Helen McGuinness

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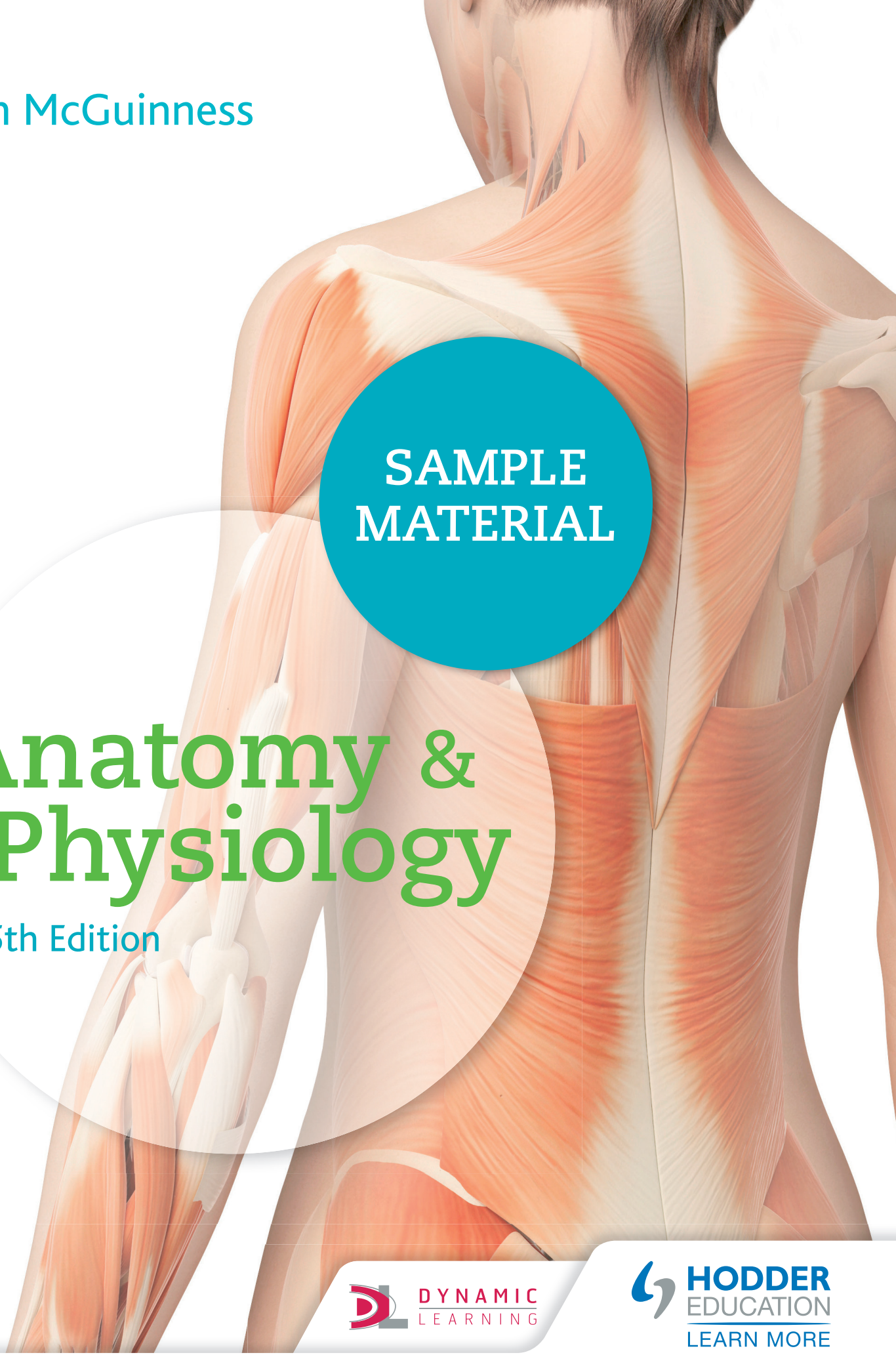
Anatomy & Physiology

5th Edition



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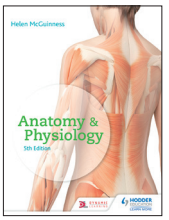

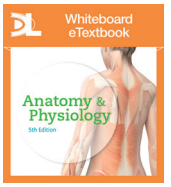

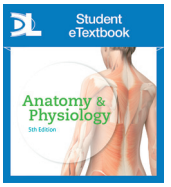

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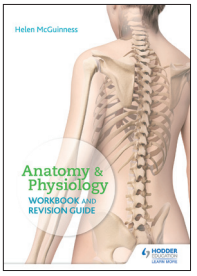

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2 Cells and tissues

The human body can be likened to a universe; it is made up of very small structures that are organised to function as a whole.

It is incredible to think that the human body, a complicated and sophisticated machine, starts its journey of life as a single cell.

In order to understand how the body functions as a whole, we first need to consider how the structure of the body is organised into its five basic levels:

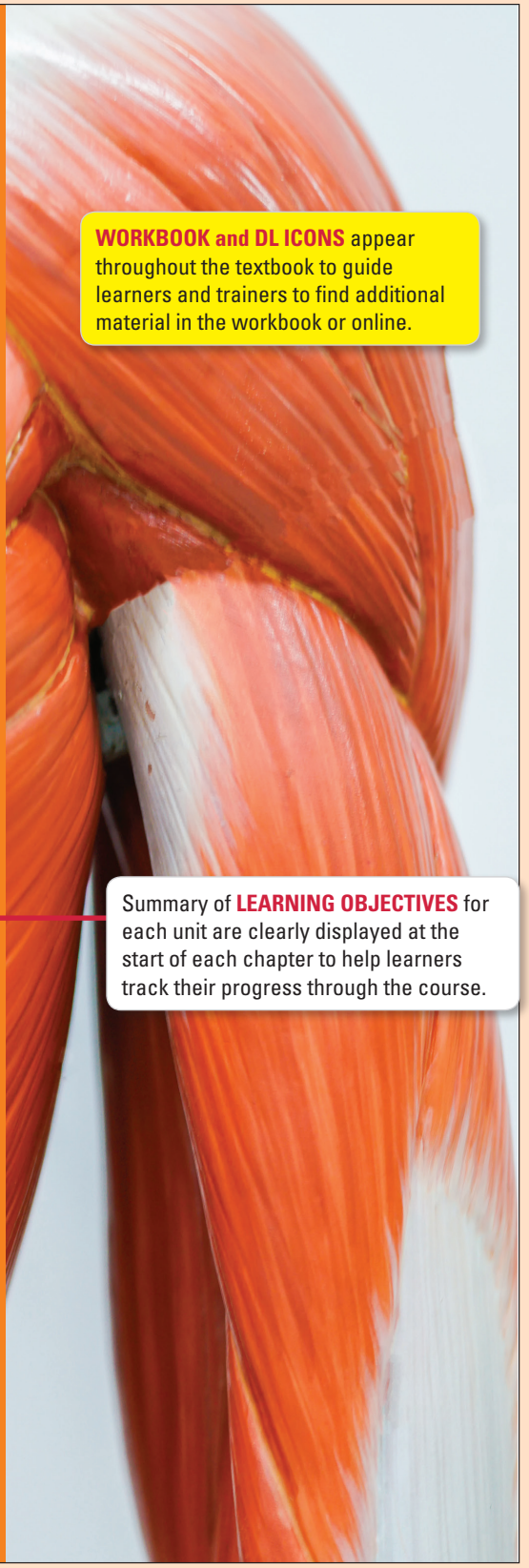
1 **chemical**
2 **cellular**
3 **tissues**
4 **organs**
5 **systems.**

