. Although many of these are far less prevalent in developed countries than was once the case, thanks to improved sanitation, they are still significant causes of illness worldwide.

15.1.6 Prions

Prions are a relatively recent threat to food safety and are still not fully understood, but their probable involvement in potentially food-borne new variant Creutzfeldt–Jakob disease, an invariably fatal brain disease, has led to a considerable concern.

15.1.7 The Most Frequent Infections

The most frequent infections are caused by *Escherichia coli, Salmonella, Campylobacter jejuni, Listeria monocytogenes,* and parasites like cryptosporidium, cryptospora, trematodes, and viruses:

- *Botulism* is a disease caused by *Bacillus botulinum*, an agent emerging from soil. The most common sources are canned meat and vegetables and the production of toxin can be regulated by controlling the acid pH of food.
- *Campylobacteriosis* is a bacterial gastrointestinal infectious disease caused by *Campylobacter jejuni*, *C. fetus*, and *C. coli*. The germs are found in the intestines of animals. Infection can be caused by handling raw poultry, eating undercooked poultry, drinking non-chlorinated water or raw milk, or handling infected animal or human faeces. Most frequently, poultry and cattle waste are the sources of the bacteria, but faeces from puppies, kittens, and birds may be contaminated too.
- *Escherichia coli* infectionis caused by different strains of *E. coli* bacteria. Harmless strains of *E. coli* can be found widely in nature, including the intestinal tracts of humans and warm-blooded animals. Disease-causing strains, however, are a frequent cause of both intestinal and urinary-genital tract infections. Several different strains of harmful *E. coli* can cause diarrhoeal disease. A particularly dangerous type is called Enterohaemorrhagic *E. coli*, or EHEC. EHEC often causes bloody diarrhoea and can lead to kidney failure in children or people with weakened immune systems. In 1982, scientists identified the first dangerous strain in the United States. The type of harmful *E. coli* most commonly found in this country is named O157:H7, which refers to chemical compounds found on the bacterium's surface. This type produces one or more related, powerful toxins, which can severely damage the lining of the intestines. This strain is now found worldwide and presents one of the most serious bacterial sources to be found in food and water.

- *Salmonellosis* is usually provoked by *Salmonella* sp. *Salmonella* sp. can be found in food products such as raw poultry, eggs, and beef, and sometimes on unwashed fruit. Food prepared on surfaces that previously were in contact with raw meat or meat products can, in turn, become contaminated with the bacteria. This is called cross-contamination. With the spread of organic farming, new cases are recorded from eating raw alfalfa sprouts grown in contaminated soil. Salmonellosis may frequently occur after handling pets.
- *Shigellosis,* also called bacillary dysentery, is an infectious disease caused by *Shigella* (*Shigella dysenteriae*, *S. flexneri*, *S. boydii*, and *S. sonnei*). It is commonly transmitted by food service workers who are sick or infected, but have no symptoms, and adequate personal hygiene.
- *Listeriosis* is caused by *Listeria monocyotogenes*. This food-borne illness in pregnant women can result in miscarriage, foetal death, and severe illness or death of a newbornn infant. Others at risk for severe illness or death are older adults and those with weakened immune systems. Listeriosis is now attributed to ready-to-eat foods and deli products.
- *Food-borne viruses* (caliciviruses, rotavirus, astrovirus, and hepatitis A virus) present in food and water are frequent cause of diarrhoea. Hepatitis A is also common throughout the world (e.g. shellfish-borne hepatitis A, food infected by food handlers, and not subsequently sufficiently heated may also transmit the disease and many cases of hepatitis A are known to be restaurant associated).
- *Norwalk virus* (a particular calicivirus) caused a number of outbreaks of food poisoning at buffets and caterings.
- *Prions.* Mad Cow Disease is the commonly used name for Bovine Spongiform Encephalopathy (BSE), a slowly progressive, degenerative, fatal disease affecting the central nervous system of adult cattle. In cattle with BSE, these abnormal types of protein, prions, initially occur in the small intestines and tonsils, and are found in central nervous tissues, such as the brain and spinal cord, and other tissues of infected animals experiencing later stages of the disease. There is a disease similar to BSE called Creutzfeldt-Jakob Disease (CJD) that is found in people. A variant form of CJD is believed to be caused by eating contaminated beef products from BSE-affected cattle.
- *Parasitic infections* (e.g. *Cryptosporidium* infection) – infection is believed to be more common than *Salmonella* infection in young children. Helminths (e.g. *Trichinella spiralis*, *Taenia saginata* and *Taenia solium*), which are acquired through consumption of undercooked or uncooked meat. *Ascaris lumbricoides* affects humans and causes the disease ascariasis. Biological contaminants are responsible for a wide range of food-borne diseases and infant diarrhoea is the dominant problem. According to WHO data almost 1.8 million children die each year in developing countries from diarrhoeal disease caused by microbes, which are present in food and water.

Despite progress in science and technology, contaminated food and water remain in this day a major public health problem. However, only a small portion of cases comes to the notice of the health services (in developed countries only about 10% are reported while in developing countries about 1% of the total). Food-borne diseases may also cause other serious health problems (e.g. chronic diarrhoea can lead to undernutrition, some diseases – listeriosis and toxoplasmosis are dangerous during pregnancy, and some food-borne infections may lead to chronic diseases (e.g. joint disease, immune system disorders, heart and vascular diseases, diseases of the renal system).

15.1.8 Factors Responsible for the Prevalence of Food-borne Diseases

Factors responsible for the prevalence of foodborne diseases are as follows:

- improved standards of living have led to an increase in consumption of food of animal origin;
- mass production of animals with the risk that many of these animals are subclinically infected by various pathogens (e.g. *Salmonella* and *Campylobacter*);
- many of the foodborne diseases are to errors in food preparation or lack of personal hygiene on the part of the foodhandlers;
- traditions and beliefs contribute to the occurrence of food-borne diseases (e.g. consumption of raw meat products, raw fish or raw milk);
- with increasing number of international travellers, some of the diseases are imported from endemic areas;
- many outbreaks occur as a result of failures during the food processing (e.g.insufficient cooking or reheating the food);
- international trade in food and animal food plays an important role in the spread of pathogens (e.g. animals given the contaminated feeds contaminated the environment);
- soil, rivers, surface water and, in turn, insects, rodents and birds with their faeces. In such a manner, the microorganisms have established themselves widely in the environment, including animals.

15.1.9 Prevention and Control of the Biological Contamination of Food

For the prevention and control of the biological contamination of food, three lines of defence are available:

- The first line of defence is to improve the hygienic quality of raw foodstuffs at the agricultural level, by applying the principles of good agricultural practice and animal husbandry.
- The second line of defence is the application of food processing technologies (e.g. pasteurization, sterilization, fermentation, or irradiation).
- The third line of defence is the most critical and will protect the health of consumers when the other two fail. This concerns education of food handlers (professional cooks, persons handling with food in food service establishment, as well as those in charge of the preparation of food at home). The education of food handlers is of special importance, because the cases of food-borne diseases frequently occur due to mishandling of food in the home, as a result of negligence, ignorance or ingrained traditions and habits.

15.2 Chemical Hazards

The presence of chemical hazards in food is usually less immediately apparent than that of bacteria and other biological hazards. *Acute toxicity caused by food-borne chemical contaminants is now very rare in developed countries.* Of much more concern is the potentially insidious effect of exposure to low levels of toxic chemicals in the diet over long periods. In some cases, this can lead to chronic illness and there is also the risk that some contaminants may be carcinogenic.

There is potential for an enormous range of chemical contaminants to enter the food chain at any stage in production. For example, agricultural chemicals, such as herbicides and insecticides, may contaminate fresh produce during primary production, some

commodities may contain 'natural' biological toxins, and chemicals such as detergents and lubricants may enter food during processing. It is also possible for chemical contaminants to leach out of packaging into foods during storage. Some of the main classes of chemical contaminant important in food safety are as follows:

- Naturally occurring toxins (alkaloids and other plant toxins, fungal toxins and mycotoxins, seafood toxins, biogenic amines)
- Environmental contaminants (e.g. dioxins and heavy metals)
- Contaminants produced during processing (e.g. acrylamide)
- Contaminants from food contact materials (e.g. plasticisers)
- Agricultural chemicals, pesticides, etc.
- Veterinary drugs
- Cleaning and sanitising chemicals
- Adulterants (e.g. illegal food dyes)

The total number of potentially harmful chemicals that may contaminate food is very large. For example, UK legislation contains maximum residue levels (MRLs) for over 28,000 pesticide/commodity combinations. The list of potential adulterants is also an extensive one.

15.2.1 Naturally Occurring Toxins

Alkaloids

Plant alkaloids are secondary metabolites having one or more nitrogen atoms. Many of them have a pharmacological activity in the animals and humans that consume them, affecting the nervous system and other essential processes. The major alkaloids possessing these properties are solanine, caffeine, morphine, lupanine, nicotine, senecionine, ergocristine, hyoscyamine, coniine and many others (Fig. 6).

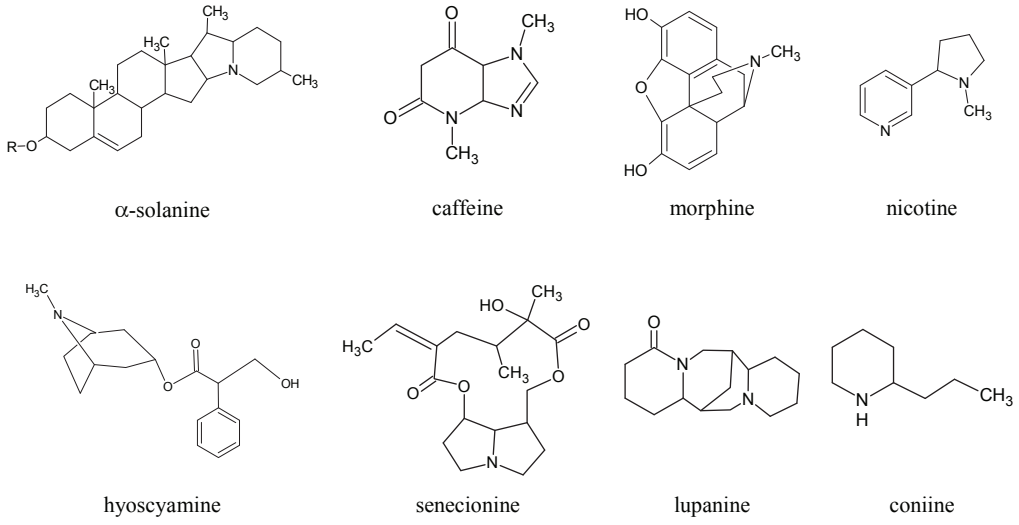


Figure 6 *Chemical structures of some common alkaloids.*

In some cases, they are found as natural components (solanum glycosides) of some important food plants such as potatoes. Potatoes, which were exposed to light, can contain up to 350 mg.kg^{-1} of glycoalkaloids. Ingestion of potatoes with high glycoalkaloid content can cause stomach pains, weakness, nausea, vomiting, and breathing difficulties between 2 and 24 h after ingestion, which may persist for several days. Solanine is not removed by

boiling, but it can be destroyed by frying. In other cases, alkaloids can contaminate food that does not itself contain them. The most important example of this is the fungus ergot, which infects mainly rye, wheat, and barley, and has achieved notoriety through major poisoning outbreaks. Alkaloid transfer into the milk of cows, sheep, and goats can also lead to human poisoning. The transfer of alkaloids from food into the milk of humans is of considerable concern, because newborn babies are very sensitive to toxins, and may derive all of their food from breast milk. Medicinal morphine and caffeine are rapidly absorbed into the blood and pass into breast milk. Nicotine and cotinine from smoking mothers also contaminates milk and can be detected in infants' urine.

Other plant toxins

Plant toxins are generally secondary metabolites having usually the defence function against animal and insect predators. Some toxin-containing plants are occasionally eaten on account of mistaken identity, but some of them may be consumed purposely as an act of suicide. The fruits of toxic plants such as the very poisonous deadly nightshade appear similar to edible fruits such as blueberries, and the very toxic poison hemlock and hemlock water dropwort resemble wild versions of carrot, parsnip, and chervil. Very young children are at the highest risk from plant toxins as they regularly put almost anything of suitable size within reach into their mouths, and might find berries and leaves attractive. Poisons can be transferred from plants to human foods also in animal products such as milk, bird's eggs, and honey produced by bees foraging on toxic plants. The most important plant toxins are: ricin, linamarin, goitrin, glucosinolate, β-ODAP, hypoglycin A and B, myristicin, and oxalic acid (Fig. 7).

