

CHAPTER 19

NUTRITION

Nutrition is the science of food and the dietary needs of the body, **food** being any solid or liquid that supplies the body with substances for energy, growth, repair and replacement of tissues (→ Fig. 19.1). All foods are a mixture of one or more macronutrients – carbohydrates, lipids and proteins – and **micronutrients** – vitamins and minerals. Water is an essential part of the diet and fibre, which is indigestible, is important for the health of the digestive tract.

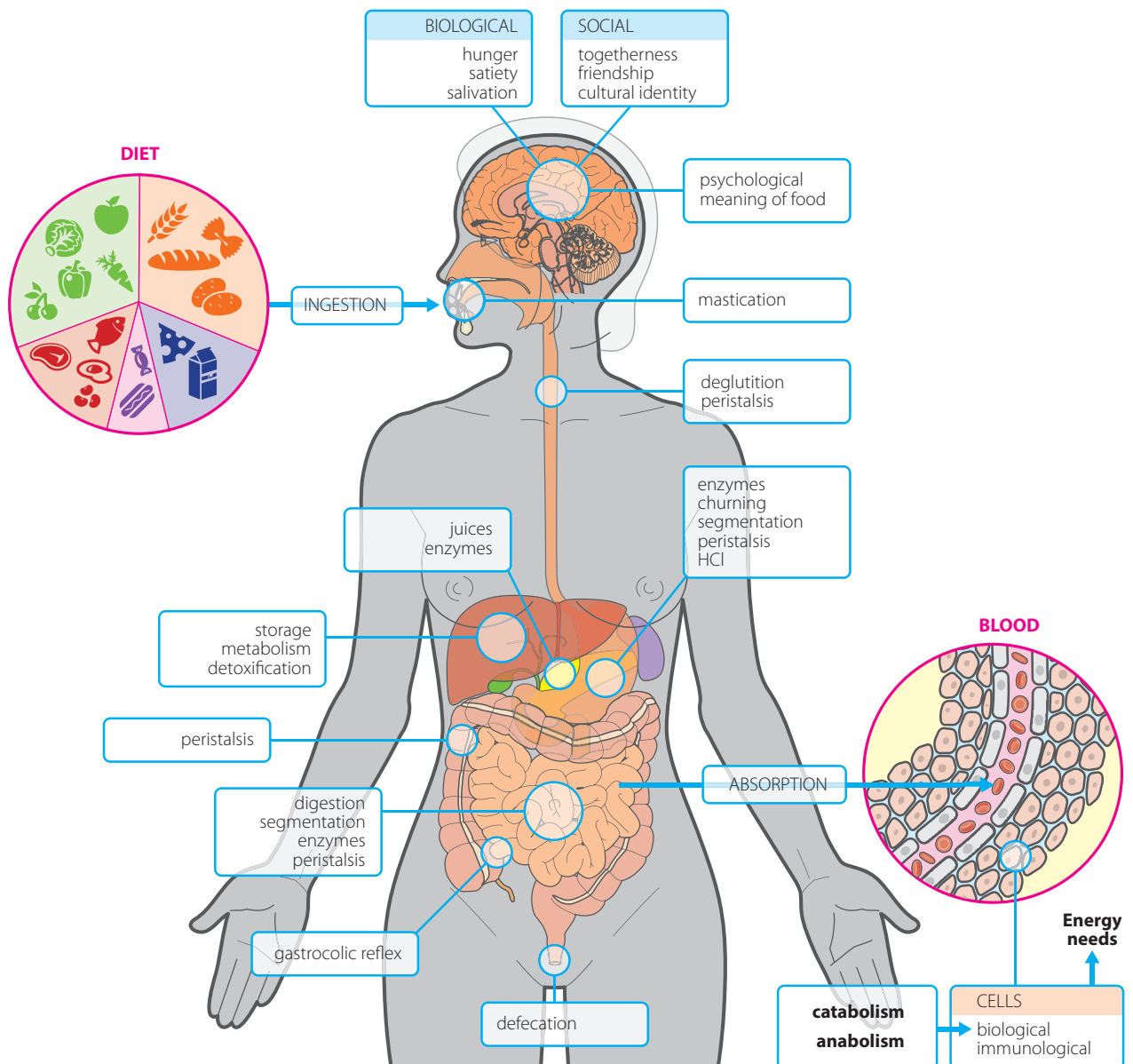


Fig. 19.1 The holistic overview of the processes involved in making ingested food available to the body's cells.

19.1 Hydration

Humans can survive for weeks without food, but they would perish within a few days without **water**, which makes up about 60% of adult body weight and must be continually replenished. Fluids such as water, tea, coffee, fruit juices, alcoholic and carbonated drinks supply about 62% of daily adult fluid intake, the balance being derived from so-called ‘solid’ foods. Vegetables contain about 85% water, the edible parts of fruit comprise 75–80%, and bread is about 35% water. A very small percentage of fluid intake, about 3%, is the water released from the various biochemical reactions of metabolism.

19.1.1 Fluid homeostasis

Fluid homeostasis (osmoregulation) must be maintained for the health and wellbeing of the body, no matter how much fluid a person ingests. The recommended daily intake of water varies depending on the climate in which people live, their typical daily diet and their level of physical activity, but the body requires more water:

- on hot days to prevent dehydration due to sweating
- following physical activity or exertion
- during lactation
- when a person has been vomiting or has diarrhoea
- to prevent persistent constipation
- during some illnesses.

19.2 Carbohydrates

Box 19.1 Carbohydrates – sugars, starches and fibre – are an essential part of a balanced diet. Cereals such as rice, wheat, barley, maize, millet and oats are staple sources of carbohydrates around the world, and whole grains contain considerably more vitamins, fibre and **protein** than refined cereals.

A carbohydrate is a compound containing atoms of carbon, hydrogen and oxygen, with the hydrogen and oxygen atoms in the same ratio as in water – H₂O (→ [Box 19.1](#)). The primary function of carbohydrates in the body is to provide **energy** in the form of glucose and to store energy as glycogen. There are many types of carbohydrate, each consisting of one or more sugar units called **saccharides** (saccharum = sugar). A sugar unit is a **monomer** – a simple molecule that can be joined to many others of the same type by glycosidic bonds to form a **polymer** – a number of similar units bonded together to form larger molecules, e.g. oligosaccharides and polysaccharides (→ [Table 19.1](#)).

