CHAPTER 1

The cell and body tissue

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AIM

The aim of this chapter is to introduce the reader to the cells and tissues of the developing human body, with a focus on childhood growth and development.

LEARNING OUTCOMES

On completion of this chapter, the reader will be able to:

- Outline the structure and function of a human cell, with reference to the developing child.
- Name and describe the functions of the main organelles within cells.
- Explain the cellular transport system and how it supports tissue growth in children.
- Describe the structure and function of the major tissue types in the body – epithelial, connective, muscle and nervous – with examples relevant to childhood.

KEYWORDS

- cytoplasm
- plasma membrane
- organelles
- nucleus
- passive transport
- active transport
- epithelial tissue
- muscle tissue
- connective tissue
- mitochondria
- mitosis
- growth plate
- myelination

Test your prior knowledge

1. What are the characteristics of human cells?
2. Describe the ways in which substances can pass through the cell membrane.
3. What is the role of the cell nucleus?
4. What are the four main roles of connective tissue?
5. How many different types of muscle tissue are there, and what are their various roles?
6. Where is epithelial tissue to be found within the body?

Cells

Introduction

Cells are the basic structural and functional units of life, forming and developing the human body. In children, they are especially active, supporting rapid growth, tissue formation and physiological change from infancy through adolescence. Many cell types exist, each with distinct roles: some create protective tissues like skin, others provide structural support such as bone, and specialised cells form organs including the heart, brain and muscles, enabling key functions such as circulation, immunity and movement.

All body cells originate from two parent cells: the ovum and the sperm. At conception, they fuse to form a single cell containing the full genetic code for human development. This cell then divides and specialises to create the diverse tissues and systems of the growing child. This genetically regulated process of growth and differentiation is particularly active in early life.

This chapter outlines cell structure and function in the context of child development, explaining how cells form tissues and what can happen when normal cellular function is disrupted. The chapter begins by outlining the common features shared by all human cells (Fig. 1.1).

Characteristics of cells

- Cells are active – carrying out specific functions.
- Cells need nutrients to survive and function. Through endocytosis, they surround and absorb substances such as bacteria to obtain the nutrients required for energy, growth and repair. In children, stem cells are especially active; these undifferentiated cells divide and develop into specialised types, supporting tissue formation, immune development and organ growth throughout infancy and adolescence.
- Cells reproduce asexually by doubling their organelles and then dividing so each new cell has the

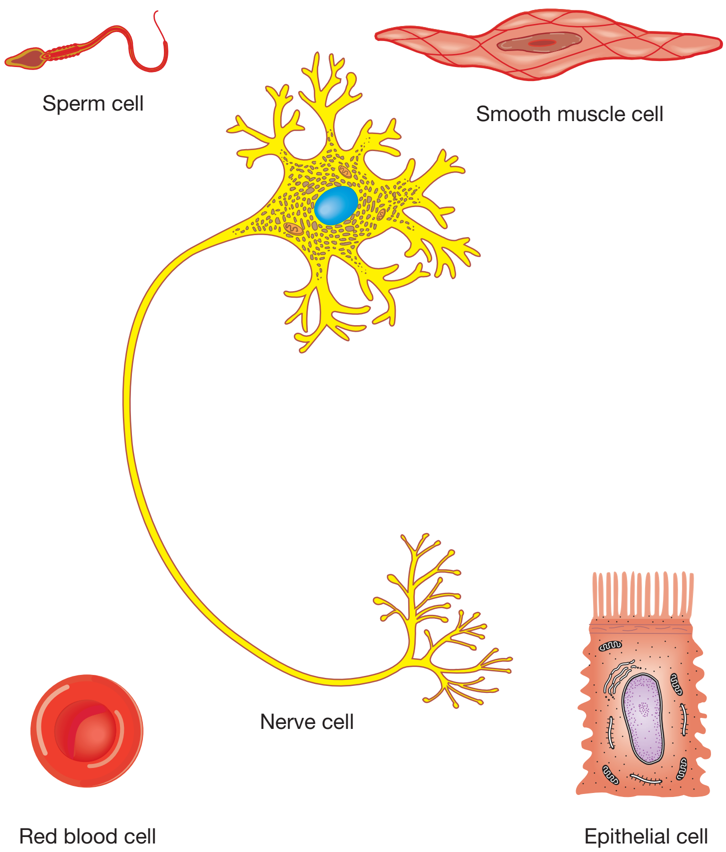

FIGURE 1.1 Examples of different types of cells in the body.
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same structures, a process known as simple fission. In children, this occurs more frequently to support growth, tissue repair and the development of new structures such as bone and muscle.

- Cells excrete waste products.
- Cells react to things that irritate or stimulate them – for example, in response to threats from chemicals and viruses.

The structure of the cell

There are four main compartments of the cell:

- cell membrane
- cytoplasm
- nucleus
- nucleoplasm.

Within these compartments are many organelles (or small organs). These organelles perform numerous roles to keep cells alive and functioning.

The cell membrane

As can be seen in Fig. 1.2, the various structures of the cell are contained within a cell membrane (also known as the plasma membrane). This cell membrane is a semi-permeable biological membrane separating the interior of the cell from the outside environment and protecting the cell from its surrounding environment. It is semi-permeable because it allows only certain substances to pass through it for the benefit of the cell itself. For example, it is selectively permeable to certain ions and molecules (Alberts *et al.*, 2022). Inside the cells are the cytoplasm and the organelles, which include, for example, the lysosomes, mitochondria and the nucleus of the cell.

The cell membrane varies in thickness from approximately 7.5 to 10 nm (Peate, 2021) and is composed of a self-sealing phospholipid bilayer with interspersed protein molecules (Fig. 1.3). Each phospholipid consists of a hydrophilic (water-attracting) polar head and hydrophobic (water-repelling) non-polar fatty acid tails. In the bilayer, the hydrophilic heads face both the extracellular and intracellular environments, while the hydrophobic tails orient towards the centre of the membrane. This arrangement creates a barrier that prevents the passive movement of water-soluble substances (Marieb, 2021).