One of the most dangerous toxins is *ricin*. This toxin can be found in the seeds of the castor oil plant (*Ricinus communis*). Intact seeds may pass through the digestive tract without releasing the toxin. Ricin poisoning can occur when broken seeds contaminate cereals, notably soya beans. The lethal dose in adults is considered to be 4–8 seeds. If ingested, symptoms may be delayed by up to 36 h but commonly begin within 2–4 h. Unless treated, death can be expected to occur within 3–5 days. On the other hand, the castor oil has qualities that give it numerous industrial uses, but it contains no toxin.

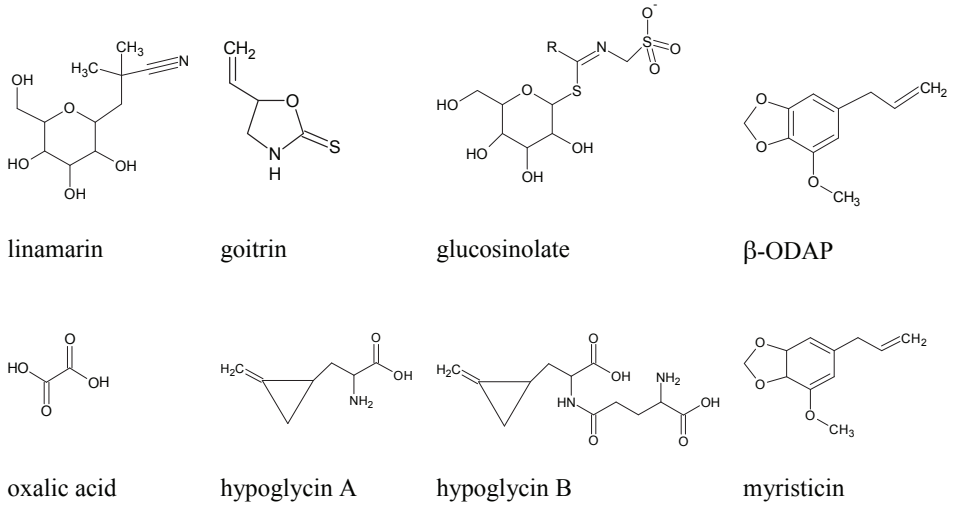


Figure 7 *Chemical structures of some plant toxins.*

Cyanogenic glycosides are compounds that can release hydrogen cyanide (HCN) under certain conditions, notably in an acid environment or through enzyme action. The major food plants that do contain cyanogenic glycosides are cassava (*Manihot esculenta*), sorghum (*Sorghum spp.*), and corn (*Zea mays*).

Glucosinolates are sulphur-containing oximes and glycosides associated with brassicas (cabbage, broccoli, cauliflower, rapeseed, mustard, horseradish, and wasabi). During the cooking, the glycosides hydrolyze and release volatile isothiocyanates or nitriles and thiocyanates. The major toxicity is associated with oxazolidine-2-thiones, such as goitrin, which are formed from these compounds, and which impair thyroid function by inhibiting the formation of thyroxine by binding iodine and suppressing thyroxine secretion from the thyroid. Nitriles released from glucosinolates depress growth and cause damage to the liver and kidneys in severe cases.

Legumes of the species *Lathyrus sativus* (Indian pea), which grow in Europe, Asia, and Africa, contain several neurotoxic amino acids (e.g. β-ODAP) that cause largescale disease epidemics. The toxins cause paralysis of the lower body and wasting disease (neurolathyrism) if eaten over a long time. Consumption of the peas has caused major poisoning incidents; most recently in India in 1958, when over 25,000 people were poisoned in one district. The neurotoxic amino acids can be removed from the seeds by soaking in water before cooking.

15.2.2 Fungal Toxins

Mushrooms and toadstools toxins

Mushrooms are the edible fruiting bodies of fungi, which are large enough to be picked by hand. Toadstools are the inedible, or poisonous, equivalents that are often mistaken for mushrooms. There are approximately 14,000 of fungi species in the world that are large enough to be considered as mushrooms or toadstools. The occurrence, toxicity, and clinical manifestations for some of the major mushroom toxin classes are summarized in Table 17.

Table 17 *Summary of mushroom toxins, their source, toxicity, and effects*

Toxin class	***Toxin***	***Fungi species***	***LD50 mg.kg^{-1}***	***Poisoning***
Acromelic acid	Acromelic acid	*Clitocybe acromelalga*		Acroduria–neuroexcitation
Cyanides	Hydrogen cyanide	*Lepista nuda*	3	Cyanosis
Cyclopeptides	Amatoxins	*Amanita phalloides*	0.2–0.5	Hepatic and renal failure
	Virotoxins	*Amanita verna*	2.5	Hepatic and renal failure
Cyclopropanes	Coprinine	*Coprinus atramentarius*	–	Antabuse syndrome
	Prop-2-ene carboxylic acid	*Russula subnigricans*	2.5	Rhabdomyolysis
Hallucinogens	Psilocybin	*Psilocybes emilanceata*	–	Hallucinations
	Bufotenine	*Amanita citrina*	200	Hallucinations
Hydrazine	Gyromitrin	*Gyromitra esculenta*	10–30	Convulsions and GI disorders
Isoxazoles	Muscimol	*Amanita muscaria*	7.5–10	Mycoatropinic and delirium
	Ibotenic acid	*Amanita pantherina*	45	Mycoatropinic and delirium
	Muscarine	*Clitocybe dealbata*	150	
	Tricholomic acid	*Tricholoma muscarium*		

Toxin class	*Toxin*	*Fungi species*	*LD50 mg.kg⁻¹*	*Poisoning*
Necatorin	Necatorin	*Lactarius necator*		
Norleucines	Aminohydroxyhexynoic acid	*Trogia venenata*	71	Sudden unexplained death
	Stizolobic acid	*A. pantherina*		Hallucination, spasms, and sleep
Nucleosides	Clitidine	*C. acromelalga*	50	Pain and red coloration of toes
Orellanines	Orellanine	*Cortinarius orellanus*	15–20	Renal failure
Terphenyls	Ustalic acid	*Tricholoma ustale*	Kills mice	Diarrhoea, tremors, and death
Trichothecenes	Roridin	*Podostroma cornu-damae*	1	
	Verrucarin	*P. cornu-damae*	0.7	
	Satratoxin	*P. cornu-damae*	0.5	
Triterpenes	Hebevinosides	*Hebeloma vinosphyllum*	66	Paralysis
	Crustulinols	*Hebeloma crustuliniforme*	100	GI disorders and renal failure
	Fasciculols	*Naematoloma fasciculare*	50–168	
Sesquiterpenes	Illudin S	*Lampteromyces japonicus*	5	GI disorders
Lectins	Bolesatine	*Boletus satanas*	3.3	Haemolytic poisoning
	Rubescenslysine	*Amanita rubescens*	0.15–0.3	Haemolytic poisoning
	Phallolysin	*A. phalloides*	0.2–0.7	Haemolytic poisoning

Abbreviation: GI, gastrointestinal

Only a few percent of them are truly poisonous (2%) and a similarly low percentage are considered as choice edible species (4–5%). The greatest cause of poisoning is mistaken identity, where a forager assumes they can identify an edible species and collects a common look-alike poisonous species. The correct identification of fungi is then at the heart of mushroom safety. A total of 500 $mg.kg^{-1}$ of amatoxins (LD_{50} = 0.2–0.5 $mg.kg^{-1}$) can be found in the death cap (*Amanita phalloides*) and this then requires only a 50 g portion of the fresh toadstool to be considered lethally dangerous (Table 17). In reality, some 95% of deaths from 'mushroom' poisoning are due to a single cause – the amatoxins, which are present in species found around the world.

Mycotoxins

Mycotoxins are fungal metabolites, which when ingested, inhaled, or absorbed through the skin, can cause sickness or death in humans or domestic animals, including birds. Mycotoxins have been responsible for major epidemics in humans and animals throughout history. The most important epidemics have been ergotism, due to growth of the fungus *Claviceps purpurea* in rye grains, which killed and maimed hundreds of thousands of people in Europe in the past millennium; alimentary toxic aleukia, caused by T-2 toxin produced by *Fusarium sporotrichioides* in grain, which was responsible for the death of at least 100,000 Russian people between 1942 and 1948; and stachybotryotoxicosis caused by growth of *Stachybotrys chartarum* in hay, which killed tens of thousands of horses in the USSR in the 1930s. The term *mycotoxicosis* was first used in 1952 for the diseases resulting from the growth of fungi in foods and feeds. The event that ushered in the modern era of mycotoxin investigation was the discovery of *aflatoxins* due to the

growth of *Aspergillus parasiticus* in a peanut meal, which killed 100,000 young turkeys in the UK in 1960. Mycotoxins exhibit four basic kinds of toxicity: acute, chronic, mutagenic, and teratogenic. The most commonly described effect of acute mycotoxin poisoning is deterioration of liver or kidney function, which in extreme cases may lead to death. Five mycotoxins are considered to be of major importance in human or animal health today: *aflatoxins, ochratoxin A, fumonisins, deoxynivalenol (and the related trichothecene nivalenol), and zearalenone* (Fig. 8).

Aflatoxins are produced by *Aspergillus* species primarily in cereals and nuts. *Ochratoxin A* is produced by both *Aspergillus* and *Penicillium* species in a range of foods – grapes and products including wines and dried vine fruits, cereals in cool temperate climates, and coffee, cocoa, and chocolate. The remaining major toxins are primarily produced by *Fusarium* species in cereals. Good agricultural practice, i.e. drying food commodities as soon as possible and keeping them dry, is the only sure defence against mycotoxin formation in stored commodities.

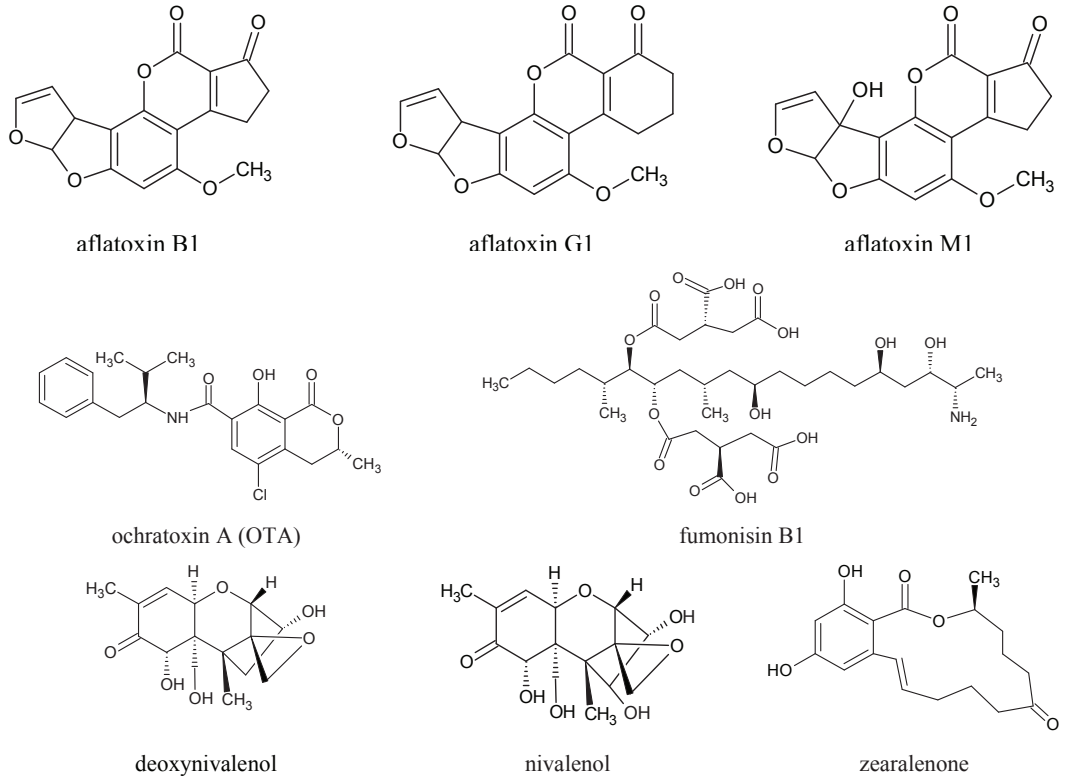


Figure 8 *Chemical structures of some mycotoxins.*

15.2.3 Seafood Toxins

Seafood constitutes a significant proportion of the world food supply, and more than 70 million tons are harvested each year. Although it is an important and popular food source, seafood ingestion is not free from associated public-health risks. In fact, seafood ranked third on the list of products most frequently associated with food-borne disease.