Table 19.1 Types of carbohydrate

Type	Monosaccharides	Disaccharides	Oligosaccharides	Polysaccharides
Unit structure	1 sugar unit C ₆ H ₁₂ O ₆ (→ Fig. 19.2)	2 sugar units C ₁₂ H ₂₂ O ₁₁	3–10 sugar units	Hundreds or thousands of sugar units
Type of bond between sugar units	none	glycosidic	glycosidic	glycosidic
Solubility	Soluble in water	Soluble in water	Soluble or insoluble	Insoluble
Examples with alternative names	Glucose (dextrose, D-sugar, grape sugar) Fructose (fruit sugar, D-fructose, levulose) Galactose (forms part of lactose)	Maltose (malt sugar) formed from two glucose units Sucrose (beet or cane sugar) formed from one glucose and one fructose unit Lactose (milk sugar) formed from one glucose and one galactose unit	A group of sugars with many functions, e.g. glycoproteins on plasma membranes and prebiotics (used by gut biota)	Starch – long unbranched chains of glucose units Glycogen – branching chains of glucose units Cellulose (fibre) – long, insoluble chains of glucose units grouped into bundles

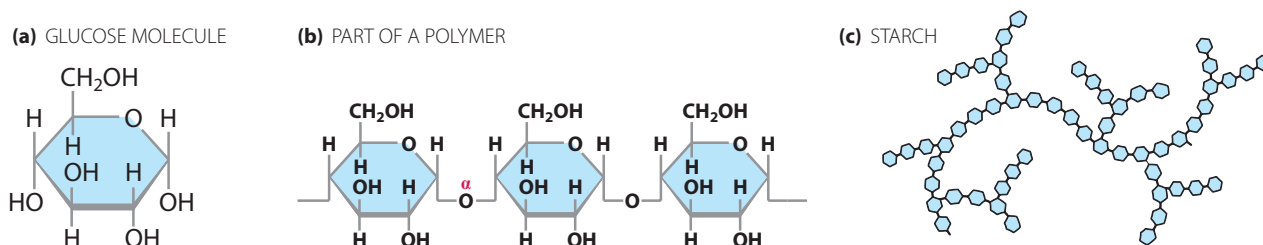


Fig. 19.2 Glucose molecules: (a) single molecule; (b) joined together to form a polymer; (c) starch formed from a branching chain of glucose molecules.

19.2.1 Carbohydrate conversion in the body

When carbohydrates are ingested, only the monosaccharides (simple sugars) can be immediately absorbed from the gut, enter the circulation and be carried around the body to be used as fuel for cells, muscles and organs (→ [Box 19.2](#)). Disaccharides (double sugars), oligosaccharides and polysaccharides (→ [Box 19.3](#)) must first be digested (broken down) into simple sugars before they can be absorbed.

The bonds between the sugar units are called **glycosidic bonds** and carbohydrates are converted from one form into another by enzymes (→ [7.6.2](#)) that either:

- **break the bonds** that hold the sugar units together, as happens in digestion when the enzyme amylase breaks down starch to glucose units and lactase splits up lactose to glucose and galactose units
- **form bonds** between the sugar units to join the glucose units in long chains. This happens in the liver and skeletal muscles when polymerase (an enzyme) bonds glucose units into long chains to form glycogen.

19.2.2 Intrinsic and extrinsic sugars

Intrinsic sugars are part of the cellular structure of unprocessed food substances. They occur in fruits and sweet-tasting vegetables like carrots and beetroot (fructose) and bean sprouts (maltose). As well as providing energy, vitamins and minerals these foods also contain cellulose (dietary fibre) which helps people to feel satiated (full).

Extrinsic sugars include honey, table sugar, glucose, corn syrup, molasses and milk sugar (lactose). They are often used in processed food to enhance the taste and act as a preservative. Extrinsic sugars supply an almost instant source of energy, but do not provide any vitamins, minerals or fibre. It is important to ensure that snacks and drinks that are high in extrinsic sugars do not displace high quality nutritious foods from the diet.

Box 19.2 Glucose is the main substrate (form of fuel) used for production of high-energy molecules – ATP.

When glucose is in excess in the diet, it is converted to glycogen and stored until needed in the liver and skeletal muscle. When these stores are filled, fatty acids (triglycerides) are synthesised and stored in adipose tissue.

Box 19.3 Oligosaccharides include raffinose, stachyose and fructans, e.g. inulin. Some are prebiotics – indigestible but can be fermented by gut microbiota, releasing the nutrients they contain and forming gases (flatulence).

19.3 Lipids

Lipids – fats and oils – are substances that are greasy to the touch and **hydrophobic**, meaning that they repel water. Although they do not dissolve in water, they can dissolve in alcohol.

Lipids are similar to carbohydrates in being composed of the elements carbon, hydrogen and oxygen, but differ from carbohydrates in that they contain less oxygen and sometimes contain nitrogen and/or phosphorus, e.g. phospholipids in plasma membranes (→ [2.2.1](#)). Lipids are medium-sized molecules and form a diverse group of compounds that includes

Box 19.4 Lipids, like proteins and carbohydrates, are **macronutrients** meaning that they are required in relatively large amounts in the diet.

Micronutrients – vitamins and minerals – are required in small amounts.

Box 19.5 Linoleic acid (LA) is an **omega-6 fatty acid** and alpha-linolenic acid (ALA) is an **omega-3 fatty acid**. They cannot be synthesised by the body, so they are considered to be **essential fatty acids (EFAs)** – essential in the diet.

fats and oils, waxes, steroids, phospholipids, lipoproteins and glycolipids (→ [Box 19.4](#)). Fats in the diet are a complex mixture of triglycerides, phospholipids and cholesterol.

19.3.1 Triglycerides

Triglycerides serve as the backbone of many types of lipids, including the fats in the diet. A **triglyceride** contains one **glycerol molecule** and three **fatty acids** (→ Fig. 19.3a). A **fatty acid** is a long hydrocarbon (H+C+H) chain with a methyl group at one end and a carboxylic group at the other end (→ Fig. 19.3b). All the fatty acids that the body requires can be manufactured in the cells except for omegas 3 and 6 (→ Box 19.5).

The properties of different types of triglyceride depend on:

- the number of hydrocarbons in each of the fatty acid chains, e.g. stearic acid contains 18 hydrocarbons (→ Fig. 19.3b)
- whether the fatty acids are **saturated** or unsaturated; this depends on the number of carbon double bonds it contains (→ Fig. 19.3c):
 - unsaturated** – no carbon double bonds, e.g. palmitic and arachidonic acids
 - saturated** – one or two carbon double bonds
 - polyunsaturated** – three or more carbon double bonds, e.g. linoleic acid.

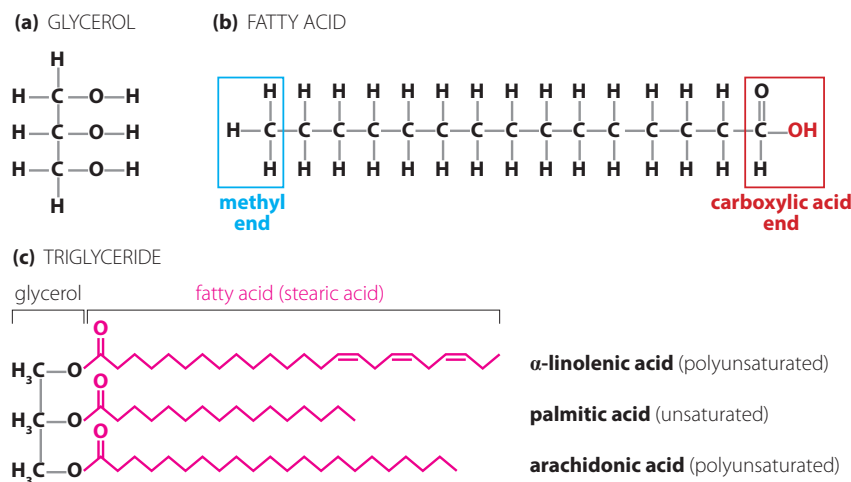


Fig. 19.3 (a) Glycerol molecule; (b) a fatty acid; (c) triglyceride, e.g. stearic acid.

