SECTION 1

The body and its constituents

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CHAPTER 1

Introduction to the human body

ANIMATIONS

The human body is rather like a highly technical and sophisticated machine. It operates as a single entity, but is made up of a number of systems that work interdependently. Each system is associated with a specific function that is normally essential for the well-being of the individual. Should one system fail, the consequences can extend to others, and may greatly reduce the ability of the body to function normally. Integrated working of the body systems ensures survival. The human body is therefore complex in both structure and function, and this book uses a systems approach to explain the fundamental structures and processes involved.

Anatomy is the study of the structure of the body and the physical relationships between its constituent parts. *Physiology* is the study of how the body systems work, and the ways in which their integrated activities maintain life and health of the individual. *Pathology* is the study of abnormalities and *pathophysiology* considers how they affect body functions, often causing illness.

Most body systems become less efficient with age. Physiological decline is a normal part of ageing and should not be confused with illness or disease although some conditions do become more common in older life. Maintaining a healthy lifestyle can not only slow the effects of ageing but also protect against illness in later life. The general impact of ageing is outlined in this chapter and the effects on body function are explored in more detail in later chapters.

The final section of this chapter provides a framework for studying diseases, an outline of mechanisms that cause disease and some common disease processes. Building on the normal anatomy and physiology, a systems approach is adopted to consider common illnesses at the end of the later chapters.

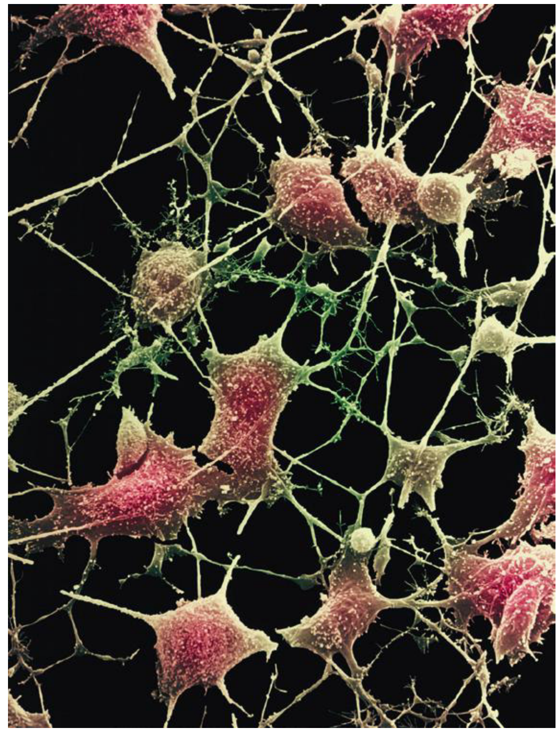


Figure 1.1 Coloured scanning electron micrograph of some nerve cells (neurones).

Levels of structural complexity

Learning outcome

After studying this section, you should be able to:

- describe the levels of structural complexity within the body.

Within the body are different levels of structural organisation and complexity. The most fundamental of these is chemical. *Atoms* combine to form *molecules*, of which there is a vast range in the body. The structures, properties and functions of important biological molecules are considered in Chapter 2.

Cells are the smallest independent units of living matter and there are trillions of them within the body. They are too small to be seen with the naked eye, but when magnified using a microscope different types can be distinguished by their size, shape and the dyes they absorb when stained in the laboratory. Each cell type has become *specialised*, enabling it to carry out a particular function that contributes to body needs. Figure 1.1 shows some highly magnified nerve cells. The specialised function of nerve cells is to transmit electrical signals (nerve impulses); these are integrated and co-ordinated allowing the millions of nerve cells in the body to provide a rapid and sophisticated communication system. In complex organisms such as the human body, cells with similar structures and functions are found together, forming *tissues*. The structure and functions of cells and tissues are explored in Chapter 3.

Organs are made up of a number of different types of tissue and have evolved to carry out a specific function. Figure 1.2 shows that the stomach is lined by a layer of epithelial tissue and that its wall contains layers of smooth muscle tissue. Both tissues contribute to the functions of the stomach, but in different ways.

Systems consist of a number of organs and tissues that together contribute to one or more survival needs of the body. For example the stomach is one of several organs of the digestive system, which has its own specific function. The human body has several systems, which work interdependently carrying out specific functions. All are required for health. The structure and functions of the body systems are considered in later chapters. 1.1

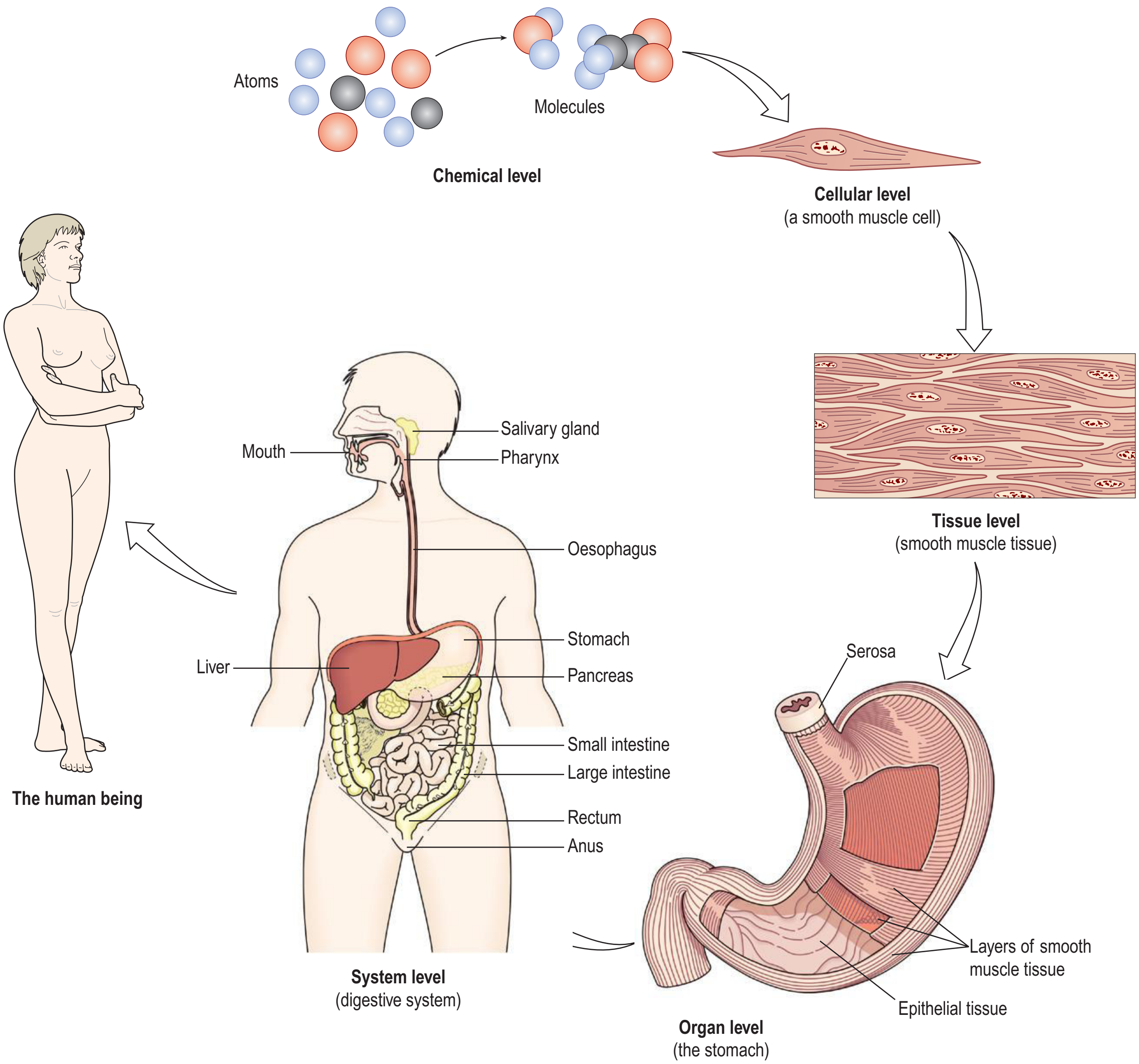


Figure 1.2 The levels of structural complexity.