One type of seafood-related disease, ciguatera fish poisoning, is the most commonly reported food poisoning caused by a chemical toxin.

Algae and microalgae toxins

Seafood-related diseases are caused by ingestion of seafood (bivalve shellfish, primarily scallops, mussels, clams, oysters, and cockles, some fish species and crabs) contaminated with potent neurotoxins that are naturally produced by marine algae and microalgae. Many types of microalgae, such as dinoflagellates and diatoms, produce some of the most powerful known natural toxins called *phycotoxins*. Phycotoxins accumulated in seafood can cause a number of human diseases upon ingestion of the contaminated seafood, including:

- neurotoxic shellfish poisoning (NSP),
- paralytic shellfish poisoning (PSP),
- amnesic shellfish poisoning (ASP),
- diarrhoeic shellfish poisoning (DSP),
- azaspiracid shellfish poisoning (AZP),
- ciguatera fish poisoning (CFP)

The main acute symptoms are:

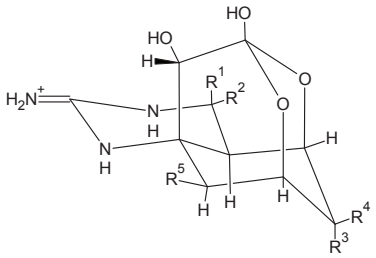
- Gastrointestinal: diarrhoea, nausea, vomiting,
- Respiratory: shortness of breath, progressing to paralysis,
- Cardiovascular: arrhythmias, hypertension or hypotension,
- Neurologic: paraesthesias of mouth and lips, weakness, dysphasia, dysphonia, etc.

The major phycotoxins are saxitoxin (20 derivatives), brevetoxin (10 derivatives), okadaic acid, dinophysistoxins (6 derivatives), domoic acid (3 derivatives), azaspiracid (5 derivatives), ciguatoxin (10 derivatives), maitotoxin, and scaritoxin.

These potent natural toxins are tasteless and odourless, and contaminated seafood appears to be completely normal. They are not destroyed by cooking or by food preservation (e.g. freezing, drying, or salting). In addition, these toxins are refractory to the action of human digestive enzymes, and there are no antidotes against their biological activity. Phycotoxin contamination of seafood is therefore a challenge for those people responsible for ensuring seafood quality and has important implications for public health (including nutrition and medical care).

Fish toxins – Tetrodotoxin and others

Tetrodotoxin (TTX, CAS number 4368-28-9) (Fig. 9) is a marine neurotoxin associated with certain fish species, notably pufferfish (22 species). Consumption of these fish can cause very severe food-borne intoxication, often referred to as pufferfish poisoning, or fugu poisoning. Unlike other marine biotoxins, it is not produced by the growth of toxic algae. It is now generally accepted that TTX is produced by certain marine bacteria – notably members of the *Vibrionaceae*, some *Pseudomonas, Shewanella, Photobacterium phosphoreum* and *Alteromona*s species. It is thought that the toxin passes up the food chain through plankton, small gastropods, and flatworms and is eventually accumulated in the tissues of pufferfish species, possibly as a defence against predators. Pufferfish appear to be immune to the toxic effects of TTX. Pufferfish poisoning has been known for many years, especially in Japan, where the fish are a delicacy and where it is required that specially trained fish cutters or chefs have a license to process and prepare puffer fish.



TTX analogue / R	R^1	R^2	R^3	R^4	R^5
TTX	H	OH	OH	11-CH_2OH	OH
4-*epi*TTx	OH	H	OH	11-CH_2OH	OH
6-*epi*TTX	H	OH	11-CH_2OH	OH	OH
11-deoxyTTX	H	OH	OH	11-CH_3	OH
11-oxoTTX	H	OH	OH	11-CHO	OH
TTX-11-carboxylic acid	H	OH	OH	11-COO^-	OH
11-norTTX-6,6-diol	H	OH	OH	OH	OH
11-norTTX-6(*S*)-ol	H	OH	OH	H	OH
11-norTTX-6(*R*)-ol	H	OH	H	OH	OH

Figure 9 *Chemical structures of tetrodotoxin and analogues.*

TTX is a very potent neurotoxin. Commonly, reports of a human mortal dose of tetrodotoxin are 1–2 mg with the victim eventually dying from respiratory paralysis. Initial symptoms appear between 20–180 min of ingestion. A slight numbness of the lips and tongue is then followed by increasing paraesthesia (tingling, 'pins and needles') in the face, hands, and feet. Victims may be completely paralysed and unable to move or speak, yet remaining conscious. Death usually occurs within 4–6 hours but may be as rapid as 20 min in some cases. TTX is relatively heat stable and is not affected by normal cooking procedures. TTX is absorbed with activated charcoal, which may reduce its toxic effect.

TTX is 10–100 times as lethal as black widow spider venom and more than 10,000 times deadlier than cyanide. It has a similar toxicity as saxitoxin, which causes paralytic shellfish poisoning and also blocks the sodium channel – both are found in the tissues of puffer fish. A recently discovered naturally occurring congener of TTX has proven to be four to five times as potent as TTX. Except for a few bacterial protein toxins, only palytoxin, a bizarre molecule isolated from certain zoanthideans (small, colonial, marine organisms resembling sea anemones) of the genus *Palythoa*, and maitotoxin, found in certain fishes associated with ciguatera poisoning, are known to be significantly more toxic than tetrodotoxin. Palytoxin and maitotoxin have potencies nearly 100 times that of TTX and saxitoxin, and all four toxins are unusual in being non-proteins.

15.2.4 Biogenic Amines

Biogenic amines are low-molecular-weight organic bases produced in a variety of foods by the decarboxylation of specific free amino acids (Table 18). *The presence of significant amounts of biogenic amines, especially in meat and fish products, is often an indicator of bacterial spoilage, can have adverse effects on health and is generally undesirable.*

Table 18 *Biogenic amines and their chemical precursors*

Biogenic amine	**Precursor**
Histamine[a]	Histidine
Putrescine[b]	Ornithine
Cadaverine[b]	Lysine
Tyramine[c]	Tyrosine
Tryptamine[a]	Tryptophan
β-phenylethylamine[c]	Phenylalanine

[a]*Heterocyclic amine,* [b]*Alipathic amine,* [c]*Aromatic amine.*

Biogenic amines are known to occur in a wide variety of food products: fish products, cheese, meat products (especially fermented meats), wine, beer, and fermented vegetable products, such as sauerkraut. Certain biogenic amines are also found naturally in a range of fruit juices and fresh fruit and vegetables, including cocoa beans, mushrooms, and lettuce. Histamine, tyramine, and to a lesser extent phenylethylamine are the main dietary biogenic amines associated with several acute adverse reactions in consumers.

Histamine is extremely stable once formed and is not affected by cooking. It can survive canning and retorting processes and is not reduced during freezing or frozen storage. Scombrotoxic (histamine) poisoning is a chemical intoxication, in which symptoms typically develop rapidly (from 10 minutes to 2 hours) after ingestion of food containing toxic histamine levels (scombroid fish – especially tuna, skipjack, bonito, and mackerel). The range of symptoms experienced is quite wide, but may include an oral burning or tingling sensation, skin rash and localised inflammation, hypotension, headaches and flushing. In some cases, vomiting and diarrhoea may develop and elderly or sick individuals may require hospital treatment. The symptoms usually resolve themselves within 24 hours. Antihistamines may be used effectively to treat the symptoms.

The threshold toxic level for histamine remains unclear. Individuals also vary in the severity of their response to histamine in fish. Analysis of outbreaks suggests that levels of histamine above 200 ppm are potentially toxic. Histamine occurs naturally in the human body; exposure to large doses can rapidly produce the symptoms of toxicity. The deleterious effects in relation to the amount of histamine ingested at one meal are as follows:

- 8 to 40 mg histamine – mild poisoning
- 70 to 1,000 mg – histamine disorders of moderate intensity
- 1,500 to 4,000 mg – histamine severe incident

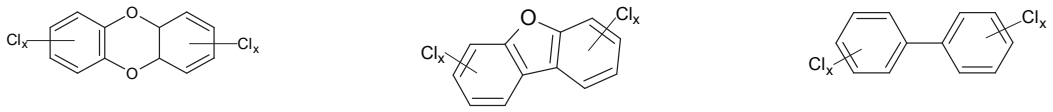
Although the role of histamine in scombrotoxic poisoning is well established, the food safety significance of other biogenic amines is much more uncertain. Tyramine, cadaverine, and putrescine all have acute oral toxicities of at least 2,000 mg per kg of body weight. Spermine and spermidine were reported to be slightly more toxic, with acute oral toxicities of 600 mg per kg of body weight. When administered intravenously, all these amines, except tyramine, caused a drop in blood pressure. Tyramine has been associated with hypertension and headaches in sensitive individuals, especially those who suffer from migraine headaches. In foods containing nitrite, such as cured meat products, putrescine and cadaverine may react with nitrate and produce carcinogenic compounds.

From a legal perspective, safe legal limits are set for histamine in certain fish and seafood products, mainly from fish species associated with high levels of histidine (e.g. 50 $mg.kg^{-1}$ in USA, 100 $mg.kg^{-1}$ in EU, 200 $mg.kg^{-1}$ in Australia). Although there are no legal guidelines that restrict the presence of biogenic amines in wine, it has been reported that different countries have applied specific histamine thresholds to reject wine imports: 2 $mg.l^{-1}$ in Germany, 5–6 $mg.l^{-1}$ in Belgium, 8 $mg.l^{-1}$ in France, and 10 $mg.l^{-1}$ in Switzerland.

15.2.5 Environmental Contaminants

Dioxins, Furans, and Dioxin-like Polychlorinated Biphenyls

Polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and dioxin-like polychlorinated biphenyls (PCDD/Fs and dl-PCBs) are ubiquitous environmental contaminants, having been found in soil, surface water, sediments, plants, and animal tissue worldwide (Fig. 10).



PCDD PCDF PCB

Figure 10 *Structures of PCDDs, PCDFs, and PCBs.*

Dioxins are often man-made contaminants and are formed as unwanted by-products of industrial chemical processes, such as the manufacture of paints, steel, pesticides and other synthetic chemicals, wood pulp and paper bleaching, and also in emissions from vehicle exhausts and incineration. Dioxins are also produced naturally during volcanic eruptions and forest fires. PCBs have been used in manufacturing industry since the early 1930s, mainly as cooling and insulating fluids in electrical equipment. The manufacture and general use of PCBs was banned in the 1970s because of environmental and health concerns. The EU has prohibited the use of most PCBs since 1978 and for certain applications since 1986. A deadline of 2010 was set for removing all PCB-containing equipment from service. Dioxins, on the other hand, cannot be banned owing to their formation as unwanted by-products of many industrial processes. Dioxins and PCBs are highly stable and they persist in animal tissues, especially fatty tissue, for long periods. They are not generally affected significantly by food processing such as heat treatments, or fermentation.

There are many different dioxins, of which 17 are known to be toxic to humans. The most toxic known dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). Significant concentrations of this compound can be measured in parts per trillion (ppt). PCBs, or polychlorinated biphenyls, are chlorinated aromatic hydrocarbons produced by the direct chlorination of biphenyls. There are about 209 related PCBs, known as congeners of PCBs, of which 20 reportedly have toxicological effects. Some of the PCBs have toxicological properties similar to those of dioxins and are therefore often referred to as "dioxin-like PCBs."

Dioxins are carcinogenic and can also cause adverse developmental and reproductive effects. Their negative health impacts are linked to their metabolic resistance and their capacity to accumulate in fat tissue in animals and humans. More than 90% of human exposure to dioxins typically occurs through the food supply, mainly fish, meat, and dairy products.