Ultimately, all the body systems, and the minute cells that are the basic components (parts) of all organs and tissues, are involved in maintaining health and keeping the body in a state of balance.

LEARNING OBJECTIVES

By the end of this chapter you will understand:

- the different levels of structural organisation in the body
- the importance of homeostasis and metabolism in correct body functioning
- the structure and function of the cell and its parts
- the structure and function of the main tissue types in the body
- how to identify the major systems of the body
- the interrelationships between the cells and tissues and other body systems
- common pathologies associated with cells and tissues.



WORKBOOK and DL ICONS appear throughout the textbook to guide learners and trainers to find additional material in the workbook or online.

Summary of **LEARNING OBJECTIVES** for each unit are clearly displayed at the start of each chapter to help learners track their progress through the course.

Build subject knowledge through clear and detailed coverage of the **KEY FACTS** structured around the specification.

In practice

In order for a therapist to carry out the most successful treatment possible for their client's needs, it is important for them to have an understanding of cells and tissues as the foundation building blocks upon which the human body is formed.

Examining cells and tissues is like looking at the body from the inside out. Understanding how the body functions from its cellular level will help therapists to understand how the body functions in both health and illness, and relate to the link between structure and function of the body's organs.

The different levels of structural organisation in the body

The human body as a whole is an organism that contains many parts to make up the whole. In order to appreciate the structure of the human body, we need to study the five principal levels of structural organisation: chemical, cellular, tissue, organ and system.

STUDY TIPS are highlighted throughout and appear as useful tips to help with revision.

Study tip

When learning the levels of structural organisation, you may find it helpful to memorise the following acronym: **C**LEVER **C**AROL **T**AKES **O**RGANISATION **S**ERIOUSLY.

1. Chemical level

Every substance in the world is made up of basic particles such as atoms and molecules.

Atoms and molecules represent the lowest level of organisational complexity in the body and are essential for maintaining life. At the chemical level, the smallest unit of matter is the atom.

An **atom** is the smallest particle of an element; an example is a hydrogen or oxygen atom.

A **molecule** is a particle composed of two or more atoms joined together; a common example is a water molecule (H_20) made of one oxygen atom and two hydrogen atoms.

KEY FACT
Molecules combine to form cells.

Study tip

When understanding the relationship between atoms and molecules, it may be helpful to think of the molecule as the wall, and the atoms as the blocks from which it is built.

2. Cellular level

Cells are the basic structural and functional unit of all living organisms, including the human body. They are, therefore, the smallest units that show characteristics of life.

There are many different types of cells in the body, which vary in structure, size and shape according to their function. An example is white blood cells (leucocytes) which help fight infection in the body.

KEY FACT
Cells combine to form tissues.

3. Tissue level

A **tissue** is a group of similar cells that perform a particular function, for example epithelial, connective, muscular or nervous tissue.

KEY FACT
Two or more types of tissue combine to form organs.

4. Organ level

An **organ** is a specialised structure made up of different types of tissues that are grouped into structurally and functionally integrated units, for example the heart or the lungs.

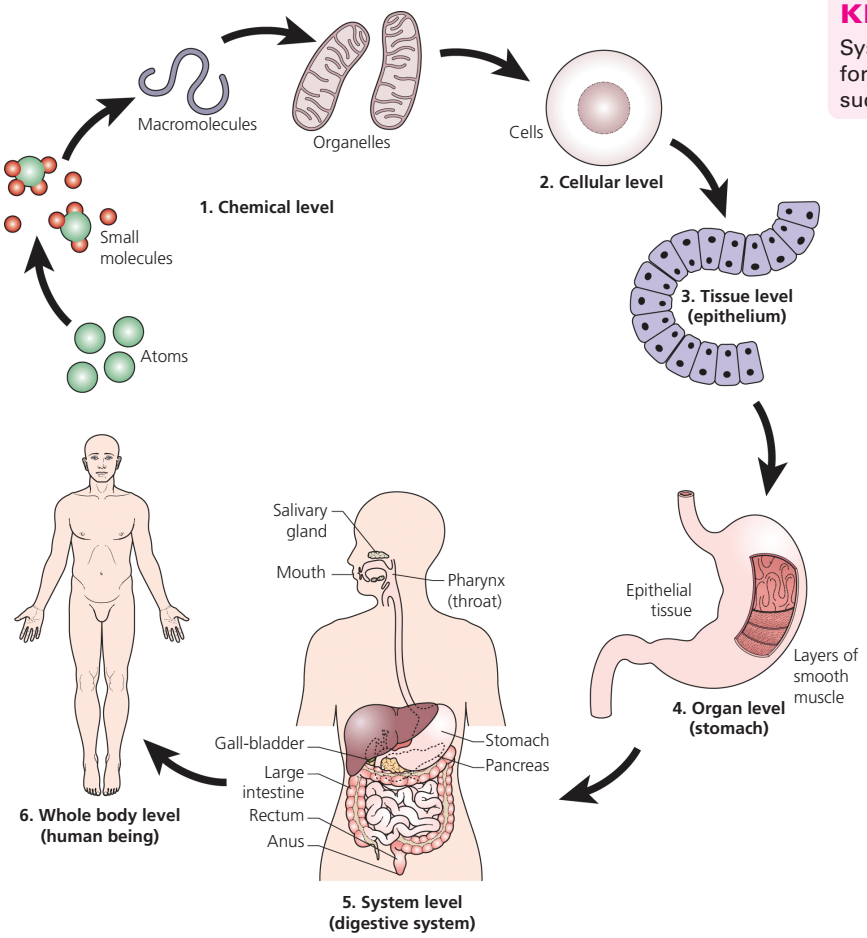
KEY FACT
Organs combine to form systems.

5. System level

A **system** is a group of organs that work together to perform specific functions. The systems of the body include the circulatory, skeletal, skin, respiratory, reproductive, muscular, endocrine, nervous, urinary and digestive systems.