The internal environment and homeostasis

Learning outcomes

After studying this section, you should be able to:

- define the terms internal environment and homeostasis
- compare and contrast negative and positive feedback control mechanisms
- outline the potential consequences of homeostatic imbalance.

The *external environment* surrounds the body and is the source of oxygen and nutrients required by all body cells. Waste products of cellular activity are eventually excreted into the external environment. The skin (Ch. 14) provides an effective barrier between the body tissues and the consistently changing, often hostile, external environment.

The *internal environment* is the water-based medium in which body cells exist. Cells are bathed in fluid called *interstitial* or *tissue fluid*. They absorb oxygen and nutrients from the surrounding interstitial fluid, which in turn has absorbed these substances from the circulating blood. Conversely, cellular wastes diffuse into the bloodstream via the interstitial fluid, and are carried in the blood to the appropriate excretory organ.

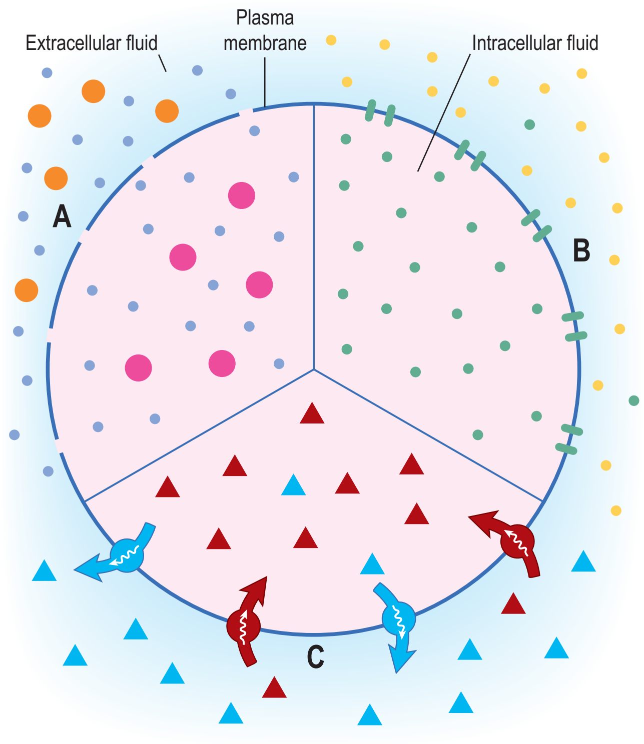


Figure 1.3 Role of cell membrane in regulating the composition of intracellular fluid. A. Particle size. **B.** Specific pores and channels. **C.** Pumps and carries.

Each cell is enclosed by its *plasma membrane*, which provides a selective barrier to substances entering or leaving. This property, called *selective permeability*, allows the cell (plasma) membrane (see p. 32) to control the entry or exit of many substances, thereby regulating the composition of its internal environment; several mechanisms are involved. Particle size is important as many small molecules, e.g. water, can pass freely across the membrane while large ones cannot and may therefore be confined to either the interstitial fluid or the intracellular fluid (Fig. 1.3A). Pores or specific channels in the plasma membrane admit certain substances but not others (Fig. 1.3B). The membrane is also studded with specialised pumps or carriers that import or export specific substances (Fig. 1.3C). Selective permeability ensures that the chemical composition of the fluid inside cells is different from the interstitial fluid that bathes them.

Homeostasis

The composition of the internal environment is tightly controlled, and this fairly constant state is called *homeostasis*. Literally, this term means 'unchanging', but in practice it describes a dynamic, ever-changing situation where a multitude of physiological mechanisms and measurements are kept within narrow limits. When this balance is threatened or lost, there is a serious risk to the well-being of the individual. Box 1.1 lists some important physiological variables maintained within narrow limits by homeostatic control mechanisms.

Box 1.1 Examples of physiological variables

Core temperature
Water and electrolyte concentrations
pH (acidity or alkalinity) of body fluids
Blood glucose levels
Blood and tissue oxygen and carbon dioxide levels
Blood pressure

Control systems

Homeostasis is maintained by control systems that detect and respond to changes in the internal environment. A control system has three basic components: detector, control centre and effector. The *control centre* determines the limits within which the variable factor should be maintained. It receives an input from the *detector*, or sensor, and integrates the incoming information. When the incoming signal indicates that an adjustment is needed, the control centre responds and its output to the *effector* is changed. This is a dynamic process that allows constant readjustment of many physiological variables. Nearly all are controlled by *negative feedback* mechanisms. *Positive feedback* is much less common but important examples include control of uterine contractions during childbirth and blood clotting.

Negative feedback mechanisms (Fig. 1.4)

Negative feedback means that any movement of such a control system away from its normal set point is negated (reversed). If a variable rises, negative feedback brings it down again and if it falls, negative feedback brings it back up to its normal level. The response to a stimulus therefore reverses the effect of that stimulus, keeping the system in a steady state and maintaining homeostasis.

Control of body temperature is similar to the non-physiological example of a domestic central heating system. The thermostat (temperature detector) is sensitive to changes in room temperature (variable factor). The thermostat is connected to the boiler control unit (control centre), which controls the boiler (effector). The thermostat constantly compares the information from the detector with the preset temperature and, when necessary, adjustments are made to alter the room temperature. When the thermostat detects the room temperature is low, it switches the boiler on. The result is output of heat by the boiler, warming the room. When the preset temperature is reached, the system is reversed. The thermostat detects the higher room temperature and turns the

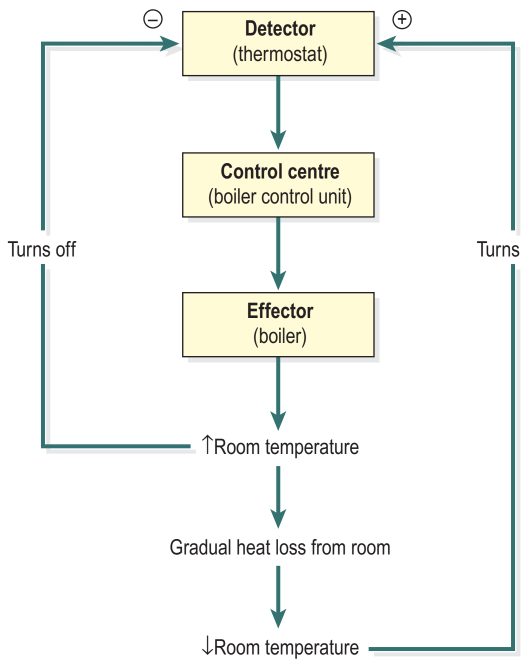


Figure 1.4 Example of a negative feedback mechanism: control of room temperature by a domestic boiler.