19.3.2 Fats and oils

Depending on the temperature, fats and oils can change from a solid into a liquid, or from liquid to solid. Fats that are liquid at room temperature are often called **oils**. These are stored in the body in adipose tissue and are the most concentrated source of energy (→ [Box 19.6](#)).

Uses of dietary fat

The body needs a diet containing fat because it:

- forms part of phospholipids and glycolipids, that are essential for the continuous process of building plasma membranes (→ 2.2)
- provides a rich source of calories for energy
- acts as an energy store in adipose tissue that is available when the carbohydrates have been used up

Box 19.6 The role of **fats in the diet** has triggered much controversy and debate: “Is eating too much of some types of fat harmful while others are vital for wellbeing and disease prevention?”

- forms part of sebum – the oily substance that helps to prevent skin and hair from drying out (→ [Chapter 3](#))
- provides fat-soluble vitamins A, D, E and K
- produces heat using brown fat – a process called non-shivering thermogenesis (→ [Box 19.7](#)).

19.3.3 Saturated and unsaturated fats

Saturated fats are fatty acids saturated with hydrogen atoms and are found mainly in meat and animal products such as milk, butter, cream and cheese. Most plant foods do not contain saturated fats but those that do include tropical oils, e.g. coconut oil, palm oil and cocoa butter.

Unsaturated fats have fatty acids with fewer hydrogen atoms than saturated fats, e.g.:

- **monounsaturated fats**, e.g. olive and canola (rapeseed) oils
- **polyunsaturated fats (PUFA)**, e.g. omega fatty acids which occur in oily fish, sunflower oil, corn oil, nuts and soya bean oils
- **omega-6 essential fatty acids** form hormone-like substances called eicosanoids which include prostaglandins that control blood flow and inflammation
- **omega-3 essential fatty acids** are needed for early development of structural components of the brain and eye, and also reduce the tendency for inflammation and blood clotting (→ [Box 19.8](#))
- **cis fats** – a type of unsaturated fat (→ [Fig. 19.4a](#))
- **trans fats** are formed when unsaturated fat is hydrogenated (hydrogen added) (→ [Fig. 19.4b](#)), and occur in small quantities in some meats, butter and dairy products (→ [Box 19.9](#)).

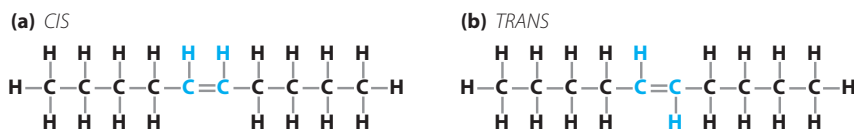


Fig. 19.4 The structure of (a) *cis* fat; (b) *trans* fat.

19.3.4 Lipids in the plasma membrane

Phospholipids are lipids that form the plasma (cell) membrane (→ [2.2](#)) which is composed of two layers, each bilayer containing trillions of phospholipid molecules. They are arranged with the hydrophilic phosphate ‘head’ groups close to water and the hydrophobic ‘tails’ of fatty acids away from water (→ [Fig. 19.5](#)). **Glycolipids** are also found in the plasma membrane where they serve as receptors for cell-to-cell communications and blood group markers.

19.3.5 Cholesterol

Cholesterol is a fat-like substance present in the blood and most tissues throughout the body, and is an essential constituent of plasma membranes

Box 19.7 Adipose tissue contains mostly white fat which acts as an energy store, and also a small amount of brown fat. Brown-fat cells are packed with mitochondria which burn energy in the body and produce heat.

Box 19.8 Omega-3 and omega-6 are **essential fatty acids** which cannot be made in the body and must be obtained from foods that contain them. Good sources of these two fatty acids are fish, especially oily fish, shellfish, corn and soya bean oil, nuts and seeds; smaller amounts occur in pork fat.

Box 19.9 The food industry produces *trans* fats from vegetable oils to improve the taste and shelf life of food. **Trans fats** in the diet are associated with a higher incidence of cardiovascular disease, although the reason is not clear, so avoiding *trans* fats may lead to better health.

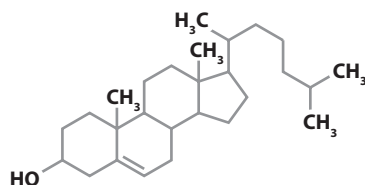


Fig. 19.6 Structure of cholesterol.

Box 19.10 The myelin sheath covers and insulates the nerve fibres of many neurons and is rich in cholesterol.

Box 19.11 High cholesterol refers to high levels of LDL in the blood and evidence strongly indicates that it can increase the risk of atherosclerosis, angina, heart attack, stroke and mini-stroke (TIA).

Box 19.12 Hypercholesterolaemia can be lowered by reducing the amount of saturated fat in the diet, taking regular exercise and not smoking. If these measures do not reduce blood cholesterol, cholesterol-lowering medication such as **statins** may be advised – if the benefits of medication outweigh any risks.

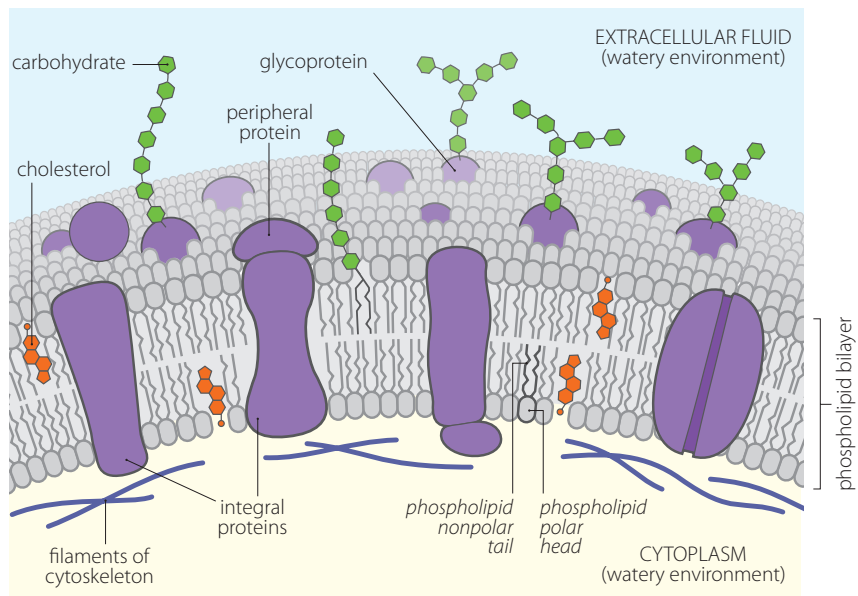


Fig. 19.5 Phospholipids in the plasma membrane.

(→ Fig. 19.6). It confers fluidity to the membrane by interacting with the phospholipids and thus enabling cells to change shape or move about. Cholesterol is a precursor of many steroid hormones, vitamin D and other vital substances (→ Box 19.10).

Although all cells can synthesise cholesterol from fat in the diet, most is formed by liver cells (hepatocytes). Liver cells also excrete cholesterol into bile. Bile emulsifies fats in the digestive tract and aids absorption of fat-soluble vitamins.

Lipoproteins

Most of the cholesterol in the blood combines with protein and is carried in the bloodstream as lipoprotein. **Lipoproteins** are protein molecules that transport lipids including triglycerides, cholesterol and phospholipids, and mainly occur in two forms: **high-density lipoprotein (HDL)** and **low-density lipoprotein (LDL)**.