KEY FACT

Systems combine to form a living organism, such as the human body.



▲ Figure 2.1 Levels of structural organisation in the body

Homeostasis

Traditionally, the body is divided into different systems according to their specific functions. However, the ultimate purpose of each system is to maintain a constant internal environment for each cell to survive.

The human body is exposed to a constantly changing external environment. These external changes are neutralised by the internal environment of blood, lymph and tissue fluids that bathe and protect the cells and keep the body functioning correctly.

Body parts function efficiently only when the concentrations of water, food

substances and oxygen, and the conditions of heat and pressure, remain within certain narrow limits. Altering even one of these conditions can affect the body's ability to function well. The process by which the body maintains a stable internal environment for its cells and tissues is called **homeostasis**.

The process of homeostasis acts like a fine-tuning mechanism that your body goes through automatically in order to restore balance among the body's systems.

When the body's systems are imbalanced through stress, pain, infection or depleted oxygen levels, the body's cells do not work at their optimal level, often leading to signs of disorder and disease. The body and its systems are constructed in such a way that all systems work synergistically (in harmony) with one another, with the overall aim of maintaining homeostasis.

Examples of homeostatic mechanisms in the body include the regulation of:

- body temperature
- blood pressure
- blood sugar levels
- pH levels.

Regulating the pH balance

The pH scale is a chemical table or rating scale used to measure the acid or alkaline (base) content of a substance.

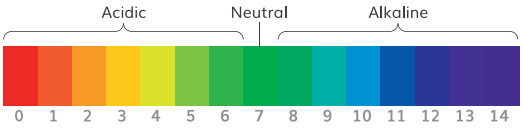
- Acids have a pH from 0 to 7.
- Alkalines (bases) have a pH of 7.0 to 14.

KEY FACT

The pH level of blood in the human body needs to be around 7.4.

If the pH level drops below 7.0 to an acidic level, the condition is known as acidosis. If the pH goes above 7.8, the condition becomes alkalosis. Both acidosis and alkalosis can be life threatening.

In order to maintain the blood at a pH of 7.4, the body's systems work together by producing buffer substances (for example, carbonate and bicarbonate), which function to regulate the pH level by absorbing excess hydrogen or hydrogen ions. The kidneys are also significant in maintaining homeostasis as they can detect if the pH of your body's fluids is too low (acidic).



▲ Figure 2.2 The pH scale

KEY FACT

The part of the brain called the hypothalamus is vital in maintaining homeostasis. Throughout the body, receptors in the blood vessels detect pressure, temperature, glucose levels and pH levels in the blood. These receptors send a signal through the nervous systems to the hypothalamus to initiate (start) changes to bring the body back to balance. (An example of this is the secretion of insulin if the blood sugar levels get too high.)

KEY FACT

Homeostasis is maintained by adjusting the metabolism of the body.

Metabolism

Metabolism is the term used to describe the physiological processes that take place in our bodies to convert the food we eat and the air we breathe into the energy we need to function. Metabolism is essentially the basic chemical working of the body cells; through metabolism, food substances are transformed into energy or materials that the body can use or store for use later.

Metabolism involves two processes:

- **Catabolism**: the chemical breakdown of complex substances by the body to form simpler ones, accompanied by the release of energy. The substances broken down include nutrients in food (carbohydrates and proteins) as well as the body's storage products (glycogen).
- **Anabolism**: the building up of complex molecules, such as proteins and fats, from simpler ones by living things.

Metabolic rate

The rate at which a person consumes energy in activities and body processes is known as the **metabolic rate**. The minimum energy required to keep the body alive is known as the **basal metabolic rate**.

How elements contribute to the body's chemical make-up

When talking about the chemical make-up of the body, we must also consider how the common major elements and compounds that are involved in the body's make-up relate to the physiological processes of the body.

Elements and compounds occur in one of three states: gas, liquid or solid. An example of this is water, which is usually a liquid although it can become solid (like ice) or turn into gas (like steam). Salt and glucose are examples of solids, and carbon dioxide an example of a gas.

It takes energy to change the state of an element or a compound.

The chemical bonds between the elements that make up the compounds are one of the ways the body stores energy. This energy, when released, may be used in a variety of ways, for example to initiate chemical processes, to aid movement or for the body's growth, maintenance and repair.

The chemical make-up of a cell

Chemically, a cell is composed of the major elements carbon, oxygen, hydrogen and nitrogen, plus trace elements of several other elements such as sodium, calcium, chlorine, magnesium, iron, iodine, potassium, sulphur and phosphorus.

Table 2.1 Overview of the chemical components of the cell

Major compound	Elements present	Main significance in body
Water	Hydrogen and oxygen	Like the body's reservoir, water provides a universal solvent for the facilitation of chemical reactions in the body's tissues Helps transport substances around the body
Carbohydrates	Carbon, hydrogen and oxygen	The main fuel for the body
Protein	Carbon, hydrogen, oxygen and nitrogen May contain sulphur	The main building blocks of the body's tissues
Fats/lipids	Carbon, hydrogen and oxygen	Energy source for the body's activities Energy store
Nucleic acids	Carbon, hydrogen, oxygen, nitrogen and phosphorus	Important molecules found inside cells (e.g. deoxyribonucleic acid, (DNA) which provides the genetic material inside the nucleus)

KEY FACT

Cells are made up of approximately 80% water, 15% protein, 3% lipids or fats, 1% carbohydrates and 1% nucleic acids.

Cells

KEY FACT
Cytology is the scientific study of cells.

The cell is the fundamental unit of all living organisms and is the simplest form of life that can exist as a self-sustaining unit. Cells are therefore the building blocks of the human body.

Cells in the body take many forms, the size and shape being largely dependent on their specialised function. For example, some cells help fight disease, others transport oxygen or produce movement; some manufacture proteins or chemicals, and cells function to store nutrients.

KEY FACT
Each type of cell has a structure that is suited to its specific function. For example, a muscle cell is long and thin to enable it to contract and shorten, while skin cells are flat to aid the skin in providing a waterproof covering.

The parts of a cell's structure

Though cells are the smallest units that show characteristics of life, they are made up of different parts: the **cell organelles**.

Cell organelles (little organs) are the basic component parts of the cells and are formed from molecules combining in very specific ways. Each organelle has a particular functional significance within the cell that allows it to live.

Study tip
When examining the function of each organelle, it is helpful to think of the cell as the 'factory' and the organelles as a 'department' within the factory. Each cell organelle is responsible for the production of a certain product or substance that is used elsewhere in the cell or body.

Despite the great variety of cells in the body, they all have the same basic structure.

Study tip
When studying the cell's structure, it is helpful to think of it in three parts:

- the **outer part**: the **cell membrane**
- the **inner part**, containing the **nucleus**
- the **middle layer**, which contains a semi-fluid substance called the **cytoplasm**, which contains all of the cell's organelles.