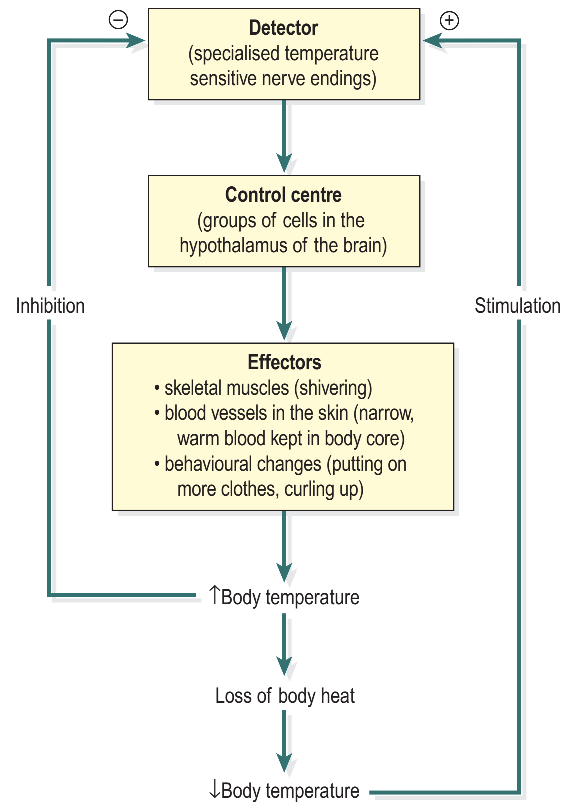


Figure 1.5 Example of a physiological negative feedback mechanism: control of body temperature.

boiler off. Heat production from the boiler stops and the room slowly cools as heat is lost. This series of events is a negative feedback mechanism that enables continuous self-regulation, or control, of a variable factor within a narrow range.

Body temperature is one example of a physiological variable controlled by negative feedback (Fig. 1.5). When body temperature falls below the preset level (close to 37°C), this is detected by specialised temperature sensitive nerve endings in the hypothalamus of the brain, where the body's temperature control centre is located. This centre then activates mechanisms that raise body temperature (effectors). These include:

- stimulation of skeletal muscles causing shivering
- narrowing of the blood vessels in the skin reducing the blood flow to, and heat loss from, the peripheries
- behavioural changes, e.g. we put on more clothes or curl up.

When body temperature rises within the normal range again, the temperature sensitive nerve endings are no longer stimulated, and their signals to the hypothalamus stop. Therefore, shivering stops and blood flow to the peripheries returns to normal.

Most of the homeostatic controls in the body use negative feedback mechanisms to prevent sudden and serious changes in the internal environment. Many more of these are explained in the following chapters.

Positive feedback mechanisms

There are only a few of these *cascade* or *amplifier* systems in the body. In positive feedback mechanisms, the stimulus progressively increases the response, so that as long as the stimulus is continued the response is progressively amplified. Examples include blood clotting and uterine contractions during labour.

During labour, contractions of the uterus are stimulated by the hormone *oxytocin*. These force the baby's head into the uterine cervix stimulating stretch receptors there. In response to this, more oxytocin is released, further strengthening the contractions and maintaining labour. After the baby is born the stimulus (stretching of the cervix) is no longer present so the release of oxytocin stops (see Fig. 9.5, p. 221).

Homeostatic imbalance

This arises when the fine control of a variable factor in the internal environment is inadequate and its level falls outside the normal range. If the control system cannot maintain homeostasis, an abnormal state develops that may threaten health, or even life itself. Many such situations, including effects of abnormalities of the physiological variables in Box 1.1, are explained in later chapters.

Survival needs of the body

Learning outcomes

After studying this section, you should be able to:

- describe the roles of the body transport systems
- outline the roles of the nervous and endocrine systems in internal communication
- outline how raw materials are absorbed by the body
- state the waste materials eliminated from the body
- outline activities undertaken for protection, defence and survival.

By convention, body systems are described separately in the study of anatomy and physiology, but in reality they work interdependently. This section provides an introduction to body activities, linking them to survival needs (Table 1.1). The later chapters build on this framework, exploring human structure and functions in health and illness using a systems approach.

Communication

In this section, transport and communication are considered. Transport systems ensure that all body cells have access to the very many substances required to support them, as well as providing a means of excretion of wastes; this involves the blood and the cardiovascular and lymphatic systems.

All communication systems involve receiving, collating and responding to appropriate information. There are different systems for communicating with the internal and external environments. Internal communication involves mainly the nervous and endocrine systems; these are important in the maintenance of homeostasis and regulation of vital body functions. Communication with the external environment involves the special senses, and verbal and non-verbal activities, and all of these also depend on the nervous system.

Table 1.1 Survival needs and related body activities

Survival need	Body activities
Communication	Transport systems: blood, cardiovascular system, lymphatic system Internal communication: nervous system, endocrine system External communication: special senses, verbal and non-verbal communication
Intake of raw materials and elimination of waste	Intake of oxygen Ingestion of nutrients (eating) Elimination of wastes: carbon dioxide, urine, faeces
Protection and survival	Protection against the external environment: skin Defence against microbial infection: resistance and immunity Body movement Survival of the species: reproduction and transmission of inherited characteristics

Transport systems

Blood (Ch. 4)

The blood transports substances around the body through a large network of blood vessels. In adults the body contains 5 to 6 litres of blood. It consists of two parts – a fluid called *plasma* and *blood cells* suspended in the plasma.

Plasma. This is mainly water with a wide range of substances dissolved or suspended in it. These include:

- nutrients absorbed from the alimentary canal
- oxygen absorbed from the lungs
- chemical substances synthesised by body cells, e.g. hormones
- waste materials produced by all cells to be eliminated from the body by excretion.

Blood cells. There are three distinct groups, classified according to their functions (Fig. 1.6).

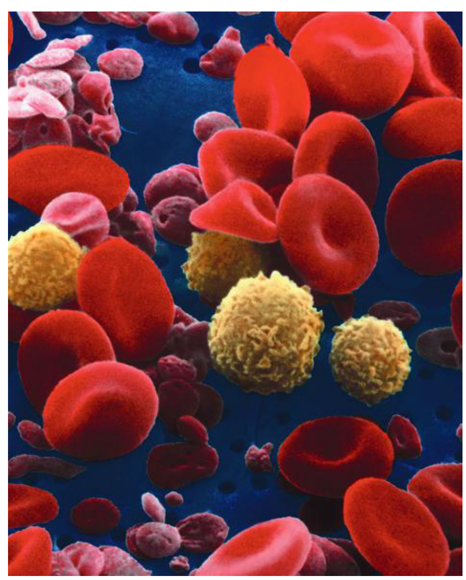


Figure 1.6 Coloured scanning electron micrograph of blood showing red blood cells, white blood cells (yellow) and platelets (pink).

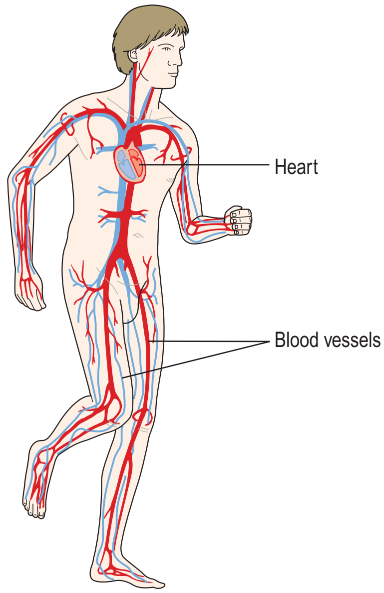


Figure 1.7 The circulatory system.

Erythrocytes (red blood cells) transport oxygen and, to a lesser extent, carbon dioxide between the lungs and all body cells.

Leukocytes (white blood cells) are mainly concerned with protection of the body against infection and foreign substances. There are several types of leukocytes, which carry out their protective functions in different ways. These cells are larger and less numerous than erythrocytes.

Platelets (thrombocytes) are tiny cell fragments that play an essential part in blood clotting.

Cardiovascular system (Ch. 5)

This consists of a network of blood vessels and the heart (Fig. 1.7). **1.2**

Blood vessels. There are three types:

- *arteries*, which carry blood away from the heart
- *veins*, which return blood to the heart
- *capillaries*, which link the arteries and veins.