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The cell membrane contains phospholipids, proteins and lipids that support transport, signalling and structural integrity. Plasma membrane proteins (PMPs) are either integral or peripheral. Integral PMPs are embedded in the lipid bilayer, some forming channels for selective transport,

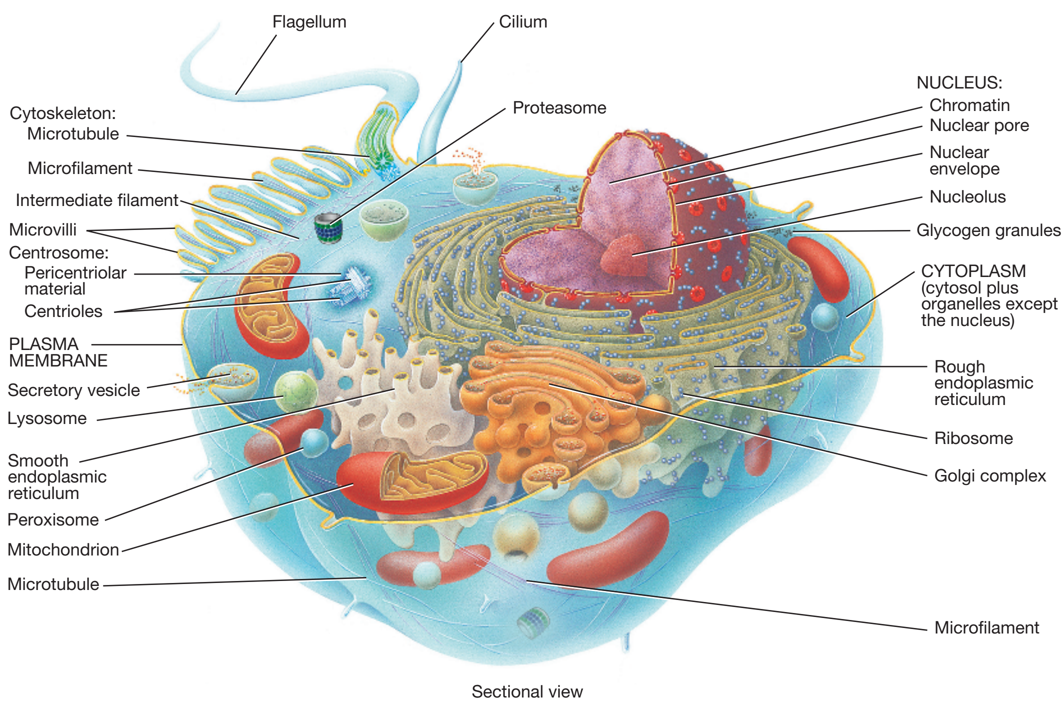

FIGURE 1.2 Structure of the cell.
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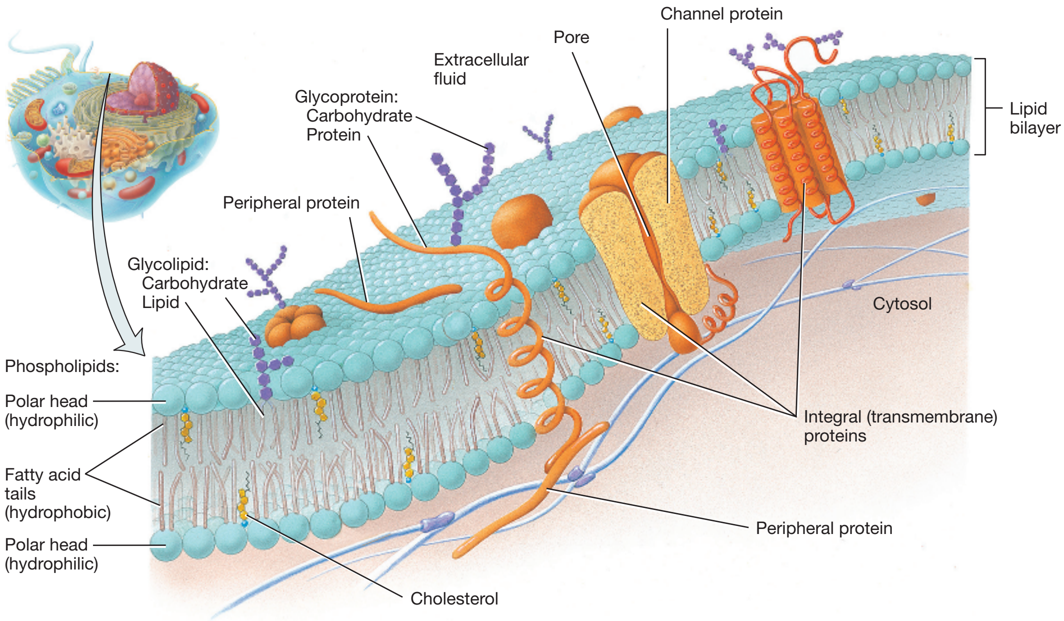

FIGURE 1.3 Cell membrane.
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others acting as receptors for molecules like insulin, neurotransmitters or bacterial components. Peripheral PMPs are loosely attached to the membrane surface and aid in cell signalling and enzymatic reactions.

Functions of the cell membrane

The cell membrane has several important physiological functions, particularly in regulating transport into and out of the cell. Two of the most significant are endocytosis and exocytosis.

Endocytosis refers to the process by which fluids and particles are taken into the cell. There are three main types:

- Phagocytosis – the ingestion of large particles, such as microbes
- Pinocytosis – the ingestion of smaller particles and extracellular fluid
- Receptor-mediated endocytosis – the highly selective uptake of specific substances, such as proteins, via membrane receptors.

During endocytosis, the cell membrane folds inward to enclose material, forming a vesicle that pinches off inside the cell. The vesicle may fuse with a lysosome to break down its contents. This process is vital for human cells and is also used by simple organisms like amoebae to obtain nutrients.

Exocytosis is the reverse process. It involves the removal of waste products or the export of substances, such as hormones or enzymes, by fusing intracellular vesicles with the cell membrane and releasing their contents outside the cell.

The cell membrane and transport

The cell membrane's selective permeability controls what enters and exits the cell. Its hydrophobic phospholipid bilayer blocks water-soluble substances, which instead pass through specialised channels or carrier proteins.

The membrane performs several transport-related roles:

- Regulates metabolism by controlling the flow of glucose and other molecules
- Maintains ion gradients, which store energy and support cell function
- Controls the rate of ion movement, ensuring precise regulation of intracellular conditions.

The controlled movement of ions and molecules supports key physiological functions:

- Nutrient uptake from the surrounding extracellular fluid
- Electrical signalling in nerve and muscle cells (nerve excitability)
- Regulation of cell volume by managing osmotic balance.

Together, these mechanisms ensure the cell can respond appropriately to its environment, maintain internal stability and carry out its specialised roles.