Because of the need to assess the risk from complex mixtures of dioxins, an approach has been adopted that assigns a factor relating to the relative potency of each congener, based on a comparison with the toxicity of 2,3,7,8-TCDD. Each chemical is assigned a toxic equivalency factor (TEF) related to the most toxic of the dioxins, 2,3,7,8-TCDD, which is given a TEF of 1. The total toxic equivalency (TEQ) of a mixture is the sum of the TEF weighed concentration of each compound in the mixture. The WHO/FAO Joint Expert Committee on Food Additives (JECFA) established a provisional tolerable monthly intake (PTMI) of dioxins to 70 pg of World Health Organization toxic equivalents (WHO-TEQ).kg^{-1} of bodyweight in June 2001. EC Regulation No. 1881/2006 sets maximum levels for certain contaminants, including dioxins and dioxin-like PCBs in foods. These limits for dioxins and PCBs are in the following range: 1.5-12.0 pg per g of fat for meat products, 1.5-10.0 pg per g of fat for oils, fats, eggs, and milk products.

Environmental Estrogens

Environmental estrogens are compounds ingested in the diet, which can mimic or interfere in estrogen action and have the potential to alter hormonal homeostasis in both women and men. The ability of compounds in the diet to influence reproductive functions was first noted in the 1920s by pig farmers after feeding their animals on mouldy grain, and concern was further stimulated in the 1940s by reports that sheep grazing on certain types of clover in western Australia became infertile ('clover disease'). More recent research has identified the estrogenic compounds in the mouldy grain to be of microbial origin and these have been termed *mycoestrogens*. The estrogenic compounds in the clover have been identified as of plant origin and have been termed *phytoestrogens*. There are also many man-made chemicals, which can mimic estrogen action and enter the food chain from environmental contamination (*xenoestrogens*). There are four main *phytoestrogens* classes: the isoflavones (genistein, daidzein), the coumestans (coumestrol), prenylated flavonoids (8-prenylnaringenin), and the lignans (enterodiol, enterolactone) (Fig. 11).

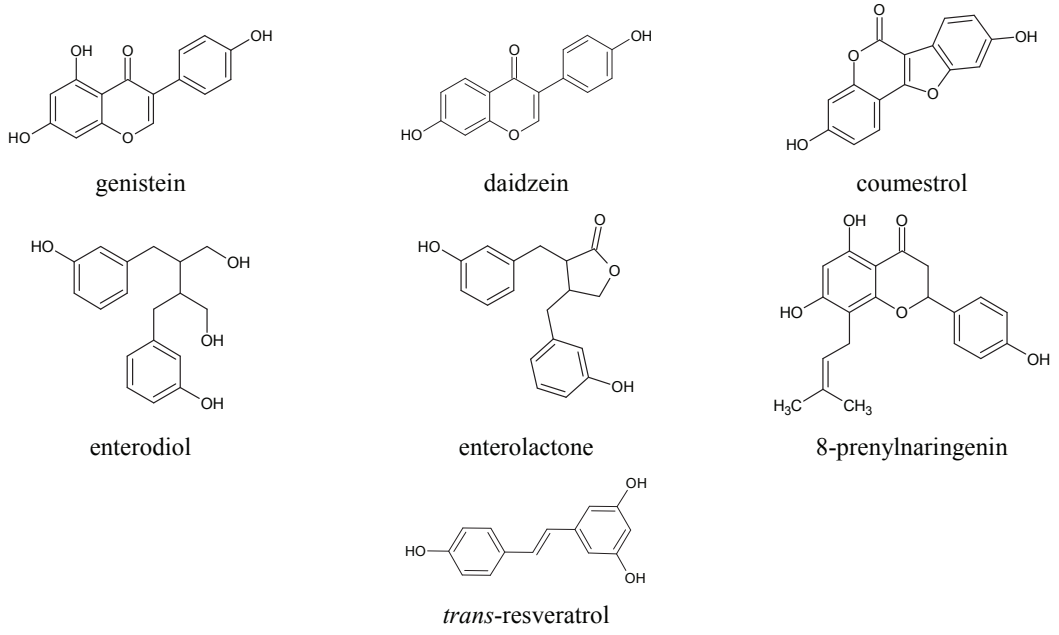
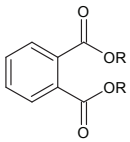


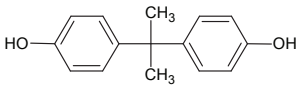
Figure 11 *Chemical structures of some environmental estrogens*

Genistein and daidzein are isoflavones found in leguminous plants, especially not only soybeans but also lentils and chickpeas. Other isoflavones in food include glycitein, biochanin A, and formononetin. Coumestrol is a coumestan found in young sprouting legumes such as clover and alfalfa sprouts and is therefore found in many animal feedstuffs. Prenylated flavonoids, including 8-prenylnaringenin and 6-prenylnaringenin, are found in hops and products made from hops such as beer. Resveratrol is a polyphenolic compound found in grapes and therefore red wine. The lignans are found in many cereals especially linseed (flaxseed) and many fruits and vegetables.

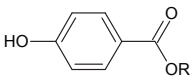
Xenoestrogens are synthetic chemicals released into the environment as pollutants. The main classes of xenoestrogens are alkyl esters of p-hydroxybenzoic acid (parabens), PCBs and dioxins, bisphenol A and some phthalate esters (Fig. 12).



phthalate ester (R = alkyl group)



bisphenol A



paraben (R = alkyl group)

Figure 12 *Chemical structures of some xenoestrogens.*

All these compounds have been shown to possess estrogenic properties in assays *in vitro* and *in vivo*. Because of concern for endocrine disruption following exposure in young children, use of bisphenol A in the manufacture of baby bottles has been ceased in Europe, Canada, and the USA.

Soy-based infant formulae have been used since the 1960s in the UK and have become popular as an alternative to cow's milk for babies with milk allergy. Daily intake of isoflavones by this route has been estimated at up to 4 $mg.kg^{-1}$ of body weight in infants, giving plasma isoflavone levels 10,000-fold higher than their own endogenous estrogen levels. Questions still exist as to whether there may be adverse reproductive consequences associated with use of soy-based infant formulas for baby boys, especially in the context of male reproductive health.

Exposure to some persistent organic pollutants, phthalates, and bisphenol A can give rise to obesity in animal models, and such compounds are increasingly implicated in the rapid rise in obesity, metabolic syndrome, and diabetes in young people.

Nitrate and Nitrite

Nitrate and nitrite are widely consumed from food and water by animals and humans, and are formed to a limited extent endogenously. Nitrate is used in agriculture as a fertilizer and in food processing as an approved food additive (antimicrobial agents, preservatives, and colour fixatives in meat and fish). Nitrate's toxicity is low, but the metabolites, nitrite, nitric oxide, and N-nitroso compounds make these substances of regulatory importance because of the potential for adverse health implications in humans and animals.

International efforts have been put in place to reduce and limit the occurrence of nitrate in water. In drinking water the maximum permitted levels are 50 mg nitrate and 0.5 mg nitrite per litre. Human exposure to nitrate is mainly exogenous whereas exposure to nitrite is mainly endogenous via nitrate metabolism. In Europe, the main dietary sources of nitrate are vegetables, preserved meat, and drinking water, with vegetables being the most important source. The acceptable daily intake (ADI) values for nitrate and nitrite were in 2002 established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA): 0–3.7 $mg.kg^{-1}$ of bodyweight for nitrate and 0–0.07 $mg.kg^{-1}$ of bodyweight for nitrite.

Perchlorate

The most common perchlorate salts are ammonium perchlorate (NH_4ClO_4), lithium perchlorate ($LiClO_4$), potassium perchlorate ($KClO_4$), and magnesium perchlorate ($Mg(ClO_4)_2$). Ammonium perchlorate and potassium perchlorate are used as an oxidizing agent in rocket propellants and with the remaining salts are found in other items (e.g. explosives, road flares, fireworks, and car airbags), occur naturally in some fertilizers, and potash. The use of these perchlorate salts and the disposal of these salts provide a pathway for them to enter into the soil and ground and surface water allowing solvation to occur.

Perchlorate is one of several chemicals that has the ability to disrupt thyroid gland function at pharmacological doses (0.02, 0.1, and 0.5 $mg.kg^{-1}$ per day). Perchlorate at these doses can competitively inhibit iodide uptake from the blood by the sodium–iodide symporter and reduces the amount of iodide that is available for organification. If the reduction of iodine is continuous and the uptake of iodine is hindered, it may cause the thyroid to become enlarged (goiter) and may result in hypothyroidism. In children, hypothyroidism leads to delays in growth and intellectual development, which is called cretinism in severe cases. In adults, it can cause a number of symptoms, such as tiredness, poor ability to tolerate cold, and weight gain.

In 2010, the Joint FAO/ WHO Expert Committee on Food Additives (JECFA) of the World Health Organization (WHO) derived a provisional maximum daily tolerable intake (PMDTI) for perchlorate: 0.01 $mg.kg^{-1}$ of bodyweight per day.

15.2.6 Toxic Metals

Foods of animal and plant origin contain many chemical elements, which depending on their amount are termed either macroelements or microelements. Macroelements, as well as basic elements, are the building materials that support tissue, teeth, skin, and hair, play an important role in water-electrolyte management and pH regulation, and are parts of many active compounds vital for metabolic processes. Some microelements are essential for the normal functions of organisms. They participate in numerous important processes, e.g. enzymatic reactions (Zn, Co, Ni, Mn, Fe, Cr, Al), glycolysis (Mn, Zn), nucleotide synthesis (Mg, Fe), erythropoesis (Fe, Cu), organic acid transformation (Fe, Zn, Ni, Mn), nitrogen exchange (Fe, Mo, Cu, Mn, V, Co), photosynthesis (Fe, Ti, Mg, Mn), and their lack or excess may be a cause of many serious diseases. Trace elements, which are not considered essential, may cause severe poisonings if administered in amounts equal to or higher than the minimal dose. Due to toxicity of some trace heavy metals and the possibility of environmental contamination, the potential for high risk is linked mainly to Hg, Cd, As, and Pb. Some others are Cu, Zn, Sn, Cr, Ni,and Al. All elements are present in the environment as salts or as metalo-organic compounds, and only in such forms they are biologically active. To limit the possibilities of food poisoning in humans caused by ingestion of excessive amounts of trace elements via food and water, the highest allowable concentrations of trace elements are fixed as the *PTWI* (permitted tolerable weekly intake).

- *Mercury*. The main source of mercury in the diet is fish, followed by fruit and vegetables. The other source is dental amalgam. It is highly toxic and can cause disruption of the nervous system, brain damage, damage to DNA and chromosomes, allergic reactions and adverse reproductive effects. The PTWI for mercury is 0.35 mg for a person weighing 70 kg.
- *Cadmium*. The main sources of cadmium in the diet are cereals, fruit and vegetables. The other sources include meat, and large fish shellfish. Long-term exposure to Cd may lead to kidney damage, as cadmium tends to accumulate in the kidneys. Other adverse health effects include diarrhoea, stomach pains and sickness, bone defects, immune system damage, possible infertility, possible damage to DNA and carcinogenic effects. The PTWI is 0.49 mg for a person weighing 70 kg.
- *Arsenic*. The major source of arsenic in the diet is fish and other seafood. Arsenic is one of the most toxic elements found, and is present in foods in organic or inorganic forms, with the latter being considered to be far more toxic than the former (100 mg of arsenic oxide is considered to be lethal). Illnesses associated with excessive inorganic arsenic intake include skin, lung and heart conditions,

gastrointestinal diseases, and possible carcinogenic effects. The PTWI for arsenic should not exceed 1.05 mg for a person weighing 70 kg.

- *Lead*. Lead enters the human body via food, water, and air. Its adverse effects include disruption of haemoglobin synthesis, kidney damage, increased blood pressure, miscarriage, nervous system disruption, reduced fertility, and learning disabilities and behavioural problems in children. Lead can cross the placenta and may damage the nervous system and brain of the developing foetus. The PTWI for lead in the EU is 1.75 mg for a person weighing 70 kg.

15.2.7 Processing Contaminants

Processing contaminants are generated during the processing of foods (e.g. heating, fermentation). They are absent in the raw materials, and are formed by chemical reactions between natural and/or added food constituents during processing. Examples are: advanced glycationend products (AGEs), chloropropanols (3-monochloropropane-1,2-diol, 1,3-dichloropropane-2-ol, 2-monochloropropane-1,3-diol, 2,3-dichloropropane-1-ol), acrylamide, polycyclic aromatic hydrocarbons (PAH) and N-nitrosodimethylamine (NDMA) (Fig. 13).