Capillaries are tiny blood vessels with very thin walls consisting of only one layer of cells, which enables exchange of substances between the blood and body tissues, e.g. nutrients, oxygen and cellular waste products. Blood vessels form a network that transports blood to:

- the lungs (*pulmonary circulation*) where oxygen is absorbed from the air in the lungs and, at the same time, carbon dioxide is excreted from the blood into the air
- cells in all other parts of the body (*general* or *systemic circulation*) (Fig. 1.8).

Heart. The heart is a muscular sac with four chambers, which pumps blood round the body and maintains the blood pressure.

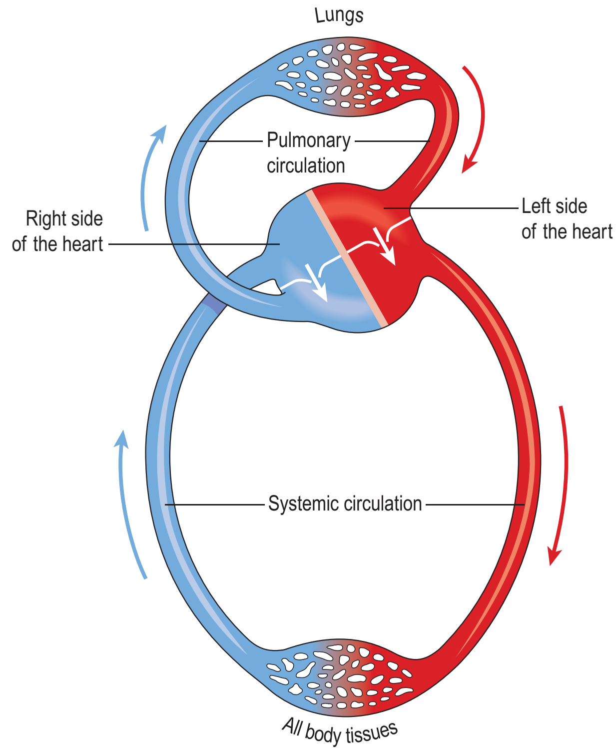


Figure 1.8 Circulation of the blood through the heart and the pulmonary and systemic circulations.

The heart muscle is not under conscious (voluntary) control. At rest, the heart contracts, or beats, between 65 and 75 times per minute. The rate is greatly increased when body oxygen requirements are increased, e.g. during exercise.

The rate at which the heart beats can be counted by taking the *pulse*. The pulse can be felt most easily where a superficial artery can be pressed gently against a bone, usually at the wrist.

Lymphatic system (Ch. 6)

The lymphatic system (Fig. 1.9) consists of a series of *lymph vessels*, which begin as blind-ended tubes in the interstitial spaces between the blood capillaries and tissue cells. Structurally they are similar to veins and blood capillaries but the pores in the walls of the lymph capillaries are larger than those of the blood capillaries. *Lymph* is tissue fluid that also contains material drained from tissue spaces, including plasma proteins and, sometimes, bacteria or cell debris. It is transported along lymph vessels and returned to the bloodstream near the heart.

There are collections of *lymph nodes* situated at various points along the length of the lymph vessels. Lymph is filtered as it passes through the lymph nodes, removing microbes and other materials.

The lymphatic system also provides the sites for formation and maturation of *lymphocytes*, the white blood cells involved in immunity (Ch. 15).

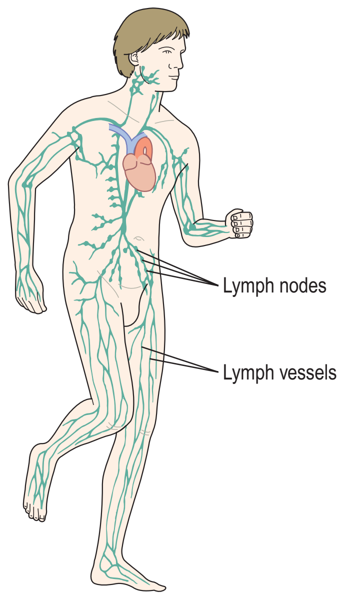


Figure 1.9 The lymphatic system: lymph nodes and vessels.

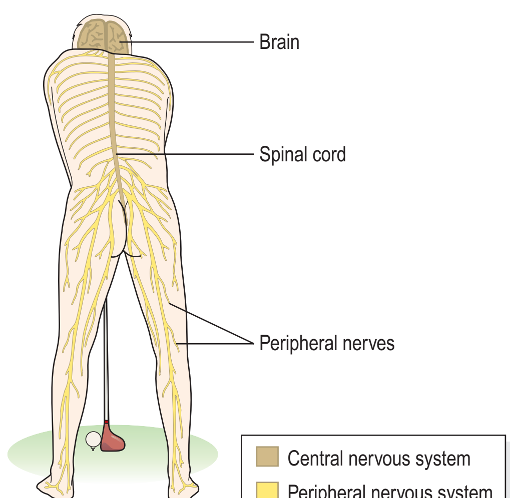


Figure 1.10 The nervous system.

Internal communication

This is carried out through the activities of the nervous and endocrine systems.

Nervous system (Ch. 7)

The nervous system is a rapid communication system. The main components are shown in Figure 1.10. The *central nervous system* consists of:

- the *brain*, situated inside the skull
- the *spinal cord*, which extends from the base of the skull to the lumbar region (lower back). It is protected from injury as it lies within the bones of the spinal column.

The *peripheral nervous system* is a network of nerve fibres, which are either:

- *sensory* or *afferent* nerves that transmit signals from the body to the brain, or
- *motor* or *efferent* nerves, which transmit signals from the brain to the effector organs, such as muscles and glands.

The *somatic* (*common*) *senses* are pain, touch, heat and cold, and these sensations arise following stimulation of specialised sensory receptors at nerve endings found throughout the skin.

Nerve endings within muscles and joints respond to changes in the position and orientation of the body, maintaining posture and balance. Yet other sensory receptors are activated by stimuli in internal organs and control vital body functions, e.g. heart rate, respiratory rate and blood pressure. Stimulation of any of these receptors sets up impulses that are conducted to the brain in sensory (afferent) nerves.

Communication along nerve fibres (cells) is by electrical impulses that are generated when nerve endings are stimulated. Nerve impulses (action potentials) travel at great speed, so responses are almost immediate, making rapid and fine adjustments to body functions possible.

Communication between nerve cells is also required, since more than one nerve is involved in the chain of events occurring between the initial stimulus and the reaction to it. Nerves communicate with each other by releasing a chemical (the *neurotransmitter*) into tiny gaps between them. The neurotransmitter quickly travels across the gap and either stimulates or inhibits the next nerve cell, thus ensuring the message is transmitted.

Sensory nerves transmit impulses from the body to appropriate parts of the brain, where the incoming information is analysed and collated. The brain responds by sending impulses along motor (efferent) nerves to the appropriate effector organ(s). In this way, many aspects of body function are continuously monitored and adjusted, usually by negative feedback control, and usually subconsciously, e.g. regulation of blood pressure.

Reflex actions are fast, involuntary, and usually protective motor responses to specific stimuli. They include:

- withdrawal of a finger from a very hot surface
- constriction of the pupil in response to bright light
- control of blood pressure.

Endocrine system (Ch. 9)

The endocrine system consists of a number of discrete glands situated in different parts of the body. They synthesise and secrete chemical messengers called *hormones* that circulate round the body in the blood. Hormones stimulate *target glands* or *tissues*, influencing metabolic and other cellular activities and regulating body growth and maturation. Endocrine glands detect and respond to levels of particular substances in the blood, including specific hormones. Changes in blood hormone levels are usually controlled by negative feedback mechanisms (see Figs 1.5 and 9.8). The endocrine system provides slower and more precise control of body functions than the nervous system.

In addition to the glands that have a primary endocrine function, it is now known that many other tissues also secrete hormones as a secondary function; some of these are explored further in Chapter 9.