Cell membrane permeability
There are four factors involved in the degree of permeability of a cell membrane, namely:

1. The size of molecules – large molecules cannot pass through the integral membrane proteins, whilst small molecules (e.g., water and amino acids) can.
2. Solubility in lipids (fats) – substances that easily dissolve in lipids (e.g., oxygen, carbon dioxide and steroid hormones) can pass through the membrane more easily than non-lipid-soluble substances can.
3. If an ion has an electrical charge that is the opposite of that found in the membrane, then it is attracted to the membrane and so can more easily pass through it.
4. Carrier integral proteins can bind to substances and carry them across the membrane, regardless of the aforementioned three processes, i.e., size, ability to dissolve in lipids or membrane electrical charge.

Movement of substances across the membrane
There are two ways for this to occur, namely, passive and active.

Passive processes

A passive process is one in which the substances move under their own volition down a concentration gradient from an area of high concentration to an area of lower concentration. In this process, the cell expends little energy on the process (like rolling down a hill).

There are four types of passive transport processes, namely:

- diffusion
- facilitated diffusion
- osmosis
- filtration.

Diffusion is the most common form of passive transport. A substance in an area of higher concentration moves to an area of lower concentration (Colbert *et al.*, 2019). The difference seen between areas of different concentrations is known as the concentration gradient. This passive transport process is essential for respiration. It is through diffusion that oxygen is transported from the lungs to the blood and carbon dioxide from the blood into the lungs.

Although similar to diffusion, facilitated diffusion differs from it by the use of a substance (a facilitator) to help in the process (see Fig. 1.4). As an example, glucose is moved using this process. To be able to pass through a membrane, glucose needs to attach itself to a carrier/transport protein (McCance & Huether, 2022).

Osmosis is the process by which water travels through a selectively permeable membrane so that concentrations of a solute (a substance that is soluble in water) are equal on both sides of the membrane. This gives rise to osmotic pressure. The higher the concentration of the solute on one side of the membrane, the higher the osmotic pressure available for the movement of water (Colbert *et al.*, 2019).

If osmotic pressure rises too much, then it can cause damage to the cell membrane. So, the body attempts to ensure that there is always a reasonably constant pressure between the cell's internal and external environments.

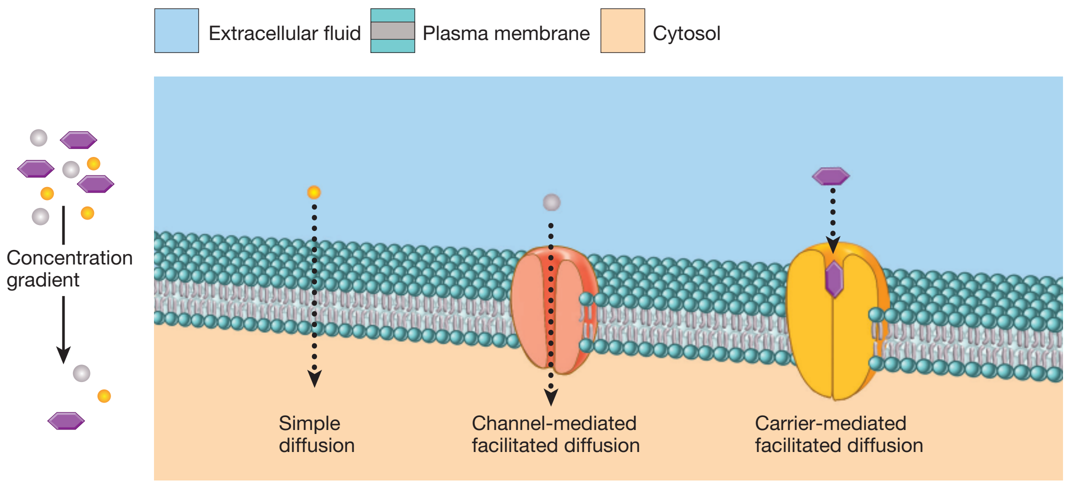

FIGURE 1.4 Facilitated diffusion.
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We can see the possible damage if, for example, a red blood cell is placed in a low-concentration solute; then it will undergo haemolysis. On the other hand, if it is placed in a highly concentrated solute, the result will be a crenulated cell. If the red blood cell is placed in a solution with a relatively constant osmotic pressure, it will not be affected because the net movement of water in and out of the red blood cell is minimal.

Filtration is similar to osmosis, with the exception that physical pressure is used in order to push water and solutes across a cell membrane. This is seen in renal filtration, where the heart beating exerts pressure as it pushes blood into the kidneys, where filtration of the blood can then take place to remove any impurities (Colbert *et al.*, 2019).

Active processes

Active processes are:

- active transport pumps
- endocytosis
- exocytosis.

An active process is one in which substances move against a concentration gradient from an area of lower to higher concentration. In order for this to happen, the cell must expend energy, which is released by the splitting of adenosine triphosphate (ATP) into adenosine diphosphate (ADP) and phosphate.

ATP is a compound of a base, a sugar and three phosphate groups (triphosphate) and is held together by phosphate bonds, which release a high level of energy when they are broken. Once one of the phosphate bonds is broken and phosphate has been released, that compound then becomes ADP. The 'spare' phosphate will then join another ADP group, so forming ATP (with energy stored in the phosphate bond). This process is continually recurring within the body.

Active transport pumps need energy to be able to function. This energy occurs as a result of the reaction mentioned earlier. It is necessary when the body is attempting to move an area that already has a high concentration of that substance. The higher the concentration already present, the more energy is required to move further molecules of that substance into that area. Fig. 1.5 demonstrates the effect of solute concentration on a red blood cell.

The organelles

These are rather like small 'organs' within the cells. The following sections give a brief overview of the many cell organelles and their functions.