The outer part of the cell

Cell membrane

The cell membrane is a fine membrane that encloses the cell and protects its contents. This membrane is semi-permeable, in that it selectively controls the inward and outward movement of molecules into and out of the cell. Oxygen, nutrients, hormones and proteins are taken into the cell as needed, and cellular waste such as carbon dioxide passes out through the membrane. As well as governing the exchange of nutrients and waste materials, its function is also to maintain the shape of the cell.

The inner part of the cell

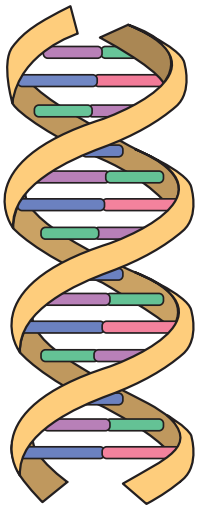
Nucleus

The nucleus is the largest organelle in the cytoplasm. It acts as the control centre of the cell, regulating the cell's functions and directing most metabolic activities. The nucleus governs the specialised work performed by the cell and the cell's own growth, repair and reproduction. All cells have at least one nucleus at some time in their existence. The nucleus is significant in that it contains all the information required for the cell to function and it controls all cellular operations.

The information required by the cell is stored in DNA (deoxyribonucleic acid), which carries the genetic materials for replication of identical molecules. The DNA strands are found in threadlike structures known as chromosomes.

A **chromosome** is one of the threadlike structures in the cell nucleus that carries the genetic information in the form of genes. The nucleus of a human cell contains 46 chromosomes, 23 of which are from the mother and 23 of which are from the father. Each

chromosome can duplicate an exact copy of itself between each cell division so that each new cell formed receives a full set of chromosomes.



▲ Figure 2.3 A strand of DNA

KEY FACT

DNA is a long, twisted molecule found in the chromatin of the cell's nucleus. It is often called the body's blueprint, as it is a record of a person's height, bone structure, hair colour, body chemistry and other characteristics. When cells divide and multiply, DNA passes on its hereditary information, ensuring that new cells are direct copies.

If the spiral of DNA in the nucleus of just one human cell were stretched out in a single line, it would extend more than 6 feet.

Chromatin

Chromatin is the substance inside the nucleus that contains the genetic material.

Nucleolus

A nucleolus is a dense spherical structure, inside the nucleus, which contains ribonucleic acid (RNA) structures that form ribosomes.

KEY FACT

RNA is the molecule that transports the genetic information out of the nucleus and allows translation of the genetic code into proteins.

Nuclear membrane

Surrounding the nucleus of a cell is a double-layered membrane called the nuclear membrane or nuclear envelope. This membrane separates the nucleoplasm (the fluid inside the nucleus) from the cytoplasm (fluid outside the nucleus).

The function of the nuclear membrane is to regulate what materials enter or exit the nucleus.

The nuclear pore is a minute passageway through the nuclear membrane. It has a sophisticated biological entry and exit control valve, only permitting selected chemicals to move in and out of the nucleus.

Study tip

The nuclear pore can be likened to a ticket gate, acting like a security control system guarding the contents and work of the cell and its nucleus.

The middle part of the cell

Cytoplasm

The cytoplasm is the gel-like substance that is enclosed by the cell membrane. The cytoplasm contains the nucleus and the small cellular structures called organelles.

Most cellular metabolism occurs within the cytoplasm of the cell.

Cytoplasm contains molecules such as enzymes, which are responsible for breaking down waste and also aid in metabolic activity.

Centrosome and centrioles

The **centrosome** is an area of clear cytoplasm found next to the nucleus, and it contains the small spherical structures called **centrioles**. These are associated with cell division, or mitosis. During cell division, the centriole divides in two; the two migrate to opposite sides of the nucleus to form the spindle poles.

Chromatids and centromere

The **chromatids** are a pair of identical strands. The portion of a chromosome where the two chromatids are joined is the **centromere**. The two chromatids separate during cell division.

Endoplasmic reticulum (smooth and rough)

The endoplasmic reticulum is a series of membranes continuous with the cell membrane. It functions like an intracellular transport system, allowing movement of materials from one part of the cell to another. It links the cell membrane with the nuclear membrane and therefore assists movement of materials out of the cell.

The endoplasmic reticulum contains enzymes and helps in the synthesis of proteins, carbohydrates and lipids. It serves to store material, and transport substances inside the cell, as well as detoxify harmful agents. Some endoplasmic reticulum appears smooth, while others appear rough due to the presence of ribosomes.

Ribosomes

Ribosomes are tiny organelles made up of ribonucleic acid (RNA) and protein. They may be fixed to the walls of the endoplasmic reticulum (known as rough ER) or may float freely in the cytoplasm. Their function is to manufacture proteins for use within the cell and also to produce other proteins that are exported out of the cell.

Mitochondria

Mitochondria are oval-shaped organelles that lie in varying numbers within the cytoplasm. The mitochondria are the site of the cell's energy production; they provide most of a cell's ATP (adenosine triphosphate), which is a compound that stores the energy needed by the cell.

The work of the mitochondria is assisted by enzymes, which are proteins that speed up chemical changes. Through cellular respiration, the mitochondria provide the energy that powers the cell's activities.

Lysosomes

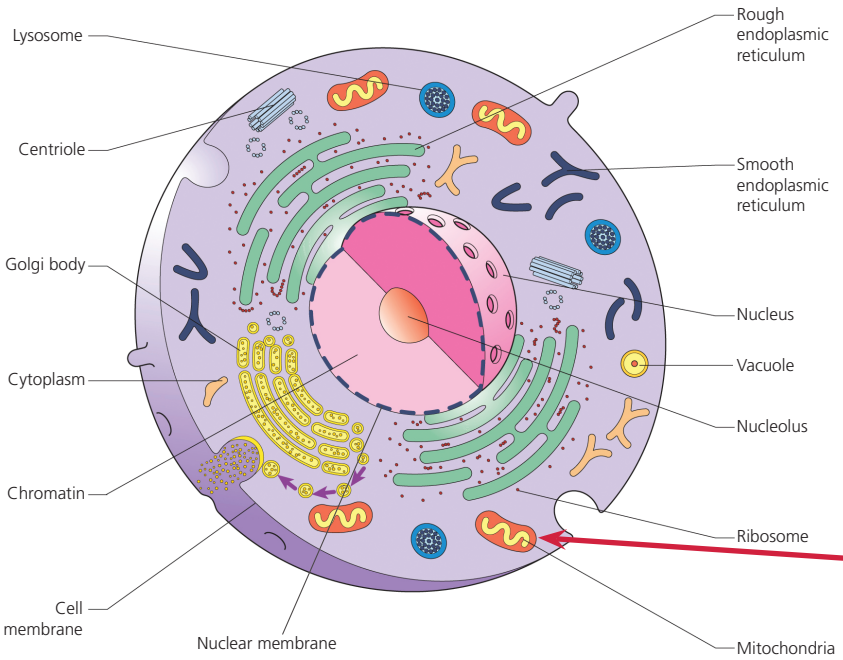
Lysosomes are round sacs present in the cytoplasm. They contain powerful enzymes capable of digesting proteins. Their function is to destroy any part of the cell that is worn out, so that it can be eliminated. This is known as lysis.