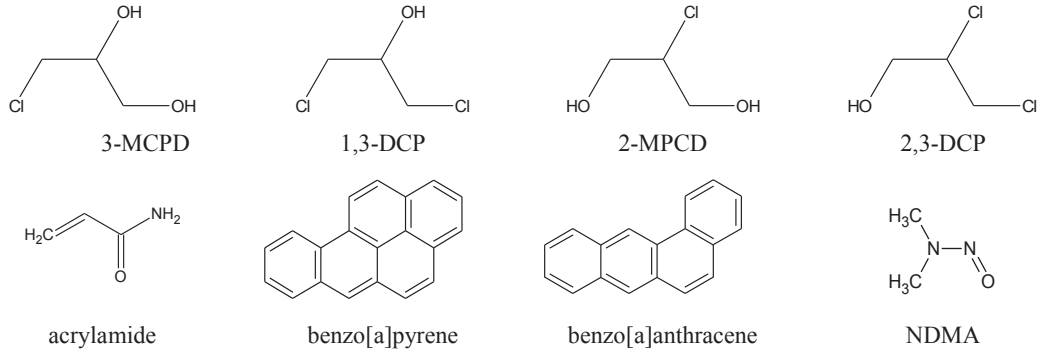


Figure 13 *Chemical structures of some processing contaminants.*

- *Acrylamide*. Acrylamide in food is formed at temperatures above 120 °C via the Maillard reaction between the reducing sugars (glucose and fructose) and the amino acid asparagine. Acrylamide has been found at microgram per kilogram levels in a wide range of heat-treated foods, for example, potato products, breakfast cereals, bread, cookies, and coffee. Acrylamide is a neurotoxin at high levels of exposure and may cause a range of symptoms such as numbness in the hands and feet. However, it is considered unlikely that the levels found in foods could result in sufficient exposure to cause neurological damage or reproductive toxicity. Acrylamide is carcinogenic in animal experiments (mainly its metabolite glycidamide), but epidemiological studies have not shown any evidence of increased cancer risk in humans due to acrylamide in food. The cancer risk associated with acrylamide in foods should be validated by the Joint FAO/WHO Expert Committee on Food Additives (JECFA).
- *Advanced Glycation End Products (AGEs)*. These compounds are a heterogeneous group of chemical compounds (also referred to as glycotoxins), which occur naturally in animal tissues and are also produced by high temperature cooking processes, such as frying, roasting and grilling of certain foods. They are highly oxidative and are known to be involved in the pathology of a number of diseases,

including diabetes, cardiovascular disease, the metabolic syndrome, insulin resistance, obesity, and Alzheimer's disease. Although a number of different AGEs have been identified, three types have been studied in some detail and have been used in studies as markers for AGEs. These are N^6-(carboxymethyl) lysine (also known as CML), pentosidine and derivatives of methylglyoxal. AGEs levels in the blood tend to increase with age because kidney function in older people is reduced and less able to remove substances from the body. The recommendations to reduce the production of AGEs in cooked foods are as follows: Cook meat and fish at temperatures of less than 200 °C and avoid prolonged cooking times. Use indirect cooking methods, such as stewing, poaching and steaming, rather than grilling, frying or barbecuing. Apply acidic marinades incorporating lemon juice or vinegar to meat before cooking.

- *Chloropropanols.* Chloropropanols are a group of related chemical contaminants that may be produced in certain foods during processing. They are formed during the manufacture of acid-hydrolysed vegetable protein (used as a savoury ingredient in soups, sauces, especially soy sauce) and have been detected in refined edible oils and fats (palm oil, margarine and spreads), but not in unrefined oils. The most common and the best studied is 3-monochloropropane-1,2-diol (3-MCPD). Chloropropanols are potentially carcinogenic and their presence in food, even at low levels, is therefore undesirable. A provisional maximum tolerable daily intake (PMTDI) for 3-MCPD is 2 micrograms per kg of bodyweight.
- *Polycyclic Aromatic Hydrocarbons (PAHs)* are a large group of lipophilic organic chemical contaminants containing two or more fused aromatic rings. They can be produced during the partial combustion or pyrolysis of organic material (wood) including the processing and preparation of food. The occurrence of PAHs in food is mainly due to food smoking, roasting, grilling (which includes barbequing), frying, drying, and steaming. The most studied PAH is benzo[a] pyrene (BaP), which is often used as a marker compound for all PAHs in food, and also in environmental studies. The maximum levels of B[a]P (micrograms per kg of wet weight) in some types of food are as follows: Foods for infants (1.0), oils and fat (2.0), smoked meats (2.0), cocoa beans and derived products (5.0), heat treated meat (5.0), bivalve mollusks smoked (6.0).
- *N-Nitrosamines* are formed by the reaction of nitrite with secondary amines. Nitrite is traditionally used for developing the pink, heat-stable pigment of cured meat. Its other important role is the inhibition of the outgrowth of *Clostridium botulinum* spores in pasteurized products. Nitrite also serves as an antioxidant and contributes to the development of the flavour of cured meat. The undesirable side effect, however, is the formation of N-nitrosamines. Many N-nitrosamines are strongly carcinogenic. The N-nitrosamine of most importance is N-nitrosodimethylamine (NDMA). Nitrates may also form N-nitrosamines through reduction to nitrites by saliva or enzymes in the intestinal tract. N-nitrosamines were found in beer, cured meats, and smoked fish. Only a few countries have imposed limits on the N-nitrosamine content of foods and these have been restricted to certain commodities.

15.2.8 Food Contact Materials

There are approximately 80,000 chemicals currently in commerce, and 2,000 new chemicals are thought to be added to this list each year. A large number of these chemicals come into contact with food.

Bisphenol A and Endocrine Disruption

Some chemicals have the potential to disrupt the endocrine system of animals, including humans. This class of chemicals is referred to as "endocrine disruptors" or "endocrine-disrupting chemicals" (EDCs). The EDCs can be natural, i.e. plant-based (phyto) estrogens, or artificial, such as herbicides, insecticides, and fungicides on food crops. Another group of EDCs are the environmental toxins (PCBs and dioxins) and a final source is the packaging itself. Epoxy resins, plastics, and other food contact materials contain chemicals with endocrine activity, and these chemicals can leach from these food contact materials into the food itself.

Bisphenol A (BPA) (Fig. 7) is a synthetic compound, which has been known since 1891 and exhibits hormone-like properties that raise concern about its suitability in some consumer products and food containers. The products using bisphenol A-based plastics have been in commercial use since 1957 and at present 3.6 million tonnes of BPA are used by manufacturers yearly. It is a key monomer in production of epoxy resins and polycarbonate plastic. BPA-based plastic is clear and tough, and is made into a variety of common consumer goods, such as baby and water bottles, sports equipment, medical and dental devices, dental fillings sealants, CDs and DVDs, household electronics, eyeglass lenses, foundry castings, and the lining of water pipes. BPA is also used in the synthesis of polysulfones and polyether ketones, as an antioxidant in some plasticizers, and as a polymerization inhibitor in PVC. Epoxy resins containing bisphenol A are used as coatings on the inside of almost all food and beverage cans and they are also used to line water pipes and in making thermal paper such as that used in sales receipts.

BPA is an endocrine disruptor and may have an effect on fertility, development, the brain, behaviour, and prostate gland in foetuses, infants, and young children. BPA may be carcinogenic, possibly leading to the precursors of breast cancer. Some reports indicate that it has liver toxicity and may even be linked to obesity by triggering fat-cell activity. Some countries have recently considered banning, or have banned the use of BPA in plastics used for baby feeding bottles. The chemical industry over time responded to criticism of BPA by promoting "BPA-free" products. Some "BPA-free" plastics are made from epoxy containing a compound called bisphenol S (BPS), but BPS like BPA has been found to be an estrogen hormone disruptor even at extremely low levels of exposure. In 2002, EU legislation was introduced setting a Specific Migration Limit (SML) of 3 mg BPA per kg of food. This was amended in 2004 to set a SML(T) of 0.6 mg BPA per kg of food. In January 2011, use of bisphenol A in baby bottles was forbidden in all EU countries. By October 2008, the EFSA issued a statement concluding that the study provided no grounds to revise the current Tolerable Daily Intake (TDI) level for BPA of 0.05 mg/kg bodyweight. In January 2015, EFSA's experts reduced the safe level of BPA from 50 micrograms per kilogram of body weight per day to 4 micrograms/kg of bw/day, the highest estimates for dietary exposure and for exposure from a combination of sources (diet, dust, cosmetics, and thermal paper) are three to five times lower than the new TDI.

Food Packaging Contaminants

Food packaging contaminants are organic or inorganic chemicals that originate from the food packaging. Chemical contamination of food from food packaging material largely depends on the type of material in contact with the packaged food. Polymers are the most important food packaging materials constituting approximately 70% of the market share, namely: low-density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET), high-density polyethylene (HDPE), polystyrene (PS) and expanded PS, and polyvinylchloride (PVC). Food packaging contaminants with their very diverse chemistry are the largest single source of chemical food contaminants. The

process of chemical partitioning from the packaging into food is called migration. The types of chemicals that can migrate from packaging into food are highly diverse and depend on the type of packaging material, the food properties (e.g. fat content) as well as the temperature and duration of storage. For example, heavy metals those are used in ceramic glazing, or are naturally present in glass raw materials, can transfer from the inner surface to the food by surface exchange. For non-inert materials, like plastics, elastomers, and paper and board, migration can occur either from the packaging material itself or from the outside of the packaging. Paper-based materials have a large pore size and this permits migration of smaller molecules from the outside to the food inside. To reduce or prevent food contamination, barrier materials can be used (a carton with an inner bag made of aluminium foil). Another source of chemical contaminants is from the degrading polymer, when small-sized monomers are released and can migrate into the food. Chemical contamination by release is relevant mainly for reusable food contact materials, like plastic baby bottles or plastic kitchenware.

The major contaminants in food packaging materials are:

- in PET (formaldehyde, acetaldehyde, antimony, ultraviolet stabilizers),
- in LDPE (polyolefin oligomeric saturated hydrocarbons, nonylphenol),
- in PVC (vinyl chloride, phthalates, organotins),
- in PS (styrene and its trimers),
- in PP (polyolefin oligomeric saturated hydrocarbons, erucamide, oleamide, butylated hydroxytoluene),
- in polycarbonate (bisphenol A),
- in cellulose (triacetin),
- in metal with inner coating (bisphenol A, Sn, Al),
- in paper and carton (polyolefin oligomeric saturated hydrocarbons, benzophenones),
- in Tetrapack carton (polyolefin oligomeric saturated hydrocarbons, benzophenones, isopropyl thioxanthone),
- in glass with closure (phthalates, lead, UV stabilisers),
- in ceramic (heavy metals).

Important food packaging contaminants are phthalates. *Phthalates* are esters of phthalic acid and are used to impart flexibility to plastic products. A number of food packaging materials can contain phthalates, including PVC and other plastics, printing inks used on flexible food packaging, adhesives used for paper and board, regenerated cellulose film (cellophane), aluminium foil–paper laminates, and closure seals in bottles. Phthalates are known to migrate from packaging into foods, especially high-fat products and oils, and the rate of migration into food from packaging rises with increasing temperature. Phthalates could cause adverse effects on the developing human male reproductive system, adverse effects on fertility and birth defects and cause kidney and liver damage. Phthalates may be potential carcinogens, endocrine disruptors and may also be linked to neurological and behavioural disorders such as attention deficit hyperactivity disorder and autism. The most used phthalates are di-(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), di-isononyl phthalate (DINP), di-isodecyl phthalate (DIDP) and benzyl butyl phthalate (BBP). The European Union has also restricted the use of BBP, DBP, and DEHP to food contact surfaces only for non-fatty foods up to 0.1%, 0.05%, and 0.1%, respectively, in the final product. It should be noted that many PVC "cling film" food wraps are no longer made with phthalates, but are now manufactured using other plasticisers.

In Europe, food-packaging contaminants are regulated by the European Commission, Directorate General Health and Consumers under the Food Packaging Framework Regulation. Migration of chemicals from packaging into food is usually assessed using

food simulants, which represent different groups of food in terms of their chemical properties. Overall migration to any of the food simulants should not exceed 10 $mg.dm^{-2}$ of food contact surface for plastics and multi-layered materials such as beverage cartons consisting of several layers of different materials.