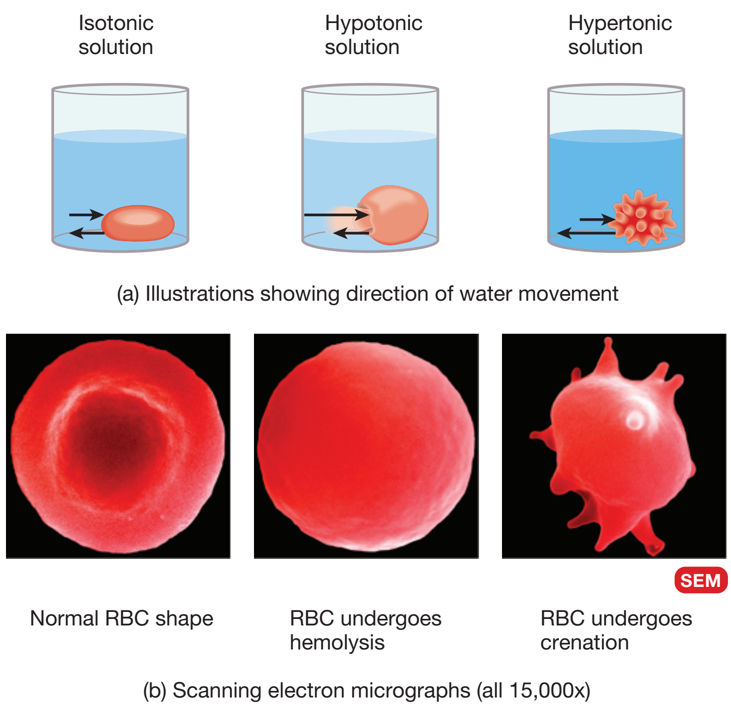

FIGURE 1.5 Effect of solute concentration on a red blood cell.
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Cytoplasm

Although not strictly an organelle, the cytoplasm is a vital part of the cell, forming the matrix in which cellular components are suspended. Part of the protoplasm, it is a thick, semi-transparent, elastic fluid containing the cytoskeleton, which provides structure and aids movement within the cell. Chemically, it consists of 75–90% water plus carbohydrates, lipids and inorganic compounds.

The role of the cytoplasm

- Cytoplasm is the substance within the cell in which chemical reactions occur.
- It receives raw materials from the external environment (e.g., from digested food) and converts them/breaks them down into usable energy by means of decomposition reactions.
- It is the site where new substances are synthesised (produced), which can then be used by the cell for its various functions.
- It is the place where various essential chemicals are packaged either for use by itself or to be transported out for other cells of the body to use.
- The cytoplasm is also the place where various chemicals help with the excretion of waste materials.

The nucleus (see Fig. 1.2)

The nucleus is the control centre of eukaryotic cells, found in animals and plants. Prokaryotic cells, such as bacteria, are simpler and often smaller. Not all human cells have a nucleus; for example, mature red blood cells lack a nucleus and are concave in shape.

There are also some human cells (some muscle fibre cells) that have more than one nucleus (see Fig. 1.1).

Some facts about the nucleus

- The nucleus is the largest structure in a human cell.
- It is surrounded by a nuclear membrane (just as the cell is surrounded by a cell membrane).
- It has its own protoplasm, although rather than 'cytoplasm', it is called 'nucleoplasm'.
- The nucleus is responsible for the reproduction of the cell and for making us what we are (see later) – it is where the processes of meiosis and mitosis take place.
- Within the nucleus is found all our genetic material, including DNA, leading to chromosomes.
- In humans, there are normally 23 pairs of chromosomes in each cell that contains a chromosome, apart from sperms and ova, which only have 23 single chromosomes.

Cell reproduction

For the body to grow and replace damaged or dying cells, cells must reproduce accurately to preserve their genetic information. Human cells with a nucleus contain 23 pairs of chromosomes. Cells reproduce via mitosis, which occurs in most cells or meiosis, which is limited to reproductive cells (sperm and ova).

Cells reproduced by mitosis are exact copies of the parent cell, with the full 23 pairs of chromosomes, whereas cells from meiosis contain only one of each chromosome. In childhood, mitosis is vital for rapidly expanding cell populations, supporting organ and tissue development and helping the body meet increasing functional demands.

In mitosis, chromosomes replicate before the cell divides, ensuring each new cell receives a full set of chromosomes. In meiosis, although the process starts similarly, additional steps result in cells with only one copy of each chromosome, which is essential for human reproduction.

In human reproduction, a sperm penetrates an egg, combining its DNA with the egg's genetic material. Sperm and egg cells carry only one copy of each chromosome due to meiosis, which halves the chromosome number. Without meiosis, fertilisation would produce cells with four copies of each chromosome, causing a genetic imbalance. Meiosis ensures the embryo has the correct two copies, maintaining genetic stability.

In children, hormones such as growth hormone, thyroid hormones and sex hormones regulate the rate and timing of cell reproduction, especially during key developmental stages and puberty.

Other organelles

All cells contain many organelles, and these are discussed in the following sections.

Endoplasmic reticulum

The endoplasmic reticulum (ER) consists of membranes that form a series of channels known as cisternae (see Fig. 1.6).

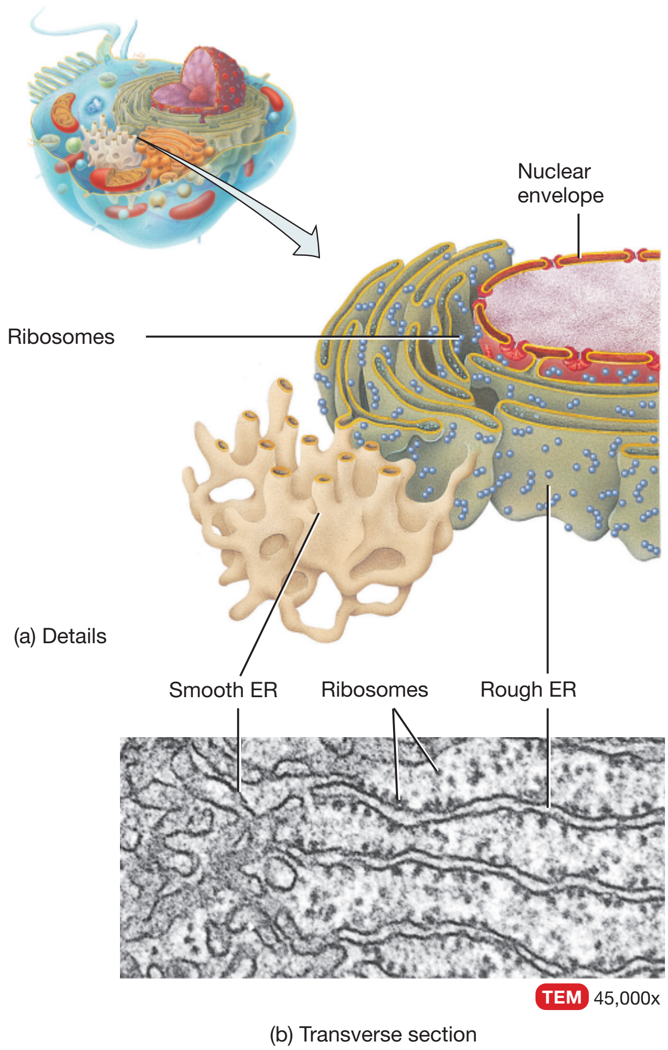

FIGURE 1.6 Endoplasmic reticulum.
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These divide the cytoplasm into compartments. There are two types of cisternae:

1. granular ER (rough), which is associated with ribosomes
2. agranular ER (smooth), which is free of ribosomes.