- **HDL** carries cholesterol away from the cells and back to the liver where it is excreted in bile or as a waste product in urine. For this reason, HDL is known as ‘good’ cholesterol.
- **LDL** has a relatively high cholesterol content and its function is to carry cholesterol from the liver to the cells. When there is more LDL in the blood than the cells can use, the surplus may build up in the walls of arteries to the heart and brain. LDL is sometimes referred to as ‘bad cholesterol’ (→ Box 19.11).

Risk factors contributing to high blood cholesterol

High levels of cholesterol in the blood (**hypercholesterolaemia**) are usually caused by too much saturated fat in the diet, smoking, diabetes and hypertension, and a family history of stroke or heart disease. A smaller number of people (about one in 250) inherit the disorder (→ Box 19.12).

19.3.6 Steroid hormones

Steroid hormones (→ 11.2.2) are manufactured from cholesterol in the adrenal glands and the gonads (ovaries and testes). They are highly active substances which have many different physiological actions:

- **glucocorticoids** regulate metabolism, inflammation and immune functions and stress responses
- **mineralocorticoids** regulate fluid and electrolyte balance
- **androgens** and **oestrogens** regulate development of sexual characteristics
- **vitamin D** increases intestinal absorption of minerals including calcium
- **progestins** are used as medication in the treatment of infertility and menopausal symptoms.

19.4 Proteins

Every cell in the body requires many different kinds of **protein** for growth and repair, for enzymes that direct the cell's metabolism, hormones for communication, and antibodies, clotting factors and complement proteins that are needed for the body's defences.

Protein molecules are built up from hundreds or thousands of small units called **amino acids** which always contain the elements carbon, hydrogen, oxygen and nitrogen and, sometimes, sulphur and phosphorus. The amino acids are linked together by **peptide bonds** to form a chain that becomes much folded into a molecule of protein. Each type of protein is specific for its function, e.g. keratin and collagen provide structure while haemoglobin carries oxygen (→ Fig. 19.7).

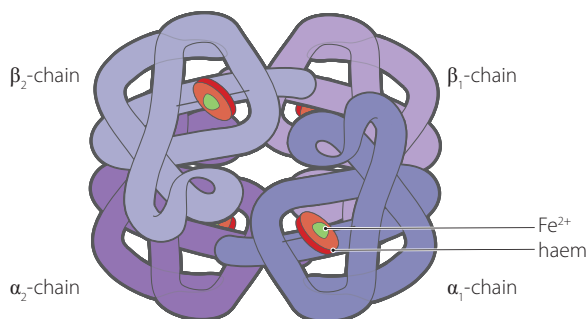


Fig. 19.7 A haemoglobin molecule composed of four folded chains of amino acids, each containing a non-protein haem group.

19.4.1 Amino acids

An amino acid is an organic compound containing an

- amine group ($-\text{NH}_2$)
- carboxyl group ($-\text{COOH}$) which is an acid
- R group (side chain) (→ Fig. 19.8).

There are about 500 naturally occurring amino acids, each with its own unique R group, and they can be arranged in an almost infinite variety of ways to form a vast number of different proteins, required by living organisms.

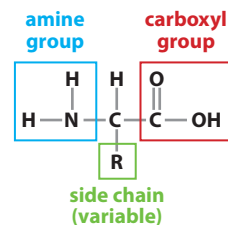


Fig. 19.8 General structure of an amino acid.

Amino acids in the diet

The human body uses 21 different amino acids to build all the different proteins required by the body, and they fall into two groups: essential and non-essential (→ Table 19.2).

- **Essential amino acids** cannot be synthesised in the body so it is vital that they are present in the diet. A mixed diet containing different types of protein should provide all the essential amino acids that the body requires.
- **Non-essential amino acids** do not need to be consumed in the diet as they can be synthesised from essential amino acids by the liver.

Table 19.2 Essential and non-essential amino acids in the human diet

Essential amino acids	Non-essential amino acids
Leucine	Alanine
Isoleucine	Serine
Valine	Proline
Lysine	Tyrosine
Tryptophan	Glutamine
Threonine	Asparagine
Methionine	Aspartic acid
Phenylalanine	Glutamic acid
Histidine (children only)	Cysteine
	Arginine
	Glycine

Conditional essential amino acids

Occasionally, a non-essential amino acid becomes essential because its synthesis is limited under special pathophysiological conditions, e.g. **phenylketonuria** (→ 12.7.4). This inherited condition develops in the newborn when the baby's body is unable to synthesise tyrosine into phenylalanine due to the absence of the correct enzyme.

19.4.2 Protein conversion in the body

During digestion, proteins in food are digested (broken down) by enzymes, first into **polypeptides** (chains of amino acids) then **peptides** (small chains) (→ Box 19.13). Peptides are broken down to individual **amino acids** which are transported in the hepatic portal vein to the liver. Hepatocytes (liver cells) carry out the following processes:

- **Synthesis:** amino acids are used to synthesise (build) most of the plasma proteins, including lipoproteins. Others are transported to the tissues where they are used by the cells to build the particular types of protein that are needed, e.g. actin and myosin in muscle cells or collagen fibres in the cells of connective tissue.
- **Transamination:** the process of converting non-essential amino acids to essential ones.

Box 19.13 The stomach wall makes and secretes the enzyme **pepsin** that can break down proteins into shorter chains called peptides. This enzyme is made in an inactive form – called pepsinogen – so that it cannot digest the stomach lining. The enzyme is activated when it enters the lumen of the stomach and comes in contact with gastric juice which is highly acidic. The enzyme has an optimum pH of 1 and is therefore not denatured by the acid.

- **Deamination:** amino acids cannot be stored in the body and those that are not required are broken down in the liver. The amino group ($-\text{NH}_2$) is removed from the amino acid and converted into ammonia. Ammonia is toxic and is rapidly converted to urea for excretion through the kidneys (→ Box 19.14).

19.5 Micronutrients

Vitamins and minerals are **micronutrients** – nutrients that the body requires in very small amounts for growth and repair of the tissues and the prevention of various diseases. They cannot be synthesised in the body and are therefore essential constituents of the diet.

19.5.1 Vitamins

The name ‘vitamin’ refers to the fact that these organic compounds are vital (vita) for life (→ Box 19.15). Vitamins are classified as either **fat-soluble** (vitamins A, D, E and K) or **water-soluble** (vitamins B and C), with each group acting differently within the body (→ Table 19.3).

Box 19.14 Protein homeostasis is complex and depends on:

- protein intake from the diet
- use of amino acids by cells for protein synthesis, e.g. cell structure, enzymes
- rate of protein synthesis by cells
- excretion of excess amino acids.

Box 19.15 Individuals need different intakes of **vitamins** at different stages of their lifespan; babies, children, adolescents, pregnant women and the elderly need different intakes.