15.2.9 Food Additives

In the EU, a food additive is defined in law (Regulation 1333/2008) as:

- *"any substance not normally consumed as a food by itself and not normally used as a typical ingredient of the food, whether or not it has nutritive value, the intentional addition of which to food for a technological (including organoleptic) purpose in the manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food results, or may be reasonably expected to result (directly or indirectly) in it or its by-products becoming a component of or otherwise affecting the characteristics of such foods".*

The definition excludes processing aids, including enzymes and extraction solvents, flavourings, substances added as nutrients, such as vitamins and minerals, and substances migrating from food contact materials (food packaging, utensils, etc.) which do not exert a technological function in the food. The term does not include contaminants and sodium chloride. Today, the use of food additives is regulated by national legislation in most countries and only additives, which are shown to be safe, can be used. Therefore, food additives are regulated as a positive list, which means that only food additives specifically listed in the regulations of a country can legally be added to food products, and the maximum levels (MLs) in food must not be exceeded. This is in contrast to chemical and microbiological contaminants, which are regulated as a negative list.

Every food additive is assigned a unique number in the International Numbering System (INS), adopted and extended by the Codex Alimentarius. The INS assigns a unique three- or four-digit reference number to each additive (e.g. ascorbic acid is 300). Within the European Union and Switzerland these numbers (prefixed by the letter E) are known as *E-numbers* (the "E" stands for "Europe"). Number ranges have been preassigned to food additive classifications, so also give information on the primary purpose of the additive, even without knowing the name:

- E100–E199 (colours)
- E200–E299 (preservatives)
- E300–E399 (antioxidants, acidity regulators)
- E400–E499 (thickeners, stabilizers, emulsifiers)
- E500–E599 (acidity regulators, anti-caking agents)
- E600–E699 (flavour enhancers)
- E700–E799 (antibiotics)
- E900–E999 (glazing agents and sweeteners)
- E1000–E1599 (additional chemicals)

Possibly the principal concern currently expressed by consumers in relation to food additives, both natural and synthetic, is the belief that their consumption may be associated with unwanted behavioural effects such as hyperactivity, especially in children. Another concern is that they may be linked to food allergies and insensitivities. The implicated food additives include:

- food dyes and colourings (such as tartrazine, ponceau 4R, quinoline yellow, sunset yellow),
- antioxidants (such as butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT)),

- flavourings and taste enhancers (such as monosodium glutamate (MSG), spices, and artificial sweeteners),
- preservatives (such as benzoates, nitrates, nitrites and sulphites).

The majority of these and other food additives have undergone reevaluation based on their human health risk assessments.

Colourants

The use of synthetic colours in foods has been an area of debate in recent years due to a proposed linked between behavioural disturbances, especially hyperactivity, in children and dietary exposure to colours in food. Some colourants are no longer approved for use in food, but are still used in some countries illegally, and may pose health risks. One of these is Sudan Red, which is a suspected carcinogen. Some other colours are of public interest: Ponceau 4R, Quinoline Yellow, and Sunset Yellow.

- *Tartrazine (E102*) is a synthetic lemon yellow azo dye primarily used as a food colouring. The European Food Safety Authority (EFSA) allows for tartrazine to be used in processed cheese, canned or bottled fruit or vegetables, processed fish or fishery products, and wines and wine-based drinks. Tartrazine appears to cause the most allergic and intolerance reactions of all the azo dyes, particularly among asthmatics and those with an aspirin intolerance.
- *Ponceau 4R(E124)* is a synthetic red azo dye used in a range of alcoholic and non-alcoholic beverages, and a variety of foodstuffs including confectionary, desserts, cheeses, meats, preserved fruits, and sauces. Known are its possible effects on children's behaviour, especially hyperactivity. In Europe, the maximum permitted levels (MPLs) in food and beverages range up to 500 and 200 $mg.kg^{-1}$, respectively.
- *Quinoline Yellow (E104)* is a synthetic colourant used in confectionery, soft drinks, as well as other food and beverages. Quinoline Yellow in food causes behavioural problems such as hyperactivity in children. In the EU, Quinoline Yellow is permitted in beverages, with a maximum level of 200 $mg.l^{-1}$ for alcoholic and 100 $mg.l^{-1}$ in non-alcoholic beverages. It is also used in a variety of foods, with MPLs ranging from 50 $mg.kg^{-1}$ in complete weight control formulas to 500 $mg.kg^{-1}$ in sauces, decorations, and coatings.
- *Sunset Yellow FCF (E110)* is a synthetic azo dye used as a colouring for beverages and variety of foods, including confectionary, desserts, soups, cheeses, savoury snacks, sauces, and preserved fruits. It has been claimed that Sunset Yellow FCF causes intolerance reactions in sensitive individuals and adverse effects on children's behaviour. In Europe, the MPLs in food and beverages range from 50 to 500 $mg.kg^{-1}$.

Antioxidants

Antioxidants are a group of food preservatives that delay or prevent the deterioration of foods by oxidative mechanisms. Some of these (BHA and BHT) attract public controversy regarding their safety to human health.

- *BHA (E320*) is a mixture of the two chemical isomers – 85% of 3-tertiary-butyl-4-hydroxyanisole (3-BHA) and 15% of 2-tertiary-butyl-4-hydroxyanisol (2-BHA) and is an effective antioxidant in animal fats used in baked products. The National Toxicological Program (NTP) has listed BHA as "reasonably anticipated to be a human carcinogen." In 2011, the EFSA established an ADI for BHA of 1.0 $mg.kg^{-1}$ of bodyweight per day.

- *BHT (E321)*, also known as butylhydroxytoluene (2.6-di-tert-butyl-4-methyl-phenol), is primarily used as a food additive. BHT at high doses can exert liver and lung tumour-promoting effects in some animal models. In 2012, the EFSA established an ADI for BHT of 0.25 $mg.kg^{-1}$ of bodyweight per day.

Flavourings and taste enhancers

Flavourings are substances used to impart taste and/or smell to food, and/or to intensify the existing flavours of products. Flavour enhancers activate receptors for the umami or savoury taste (the four other tastes are sweet, salt, sour, and bitter) and, thus, introduce a new taste to products. General method for the safety evaluation of flavouring agents takes the approach that in most cases, dietary exposure to these substances is low, and the majority of flavours are metabolized rapidly to innocuous end products. The most contentious flavour enhancer added to food from the perspective of a safety to human health is monosodium L-glutamate (MSG).

- *Monosodium L-glutamate (E621)* is used as flavour enhancers for over a century. MSG is now considered to be one of the most intensively scrutinized food additives because it has been reported to trigger minor adverse reactions now called the "MSG symptom complex" (headaches, general weakness, palpitations, and pain at the back of the neck starting about an hour after eating food containing MSG, and lasting for 2 h with no apparent long-term effect). However, studies to date have failed to prove an unequivocal link between MSG and the reported symptoms. The largest palatable level for humans is approximately 60 $mg.kg^{-1}$ of bodyweight with higher doses causing nausea.

Preservatives

The efficiency of preservatives depends primarily on the concentration of the preservative, the composition of food, and the type process to be inhibited. There are food preservatives that inhibit microbes (nitrites, benzoates, ascorbates, and sorbates), preservatives that act as antioxidants (BHA, BHT) and some can be used for both (sulphites and sulfur dioxide). The safety of certain preservatives has been the subject of debate among the consumer groups, academics, and food regulators.

- *Potassium nitrite (E249), sodium nitrite(E250), sodium nitrate(E251), potassium nitrate (E252)* have been used as food additives in cured meats for many years primarily to prevent growth and toxin production by *Clostridium botulinum*. The use of nitrite to cure meat was also seriously questioned in the 1970s due to the potential for the presence of preformed N-nitrosamines, which may have a carcinogenic potential. The toxicology of nitrate and nitrite has been comprehensively reviewed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA), which established acceptable daily intakes (ADIs) of 0–3.7 $mg.kg^{-1}$ of bodyweight for nitrate and 0–0.07 $mg.kg^{-1}$ of bodyweight for nitrite.
- *Benzoic acid (E210) and sodium benzoate (E211)* have inhibitory effects on the yeast growth and their ADIs were established by the JECFA at 0–5 $mg.kg^{-1}$ of bodyweight.
- *Sodium and Potassium Sulphites (E221, E225) and Suphfur dioxide (E220)* are used as antioxidants to prevent the discolouration of light-coloured fruits and vegetables, such as dried apples and dehydrated potatoes. They are also used in the wine-making process because they inhibit bacterial growth without interfering with the development of yeasts. The use of sulphites in foods that are important sources of thiamine (vitamin B1) is prohibited because of their ability to destroy thiamine. The ADIs for sulphites were established by the JECFA at 0–0.7 $mg.kg^{-1}$ of bodyweight.

- *Sorbic acid (E200), sodium sorbate (E201), potassium sorbate (E202)* are antimicrobial agents often used as preservatives in food and drinks to prevent the growth of mould, yeast, and fungi without affecting the taste, colour, or flavour. The ADI for sorbic acid is 0–25 mg/kg of bodyweight.

Sweeteners

Sweeteners are food additives used as substitutes for sugar, mainly sucrose and fructose. Some of them have a relative sweetness many times that of sugar, which means they can be used in much smaller amounts. The most widely approved intensely sweet sugar substitutes are stevia, aspartame and its derivative neotame, sucralose, acesulfame, and saccharin. The toxicology of two of them (aspartame and saccharin) was intensively studied.

- *Aspartame (E951)* is one of the most widely used non-nutritive, intense sweeteners in the world. It is approximately 200 times sweeter than sugar and is used in a range of foods (desserts, carbonated soft drinks, yoghurt, weight-control products, and confectionary). The food safety issue in relation to the consumption of aspartame is for a very small proportion of the population that has the rare genetic disorder, phenylketonuria. In 2002,the Scientific Committee on Food (SCF) established the ADI of aspartame as 40 $mg.kg^{-1}$ of bodyweight.
- *Saccharin (E954)* is approximately 300–500 times sweeter than sugar and can be used in cooking and baking, as well as a sweetener for foods and beverages. Although saccharin has been in use for more than a century, its safety has repeatedly been questioned. The epidemiological studies on saccharin did not show any evidence that saccharin ingestion increases the incidence of bladder cancer in human population. The ADI of 5 $mg.kg^{-1}$ of bodyweight was allocated by the JECFA to saccharin and its calcium, potassium, and sodium salts. In a December 14, 2010 release, the EPA stated that saccharin is no longer considered a potential hazard to human health.
- *Steviol Glycosides (E960)* are compounds extracted from the leaves of the plant *Stevia rebaudiana.* Two of the major steviol glycosides contributing to the sweet taste of stevia extracts, namely stevioside and rebaudioside A, are reported to be 100–400 times as sweet as sucrose. Steviol glycosides were approved as food additives in Europe in 2011 and are permitted in a large variety of foods and beverages. The ADI of 4 $mg.kg^{-1}$ of bodyweight for steviol glycosides was established by the EFSA in 2011.

Some special analytical methods are used today for regulatory purposes to ensure that food additives do not exceed their maximum levels or are not being used for unapproved uses or in unapproved foods. These methods can be found in a number of internationally published sources of monographs:

- Combined Compendium of Food Additive Specifications, FAO JECFA,
- Food Chemicals Codex,
- European Union (EU) directives on food additives specification.

Food additives are among the safest chemicals present in food because of the rigorous testing that is required before they may legally be used in food.

15.2.10 Pesticide Residues

The term *pesticides* includes all chemical, natural or synthetic substances used to fight parasites on crops. Though pesticides are used mainly for this purpose, they can also be used to fight the carriers of illnesses such as malaria, yellow fever, typhoid fever, etc.,

or even against domestic insects. About 20% of the production of insecticides is used for this purpose. They are normally classified according to their target as insecticides, fungicides, and herbicides.

Conazoles

The conazole fungicides (bitertanol, cyproconazole, diniconazole, epoxiconazole, flusilazole, propiconazole, triadimefon, etc.) represent a large group of compounds widely used in agriculture for protection and treatment of fungal diseases in crop plants (cereals, oil seeds, fruit trees, grapes, vegetables, sugar beets). A number of adverse effects have been observed in laboratory animals after repeated administration of conazoles: developmental effects, effects on reproduction, hepatotoxicity, hepatocarcinogenicity in mice, and production of other types of tumours (thyroid, testis), via non-genotoxic mechanisms. There are no reported effects in humans similar to those described in experimental animals. Risks from long-term and short-term dietary intakes of residues of conazole fungicides have been assessed by the Joint FAO/WHO Meeting on Pesticide Residues. The ADIs values (mg per kg of bw) for long-term intake of conazoles residues are from 0.007 (flusilazole) to 0.07 (propiconazole).