Ribosomes include tiny particles of RNA – these are formed in the cell nuclei and are associated with the synthesis of proteins needed by the cell.

- The membranes of the ER contain many enzymes that speed up chemical reactions within the cells.
- ER consists of a series of channels (cisternae), which are concerned with the transport of materials – particularly proteins.
- ER contains a number of enzymes that are important for cell metabolism – such as digestive enzymes, enzymes that are involved in the synthesis (production) of steroids and enzymes that lead to the removal of toxic substances from the cell (McCance & Huether, 2022).
- The alteration/addition of proteins exported from the cell also occurs in the cisternae.
- ER is also present in liver cells, where it has a role to play in drug detoxification.
- Granular ER is particularly found in cells that actively synthesise and export proteins.
- Agranular ER is found in steroid hormone-secreting cells, such as the cells of the adrenal cortex or, in males, the testes.

Golgi complex (Fig. 1.2)

The Golgi complex (also known as the Golgi apparatus) is a collection of membranous tubes and elongated sacs. These are actually flattened cisternae that are stacked together. The Golgi complex has two major roles:

1. Helping to concentrate and package some of the substances that are made in the cell itself, for example, lysosomal enzymes.
2. Helping with the assembly of substances for secretion outside of the cell. Secretory cells (such as those found in the mucous membrane) have many Golgi stacks, whilst non-secretory cells have few Golgi stacks per cell.

Proteins destined for export are first synthesised on ribosomes, then pass through the ER to Golgi vesicles. These vesicles fuse with the cell membrane via exocytosis, releasing their contents outside the cell. The Golgi complex also helps form glycoproteins.

Lysosomes (Fig. 1.2)

Lysosomes are organelles that are bound to the cell membrane, and they contain a variety of enzymes. They have a number of functions:

- They are responsible for the digestion of material (e.g., pathogenic organisms) taken up by the process of endocytosis.
- They are capable of breaking down components within a cell when they are not needed. For example, during human embryonic development, the fingers and toes of the embryo are connected by tissue and appear webbed, and the lysosomal enzymes facilitate the removal of these cells making up the webbing from between the digits separated.
- After the baby's birth, the uterus (which can weigh around 2 kg at full term) is invaded by phagocytic cells that are rich in lysosomes. These then reduce the uterus to its non-pregnant weight of approximately 50 g within about 9 days.
- In normal cells, some of the synthesised proteins may be faulty, and so, consequently, it is the lysosomes that are responsible for their removal and destruction.

It is vital that lysosomes do not rupture within living cells, as their enzymes could digest and destroy the cell, contributing to degenerative diseases such as rheumatoid arthritis. Lysosomal rupture in macrophages may drive the destruction of essential cells and tissues. Lysosomes also aid hormone production, including thyroxine, which regulates physiological activities such as metabolism.

Peroxisomes (Fig. 1.2)

Peroxisomes are small, lysosome-like organelles, abundant in liver cells, containing enzymes that can be toxic to the body. Their main role is detoxifying harmful substances, such as alcohol and formaldehyde, and neutralising dangerous free radicals – highly reactive chemicals that can damage molecules. Peroxisomes are organelles that are similar in structure to lysosomes. However, they are much smaller. These organelles are particularly abundant in the cells of the liver, and they contain several enzymes that are toxic to cells of the body.

The role of peroxisomes in cells appears to be one of detoxification of harmful substances – such as alcohol and formaldehyde – within the cell. Importantly, they also neutralise dangerous free radicals. Free radicals are highly reactive chemicals that contain electrons that have not been 'paired off' and so are 'free' to disrupt the structure of molecules (Marieb, 2021).

Mitochondria (Fig. 1.2)

Mitochondria, the cell's 'powerhouses', produce most of the cell's ATP energy and are concentrated in areas of high metabolic activity. Anatomically, mitochondria consist of two membranes (an inner and an outer) and an intermembrane space.

The inner membrane has many folds (cristae) that increase the surface area available for chemical reactions to occur, such as the production of ATP (a coenzyme used as an energy carrier in the cells of all known organisms, which is responsible for the process by which energy is moved throughout the cell). This process is collectively known as internal respiration. The inner membrane is of the same thickness as the outer membrane and is responsible for oxidative phosphorylation.

The mitochondrial matrix is the name given to the space that is surrounded by the inner membrane. It contains enzymes of the tricarboxylic acid (TCA) cycle, as well as those enzymes involved in fatty acid oxidation. In children, mitochondria are especially important due to their role in meeting the high energy demands of growth, repair, learning and physical activity. Their increased metabolic rate relies on efficient mitochondrial energy production. About two-thirds of the total protein is found in mitochondria, and, with the inner membrane, they play an important role in the production of ATP and contain a very concentrated mixture of hundreds of enzymes.

The intermembrane space: Because the outer membrane is freely permeable to small molecules, there is a high concentration of small molecules, such as ions and sugars. However, larger molecules cannot enter this space unless they possess a specific signalling code that allows them to be able to pass through the outer membrane.

The outer mitochondrial membrane encloses the entire organelle. It contains large numbers of integral membrane proteins, known as porins, which form channels in the membrane to allow small molecules to diffuse easily from outside the mitochondria to the intermembrane space, and vice versa. Any disruption of the outer membrane allows proteins in the intermembrane space to leak into the intercellular fluid in the cell (cytosol), leading to certain cell death.

Mitochondria generate the cell's energy by converting the chemical energy in food into ATP. This process occurs in multiple enzyme-driven stages, with enzymes arranged in the mitochondrial membranes to ensure reactions happen in the correct sequence, preventing potentially harmful errors.

Mitochondria are self-replicating, in that, although most of a cell's DNA is contained in the cell nucleus, the mitochondrion has its own independent genetic organisation that is really quite similar to that of bacteria. DNA that is incorporated into the mitochondrial structure controls its own replication system.