Vacuoles

Vacuoles are empty spaces within the cytoplasm. They contain waste materials or secretions formed by the cytoplasm, and are used for temporary storage, transportation or digestive purposes in different kinds of cells.

Golgi body/apparatus

The Golgi body or apparatus is a collection of flattened sacs within the cytoplasm. It is typically located near the nucleus and attached to the endoplasmic reticulum. It functions like the 'packaging department' of the cell, storing the protein manufactured in the endoplasmic reticulum and later transporting it out of the cell.



▲ Figure 2.4 The structure of a cell

Large, colourful and clearly labelled diagrams and tables build understanding and help make the more difficult aspects of the new content accessible for learners.

Table 2.2 Summary of the main cell organelles

Cell organelle	Description	Location	Function
Cell membrane	Fine membrane that encloses the cell	Outer part of cell	Selectively controls the movement of molecules into and out of the cell
Nucleus	Largest organelle in the cytoplasm, containing chromosomes and DNA	Inner part of cell	The control centre of the cell, regulating the cell's functions
Nuclear membrane	Double-layered membrane surrounding the cell nucleus	Inner part of cell	Regulates which materials enter or exit the nucleus
Cytoplasm	Gel-like substance that is enclosed by the cell membrane	Middle part of cell	Substance that fills the cell Most cellular metabolism occurs within the cytoplasm
Ribosome	Tiny organelle made up of ribonucleic acid (RNA) and protein	Middle part of cell	Manufactures proteins for use within the cell; produces other proteins that are exported out of the cell
Endoplasmic reticulum (ER)	Series of membranes continuous with the cell membrane	Middle part of cell	Intracellular transport system, allowing movement of materials from one part of the cell to another
Mitochondria	Oval-shaped organelles that lie within the cytoplasm	Middle part of cell	Provide the energy which powers the cell's activities
Golgi body/ apparatus	Collection of flattened sacs within the cytoplasm	Middle part of cell	Stores the protein manufactured in the ER and later transports it out of the cell
Lysosome	Round sac located in the cytoplasm	Middle part of cell	Destroys any part of the cell that is worn out

Exam Prep tips will provide useful tips to help learners become prepared for the exam at the end of their studies.

Classroom based and personal study **ACTIVITIES** help learners to reinforce their learning and cement their knowledge.

Activity

Draw a simple cell with the following cell organelles:

- Cell membrane
- Nucleus
- Nuclear membrane
- Ribosome
- Mitochondria
- Endoplasmic reticulum
- Golgi body/apparatus
- Lysosome.

Functions of cells

In order for a cell to survive, it must be able to carry out a variety of functions such as growth, respiration, reproduction, exertion, sensitivity/sensation, movement and nutrition.

Study tip

When learning the functions of cells, it may be helpful to remember the following acronym:
GREEDY **R**ACHAEL **R**EGULARLY **E**ATS **S**WEETS **M**ORNING **N**OON AND **E**VERY **N**IGHT.]

Growth

Cells have the ability to grow until they are mature and ready to reproduce. A cell can grow and repair itself by manufacturing protein.

Respiration

Every cell requires oxygen for the process of metabolism. Oxygen is absorbed through the cell's semi-permeable membrane and is used to oxidise nutrient material to provide heat and energy. The waste products produced as a result of cell respiration include carbon dioxide and water. These are passed out from the cell through its semi-permeable membrane.

Reproduction

When growth is complete in a cell, reproduction takes place. The cells of the human body reproduce or divide by the process of mitosis.

IN PRACTICE appears throughout this textbook as a helpful feature to put knowledge into practical context.

Excretion

During metabolism, various substances are produced that are of no further use to the cell. These waste products are removed through the cell's semi-permeable membrane.

Sensitivity (sensation)

A cell has the ability to respond to a stimulus (a cause/trigger of a reaction), which may be physical, chemical or thermal. For example, a muscle fibre contracts when stimulated by a nerve cell.

Movement

Movement may occur in the whole or part of a cell. White blood cells, for instance, are able to move freely.

Nutrition

The endoplasmic reticulum and Golgi apparatus/body manufacture different substances like protein and fats, either as needed by the cell or according to its specific function. The cell utilises basic nutrient molecules that are either dissolved in the cytoplasm or in specific substances contained within vesicles.

Some nutrients, specifically carbohydrates, are transported to the mitochondria, where they are broken down further to yield energy. In the process, high-energy molecules known as adenosine triphosphate (ATP) are manufactured and provide energy for other organelles.

In practice

Cell growth and reproduction rely on favourable conditions such as an adequate supply of food, oxygen and water, suitable temperatures and the ability to eliminate waste. Practitioners should warn clients that some factors create unfavourable conditions for the skin, e.g. smoking, sun damage and air pollution. These can impair cell function and skin cells may subsequently be destroyed, resulting in loss of elasticity, lines, wrinkles and dehydration.

In these cases, massage treatments can be beneficial. Massage procedures encourage cell nutrition as well as increasing elimination of waste from the cells and tissues, so clients should be advised to have treatments regularly to aid cell regeneration.

The cell's life cycle

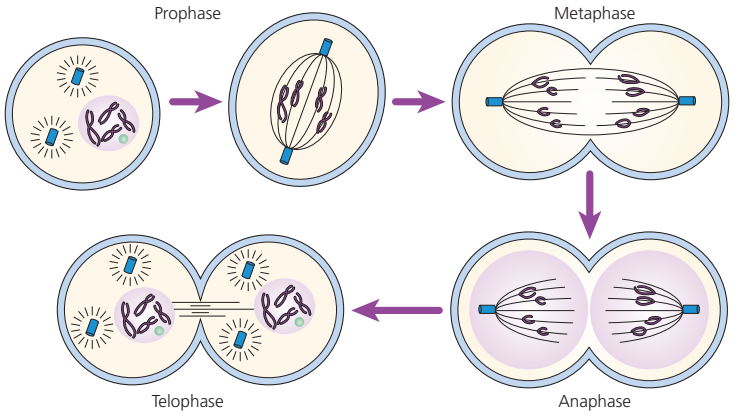
It is vital for living cells to reproduce themselves in order to continue life. Consequently, cells undergo many divisions from the time of fertilisation to physical maturity. When a single cell undergoes division, it forms two daughter cells that are identical to the original cell. A cell may live from a few days to many years, depending on its type.