Communication with the external environment

Special senses (Ch. 8)

Stimulation of specialized receptors in sensory organs or tissues gives rise to the sensations of sight, hearing, balance, smell and taste. Although these senses are usually considered to be separate and different from each other, one sense is rarely used alone (Fig. 1.11). For example, when the smell of smoke is perceived then other senses such as sight and sound are used to try and locate the source of a fire. Similarly, taste and smell are closely associated in the enjoyment, or otherwise, of food. The brain collates incoming information with information from the memory and initiates a response by setting up electrical impulses in motor (efferent) nerves to effector organs, muscles and glands. Such responses enable the individual to escape from a fire, or to subconsciously prepare the digestive system for eating.

Verbal communication

Sound is produced in the larynx when expired air coming from the lungs passes through and vibrates the *vocal cords* (see Fig. 10.8) during expiration. In humans, recognisable sounds produced by co-ordinated contraction of the muscles of the throat and cheeks, and movements of the tongue and lower jaw, is known as *speech*.

Figure 1.11 Combined use of the special senses: vision, hearing, smell and taste.

Non-verbal communication

Posture and movements are often associated with non-verbal communication, e.g. nodding the head and shrugging the shoulders. The skeleton provides the bony framework of the body (Ch. 16), and movement takes place at joints between bones. Skeletal muscles move the skeleton and attach bones to one another, spanning one or more joints in between. They are stimulated by the part of the nervous system under voluntary (conscious) control. Some non-verbal communication, e.g. changes in facial expression, may not involve the movement of bones.

Intake of raw materials and elimination of waste

This section considers substances taken into and excreted from the body, which involves the respiratory, digestive and urinary systems. Oxygen, water and food are taken in, and carbon dioxide, urine and faeces are excreted.

Intake of oxygen

Oxygen gas makes up about 21% of atmospheric air. A continuous supply is essential for human life because it is needed for most chemical activities that take place in the body cells. Oxygen is necessary for the series of chemical reactions that result in the release of energy from nutrients.

The upper respiratory system carries air between the nose and the lungs during breathing (Ch. 10). Air passes through a system of passages consisting of the pharynx (throat, also part of the digestive tract), the larynx (voice box), the trachea, two bronchi (one bronchus to each lung) and a large number of bronchial passages (Fig. 1.12). These end in alveoli, millions of tiny air sacs in each lung. They are surrounded by a network of tiny capillaries and are the sites where vital gas exchange between the lungs and the blood takes place (Fig. 1.13). **1.3**

Nitrogen, which makes up about 80% of atmospheric air, is breathed in and out, but it cannot be used by the body in gaseous form. The nitrogen needed by the body is obtained by eating protein-containing foods, mainly meat and fish.

Ingestion of nutrients (eating)

Nutrition is considered in Chapter 11. A balanced diet is important for health and provides *nutrients*, substances that are absorbed, usually following digestion, and promote body function, including cell building, growth and repair. Nutrients include water, carbohydrates, proteins, fats, vitamins and mineral salts. They serve vital functions including:

- maintenance of water balance within the body
- provision of fuel for energy production, mainly carbohydrates and fats

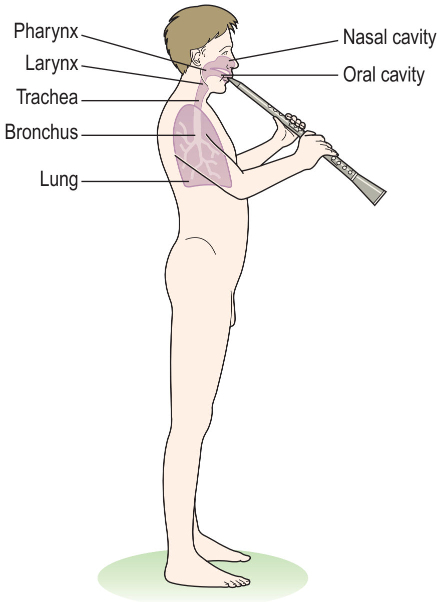


Figure 1.12 The respiratory system.

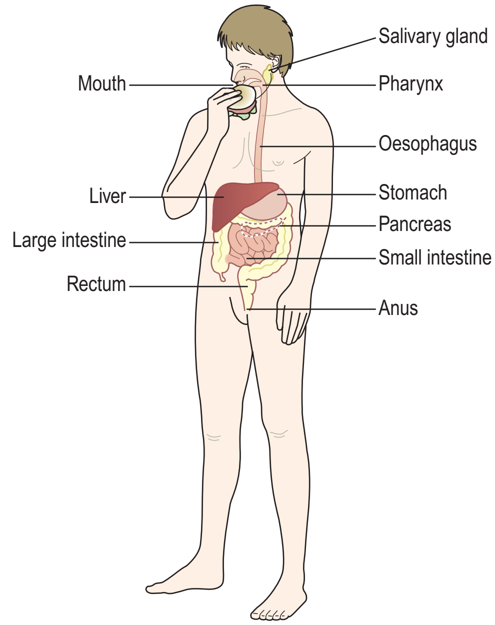


Figure 1.14 The digestive system.

- provision of the building blocks for synthesis of large and complex molecules, needed by the body.

Digestion

The digestive system evolved because food is chemically complex and seldom in a form that body cells can use. Its function is to break down, or digest, food so that it can be absorbed into the circulation and then used by body cells. The digestive system consists of the alimentary canal and accessory organs (Fig. 1.14).

Alimentary canal. This is essentially a tube that begins at the mouth and continues through the pharynx, oesophagus, stomach, small and large intestines, rectum and anus. **1.4**

Accessory organs. These are the *salivary glands, pancreas* and *liver* (Fig. 1.14), which lie outside the alimentary canal. The salivary glands and pancreas synthesise and release *digestive enzymes*, which are involved in the chemical breakdown of food while the liver secretes *bile*; these substances enter the alimentary canal through connecting ducts.

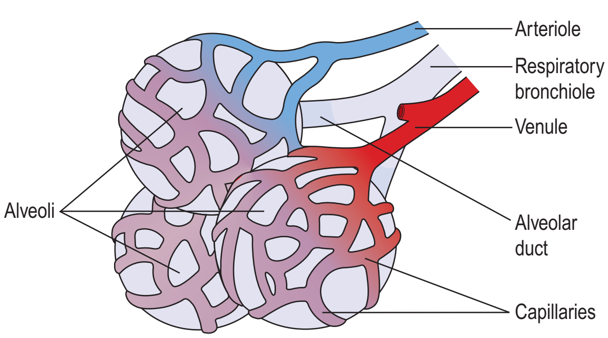


Figure 1.13 Alveoli: the site of gas exchange in the lungs.

Metabolism

This is the sum total of the chemical activity in the body. It consists of two groups of processes:

- *anabolism*, building or synthesising large and complex substances
- *catabolism*, breaking down substances to provide energy and raw materials for anabolism, and substances for excretion as waste.

The sources of energy are mainly dietary carbohydrates and fats. However, if these are in short supply, proteins are used.

Elimination of wastes

Carbon dioxide

This is a waste product of cellular metabolism. Because it dissolves in body fluids to make an acid solution, it must be excreted in appropriate amounts to maintain pH (acidity or alkalinity) within the normal range. The main route of carbon dioxide excretion is through the lungs during expiration.