The cytoskeleton

The cytoskeleton is a lattice-like collection of fibres and fine tubes, and these are found in the cytoplasm of the cell. It is involved with the cell's ability to maintain and alter its shape as required (see Fig. 1.7).

There are three components that make up the cytoskeleton:

- microfilaments
- microtubules
- intermediate filaments.

Microfilaments

Microfilaments are rod-like structures that are approximately 6 nanometres (6 nm) in diameter and are made of a protein called actin. In muscles, both actin (which is thick) and another protein – myosin (which is thin) – combine together to allow the contraction of muscle fibres. In non-muscle cells, microfilaments help to provide support and shape to the cell. Microfilaments also assist in the movement of the cells themselves, as well as movement within the cells.

Microtubules

Microtubules are relatively straight, slender, cylindrical tubules that range in diameter from 18 to 30 nm. They consist of another protein – tubulin.

- Microtubules and microfilaments help provide shape and support for cells.
- They provide conducting channels – like tunnels – through which various substances can move through the cytoplasm.

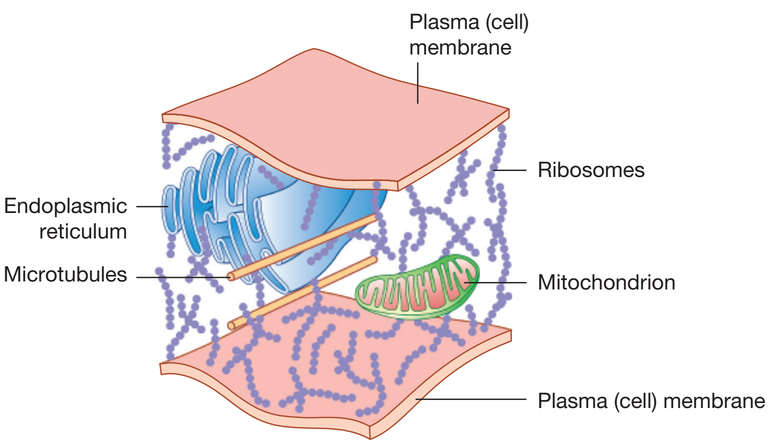

FIGURE 1.7 The cytoskeleton.
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- They also assist in the movement of pseudopodia (false arms/legs) – temporary projections of eukaryotic cell membranes. The functions of pseudopodia include locomotion (movement) and the capturing of prey. Pseudopodia sense prey that can then be engulfed. The engulfing pseudopodia are used by phagocytic white cells.

Intermediate filaments
These help determine the shape of a cell and range in size from 8 to 12 nm. Examples of intermediate filaments are neurofilaments, which are found in nerves.

Centrioles

These cylindrical structures are found in most animal cells and are composed of nine sets of microtubule cylinders arranged in a circular pattern. They are particularly involved in cell reproduction. Centrioles are involved in the organisation of the mitotic spindle.

Cilia and flagella

These 'hair-like' structures extend from the surface of some cells. They possess the facility to bend, which causes the cells to move.

In humans, cilia generally have the function of moving fluid or particulates over the surface of the cells. However, ciliated cells of the respiratory tract have a very important role to play in our immune and respiratory system in that they are able to move mucus that has trapped foreign particles, including bacteria and viruses, over the surface of respiratory tissues and towards the mouth or nose, thus preventing them from causing illness.

A flagellum (singular of flagella) is usually a much larger structure than a cilium (singular of cilia), and it is often used like a fish's tail to propel the cell forward. The only example of a human cell with a flagellum is a spermatozoon, where the flagellum acts as a tail and propels the spermatozoon towards an ovum.

Conclusion

This concludes the section on cells. Understanding their structure and function is essential for grasping how the human body works. The next section will examine the body's organs and structures, all composed of billions of cells.

Tissues

Introduction

Each human begins as a single fertilised egg, which divides to form an embryo, then a foetus and finally a baby. Cells divide in a controlled way, becoming specialised, such as muscle, skin or blood cells, and group into tissues, which combine to form the body. Tissues are groups of similar cells performing the same functions (McCance & Huether, 2022).

There are four primary types of tissues:

- epithelial
- connective
- muscle
- nervous.

These four primary tissue types then interweave to form the fabric of the body (Marieb, 2021). Each of the four types of tissue has a specific role to perform within the body. In simple terms:

- Epithelial tissue is concerned with covering and/or lining the body, both internally and externally.
- Connective tissue is concerned with supporting the body and the tissues and organs that make up the body.
- Muscle tissue is concerned with movement – both of the body and within the body.
- Nervous tissue is concerned with the control of the body – both internally and externally (Marieb, 2021).

These specialist cells form themselves into tissues in one of two ways:

1. The first way is by means of a process known as 'mitosis'. Cells formed as a result of the process of mitosis are clones of the original cell. Therefore, if one cell with a specialised function undergoes mitosis, and subsequent generations of daughter cells continue to undergo mitosis, then the resulting hundreds and thousands of cells will all be identical and of the same type, meaning that they will all have the same function. If these identical cells join together, they will become a specialised tissue. So, for example, epithelial cell sheets (such as skin) are formed as a result of mitosis (McCance & Huether, 2022).
2. The second way is by migrating to the site of tissue formation and assembling with other cells to form a tissue. This is particularly seen during the development of the embryo when, for example, cells migrate

to sites in the embryo where they differentiate and assemble into a variety of tissues (McCance & Huether, 2022). This movement of cells is known as 'chemotaxis'. Chemotaxis is the movement of cells along a chemical gradient caused by chemical attraction (McCance & Huether, 2022).

Types of tissues

Epithelial tissue

Epithelial tissue lines and covers areas of the body – both outside and inside – as well as forming the glandular tissue of the body. Thus, the exterior of the body (i.e., skin) is covered by one type of epithelial tissue, whilst other types of epithelial tissue line digestive organs, such as the stomach and the small intestines, along with the kidneys, and so on. So it can be seen that epithelial tissue covers or lines most of the internal and external surfaces of the body.

Classification

Epithelial tissue is classified in two ways:

1. The number of cell layers:
   - simple – where the epithelium is formed by a single layer of cells (Fig. 1.8)
   - stratified – where the epithelium has two or more layers of cells (Fig. 1.9).
2. Shape:
   - squamous
   - cuboidal
   - columnar.

Simple epithelial tissue is most concerned with absorption, secretion and filtration of fluids and particulates. However, because this tissue is usually very thin, it is not involved in protection.