Table 19.3 Vitamins important in the diet

Vitamin	Function	Good sources	Deficiency disease
Fat-soluble vitamins			
A Retinol	maintains immune cells; regeneration of rhodopsin (→ 10.2.3) and for healthy skin and mucosa	dairy products, eggs, fortified spreads; carrots – carotene can be converted into retinol	dry keratinised skin; night blindness; xerophthalmia
D Calciferol	helps to keep bones and teeth healthy by regulating the levels of calcium and phosphate in the body	sunlight on the skin; butter; oily fish; egg yolk; fortified fat spreads	softening of the bones causing rickets in children and osteomalacia in adults
E Tocopherol	antioxidant that protects tissues from damage caused by reactive oxygen (free radicals)	vegetable oils, e.g. sunflower and corn oils; wheat germ; nuts, e.g. peanuts and almonds	muscle weakness nerve damage visual problems
K Phylloquinone	blood coagulation; bone and vascular metabolism	green vegetables; vegetable oils; cereals; gut bacteria	blood is slow to clot
Water-soluble vitamins			
B1 Thiamine	helps release energy from food; maintains health of nerves and muscle tissue	vegetables; fresh and dried fruit; eggs; wholegrain breads; liver; some fortified breakfast cereals	beriberi – nervous disorder, muscle weakness and heart failure
B2 Riboflavin	keeps skin, eyes and the nervous system healthy	milk; eggs; fortified breakfast cereals; rice	lesions in mucosal linings of mouth and throat; dermatitis
B3 Niacin	helps the digestive system, skin and nerves to function	meat; fish; wheat flour; cornflour; eggs; milk	pellagra – scaly dermatitis; diarrhoea; depression
B6 Pyridoxine	use and storage of energy from food	wide variety of foods	dermatitis and nerve disorders
Folic acid (folate)	works with B12 to form healthy red cells	green vegetables; liver; chickpeas; brown rice; some fortified breakfast cereals	spina bifida in unborn babies
B12	makes red cells; processes folic acid	most animal products; some fortified cereals	B12 deficiency anaemia (pernicious anaemia)
C Ascorbic acid	maintains healthy connective tissues; helps wound healing	fresh fruit and vegetables, but reduced when stored/cooked	scurvy – bleeding under the skin; wounds not healing

- **Fat-soluble vitamins** are usually absorbed in the form of fat globules (chylomicrons) by the lacteals (of the lymphatic system), circulate in the bloodstream and become stored in the liver and adipose tissue where they tend to remain until needed. Therefore fat-soluble vitamins do not need to be eaten every day.
- **Water-soluble vitamins** are not stored in the body so need to be eaten more frequently. If more is ingested than the body needs, the excess is excreted in urine. Unlike fat-soluble vitamins, they can be destroyed by heat, as happens when foods containing them are cooked.

19.5.2 Minerals

Dietary minerals (mineral nutrients) are the chemical elements obtained from food and used to build and maintain the body's tissues. The minerals are originally absorbed from the soil by plants and used to build and maintain the plant body. Humans and other animals obtain minerals by eating plants and animal foods. People who ingest a balanced diet take in more minerals than are needed and the surplus is either not absorbed or is excreted in urine. Minerals in the diet are:

- **macrominerals** – required in larger amounts (→ [Table 19.4](#))
- **microminerals (trace elements)** – required in smaller amounts (→ [Table 19.5](#)).

Table 19.4 Macrominerals

Mineral	Function in the body	Good sources	Deficiency disease
Sodium	Major component of body fluids homeostatically regulated by kidneys; nerve impulses	table salt processed foods	when lost in sweat, causes muscle cramps, dehydration, vomiting, dryness of the mouth and nausea
Potassium	Major component of intracellular fluid and blood**	green leafy vegetables, nuts, seeds, avocados, bananas, fish, dark chocolate	weakness, tiredness, cramping in arm or leg muscles
Chloride	Helps maintain the balance of body fluids and pH; component of hydrochloric acid	table salt processed foods	fluid loss from excessive sweating, vomiting or diarrhoea heart arrhythmias
Calcium	Strong bones and teeth; regulates the heartbeat; blood clotting	dairy foods, hard water, white bread*, green leafy vegetables	confusion, rickets, osteoporosis
Phosphorus*	Mineralisation of bones; carbohydrate and fat metabolism; used to make protein for cell growth	meats, poultry, fish, nuts, beans and dairy products	rickets, osteomalacia and osteoporosis
Magnesium	Nerve and muscle function; healthy immune system; steady heartbeat; major constituent of bone; cofactor for enzymes	whole grains and flour, green leafy vegetables, nuts, beans, quinoa	muscular weakness
Sulphur	Essential for two amino acids; part of some B vitamins; concentrated in skin, nails and hair	vegetables, dairy (except butter), eggs, dried fruits, garlic	inflammation-related muscle and skeletal disorders, obesity, heart disease, Alzheimer's, chronic fatigue

* Added by UK government regulation ** abnormally high levels of potassium in the blood (**hyperkalaemia**) can cause heart arrhythmias.

Table 19.5 Microminerals (trace elements)

Micromineral	Function in the body	Good sources	Example physiological disorders
Iron	Required for red blood cells; carries oxygen around the body	meat, bread, potatoes, white bread*	iron-deficiency anaemia
Zinc	Growth; night vision; many enzymes; replication of nucleic acids	meat, eggs; dairy produce shellfish; outer layers of grains	alopecia (hair loss)
Iodine*	Thyroid hormones	seafood; seaweed; added to iodised table salt	thyroid disorders; goitre
Selenium	Antioxidant	meat, especially offal; dairy products; Brazil nuts; fish; grains; fruit	muscle weakness; altered mood
Fluoride	Prevents caries in teeth	water and water-based beverages; fluoride toothpaste	dental caries
Chromium	Carbohydrate metabolism; regulation of blood lipids	many unprocessed foods	high blood insulin
Manganese	Bone formation; prevents cell damage by reactive oxygen	nuts, pulses and cereals; seafood; chocolate	impaired metabolism
Molybdenum	Cofactor for many enzymes	nearly all foods	poorly understood

* Added by UK government regulation.

19.6 Dietary fibre

Dietary fibre is plant material that cannot be digested, mainly cellulose but also other polysaccharides such as pectin and those in fruit skins. Fibre can be described as insoluble or soluble:

- **insoluble fibre** absorbs water like a sponge, e.g. wheat bran
- **soluble fibre** forms a gel with water, e.g. oat bran.

Although fibre in food has no, or very little, nutritive value, it has a number of health benefits.

- It **prevents constipation**. When eaten, fibre absorbs water and swells, making the faeces softer and bulkier. The increased bulk stimulates the bowel muscles to become more active by increasing the rate of peristalsis, and the increased softness enables the faeces to be evacuated more easily.
- It **seems to have a protective effect** by lowering the risk of a range of conditions including diabetes, heart disease, gallstones and some cancers.
- It **helps in losing weight**. Foods high in fibre are much bulkier than high calorie foods and make the stomach feel full more quickly.
- It **relieves the symptoms of diverticular disease**. Diverticula are small bulges that stick out from the side of the colon and thought to be formed by the pressure of hard stools as they pass through the colon (→ Box 19.16).

19.7 Influence of diet on health

The diet is the type of food that is regularly consumed and depends on cultural differences and personal preferences:

- a **balanced diet** is one that contains suitable amounts of energy, nutrients and fibre to maintain optimum health

Box 19.16 Diverticular disease (**diverticulitis**) is sometimes called the 'western disease' because it occurs more often in people in western countries who tend to eat less fibre than those in Africa and Asia. The disorder is often associated with ageing, the symptoms including intermittent abdominal pain and bloating, which may be accompanied by tiredness, fever, nausea or vomiting.