Urine

This is formed by the kidneys, which are part of the urinary system (Ch. 13). The organs of the urinary system are shown in Figure 1.15. Urine consists of water and waste products mainly of protein breakdown, e.g. urea. Under the influence of hormones from the endocrine system, the kidneys regulate water balance. They also play a role in maintaining blood pH within the normal

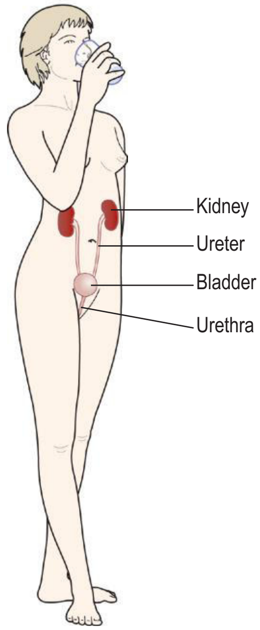


Figure 1.15 The urinary system.

range. The bladder stores urine until it is excreted during *micturition*. 1.5

Faeces

The waste materials from the digestive system are excreted as faeces during *defaecation*. They contain indigestible food residue that remains in the alimentary canal because it cannot be absorbed and large numbers of microbes.

Protection and survival

Body needs and related activities explored in this section are: protection against the external environment, defence against infection, movement and survival of the species.

Protection against the external environment

The skin (Fig. 1.16) forms a barrier against invasion by microbes, chemicals and dehydration (Ch. 14). It consists of two layers: the epidermis and the dermis.

The *epidermis* lies superficially and is composed of several layers of cells that grow towards the surface from its deepest layer. The skin surface consists of dead flattened cells that are constantly being rubbed off and replaced from below. The epidermis provides the barrier between the moist internal environment and the dry atmosphere of the external environment.

The *dermis* contains tiny sweat glands that have little canals or ducts, leading to the surface. Hairs grow from follicles in the dermis. The dermis is rich in sensory nerve endings sensitive to pain, temperature and touch. It is a vast organ that constantly provides the central nervous system with sensory input from the body surfaces. The skin also plays an important role in the regulation of body temperature.

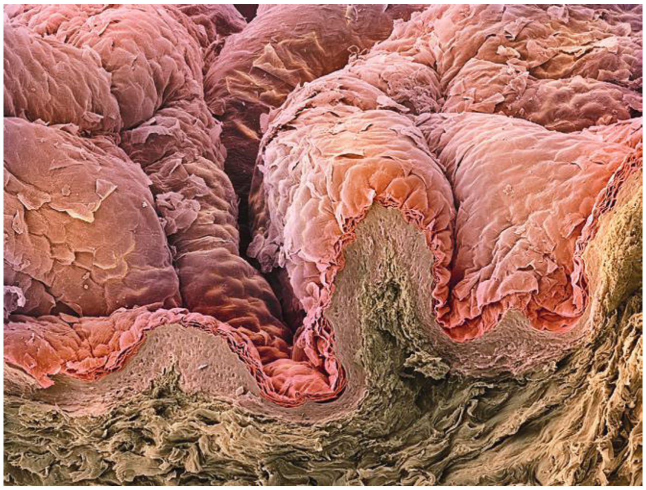


Figure 1.16 Coloured scanning electron micrograph of the skin.

Defence against infection

The body has many means of self-protection from invaders, which confer resistance and/or immunity (Ch. 15). They are divided into two categories: specific and non-specific defence mechanisms.

Non-specific defence mechanisms

These are effective against any invaders. The skin protects most of the body surface. There are also other protective features at body surfaces, e.g. sticky *mucus* secreted by mucous membranes traps microbes and other foreign materials. Some body fluids contain *antimicrobial substances*, e.g. gastric juice contains hydrochloric acid, which kills most ingested microbes. Following successful invasion other non-specific processes that counteract potentially harmful consequences may take place, including the inflammatory response (Ch. 15).

Specific defence mechanisms

The body generates a specific (immune) response against any substance it identifies as foreign. Such substances are called *antigens* and include:

- pollen from flowers and plants
- bacteria and other microbes
- cancer cells or transplanted tissue cells.

Following exposure to an antigen, lifelong immunity against further invasion by the same antigen often develops. Over a lifetime, an individual gradually builds up immunity to millions of antigens. *Allergic reactions* are abnormally powerful immune responses to an antigen that usually poses no threat to the body, e.g. the effects of pollen in people with hay fever.

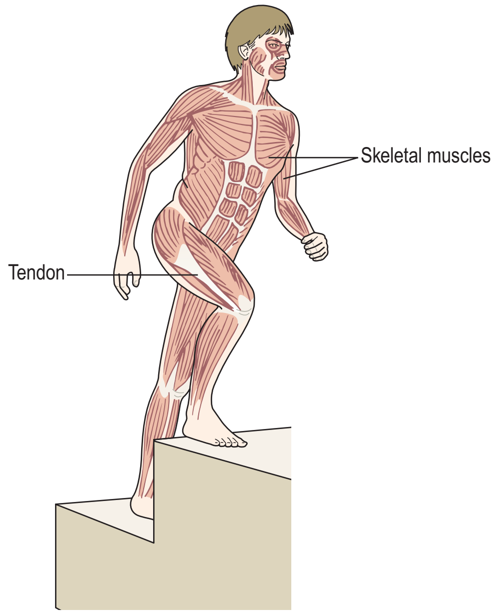


Figure 1.17 The skeletal muscles.

Movement

Movement of the whole body, or parts of it, is essential for many body activities, e.g. obtaining food, avoiding injury and reproduction.

Most body movement is under conscious (voluntary) control. Exceptions include protective movements that are carried out before the individual is aware of them, e.g. the reflex action of removing one's finger from a very hot surface.

The musculoskeletal system includes the *bones* of the skeleton, *skeletal muscles* and *joints*. The skeleton provides the rigid body framework and movement takes place at joints between two or more bones. Skeletal muscles (Fig. 1.17), under the control of the voluntary nervous system, maintain posture and balance, and move the skeleton. A brief description of the skeleton is given in Chapter 3, and a more detailed account of bones, muscles and joints is presented in Chapter 16.

Survival of the species

Survival of a species is essential to prevent its extinction. This requires the transmission of inherited characteristics to a new generation by reproduction.

Transmission of inherited characteristics

Individuals with the most advantageous genetic make-up are most likely to survive, reproduce and pass their genes on to the next generation. This is the basis of natural selection, i.e. 'survival of the fittest'. Chapter 17 explores the transmission of inherited characteristics.

Reproduction (Ch. 18)

Successful reproduction is essential in order to ensure the continuation of a species and its genetic characteristics

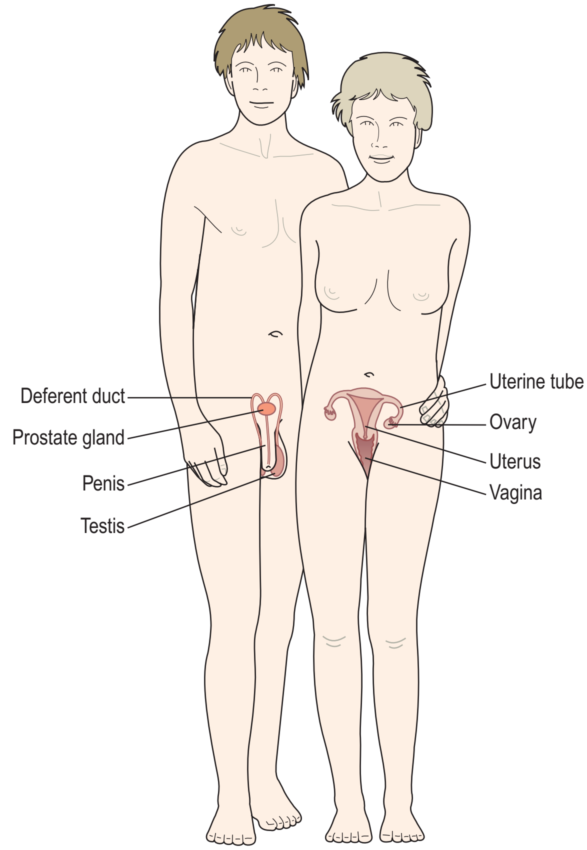


Figure 1.18 The reproductive systems: male and female.

from one generation to the next. Ova (eggs) are produced by two *ovaries* situated in the female pelvis (Fig. 1.18). During a female's reproductive years only one ovum usually is released at about monthly intervals and it travels towards the *uterus* in the *uterine tube*. In males, spermatozoa are produced in large numbers by the two *testes*, situated in the *scrotum*. From each testis, spermatozoa pass through the *deferent duct* (vas deferens) to the *urethra*. During sexual intercourse (coitus) the spermatozoa are deposited in the *vagina*.