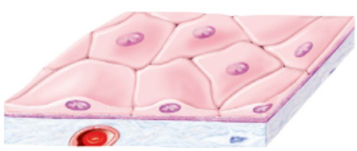

FIGURE 1.8 Simple epithelium.
Source: Peate & Gormley-Fleming (2015)/with permission of John Wiley & Sons.

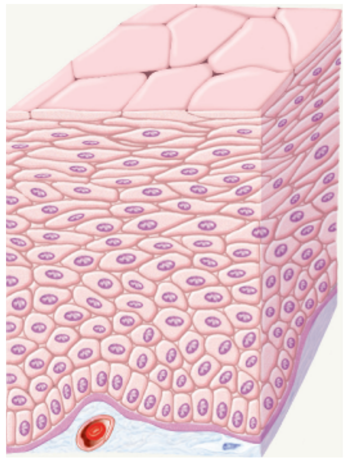

FIGURE 1.9 Stratified epithelium.
Source: Peate & Gormley-Fleming (2015)/with permission of John Wiley & Sons.

Simple squamous epithelium rests on a basal layer known as the 'basement membrane'. This is composed of a structural material that is secreted by the cells themselves (Marieb, 2021). The basement membranes provide a layer of cells that supports and separates epithelial tissue from the underlying connective tissue (Fig. 1.10). The squamous epithelial cells fit very closely together to give a thin sheet forming the tissue. This type of epithelial tissue is found in the alveoli of the lungs as well as in the walls of capillaries. It is this very thin tissue that easily allows for rapid diffusion into and out of the cell, thus facilitating oxygen and carbon dioxide exchange through the epithelial tissue that is lining the alveoli of the lungs and allowing nutrients and gases to pass easily through the epithelial tissue from the cells into the capillaries – and vice versa.

Simple squamous epithelial cells also form the serous membranes that line certain body cavities and organs.

Simple cuboidal epithelial tissue consists of one layer of cells resting on a basement membrane (Fig. 1.11). However, because cuboidal epithelial cells are thicker than squamous epithelial cells, they are found in different places within the body and also perform different functions. This type of epithelial tissue is found in glands, such as the salivary glands and the pancreas. In addition, they form the walls of the kidney tubules as well as covering the surface of the ovaries (Marieb, 2021).

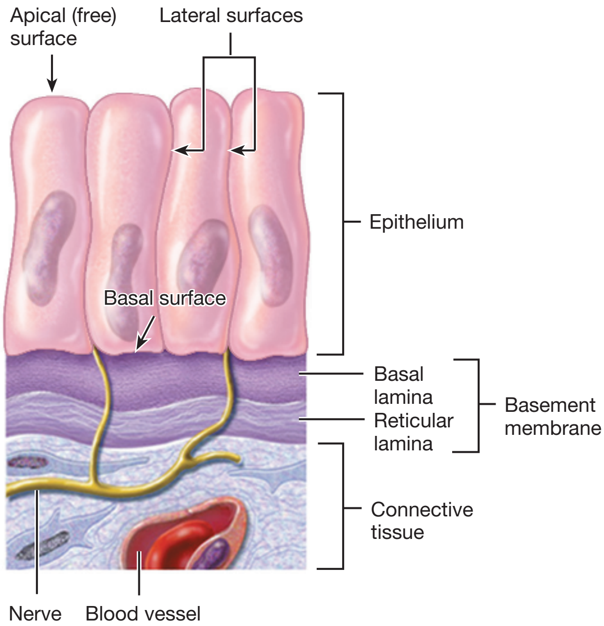

FIGURE 1.10 Connective tissue reinforces epithelial tissue.
Source: Reproduced with permission of Peate & Gormley-Fleming (2015)/John Wiley & Sons.

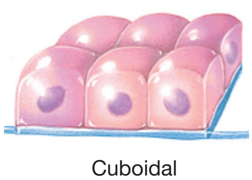

FIGURE 1.11 Simple cuboidal.
Source: Reproduced with permission of Peate & Gormley-Fleming (2015)/John Wiley & Sons.

Simple columnar epithelium (Fig. 1.12) is the third type of simple epithelial tissue. Like the other types of simple epithelium, it is composed of a single layer of cells, although these cells are relatively tall. However, similar to the other types, they still fit closely together. It is this type of epithelial tissue, which also contains goblet cells, that lines the entire length of the digestive tract from the stomach to the anus. Goblet cells produce mucus and, so, consequently, the simple columnar epithelial tissues that line all the body cavities that are open to the exterior of the body are known as mucous membranes (Marieb, 2021).

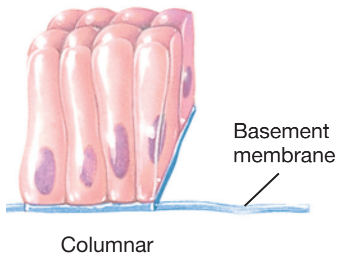

FIGURE 1.12 Simple columnar.
Source: Reproduced with permission of Peate & Gormley-Fleming (2015)/John Wiley & Sons.

Stratified epithelial tissue, unlike simple epithelial tissue, consists of two or more cell layers – so they lie in strata (hence the name). Because these stratified epithelial tissues have more than one layer of cells, they are stronger and harder than simple epithelia. As a consequence, a primary function of stratified epithelia is protection.

Stratified squamous epithelial tissue consists of several layers of cells and is the most common stratified epithelium found within the human body (Marieb, 2021). Despite being called 'squamous epithelium', it is not composed entirely of squamous cells. Only the cells at the free edges of the epithelial tissue are squamous, while those cells that are close to the basement membrane are made up of either cuboidal or columnar cells. This tissue is to be found in parts of the body that are most at risk of everyday damage, such as the oesophagus, the mouth and the outer layer of the skin.

Stratified cuboidal epithelial tissue has just two layers of cells and is only found in the ducts of large glands, such as the sweat glands, mammary glands and salivary glands, where its role is to protect the ducts of these glands.

Stratified columnar epithelial tissue is also found only in a few particular places in the body, such as in the conjunctiva of the eye, parts of the pharynx and anus, the uterus and the male urethra and vas deferens. It is also found in ducts located within the salivary glands.

Transitional epithelium, a specialised stratified squamous epithelium, lines the urinary bladder, ureters and part of the urethra. It allows these organs to stretch: when empty, the tissue has many layers with rounded surface cells; when distended with urine, the cells flatten and slide past each other, enabling expansion and greater urine storage until micturition.