Cells divide in two ways:

- **mitosis**: the dividing of one cell into two genetically identical daughter cells
- **meiosis**: the dividing of one cell into four genetically different daughter cells.

Mitosis

Mitosis is when a single cell produces two genetically identical daughter cells. It is the way in which new body cells are produced for both growth and repair. Division of the nucleus takes place in four main phases (prophase, metaphase, anaphase and telophase) and is followed by the division of the cytoplasm to form the daughter cells.



▲ Figure 2.5 The stages of mitosis

Study tip

It is helpful to remember the acronym PMAT (prophase, metaphase, anaphase and telophase) when learning the stages of mitosis.

- **P**rophase = condense (chromosomes condense)
- **M**etaphase = line up (chromosomes line up in the centre)
- **A**naphase = separate (chromosomes are separated)
- **T**elophase = decondense (chromosomes decondense)

Interphase (preparation for mitosis)

Before mitosis can divide the DNA and organelles into two equal daughter cells, the cell must prepare itself. Just before mitosis occurs, the cell is in a state known as interphase (between phases), when the cell makes a copy of all its DNA.

Once the cell has duplicated its DNA and organelles, it can proceed into mitosis.

Prophase

1 Centrioles duplicate as chromatids in the nucleus, and change to become individual chromosomes.

2 Centrioles separate and form spindles.

Metaphase

1 Chromosomes align themselves in the centre of the cell, midway between the centrioles, as the nucleus and its protective membrane disappear.

2 The centromere of each chromosome then replicates.

Anaphase

Centromeres divide and identical sets of chromosomes move to opposite poles of the cell.

Telophase

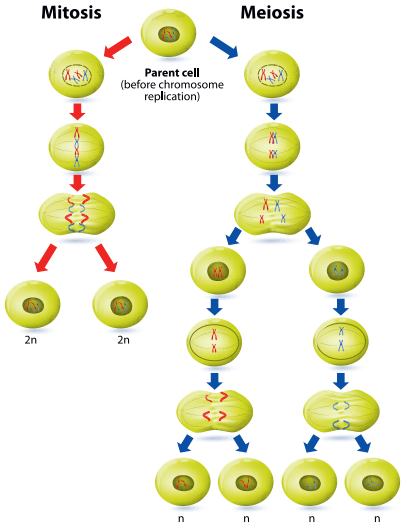
This is the final stage of mitosis.

1 A nuclear membrane forms around each nucleus and spindle fibres disappear.

2 The cytoplasm compresses and divides in half (cytokinesis).

Cytokinesis

Usually, after telophase, the cell will also divide its cytoplasm and pinch off into two separate but identical daughter cells. Each daughter cell is an exact copy of the parent cell before the DNA was duplicated during interphase.



▲ Figure 2.6 Mitosis and meiosis

Meiosis

Meiosis is a type of cell division that produces four daughter cells, each having half the number of chromosomes of the original cell. Meiosis involves the production of a new organism, formed by the fusion of a sperm from the male and an egg from the female.

Before fertilisation, there are only 23 chromosomes present in the sperm and the egg. After fertilisation has taken place, the egg and the sperm fuse together to form a single cell called a zygote, with 46 chromosomes (23 from each parent). The zygote is then able to reproduce itself by cell division or mitosis to form an embryo, a foetus and eventually a fully formed individual.

KEY FACT

There is virtually no limit to the ways the reproductive cell's 23 chromosomes can be combined during meiosis, meaning each sperm or egg contains hereditary information that is slightly different. Consequently, the genetic characteristics of brothers and sisters are never the same (except for identical twins, who share the same genetic code).

Cellular respiration

All cellular functions depend on energy generation and the transportation of substances within and among cells.

In order to function properly, a cell must maintain a stable internal environment; therefore, the transport of materials has to be achieved without an excessive build-up of chemicals. Cell respiration refers to the cell's controlled exchange of nutrients (such as oxygen and glucose) and waste (such as carbon dioxide) to activate the energy needed for the cell to function.

In order for cells to carry out their work, they need to produce enough energy or fuel. Fuel is provided by glucose from carbohydrate metabolism; in order for the glucose to be released or 'oxidised', oxygen is absorbed from the respiratory system into the bloodstream.

Cells are bathed in a fluid known as tissue fluid or interstitial fluid, which allows the interchange of substances between the cells and the blood, known as internal respiration.

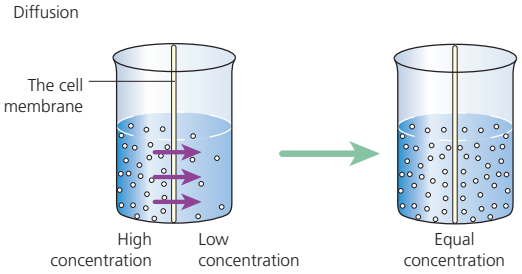
Cell transport

As explained, cells export some materials out of the cell body and also receive substances from the outside.

The body's internal transport system, the blood, carries oxygen from the respiratory system, and nutrients such as glucose from the digestive system, to the cells. These are absorbed through the cell membrane in several different ways: **diffusion**, **osmosis**, **active transport** and **filtration.** When certain molecules are needed, such as glucose, the cell will take these in and discard other materials in order to preserve the equilibrium.

Diffusion

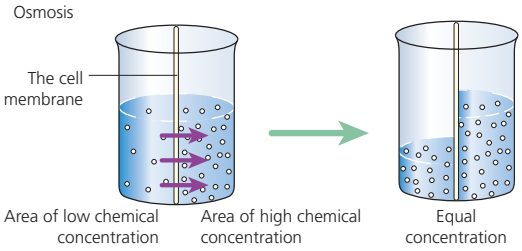
As chemicals become concentrated outside the cell, a flow of small molecules takes place through the cell membrane until a balance exists. This process, in which small molecules move from areas of high concentration to those of lower concentration, is called diffusion. Diffusion is the basis by which the cells lining the small intestines take in digestive products to be utilised by the body.



▲ Figure 2.7 Diffusion: the process by which small molecules move from an area of high concentration to one of lower concentration

Osmosis

Osmosis refers to the movement of water through the cell membrane from areas of low chemical concentration to areas of high chemical concentration. This process allows for the dilution of chemicals, which are unable to cross the cell membrane by diffusion, in order to maintain equilibrium within the cell.



▲ Figure 2.8 Osmosis: the movement of water through the cell membrane from areas of low to high chemical concentration

Active transport

Active transport is an energy-dependent process in which certain substances, including ions, some drugs and amino acids, are able to cross cell membranes against a concentration gradient (that is, from a low concentration to a higher concentration). This is the process, using chemical energy, by which the cell takes in larger molecules that would otherwise be unable to enter in sufficient quantities. Carrier molecules within the cell membrane bind themselves to the incoming molecules, rotate around them and release them into the cell. This is the means by which the cell absorbs glucose.