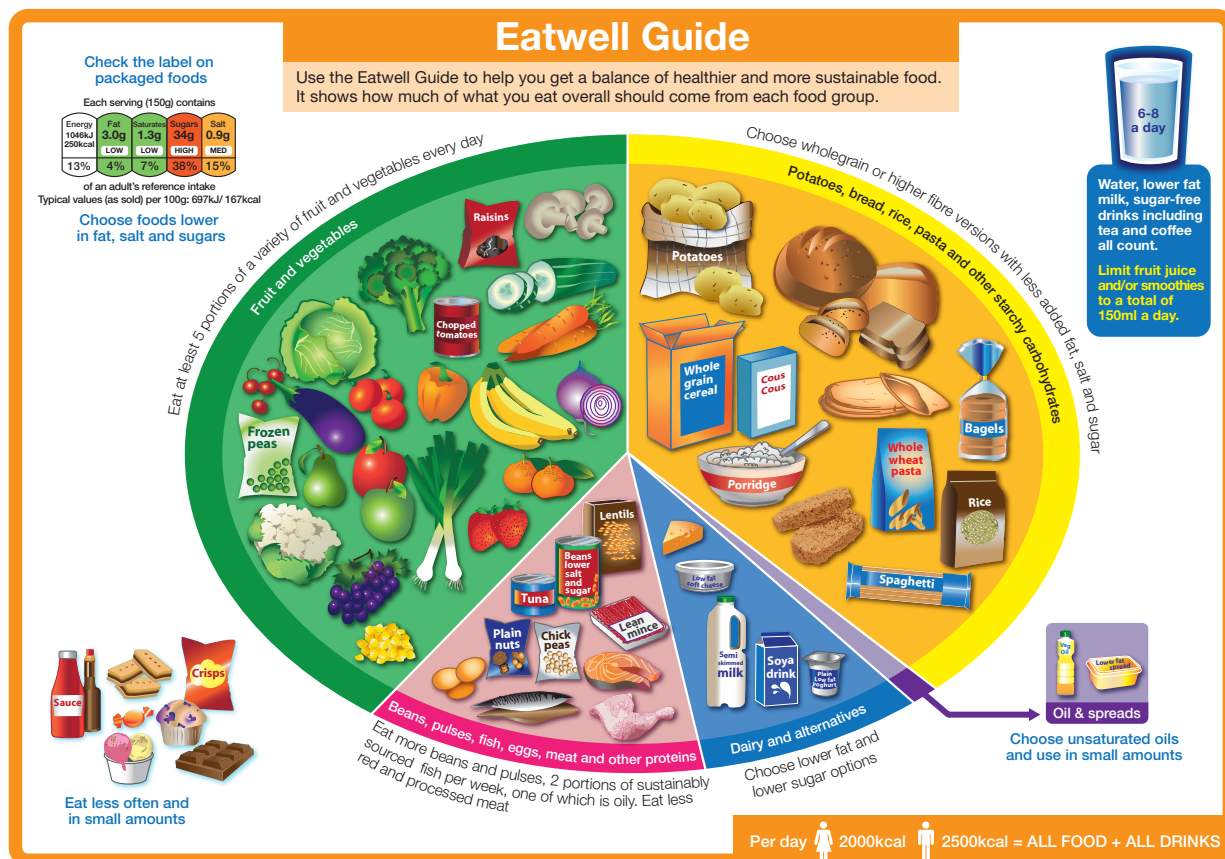
- an **unbalanced diet** results from the imbalance between what a person eats and what is required to maintain health. It is the cause of a number of serious conditions including **undernutrition** and eating disorders, and **overnutrition** and **obesity**.

In nutritional terms, there are no “good” or “bad” foods and no single food can provide all of the nutrients that the human body needs. Individuals vary in their nutritional needs depending on age, gender, level of physical activity, rate of metabolism and growth, and individual health. The proportions of foods that are eaten to provide daily needs should reflect the groups in the Eatwell Guide to obtain optimum levels of nutrients to sustain wellbeing (→ Fig. 19.9).

19.7.1 Nutritional guidelines for a balanced diet

Choose a diet that is based on foods suitable for promoting health and wellbeing, as shown in the Eatwell Guide.

- **Eat regularly** and enjoy a wide variety of food.
- **Drink** 1.5–2 litres of water or sugar-free drinks to maintain hydration. Extra fluid is needed on hot days or when energy expenditure is high.
- **Snacks** contribute to total daily food intake.
- **Avoid being overweight**, but eat enough to maintain a healthy weight.
- **Starchy foods** are high in complex carbohydrates and fibre that cause



Source: Public Health England in association with the Welsh government, Food Standards Scotland and the Food Standards Agency in Northern Ireland

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Fig. 19.9 UK dietary guidelines.

glucose to be released slowly into the bloodstream, e.g. whole grains, legumes (peas, beans) and pulses, e.g. lentils.

- **Sugary, sweetened, processed foods**, e.g. cakes, biscuits and soft drinks, cause rapid rises in blood glucose.
- **Vegetables and fruits** contain soluble fibre, vitamins, minerals and antioxidants.
- **Dried fruits** such as dates contain very concentrated forms of sugar so should be eaten in small quantities.
- **Fats** are an essential item in the diet but large quantities increase the risk of heart disease.
- **Salt** in large quantities can contribute to hypertension (high blood pressure) so its use needs to be limited in cooking.
- **Salty foods and 'hidden' salt** in processed foods, including smoked and tinned foods, need to be eaten in limited amounts.
- **Alcohol** consumption needs to be kept at moderate levels.

19.8 Energy balance and body weight

Food contains energy and the **energy balance** in the body (homeostasis) is achieved by matching the intake of food with energy used by the body's activities; when this is achieved, body weight remains stable (→ [Box 19.17](#)). Excess energy is stored as fat in adipose tissue under the skin and around the internal organs, and body weight increases. When less food is eaten than the body needs, the fat store is used for energy; when this is depleted, muscle tissue is then used, and the body becomes thin and undernourished.

19.8.1 Basal metabolic rate

The **basal metabolic rate (BMR)** is the minimum amount of energy required to keep the body alive and functioning at rest (→ [Box 19.18](#)). The BMR is the largest component of an individual's daily energy expenditure, accounting for 60–75% of daily calorie consumption. It includes the energy used for basic life processes including breathing, blood circulation, thermoregulation, nervous system function, cell growth and contraction of muscles.

19.8.2 Metabolic rate

The **metabolic rate** is the amount of energy used by the body in a set time and expressed in either kilojoules or kilocalories. It varies between individuals because it includes both the BMR and other factors:

- **surface area.** A small person has a relatively higher BMR than a large person because, proportionately, there is a greater surface area through which heat can be lost
- **age.** BMR decreases with age
- **gender.** Men have a higher BMR than women because they have a higher proportion of muscle tissue and a lower proportion of fat
- **level of physical activity.** A sedentary lifestyle provides a lower metabolic rate compared with very active lifestyle
- **thyroid hormone.** Hypothyroidism and hyperthyroidism affect the metabolic rate (→ [Box 19.19](#)).