They then swim upwards through the uterus and fertilise the ovum in the uterine tube. Fertilisation (Fig. 1.19) occurs when a female egg cell or *ovum* fuses with a male sperm cell or *spermatozoon*. The fertilised ovum (*zygote*) then passes into the uterus, embeds itself in the uterine wall and grows to maturity during pregnancy or *gestation*, in about 40 weeks.

When the ovum is not fertilised it is expelled from the uterus along with the uterine lining as bleeding, known as *menstruation*. In females, the *reproductive cycle* consists of phases associated with changes in hormone levels involving the endocrine system.

A cycle takes around 28 days and they take place continuously between *puberty* and the *menopause*, except during pregnancy. At *ovulation* (see Fig. 18.10, p. 457) an ovum is released from one of the ovaries mid-cycle. There

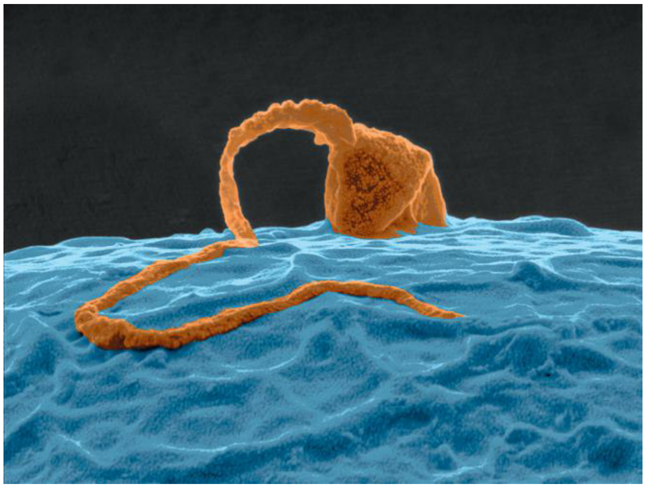


Figure 1.19 Coloured scanning electron micrograph showing fertilisation (spermatozoon: orange, ovum: blue).

is no such cycle in the male but hormones, similar to those of the female, are involved in the production and maturation of spermatozoa.

Introduction to ageing

Learning outcomes

After studying this section, you should be able to:

- List the main features of ageing
- Outline the implications of ageing human populations.

After birth many changes occur as the body grows and develops to maturity. The peak of mature physiological function is often relatively short lived, as age-related changes begin to impair performance; for example, kidney function begins to decline from about 30 years of age. At both extremes of the lifespan many aspects of body function are less efficient, for example temperature regulation is less effective in infants and older adults.

Maturity of most body organs occurs during puberty and maximal efficiency during early adulthood. Most organs are able to repair and replace their tissues, with the notable exceptions of the brain and myocardium (heart muscle). At maturity, many organs have considerable functional reserve, or 'spare capacity', which usually declines gradually thereafter. The functional reserve means that considerable loss of function must occur before physiological changes are evident. Alterations in body function during older life need careful assessment as ageing is generally associated with decreasing efficiency of body organs and/or increasing frailty. Although a predisposing factor for some conditions, the ageing process is not accompanied by any specific illnesses or diseases.

The process of ageing is poorly understood although it affects people in different ways. There is no single cause known although many theories have been proposed and there is enormous individual variation in the rate of ageing. The lifespan of an individual is influenced by many factors, some of which are hereditary (Ch. 17) and outwith individual control. Others not readily susceptible to individual influence include poverty, which is associated with poor health. However peoples' lifestyle choices may also strongly influence longevity, e.g. lack of exercise, cigarette smoking and alcohol misuse contribute to a shorter lifespan.

Several common age-associated changes that occur in particular organs and systems are well recognised and include greying hair and wrinkling of the skin. Further examples are shown in Figure 1.20 and these and others are highlighted together with their physiological and, sometimes, clinical consequences at the end of the physiology section in relevant chapters. Increasing age is a risk factor for some diseases, e.g. most cancers, coronary heart disease and dementia.

The World Health Organisation (WHO, 2012) predicts that the number of people aged 60 years and over globally will increase from 605 million to 2 billion between 2000 and 2050 (Fig. 1.21). The 20th century saw the proportion of older people increasing in high income countries. Over the next 40 years, this trend is predicted to follow in most areas of the world including low- and middle-income countries. Increasing life expectancy will impact on health care, and the role of prevention of and early interventions in ill-health will become increasingly important.

Physiological changes

Nervous system
- Motor control of precise movement diminishes
- Conduction rate of nerve impulses becomes slower

Special senses
- Ear – hair cells become damaged
- Eye – stiffening of the lens; cataracts (opacity of the lens)
- Taste and smell – diminished perception

Respiratory system
- Less mucus produced
- Stiffening of ribcage
- Decline in respiratory reflexes

Cardiovascular system
- Stiffening of blood vessel walls
- Reduction in cardiac function and efficiency

Endocrine system
- Pancreatic islet cells – decline in function of β-cells
- Adrenal cortex – oestrogen deficiency in post-menopausal women

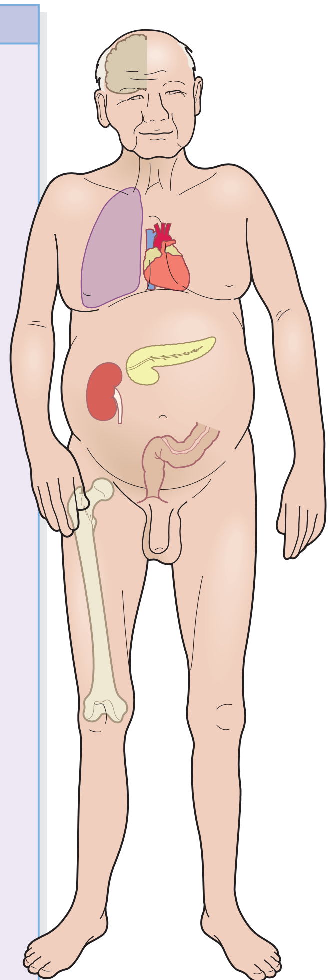
Digestive system
- Loss of teeth
- Peristalsis reduced
- Decline in liver mass

Urinary system
- Fewer nephrons, lower glomerular filtration rate

Resistance and immunity
- Declines

Musculoskeletal system
- Thinning of bone
- Stiffening of cartilage and other connective tissue

Reproductive systems
- Female menopause



Common consequences

Nervous system
- Takes longer to carry out motor action, more prone to falls
- Poorer control of e.g. vasodilation, vasoconstriction and baroreceptor reflex

Special senses
- Hearing impairment
- Difficulty reading without glasses; good light needed for vision
- Food may taste bland, smells e.g. burning may go unnoticed

Respiratory system
- Increased risk of infections
- Reduced respiratory minute volume
- Less able to respond to changes in arterial blood gas levels

Cardiovascular system
- Increased blood pressure, increased risk of vessel rupture and haemorrhage
- Reduction in cardiac output and cardiac reserve

Endocrine system
- More prone to type 2 diabetes, especially if overweight

Digestive system
- Difficulty chewing
- Constipation
- Reduced liver metabolism with increased risk of e.g. drug toxicity

Urinary system
- Less able to regulate fluid balance
- More prone to effects of dehydration and overload

Resistance and immunity
- Increased risk of infection
- Longer healing times

Musculoskeletal system
- Increased risk of fractures
- Stiffening of joints
- Osteoporosis

Reproductive systems
- Cessation of female reproductive ability
- Reduced fertility in males

Figure 1.20 Effects of ageing on body systems.