Dithiocarbamates

Dithiocarbamates are sulphur compounds of which 21 known compounds are employed as pesticides to protect fruits and vegetables. Most of these compounds are rapidly degraded in the environment to yield thioureas such as ethylenethiourea (ETU), ethyleneurea (EU), and propylenethiourea. ETU is of toxicological concern due to its carcinogenicity, teratogenicity, and antithyroid properties. Maneb, mancozeb, and metiram can induce thyroid cancer in laboratory animals possibly via the formation of ETU. The hazard associated with the use of dithiocarbamates for the general population is the residue left on the foodstuff, which can be conveniently reduced or eliminated by washing or peeling fruit and vegetables before eating or cooking. Recommended ADIs values (mg per kg of bw) for dithiocarbamates are from 0.0003 (ethylenethiourea, propylenethiourea) to 0.05 (maneb, mancozeb).

Herbicides

Herbicides represent a diverse group of chemicals, which are used to control weeds. The European Union pesticides database lists 324 herbicides. The toxicity of herbicides varies between classes as well as individual chemicals. Some of them (paraquat, 2,4-D, glyphosate) have been involved in a number of human poisoning cases. The primary target organs are the kidney and the heart. For example, the lethal oral dose of paraquat is approximately 2 g for an adult (approximately 30 per kg bw). Genetically modified, herbicide resistant crops permit the use of certain herbicides (e.g. glyphosate in Monsanto's Roundup herbicide formulation) while crops are growing. This can result in significant residues of the herbicide and/or metabolites. Dietary exposures to herbicides are generally well below reference doses; however, if the herbicides are not degraded in the environment they might be transported to water sources resulting in human exposures via drinking water. The ADIs values (mg per kg of bw) for herbicides are from 0.002 (diquat, terbutylazine) to 0.3 (2,4-D). The TDI value for glyphosate was established as 1.75 mg per kg of bw, but some recent studies have recommended the re-evaluation of this value.

Inorganic and Other Metal-Containing Compounds

At present, in most developed countries, only copper compounds are used in significant amount as fungicides. It is believed that some organotins are still used in

some developing countries. The others have been banned for either toxicological or environmental reasons.

- *Copper* is present in almost all foods, and most human diets naturally include between 1 and 2 mg per person per day of copper. Copper is included in fungicidal formulations as oxychloride ($Cu_2Cl(OH)_3$), sulphate ($CuSO_4 \cdot 5.H_2O$) or hydroxide ($Cu(OH)_2$). Copper hydroxide and the Bordeaux mixture may cause toxic effects by inhalation and present a risk of serious damage to eyes. Target organs of excess copper after oral administration are the liver and kidneys. The upper limit of copper intake without adverse effect is not well defined, but is well recognised to be between 10 and 12 mg Cu per person per day. In the EU, the following maximum residue level (MRL) have been set: 5 $mg.kg^{-1}$ for tomatoes, 20 $mg.kg^{-1}$ for table grapes, and 50 $mg.kg^{-1}$ for wine grapes.
- *Tin.* Organic tin compounds, such as triphenyltin (fentin) acetate and triphenyltin (fentin) hydroxide, are used as fungicides, whereas others such as cyhexatin and the closely related azocyclotin are also used as acaricides in several crops. Azocyclotin and cyhexatin have moderate acute toxicity by the oral route and their ADIs values were established of 0–0.003 mg per kg of bw. Fentin showed immunosuppressive properties in toxicity studies and the US EPA established for it an ADI of 0–0.00003 mg per kg bw.

Organophosphates and Carbamates

Organophosphates(OPs) and carbamates (CAs) are the most used insecticides after the banning of most organochlorines such as DDT. They are also used in public health against vectors of diseases such as the malaria mosquitoes even indoors. Some of them are used for the treatment of human diseases such as parasitosis, myasthenia, or glaucoma. The toxicity of OPs and CAs is due to the accumulation of acetylcholine at nerve terminals because of acetylcholinesterase inhibition. The ADIs values (mg per kg bw) for long-term intake of OPs and CAs residues are from 0.0006 (Terbufos (OP)) to 0.3 (pirimiphos-methyl (OP), malathion (OP)).

Organochlorines

Organochlorinated pesticides (OCPs) have broad-spectrum insecticidal activity and primarily act as excitatory neurotoxins. They have been used for several applications and have been widely dispersed into the environment over the past 50 years. Now, many of these compounds (aldrin, chlordane, chlordecone, diendrin, endrin, heptachlor, lindane, etc.) are ubiquitously found as trace contaminants in soil, sediment, air, biota, and food, even in places where they were never used, including Antarctica. DDT has been employed as an insecticide in agriculture and public health. Banned for use in agriculture, its only permitted use is for indoor spraying of walls to control the malaria vector mosquito. Human exposure mainly occurs through trace environmental contamination of food (meat and meat products, fish, milk, and other dairy products). The toxicity of OCPs in humans differs significantly and the CNS is the main target organ, where they cause either depression or stimulation. The ADIs values (mg per kg of bw) for intake of OCPs are from 0.0005 (Chlordane) to 0.02 (Chlorobenzilate).

Pyrethroids

Pyrethroids are synthetic insecticides derived from the naturally occurring pyrethrins, the six insecticidal compounds of pyrethrum isolated from the *Chrysanthemum* genus of plants. The insecticidal properties of pyrethroids (cyfluthrin, cyhalothrin, etofenprox, cypermethrin, bifenthrin, deltamethrin, esfenvalerate, tefluthrin, etc.) are

due to their ability to disrupt the electrical signalling in the nervous system, an effect that is also relevant to mammals. The ADIs values (mg per kg bw) for long-term intake of pyrethroids are from 0.01 (bifenthrin) to 0.04 (cyfluthrin).

15.2.11 Veterinary Drugs Residues

The Codex Alimentarius Commission defines a veterinary drug as any substance applied or administered to any food-producing animal for therapeutic, prophylactic, or diagnostic purposes, or for modification of physiological functions or behaviour. This broad definition includes drugs for:

- treatment of diseases or other pathological conditions,
- prevention of diseases or other pathological conditions,
- diagnosis of diseases,
- zootechnical purposes such as oestrus synchronization, induced ovulation, chemical castration, etc.,
- improved production such as increase in growth rate, feed efficiency, milk production, etc.,
- behaviour modification, such as tranquilizers.

In the European Union, some substances such as anticoccidial compounds administered in animal feed are regulated as feed additives; however, these substances are considered to be veterinary drugs within the Codex Alimentarius Commission. The Codex Alimentarius Commission has examined the most commonly used veterinary drugs and established appropriate MRLs for meat, poultry, fish, milk, eggs, and honey. Toxicological testing for veterinary drugs is based on the same battery of tests used in evaluating food additives and pesticides.

Antibacterials

To assure the long-term care, health, and welfare of food-producing animals, antibacterial compounds (aminoglycosides, amphenicols, tetracyclines, streptogramins, sulfonamides, etc.) are used for three purposes:

- therapeutic use to treat sick animals,
- prophylactic use to prevent infection in flocks/herds of food-producing animals,
- as growth promoters to improve feed utilization and reduce production time.

On 1 January 2006, the EU banned the feeding of all antimicrobials and related drugs to food-producing animals for growth-promoting purposes. Currently, in Europe no antimicrobial agents can be used in farm animals for growth promotion purposes. Several different classes of antibacterials are now recognized and many of these are used in both animal and human medicine. It has been suggested that those antibacterials that are important in human medicine should not be used therapeutically in food-producing animals (to avoid the resistance problems). Residues of antimicrobial compounds in foods of animal origin could also negatively affect some food-processing procedures (they could inhibit the activity of starter cultures used in the production of certain fermented meats, yogurt, and cheeses, leading to economic losses for food producers). In Europe, tests are regularly performed to detect the presence of antibacterial residues in food. Before the animal or animal products can be sold for slaughter/consumption, a withholding period must be observed which is of sufficient duration to allow any residues to be eliminated, such that antibacterial residues are no longer detected at concentrations above the maximum residue limit (MRL).

Anthelmintics

Anthelmintics (also called parasiticides, endectocides, and nematocides) are usually used to treat parasitic worm infections. Three main families of anthelmintics are known as follows: benzimidazoles, nicotinic receptor agonists, and macrocyclic lactones. Moreover, the presence of anthelmintic residues (albendazole, fenbendazole, flubendazole, abamectin, doramectin, emamectin, levamisole, morantel, etc.) in livestock may have serious consequences on consumers, so in order to assure food safety maximum residue limits (MRLs) of these compounds in several matrices were established. For example, the MRLs values (micrograms per kg) for muscle are from 10 (levamisole in bovine, ovine, porcine, and poultry) to 225 (triclabendazole in all ruminants).

Anabolics

The use of hormonally active steroids as growth promoters in farm animals can increase the production of veal and beef significantly (up to 15%), but very few issues involving veterinary medicines have resulted in more controversies over the years than those surrounding the use in animals of drugs that promote anabolism and the safety of food produced from those treated animals. Here is an example: the USA and a number of other countries worldwide have approved some of these substances for use in beef cattle. In 1985 the EU prohibited the use of synthetic hormones and imports of meat from animals that had been administered these hormones and in 1989, the EU banned the import of US beef produced with the six FDA-approved hormones (estradiol, progesterone, testosterone, trenbolone acetate, zeranol, and melengestrol acetate). This action dramatically reduced beef exports to the EU Member States. In April 2012, after prolonged trade dispute, an agreement was reached when the EU Member States agreed to increase the quota of "no hormone added" beef permitted to be imported into the EU and the USA agreed to drop its *ad valorem* punitive duties on EU products exported to the USA. Another problem is illegal use of anabolics in food-producing animals and sale of "hormone cocktails" by a "hormone mafia" in the EU as well as several reports of serious health effects from consuming the meat from treated animals. Very popular are so called "beta-agonists" (ractopamine hydrochloride, clenbuterol, etc.), which have the ability to increase muscle mass. Ractopamine has been approved for use as a veterinary drug in swine in 21 countries, but the EU and China have not approved ractopamine for domestic use and do not allow residues of ractopamine in imported food.

Coccidiostats

Coccidiosis is a parasitic disease, which can occur wherever animals are housed in small areas that are contaminated with coccidial oocysts. Coccidiosis has affected historically all species of wild and domestic birds. Coccidia are without question the most important parasites of poultry in terms of distribution, frequency, and economic losses. The main method of controlling coccidiosis is through the addition of drugs used as anticoccidial drugs or coccidiostats in the feed at the authorized levels and observing the prescribed hygiene requirements. The coccidiostats or anticoccidial drugs can be grouped into two major classes:

- *polyether ionophore antibiotics* - monensin sodium, lasalocid sodium, maduramicin ammonium, narasin, salinomycin sodium, and semduramicin sodium
- *non-polyether ionophores* – decoquinate, robenidine, amprolium, halofuginone, diclazuril, sulfonamides, etc.

The maximum content of coccidiostats in food was in 2012 established in the EU. These values (micrograms per kg of wet weight) are from 1 (lasalocid sodium, narasin, halofuginone in milk) to 300 (nicarbazin in eggs or liver).

Ectoparasiticides

Food-producing animals are infected by a number of ectoparasites, including lice, ticks, mange mites, myiasis larvae, and nuisance flies. Control of the parasites is largely based on the use of chemicals that are usually applied topically to the skin and have a direct effect on the parasite. Most ectoparasiticides are neurotoxins (organochlorines, organophosphates and carbamates, pyrethrins and pyrethroids, formamidines, macrocyclic lactones, etc.). The chronic effects of ectoparasiticides from food intake on human health are not well defined, but there is increasing evidence of carcinogenicity, disruption in hormonal function, and genotoxicity. Restrictions are therefore applied to many of the ectoparasiticides indicated for use in food-producing animals to ensure that unacceptable residues are not present in products intended for human consumption.

15.2.12 Prevention and Control of the Chemical Contamination of Food

For the prevention and control of the chemical contamination of food, three lines of defence are available:

- The first line of defence is the production of food in which the quantities of added chemicals and their quality lie within the limits permitted by legislation. For this purpose, the primary industry as agriculture and processing industries have to comply with laws and observe the principles of good agricultural and manufacturing practices.
- The second line of defence is the application of technologies, which can prevent or reduce the use of chemicals in food (e.g. pesticides).
- The third line of defence is the strict control and monitoring of levels of chemicals in food, the responsibility for which is laid on governments' food control agencies.

15.3 Physical Hazards

Physical hazards are foreign matter that accidentally gets into food. This can be the result of environmental contamination during production, processing, storage, packaging, and transport, or from fraudulent practices. It is important to identify foreign objects and to locate the source as far as possible, in order to determine when, where, how, and why the object got into the food. Illness complaints from the ingestion of foreign matter include nausea and vomiting, diarrhoea, headache, fever and dizziness, and chest pain. These may be due to chemical hazards, microbiological contamination, or a psychosomatic response to the belief that foreign matter has been ingested. Potential hazards caused by foreign matter can be grouped into several classes.