Filtration

Filtration is the movement of water and dissolved substances across the cell membrane due to differences in pressure. The force of the weight of the fluid pushes against the cell membrane, thereby moving it into the cell. One site of filtration in the body is in the kidneys. Blood pressure forces water and small molecules through plasma membranes of cells and the filtered liquid then enters the kidneys for filtration.

Pinocytosis and phagocytosis

Like us, cells need to drink and eat. There are two main processes that facilitate this for cells: pinocytosis and phagocytosis.

Study tip

Remember:

- Pinocytosis = cell drinking
- Phagocytosis = cell eating

Pinocytosis

The word pinocytosis comes from the Greek for 'cell drinking'. Pinocytosis is the method by which a cell absorbs (drinks) small particles outside the cell and brings them inside. During this process, the cell surrounds particles and then pinches off part of its membrane to enclose the particles within vesicles, which are small spheres of the membrane. This process is usually used for taking in **extracellular fluid**.

Pinocytosis is widely used among the cells of the body, but there are specific situations where it plays a major role. For instance, the microvilli in the small intestine use this process to absorb nutrients from food.

Phagocytosis

The word phagocytosis comes from the Greek word *phago*, meaning 'to eat'. It describes the process by which a cell engulfs (eats) particles such as bacteria, other micro-organisms, aged red blood cells, foreign matter, etc.

The principal phagocytes include the neutrophils and monocytes (types of white blood cells).

Pinocytosis and phagocytosis are similar processes, but they have some key differences:

- Phagocytosis is used to absorb materials much bigger than the particles that can be absorbed by pinocytosis, such as bacteria.
- Phagocytosis involves the ingestion of solid materials, while pinocytosis involves the ingestion of liquids and solute particles.
- During pinocytosis, the contents of the vesicles are emptied directly into the cell, but this doesn't happen in phagocytosis because the contents of the vesicles are too big.
- In phagocytosis, lysosomes must combine with the vesicles to break down the contents. This process does not occur in pinocytosis.

Interrelationships with other systems

Cells and tissues

At the end of every chapter, there is a **helpful list** of how different systems have interrelationships with one another.

Cells and tissues link to the following body systems.

Skin

Keratinised stratified epithelium (a type of tissue containing layers of cells) is found on dry surfaces such as the skin, hair and nails.

Skeletal

Bone is the hardest and most solid type of connective tissue in the body, which is needed for building the structures of the skeletal framework.

Muscular

There are three types of muscle tissue:

- skeletal muscle, which controls voluntary movements
- smooth muscle, which controls involuntary movements
- cardiac muscle, which controls the heart.

Circulatory

Blood is a form of liquid connective tissue whose role is in transporting substances to and from the cells.

Respiratory

A type of tissue called ciliated columnar epithelium lines the respiratory tract, which carries unwanted particles out of the system

Nervous

Neurones and neuroglia are the specialised cells that form nervous tissue, which enables the body to receive and transmit nerve impulses in order to regulate and co-ordinate body activities.

Endocrine

The endocrine glands are made from epithelial tissue. They secrete hormones directly into the bloodstream to influence the activity of another organ or gland.

Digestive

The digestive system is lined with epithelial tissue with goblet cells that secrete mucus to aid the flow of the digestive processes.

Urinary

The bladder is lined with transitional epithelium, which allows the bladder to expand when full and deflate when empty.

KEY WORDS are explained to enhance learners' vocabulary, with full definitions provided at the end of each chapter.

Key words

Cells

Active transport: the process by which dissolved molecules move across a cell membrane from a lower to a higher concentration.

Atom: the smallest particle of an element.

Cell: the basic unit of all living organisms.

Cell membrane: a fine membrane that encloses the cell and protects its contents.

Cell respiration: the chemical process that generates most of the energy in the cell.

Centrioles: small spherical structures that are associated with cell division.

Centromere: the portion of a chromosome where the two chromatids are joined

Centrosome: an area of clear cytoplasm that is found next to the nucleus, and contains the centrioles.

Chromatids: a pair of identical strands that are joined at the centromere and separate during cell division.

Chromatin: the substance inside the nucleus that contains the genetic material.

Chromosome: the threadlike structure in the cell nucleus that carries the genetic information in the form of genes.

Cytokinesis: the cytoplasmic division of a cell at the end of mitosis or meiosis, bringing about the separation into two daughter cells.

Cytoplasm: a gel-like substance that is enclosed by the cell membrane.

Diffusion: the process in which small molecules move from areas of high concentration to those of lower concentration.

Endoplasmic reticulum: a series of membranes continuous with the cell membrane; allows movement of materials from one part of the cell to another.

Filtration: the movement of water and dissolved substances across the cell membrane due to differences in pressure.

Golgi body apparatus: a collection of flattened sacs within the cytoplasm.

Homeostasis: the process by which the body maintains a stable internal environment for its cells and tissues.

Lysosome: round sacs present in the cytoplasm. They contain powerful enzymes, which are capable of digesting proteins.

Meiosis: the dividing of one cell into four genetically different daughter cells.

Metabolism: a physiological process in the body that converts energy from food into fuel.

Mitochondria: oval-shaped organelles in the cell's cytoplasm; sites of energy production.

Mitosis: the dividing of one cell into two genetically identical daughter cells.

Molecule: a particle composed of two or more atoms joined together.

Nuclear membrane: a double-layered membrane surrounding the nucleus that regulates what materials enter or exit the nucleus.

Nuclear pore: a minute passageway through the nuclear membrane, which acts like a security control system guarding the contents and work of the cell and its nucleus.

Nucleolus: dense spherical structure inside the nucleus; contains ribonucleic acid (RNA).

Nucleus: control centre of the cell; regulates the cell's functions.

Organ: specialised structure made up of different types of tissue.

Osmosis: the movement of water through the cell membrane from areas of low chemical concentration to areas of high chemical concentration.

pH scale: a chemical table or rating scale used to measure the acid or alkaline (base) content of a substance.

Phagocytosis: process by which a cell engulfs particles such as bacteria.

Pinocytosis: the method by which a cell absorbs small particles outside the cell and brings them inside.

Ribosome: tiny organelles that may be attached to the endoplasmic reticulum or may be within the cytoplasm. They help to manufacture protein for use within the cell.

System: a group of organs that work together to perform specific functions.

Expanded end of chapter sections include a **REVISION SUMMARY** which provides concise summaries of key unit content.