19.8.3 Physical activity and energy balance

Heat is a form of energy and is produced during cell respiration and metabolism. Although energy expenditure is continuous, it varies depending

Box 19.17 Energy is measured in kilojoules (kJ) or kilocalories (kcal), commonly referred to as 'calories'.

To convert kilojoules to kilocalories:

1 kcal = 4.2 kJ (approx.)

1 gram of carbohydrate provides 4 kcal (16 kJ) (approx.)

1 gram of fat provides 9 kcal (39 kJ) (approx.)

1 gram of protein provides 4 kcal (17 kJ) (approx.)

Box 19.18 The **BMR** is defined as the rate of energy expenditure when in a physiologically and psychologically undisturbed complete state of rest, in a thermoneutral environment while in the post-absorptive state – not actively digesting food. BMR is calculated in energy units per unit time (kilojoules per hour per unit of body mass).

Box 19.19 Thyroxine (→ [11.4](#)) is the main hormone that controls BMR. The higher the BMR, the more kilocalories that are used to supply energy; the lower the BMR, the fewer kilocalories needed. This explains why people who have an overactive thyroid may lose weight, and those with an underactive thyroid may gain weight.

Box 19.20 Malnutrition Universal Screening Tool ('MUST') is a five-score screening tool to identify adults who are undernourished or obese, or at risk of either condition. It is based on calculations of BMI (→ 17.7.1) and consideration of recent unplanned weight loss, e.g. due to acute illness.

Adult BMI index with units in kg/m²

Underweight	BMI <18.5
Ideal	BMI 18.5–24.9
Overweight	BMI 25–29.9
Obese	BMI 30–39.9
Morbidly obese	BMI >40

Box 19.21 Hyperemesis gravidarum is a complication of pregnancy characterised by severe nausea, vomiting, weight loss and possibly dehydration.

Box 19.22 Percutaneous endoscopic gastrostomy (PEG) is used when swallowing is impaired. It is a medical procedure in which a tube (PEG tube) is passed into a patient's stomach through the abdominal wall.

Box 19.23 Eating disorders are associated with low self-esteem, depression, self-harm and alcohol misuse. Treatment includes cognitive behavioural therapy (→ 9.14) and self-help therapy, sometimes with medication.

on activity levels and sleep. **Physical activity** enhances energy expenditure and increases metabolic rate because exercising muscles use glucose and fats as a source of energy which is used to produce movement and heat.

- Dietary intake of energy varies during each day and from week to week and so the energy systems of the body are continually adapting to changing conditions and different demands.
- It is therefore only possible to review energy balance over a period of weeks in terms of weight loss or weight gain.

19.8.4 Weight gain and weight loss

Weight gain and weight loss are an indicator of energy imbalance (→ Box 19.20). The extreme forms of energy imbalance are:

- **obesity** – a state of energy surplus due to food energy intake being greater than energy expenditure
- **cachexia** – a state of negative energy balance due to reduced appetite and increased energy expenditure (e.g. in cancer) when adipose and muscle tissue are broken down to meet everyday body energy requirements.

19.9 Undernutrition

Undernutrition can be due to an inadequate diet or a problem with absorbing nutrients from food. There are many reasons why this might happen, e.g. famine, reduced mobility, a low income, depression, loss of appetite, lack of teeth to bite and chew food or a long-term digestive condition such as coeliac disease, Crohn's disease and hyperemesis gravidarum (→ Box 19.21). Extreme undernutrition results in **starvation** and occurs when there are not enough nutrients for the maintenance of life.

19.9.1 Nutritional support

Nutritional support to prevent malnutrition can be given to people who cannot chew or swallow. Fortified liquid food delivered by oral, enteral and parenteral methods.

Oral nutrition support is given as supplements to improve nutritional intake. This can be delivered in the form of food fortified with protein, carbohydrate and/or fat, plus minerals and vitamins, snacks or oral nutritional supplements.

Enteral tube feeding delivers nutritional products via a tube into the digestive system and the normal processes of digestion then take over. This may be used following head and neck surgery, radiotherapy or blockage of the oesophagus (→ Box 19.22).

Parenteral nutrition bypasses the digestive system and delivers specialist nutritional products directly into the bloodstream.

19.9.2 Eating disorders

Eating disorders are defined as severe mental illness characterised by an unhealthy preoccupation with eating, exercise, body weight or shape. Significant physiological, psychological, behavioural, emotional and social disturbances are associated with eating disorder syndromes, which makes them difficult to treat (→ Box 19.23).

Anorexia nervosa

Anorexia nervosa (AN) leads to extreme self-induced undernutrition and wastage of tissue. It occurs most often in teenage girls although it can occur at any age, and is now becoming more common in boys and men. This condition is characterised by:

- restricted energy intake accompanied by excessive exercise, vomiting or purging (using laxatives, enemas or diuretics)
- an endocrine disorder that manifests in women as amenorrhoea (loss of periods) and in men as loss of sex drive and potency
- intense fear of gaining weight
- body dysmorphism – dread of fatness persists as an intrusive and disturbing idea
- weight loss may become life-threatening
- the effect on teeth.

Bulimia nervosa

Bulimia nervosa (BN) is a condition in which people have a persistent preoccupation with eating and a morbid dread of fatness. Intense cravings for food result in periods of overeating binges followed by purging, vomiting and starvation.

19.9.3 Effects of undernutrition

Deficiency of energy, protein and other nutrients can cause measurable physiological problems that lead to poor health and adverse clinical outcomes. In females, it reduces fertility and can include cessation of ovulation and periods (→ Fig. 19.10).

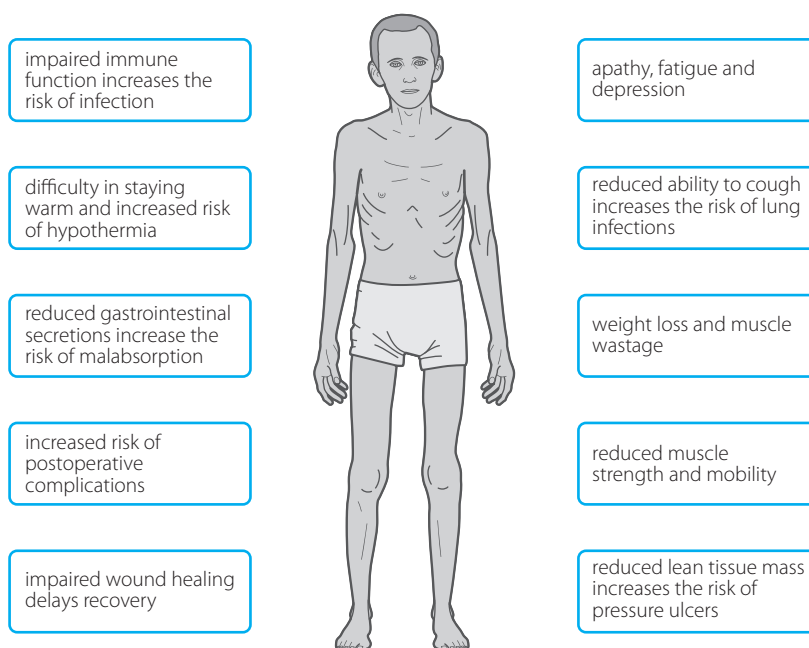


Fig. 19.10 Physiological effects of undernutrition.