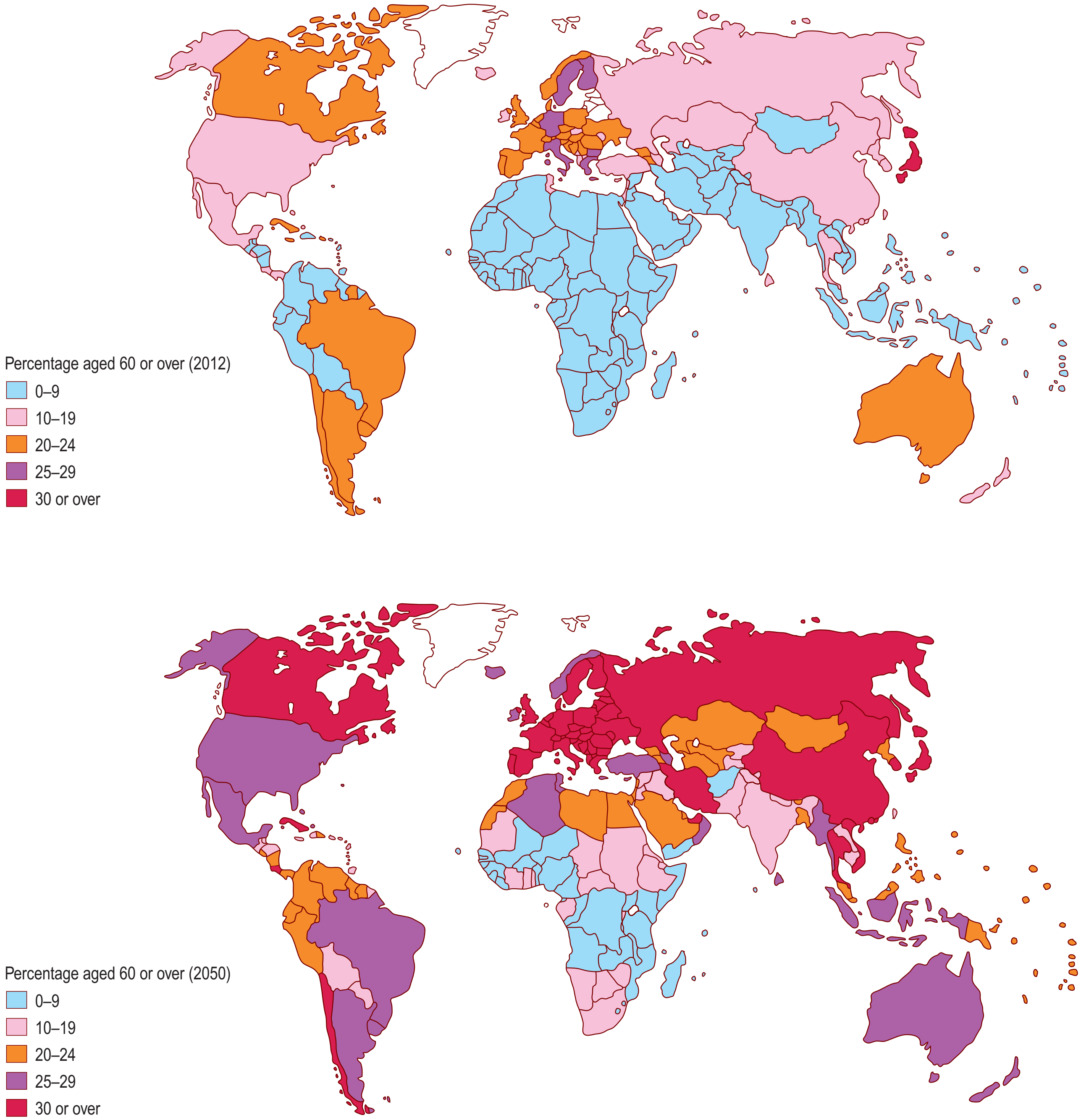


Figure 1.21 Global ageing trends.

Introduction to the study of illness

Learning outcomes

After studying this section, you should be able to:

- list mechanisms that commonly cause disease
- define the terms aetiology, pathogenesis and prognosis
- name some common disease processes.

In order to understand the specific diseases described in later chapters, knowledge of the relevant anatomy and physiology is necessary, as well as familiarity with the pathological processes outlined below.

There are many different illnesses, disorders and diseases, which vary from minor, but often very troublesome conditions, to the very serious. The study of abnormalities can be made much easier when a systematic approach is adopted. In order to achieve this in later chapters where specific diseases are explained, the headings shown in Box 1.2 will be used as a guide. Causes (*aetiology*) are outlined first when there are clear links between them and the effects of the abnormality (*pathogenesis*).

Aetiology

Diseases are usually caused by one or more of a limited number of mechanisms that may include:

- genetic abnormalities, either inherited or acquired
- infection by micro-organisms, e.g. bacteria, viruses, microbes or parasites, e.g. worms
- chemicals
- ionising radiation
- physical trauma
- degeneration, e.g. excessive use or ageing.

In some diseases more than one of the aetiological factors listed above is involved, while in others, no specific cause has been identified and these may be described as *essential*, *idiopathic* or *spontaneous*. Although the precise cause of a disease may not be known, *predisposing* (*risk*) *factors* are usually identifiable.

Box 1.2 Suggested framework for understanding diseases

Aetiology: cause of the disease
Pathogenesis: the nature of the disease process and its effect on normal body functioning
Complications: other consequences which might arise if the disease progresses
Prognosis: the likely outcome

Pathogenesis

The main processes causing illness or disease are outlined below. Box 1.3 contains a glossary of disease-associated terminology.

Inflammation. (p. 377) – This is a tissue response to any kind of tissue damage such as trauma or infection. Inflammatory conditions are recognised by the suffix -itis, e.g. appendicitis.

Tumours. (p. 55) – These arise when abnormal cells escape body surveillance and proliferate. The rate of their production exceeds that of normal cell death causing a mass to develop. Tumours are recognised by the suffix -oma, e.g. carcinoma.

Abnormal immune mechanisms. (p. 385) – These are responses of the normally protective immune system that cause undesirable effects.

Thrombosis, embolism and infarction. (p. 119) – These are the effects and consequences of abnormal changes in the blood and/or blood vessel walls.

Degeneration. – This is often associated with normal ageing but may also arise prematurely when structures deteriorate causing impaired function.

Metabolic abnormalities. – These cause undesirable metabolic effects, e.g. diabetes mellitus, page 236.

Genetic abnormalities. – These may be either inherited (e.g. phenylketonuria, p. 446) or caused by environmental factors such as exposure to ionising radiation (p. 55).

Box 1.3 Glossary of terminology associated with disease

Acute: a disease with sudden onset often requiring urgent treatment (compare with chronic)
Acquired: a disorder which develops any time after birth (compare with congenital)
Chronic: a long-standing disorder which cannot usually be cured (compare with acute)
Communicable: a disease that can be transmitted (spread) from one individual to another
Congenital: a disorder which one is born with (compare with acquired)
Iatrogenic: a condition that results from healthcare intervention
Sign: an abnormality seen or measured by people other than the patient
Symptom: an abnormality described by the patient
Syndrome: a collection of signs and symptoms which tend to occur together

Further reading

World Health Organization 2012 Good health adds life to years. Global brief for World Health Day 2012. WHO 2012, Geneva. Available online at http://whqlibdoc.who.int/hq/2012/WHO_DCO_WHD_2012.2_eng.pdf (p. 10) Accessed 3 September 2013

For a range of self-assessment exercises on the topics in this chapter, visit Evolve online resources: https://evolve.elsevier.com/Waugh/anatomy/