15.3.1 Physical Objects

Hard objects such as glass fragments, metal, and bone pose the biggest food safety concern because they can cause injuries such as cuts, broken teeth, choking, and intestinal perforation. There is a risk of cuts or lacerations to the hands during food preparation and to the mouth, oesophagus, stomach, or intestines. There is also a risk of chipped teeth, broken dental fillings, and damage to prosthetics (dentures). Approximately 80% of reported foreign matter ingestions occur in children, and 80–90% of such ingested

foreign objects will pass through spontaneously over the following 4–7 days. It was estimated that only 1–5% of ingested foreign objects resulted in actual injury. There are three main factors, which determine whether an object may be hazardous:

- *size* – foreign particles greater than 20 mm (e.g. bones) have the potential to be a food safety hazard and may cause injury to consumers,
- *shape* – spherical or cylindrical objects present a greater risk for choking, whereas slender and sharp objects (e.g. fish bones) present a greater risk of laceration or perforation,
- *consistency of the object* – rigid objects such as coins caused most choking deaths in 3-year and older children, whereas conforming objects such as balloons caused more choking deaths in children under the age of 3 years.

15.3.2 Chemicals

Some foreign objects may represent possible chemical hazards to a person consuming them:

- poisonous products, which may be accidentally harvested with field crops (e.g. ergots),
- medical tablets or capsules in food,
- pests, which have been killed by commercial pesticides,
- food ingredients from other recipes (nuts – risk of causing an allergic reaction).

15.3.3 Biological Objects

Foreign matter with potential biological hazards (such as blood, used wound dressings, etc.) can be found in food products which may evoke fear that diseases (such as AIDS) may be transmitted to them by such means. In fact, most of these diseases are quite difficult to transmit indirectly by such means, and if the offending item has been subjected to heat processing, any infective agent has been killed.

The foreign matter that can be found in foods includes:

- insects (domestic flies) or pests (caterpillars) that feed either on the food product or on something closely connected with it, mould spores, insect eggs, animal droppings,
- plant material (bits of leaf or stalk) is frequently found in vegetables and fruits,
- other hard material – stones, sand, soil may be incorporated when soil-based crops are harvested, material from production line and packaging like plastics, paperboard, pieces of metals, fragments of glass (but most of the glass fragments originate from end-use of the product rather than from its manufacture).

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16 FOOD SAFETY MANAGEMENT

Food quality and safety can only be insured through the application of quality-control systems throughout the entire food chain. They should be implemented at farm level with the application of good agricultural practices and good veterinary practices at production, good manufacturing practice at processing, and good hygiene practices at retail and catering levels.

16.1 HACCP and Food Safety Management Systems

HACCP is an acronym for *Hazard Analysis Critical Control Point*, a science-based food safety management system that has its origins in the USA manned space flight programme of the 1960s and 1970s. The HACCP approach to food safety is based on a detailed examination of every stage in the production process for an individual food product. The objective is to identify where and when hazards could occur and to design effective controls for each hazard.

HACCP consists of seven principles that outline how to establish, implement, and maintain a quality assurance plan for a food establishment:

1. Conduct a hazard analysis. (Prepare a list of steps in the process where significant hazards occur and describe the preventive measures. Assess the likelihood of occurrence of the hazard(s) and identify the measures for their control).
2. Identify the critical control points (CCPs) in the process. (Determine the points, procedures or operational steps that can be controlled to eliminate the hazard(s) or minimize its (their) likelihood of occurrence).
3. Establish critical limits for preventative measures associated with each identified CCP.
4. Establish CCP monitoring requirements. (Establish procedures from the results of monitoring to adjust the process and maintain control).
5. Establish corrective actions to be taken when monitoring indicates a deviation from an established critical limit.
6. Establish effective record-keeping procedures that document the HACCP system.
7. Establish procedures for verification that the HACCP system is working correctly.

Over the last 25 years, HACCP has become the preferred method of ensuring safe food all over the world. The widespread adoption of HACCP in the food industry has led to the development of a number of formal standards and less formal codes of practice designed to facilitate the integration of HACCP principles and practice into the overall management of food safety. The International Organization for Standardization (ISO) has developed the ISO 22000:2005 Food Safety Management Systems Standard *(ISO 22000, Food safety management systems – Requirements for any organization in the food chain*) that utilizes HACCP principles to outline methods for controlling food safety hazards and brings together many of the other key elements in an effective food

safety management system. Since 2005, several other standards were published by ISO concerning the food safety:

- ISO/TS 22002-1:2009 – Prerequisite programmes on food safety. Part 1: Food manufacturing.
- ISO TS 22003:2007 – Food safety management systems for bodies providing audit and certification of food safety management systems.
- ISO TS 22004:2005 – Food safety management systems. Guidance on the application of ISO 22000:2005.
- ISO 22005:2007 – Traceability in the feed and food chain. General principles and basic requirements for system design and implementation.

16.2 Food Safety Legislation in the EU

Food safety legislation in the countries of the EU originates from the European Commission (EC). There are two main legal instruments by which the Commission can introduce new food legislation:

- The first instrument is the *Directive*, which sets out an objective, but allows national authorities to determine how that objective is to be achieved, and cannot be enforced in individual Member States until implemented into national legislation.
- The second instrument is the *Regulation*, which is 'directly applicable' and becomes law in all Member States as soon as it comes into force, without the need to change national legislation.

It is usual for the EC to submit a request for a risk analysis to be undertaken by the European Food Safety Authority (EFSA) before legislative proposals are drawn up. On 1st January 2006 there came into force the "Food Hygiene Package" of EU legislation, which consists of three main Regulations:

- EC Regulation No. 852/2004 on the hygiene of foodstuffs,
- EC Regulation No. 853/2004 setting out specific hygiene requirements for foods of animal origin,
- EC Regulation No. 854/2004 setting out specific requirements for organising official controls on products of animal origin intended for human consumption.

16.3 Labeling and Information for Consumers

Starting from 13 December 2014 there is a new Regulation (EU) No. 1169/2011 concerning consumer information on foodstuff. The mandatory particulars must be easy to understand and visible, clearly legible, and, where appropriate, indelible. The height of «x» the characters must be at least 1.2 mm (except for small-sized packaging or containers).

The mandatory particulars concern: the name, the list of ingredients, the substances causing allergies or intolerances (nuts, milk, mustard, fish, grains containing gluten, etc.), the quantity of certain ingredients or categories of ingredients, the net quantity of the food, the date of minimum durability or the 'use by' date, any special storage conditions and/or conditions of use, the name or business name and address of the food business operator or importer, the country of origin or place of provenance for certain types of meat, milk or where failure to indicate this might mislead the consumer, instructions for use where it would be difficult to make appropriate use of the food in the absence of such instructions, for beverages containing more than 1.2% by volume of alcohol, the actual alcoholic strength by volume, and a nutritional declaration.

Information provided voluntarily must meet the following requirements: it shall not mislead the consumer, it shall not be ambiguous, or misleading, it shall, where appropriate, be based on the relevant scientific data.

16.4 Institutions Involved in Food Safety

There are many institutions involved in food safety. The most important ones are as follows:

- FAO –Food and Agricultural Organization of the United Nations
- WHO– World Health Organization
- CAC FAO/WHO –Codex Alimentarius Commission
- JECFA –Joint FAO/WHO Expert Committee on Food Additives
- JEMRA –Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment
- JMPR –Joint FAO/WHO Meetings on Pesticide Residues
- EC –European Commission (European Union)
- EFSA –European Food Safety Authority
- ISO –International Standards Organization

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17 FOOD QUALITY ASSURANCE

The main actors in the food quality assurance include the government, consumers, and the food industry.

Food quality is determined by organoleptic (sensoric), nutritional, functional, and hygienic properties.

In order to ensure or stimulate food preparation at home, it is important to realize that the general public, especially in the industrialized world, has a different perception on food related health risks as compared to the ranking order of food hazards based on objective scientific criteria. The difference in ranking order between consumers and scientists is a cause of concern, especially as risk prevention is also partly the responsibility of the consumer. The observed difference is partially attributable to information in the media as well as to psychological factors.

The household is perhaps the most relevant place for development measures to combat food-borne illnesses, as it is the location where the consumer can exert the mostly control over what he or she eats.

Illness due to contaminated food is a widespread health problem; in infants and the elderly, its consequences can be fatal. WHO data indicate that only a small number of factors are responsible for a large proportion of food-borne disease episodes.

Common errors include:

- preparation of food too far ahead of consumption;
- prepared food being left too long at a temperature that permits bacterial proliferation;
- inadequate heating;
- cross-contamination;
- an infected or "colonized" person handling with the food.

17.1 The Golden Rules of Food Safety

The Ten Golden Rules presented below offer advice that can reduce the risk that food-borne pathogens will be able to contaminate, to survive, or to multiply. The rules have been drawn up by the World Health Organization to provide guidance to members of the community on safe food preparation in the home. They should be adapted, as appropriate, to local conditions.

1. Choose foods processed for safety

While many foods, such as fruits and vegetables, are best in their natural state, others simply are not safe unless they have been processed. For example, always buy pasteurized as opposed to raw milk and, if you have the choice, select fresh or frozen poultry treated with ionizing radiation. When shopping, keep in mind that food processing was invented to improve safety as well as to prolong shelf life. Certain foods eaten raw, such as lettuce, need thorough washing.

2. Cook food thoroughly

Many raw foods, most notably poultry, meats, and unpasteurized milk, are very often contaminated with disease-causing pathogens.

Thorough cooking will kill the pathogens, but remember that the temperature of all parts of the food must reach at least 70 °C. If cooked chicken is still raw near the bone, put it back in the oven until it is done-all the way through. Frozen meat, fish, and poultry must be thoroughly thawed before cooking.

3. Eat cooked foods immediately

When cooked foods cool to room temperature, microbes begin to proliferate. The longer they wait, the greater is the risk. To be on the safe side, eat cooked foods as soon as they come off the heat.

4. Store cooked foods carefully

If you must prepare foods in advance or want to keep leftovers, be sure to store them under either hot (near or above 60 °C) or cool (near or below 10 °C) conditions. This rule is of vital importance if you plan to store foods for more than four or five hours. Foods for infants should preferably not be stored at all. A common error, responsible for countless of foodborne disease, is to put too large a quantity of warm food in the refrigerator. In an overburdened refrigerator, cooked foods cannot cool to the core as quickly as they must. When the centre of food remains warm (above 10 °C) too long, microbes thrive, quickly proliferating to disease-producing levels.

5. Reheat cooked foods thoroughly

This is your best protection against microbes that may have developed during storage (proper storage slows down microbial growth but does not kill the organisms). Once again, thorough reheating means that all parts of the food must reach at least 70 °C.

6. Avoid contact between raw foods and cooked foods

Safely cooked food can become contaminated through even the slightest contact with raw food. This cross-contamination can be direct, as when raw poultry meat comes into contact with cooked foods. It can also be more subtle. For example, do not prepare a raw chicken and then use the same unwashed cutting board and knife to carve the cooked bird. Doing so can reintroduce all the potential risks for microbial growth and subsequent illness present prior to cooking.

7. Wash hands repeatedly

Wash hands thoroughly before you start preparing food and after every interruption–especially if you have to change the baby or have been to the toilet. After preparing raw foods such as fish, meat, or poultry, wash again before you start handling with other foods. Moreover, if you have an infection on your hand, be sure to bandage or cover it before preparing food. Remember too, that household pets – dogs, birds, and especially turtles–often harbour dangerous pathogens that can pass from your hands into food.

8. Keep all kitchen surfaces meticulously clean

Since foods are easily contaminated, any surface used for food preparation must be kept absolutely clean. Think of every food scrap, crumb or spot as a potential reservoir of germs. Cloths that come into contact with dishes and utensils should be changed every day and boiled before reuse. Separate cloths for cleaning the floors also require frequent washing.

9. Protect foods from insects, rodents, and other animals

Animals frequently carry pathogenic microorganisms, which cause food-borne disease. Storing foods in tightly sealed containers is your best protection.

10. Use pure water

Pure water is just as important for food preparation as for drinking. If you have any doubts about the water supply, boil water before adding it to food or making ice for drinks. Be especially careful with any water used to prepare an infant's meal.

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