Box 19.24 Being obese at any age can affect the quality of life and lead to psychological problems such as low self-esteem or depression. It also increases the risk of a number of serious and potentially life-threatening conditions, e.g. type 2 diabetes, coronary heart disease, stroke and some types of cancer.

19.10 Overnutrition

Overnutrition is the excess intake of food over time that results in excessive and unhealthy amounts of adipose tissue, and weight in excess of 20% more than the body's ideal weight – a condition known as **obesity** (→ 16.7). The usual cause is eating more calories than are metabolised, with the excess energy being stored by the body as fat. Obesity is an increasingly common problem in many 21st century lifestyles in which excessive amounts of energy-dense, high-calorie foods are eaten, particularly those with high fat and/or high sugar content, combined with lack of exercise (→ Box 19.24).

19.10.1 Managing obesity

There is no quick or easy way to treat obesity. Weight loss programmes take time and commitment; they require a change to a balanced, calorie-controlled diet so that the fat stored in adipose tissue is removed by using it to supply the body with energy. For most people, the fat removal process is enhanced by regular physical activity of any kind and, the more intense the exercise, the more energy is required.

Bariatric surgery is any surgical procedure that changes the structure of the digestive system in order to achieve weight reduction, e.g. gastric bypass or stomach stapling. Candidates for bariatric surgery are severely obese individuals with a:

- BMI of 40 or more
- BMI of 35–39 with serious medical conditions such as diabetes mellitus, heart disease, hypertension or sleep apnoea.

19.11 Appetite

Appetite is the physical desire for food, felt as hunger. It plays an important role in controlling energy intake, which depends on the amount and type of food eaten. The appetite is satisfied more quickly by a diet low in fat and high in carbohydrate and dietary fibre, but because high-fat foods are perceived as being so palatable and appetising, there is a tendency for more calories to be eaten than the body really needs, which can lead to obesity.

19.11.1 Effects of stress on appetite

The effect on appetite tends to depend on whether the stress is short-term or long-term. Many people when dealing with **acute stress** find that their appetite is decreased or even eliminated because food intake is no longer a priority, having been superseded by other more pressing concerns.

Chronic stress is a long-term condition and the brain acts by stimulating the build-up of energy reserves and increasing the craving for foods high in sugar, fat and salt, often with the effect of weight increase.

19.11.2 Hormones involved in appetite

A range of hormones are secreted in response to blood glucose levels and these exert an influence over the hypothalamus and appetite, hunger and satiety.

- **Ghrelin** (the 'hunger hormone') has a short-term effect and is secreted by the stomach just before an expected meal. It strongly increases the desire for food.
- **Leptin** (the 'satiety hormone') is produced mainly by adipose tissue and suppresses food intake.

- **Orexin** (from Greek orexis = appetite) is a neuropeptide from the hypothalamus that integrates energy expenditure, with levels of wakefulness, feeding and other behaviours. It increases the craving for food, but is inhibited by leptin.
- **Peptide tyrosine tyrosine** (PYY) is a hormone produced soon after eating by cells lining the lower small intestine (ileum) and the colon. The release of PYY into the blood begins before nutrients arrive in the ileum and the colon and inhibits gastric motility, increases absorption in the colon and may also suppress pancreatic secretion.

19.11.3 Hunger and appetite regulation

The way the **appetite** is regulated is extremely complex and not fully understood but is known to involve the brain, gastrointestinal tract, some hormones, and the type of food eaten.

The **hypothalamus** in the brain receives a variety of signals from the external and internal environments that affect the appetite, and the homeostatic set point that relates to energy balance for each individual (→ Fig. 19.11).

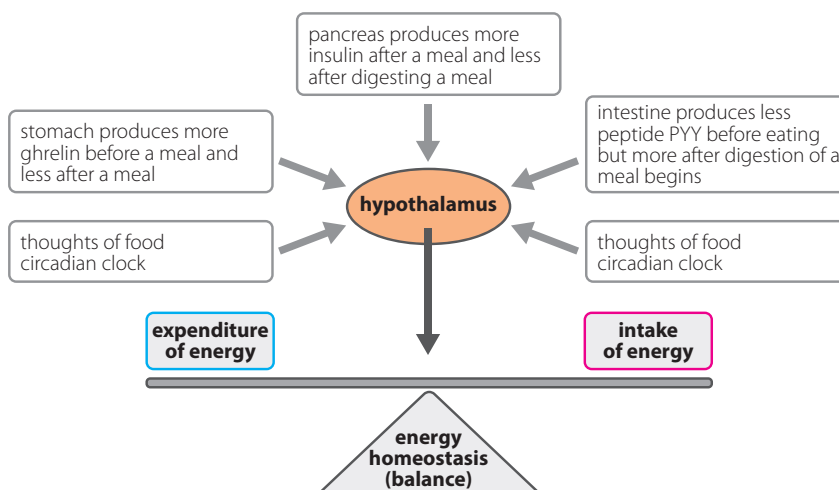


Fig. 19.11 The hypothalamus integrates body temperature, meal size and energy expenditure as part of the control of food intake.

Biological clock and appetite

The biological clock and appetite are controlled by the hypothalamus which:

- responds to the time of the day and feelings of hunger by producing the hormone **ghrelin**
- responds to satiety after meals by producing the hormone **leptin** (→ Fig. 19.12)
- stimulates the production of **leptin** during the hours of sleep when appetite is suppressed.

Emotional aspects of eating

The emotional aspects of eating also influence the appetite:

- feelings of pleasure when having a meal with friends or family
- mood often affects desire for food when people are feeling depressed, stressed or anxious and can either increase or decrease the levels of hunger.

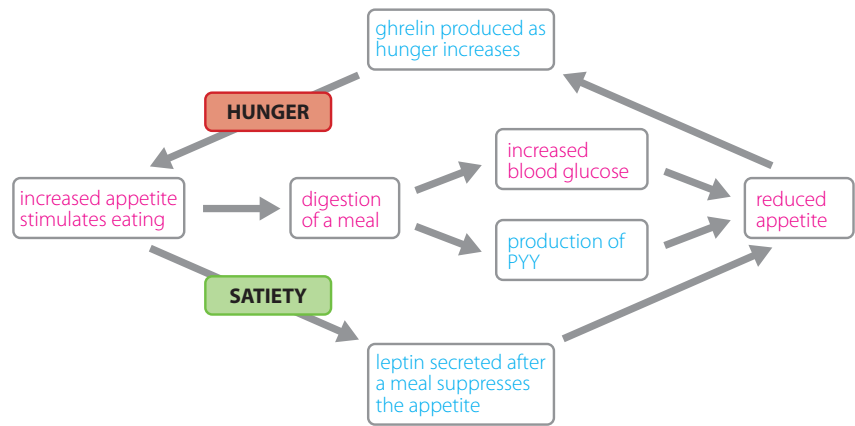


Fig. 19.12 Endocrine regulation of the appetite.

Key points

1. The human body requires a continual supply of nutrients from the diet to sustain health and wellbeing.
2. Macronutrients – carbohydrates, proteins and fats – are required in relatively large amounts.
3. Micronutrients – vitamins and minerals – are needed in relatively small amounts.
4. When energy intake from the diet matches energy output of the body, weight remains stable.
5. There is a relationship between food intake and body weight.
6. Appetite is the desire for food and is experienced as hunger.