Revision summary

Cells

- The human body involves five levels of structural organisation: atoms and molecules, cells, tissues, organs and systems.
- **Atoms and molecules** are the lowest level of organisational complexity in the body.
- **Cells** are the smallest units that show characteristics of life.
- **Tissues** are a group of similar cells that perform a certain function.
- **Organs** are tissues grouped into structurally and functionally integrated units.
- **Systems** are a group of organs that work together to perform specific functions.
- **Homeostasis** is the process by which the body maintains a stable internal environment for its cells and tissues.
- Homeostatic mechanisms in the body include the regulation of body temperature, blood pressure, blood sugar levels and pH levels.
- **Metabolism** is the term used to describe the physiological processes that take place in our bodies to convert the food we eat and the air we breathe into the energy we need to function.
- The minimum energy required to keep the body alive is known as the **basal metabolic rate**.
- The body is made up of major elements and compounds of elements (for example, water, a compound of hydrogen and oxygen).
- Chemically, a cell is composed of the major elements carbon, oxygen, hydrogen and nitrogen.
- Cells are made up of approximately 80% water, 15% protein, 3% lipids or fats, 1% carbohydrates and 1% nucleic acids.
- A **cell** is the basic, living, structural and functional unit of the body.
- The principal parts of the cell are the **cell membrane** and its **organelles**, which play specific roles in cellular growth, maintenance, repair and control.
- The **cell membrane** encloses the cell and protects its contents. It is semi-permeable and governs the exchange of nutrients and waste materials.
- The **nucleus** controls the cell's activities and contains the genetic information.
- The **cytoplasm** is the substance inside the cell between the plasma membrane and the nucleus.
- The **ribosomes** are sites of protein synthesis.
- The **endoplasmic reticulum** links the cell membrane with the nuclear membrane and assists movement of materials out of the cell.
- The **Golgi body** processes, sorts and delivers proteins and lipids (fats) to the plasma membrane, lysosomes and secretory vesicles.
- The **lysosome** is a round sac in the cytoplasm that contains powerful enzymes to help destroy waste and worn out cell materials.
- The **mitochondria** are the 'powerhouses' of the cell.
- The **centrosome** is a dense area of cytoplasm, containing the centrioles.
- The **centrioles** are paired small spherical structures associated with cell division or mitosis.
- The **chromatids** are a pair of identical strands that are joined at the centromere and separate during cell division.
- The **centromere** is the portion of a chromosome where the two chromatids are joined.
- Functions of cells include **respiration, growth, excretion, movement, irritability and reproduction.**
- Cell division is the process by which cells reproduce themselves.
- **Mitosis** is cell division that results in an increase in body cells and involves division of a nucleus.
- **Meiosis** is reproductive cell division and results in the fusion of an egg and a sperm into a zygote.
- Cells function through the exchange of fluids, nutrients, chemical and ions, carried out by passive processes such as **diffusion**, **osmosis** and **filtration**, and active processes such as **active transport**.
- **Cell respiration** is the controlled exchange of nutrients such as oxygen and glucose, and waste such as carbon dioxide, by the cell to activate the energy needed for the cell to function.

- The fuel required by cells is provided by **glucose** from carbohydrate metabolism and **oxygen** absorbed from the respiratory system into the bloodstream.
- Cells are bathed in a fluid known as **tissue fluid** or interstitial fluid, which allows the interchange of substances between the cells and the blood, known as internal respiration.

Tissues

- A **tissue** is a group of similar cells that are specialised for a particular function.
- The tissues of the body are classified into four main types: **epithelial, connective, muscular** and **nervous**.
- **Epithelial tissue** provides coverings and linings for many organs and vessels.
- There are two categories of epithelial tissue: **simple** (single layer) and **compound** (multi-layer).
- There are four different types of simple epithelium: **squamous, cuboidal, columnar** and **ciliated**.
- There are two different types of compound epithelium: **stratified** and **transitional**.
- **Connective tissue** is the most abundant type of body tissue. It connects tissues and organs to give protection and support.
- Connective tissue consists of the following different types: **areolar, adipose, white fibrous, yellow elastic, lymphoid, blood, bone** and **cartilage**.
- **Muscle tissue** is elastic and is therefore modified for contraction. It is found attached to bones (skeletal muscle), in the wall of the heart (cardiac muscle), and in the walls of the stomach, intestines, bladder, uterus and blood vessels.
- **Nervous tissue** is composed of nerve cells called neurones, which pick up and transmit nerve signals.
- **Membranes** are thin, soft, sheet-like layers of tissue.
- **Mucous membrane** lines cavities that open to the exterior, such as the digestive tract.
- **Serous membranes** line body cavities that are not open to the external environment (the lungs and the heart).
- **Synovial membrane** lines joint cavities of freely moveable joints such as the shoulder, hip and knee.

Test your knowledge

Multiple-choice questions

1 The process by which the body maintains a stable internal environment of its cells and tissues is:
   a physiology
   b metabolism
   c homeostasis
   d anatomy

2 Cells consist of the primary elements:
   a carbon, oxygen, hydrogen and nitrogen
   b carbon, oxygen, iron and sodium
   c carbon, oxygen, iron and nitrogen
   d carbon, oxygen, hydrogen and iron

3 The process by which new body cells are produced for both growth and repair is called:
   a meiosis
   b metaphase
   c mitosis
   d none of the above

4 During which phase of mitosis are chromosomes formed?
   a prophase
   b anaphase
   c telophase
   d metaphase

5 The organelle that powers the cell's activities is:
   a the nucleus
   b the lysosome
   c the mitochondria
   d the endoplasmic recticulum

6 The process in which small molecules move from areas of high concentration to those of lower concentration is:
   a osmosis
   b diffusion
   c filtration
   d active transport

7 Which of the following is a type of connective tissue?
   a nervous
   b lymphoid
   c serous
   d muscular

8 Where would you find squamous epithelium?
   a in the lungs
   b in the brain
   c in the kidneys
   d in the ovaries

9 Which is the most widely distributed type of connective tissue in the body?
   a areolar tissue
   b adipose tissue
   c epithelial tissue
   d white fibrous tissue

10 What is the excess tissue that develops when cells in an area of the body divide without control?
   a lymphoma
   b sarcoma
   c metastasis
   d tumour

Exam-style questions

1 List the five levels of organisation of the body. (5 marks)

2 List three functions of cells. (3 marks)

3 State three functions of the cell membrane. (2 marks)

4 Which part of the cell contains the genetic materials for replication? (1 mark)

5 List the four major types of tissues in the human body. (4 marks)

6 List the four different types of simple epithelium. (4 marks)

End of unit TEST YOUR KNOWLEDGE questions will help to recap and reinforce learning. It will also help with preparation for the exam and the **multiple-choice questions** section will help prepare for VRQ assessment.
Exam-style questions will vary in difficulty from more simple, short answer questions to those requiring extra depth in response to reflect pass, merit and distinction grades/attainment.

Anatomy & Physiology

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