Case study: epidermolysis bullosa (EB)

Patient profile

Emily, a 6-month-old infant, was admitted to the hospital with persistent blistering of the skin following minimal friction. Initially, concerns were raised about potential non-accidental injury, leading to a referral to Social Services.

Diagnosis

An experienced paediatric dermatologist recognised the clinical presentation as indicative of *junctional epidermolysis bullosa* (JEB), a rare genetic skin disorder. JEB is characterised by mutations affecting proteins that anchor the epidermis to the dermis, resulting in skin fragility and blister formation upon minor trauma.

Epidemiology

In the United Kingdom, the prevalence of all EB types is approximately 34.8 per million people. JEB accounts for about 1 per million, making it one of the rarer subtypes.

Pathophysiology

Human skin comprises two primary layers: the epidermis (outer layer) and the dermis (inner layer), connected by anchoring proteins. In JEB, mutations in genes such as *LAMA3*, *LAMB3* or *LAMC2* disrupt these connections, leading to skin separation and blistering.

Clinical implications

Beyond skin involvement, JEB can affect mucous membranes, leading to complications in the mouth, oesophagus and gastrointestinal tract. There is also an increased risk of developing squamous cell carcinoma in severe cases.

Advancements in treatment

Recent developments have introduced promising therapies:

- **Zevaskyn™ (prademagene zamikeracel or pz-cel):** Approved by the Food and Drug Administration (FDA) in April 2025, this autologous, cell-based gene therapy targets the underlying genetic defects in recessive dystrophic EB (RDEB) by correcting the *COL7A1* gene.
- **Vyjuvek™ (beremagene geperpavec):** A topical gene therapy approved in 2023, delivering functional *COL7A1* genes to promote wound healing in dystrophic EB patients.
- **Filsuvez® (birch triterpenes):** A topical gel approved in the EU in 2022 for treating partial-thickness wounds in both dystrophic and junctional EB.

Multidisciplinary care approach

Management of EB requires a comprehensive, multidisciplinary team, including:

- **Dermatologists:** For diagnosis and ongoing skin management.
- **Nurses:** Specialised in wound care and patient education.
- **Genetic counsellors:** To advise families on inheritance patterns and future family planning.
- **Psychologists and social workers:** Providing emotional support and resources.
- **Educational staff:** Assisting with school integration and accommodations.

Investigations

Diagnosis is confirmed through:

1. **Skin Biopsy:** Histological examination reveals sub-epidermal blistering with neutrophil infiltration.
2. **Direct Immunofluorescence (DIF):** Perilesional skin samples may show deposits of immunoglobulins (IgG, IgM and IgA), aiding in subtype classification.

Red Flag

Due to the rarity of EB, its symptoms can be mistaken for signs of abuse. Healthcare professionals must approach such cases with sensitivity, ensuring accurate diagnosis to prevent unwarranted social interventions.

Conclusion

Although there is no cure for EB, advances in gene therapy and supportive care have improved outcomes. Early diagnosis and a holistic care approach are key to managing the condition and enhancing the quality of life for patients and their families.

Glandular epithelium

Glandular epithelial tissue is found within the glands. According to Marieb (2021), a gland consists of several cells that make and secrete a particular product.

There are two major types of glands developed from sheets of epithelial cells:

- exocrine glands
- endocrine glands.

Exocrine glands have ducts that carry secretions to epithelial surfaces, such as sweat glands, the liver and the pancreas. Endocrine glands lack ducts; their secretions, hormones, diffuse directly into blood vessels and include the thyroid, adrenal and pituitary glands.

Connective tissue

Connective tissue is found throughout the body and, as the name suggests, it connects and supports other tissues and organs (see Fig. 1.10). It is the most abundant of the four primary tissue types.

Despite its varied structure, connective tissue shares four main functions:

- Protection
- Support
- Binding together of other tissues (Marieb, 2021)
- Storage of nutrients (McCance & Huether, 2022).

Its most common role is to act as a framework on which other tissues, like epithelium, are built to form organs (McCance & Huether, 2022).

Connective tissue contains fewer cells than other tissues, with a large extracellular matrix that provides strength and flexibility. The matrix is made of:

- Ground substance (mainly water, proteins and large sugar molecules)
- Fibres, produced by cells called fibroblasts.

There are three types of fibres in connective tissue:

- Collagen fibres – strong and supportive
- Elastic fibres – stretchy and able to recoil
- Reticular fibres – form delicate networks in soft organs like the spleen.

The ground substance varies from fluid to a jelly-like consistency. It acts as a water reservoir and supports cell attachment.

Connective tissue also acts as a protective layer around organs and helps the body absorb mechanical stress. It can withstand weight, stretching and pressure. Different types of connective tissue vary in strength and flexibility. For example:

- Fat tissue contains mostly cells and a soft matrix.
- Bone and cartilage contain fewer cells but a hard matrix, making them strong.

Blood supply also varies as:

- Most connective tissues (like bone) have a good blood supply and heal quickly.
- Tendons and ligaments have limited blood supply and heal more slowly.
- Cartilage has no direct blood supply, which makes healing very slow (Marieb, 2021).

Types of connective tissue

Bone

Bone, the most rigid connective tissue, consists of bone cells in a hard matrix of calcium and collagen, providing protection, support and muscle attachment. In children and adolescents, bones lengthen at epiphyseal (growth) plates, where cartilage is gradually replaced by bone through endochondral ossification until the plates close in late adolescence.

Cartilage

Cartilage is not as hard as bone, but it is more flexible. It is found in only a few places in the body (see Fig. 1.13). For example, hyaline cartilage supports the structures of the larynx. It also attaches the ribs to the sternum and covers the ends of bones where they form joints. Another type of cartilage is fibrocartilage, which can be compressed and forms the discs between the spinal and neck vertebrae. Elastic cartilage is found in the external ear, where a degree of elasticity is necessary.

Dense connective tissue

This forms strong, stringy structures such as tendons (which attach skeletal muscles to bones) and the more elastic ligaments (which connect bones to other bones at joints). Dense connective tissue also makes up the lower layers of skin (the dermis). These tissues have collagen fibres as the main matrix element, with many fibroblasts found between the collagen fibres. Fibroblasts are involved in the manufacturing of fibres.

Loose connective tissue

These tissues are softer and contain fewer fibres but more cells than other types of connective tissue (with the exception of blood). There are four types of connective tissue:

- areolar tissue
- adipose tissue
- reticular tissue
- blood.

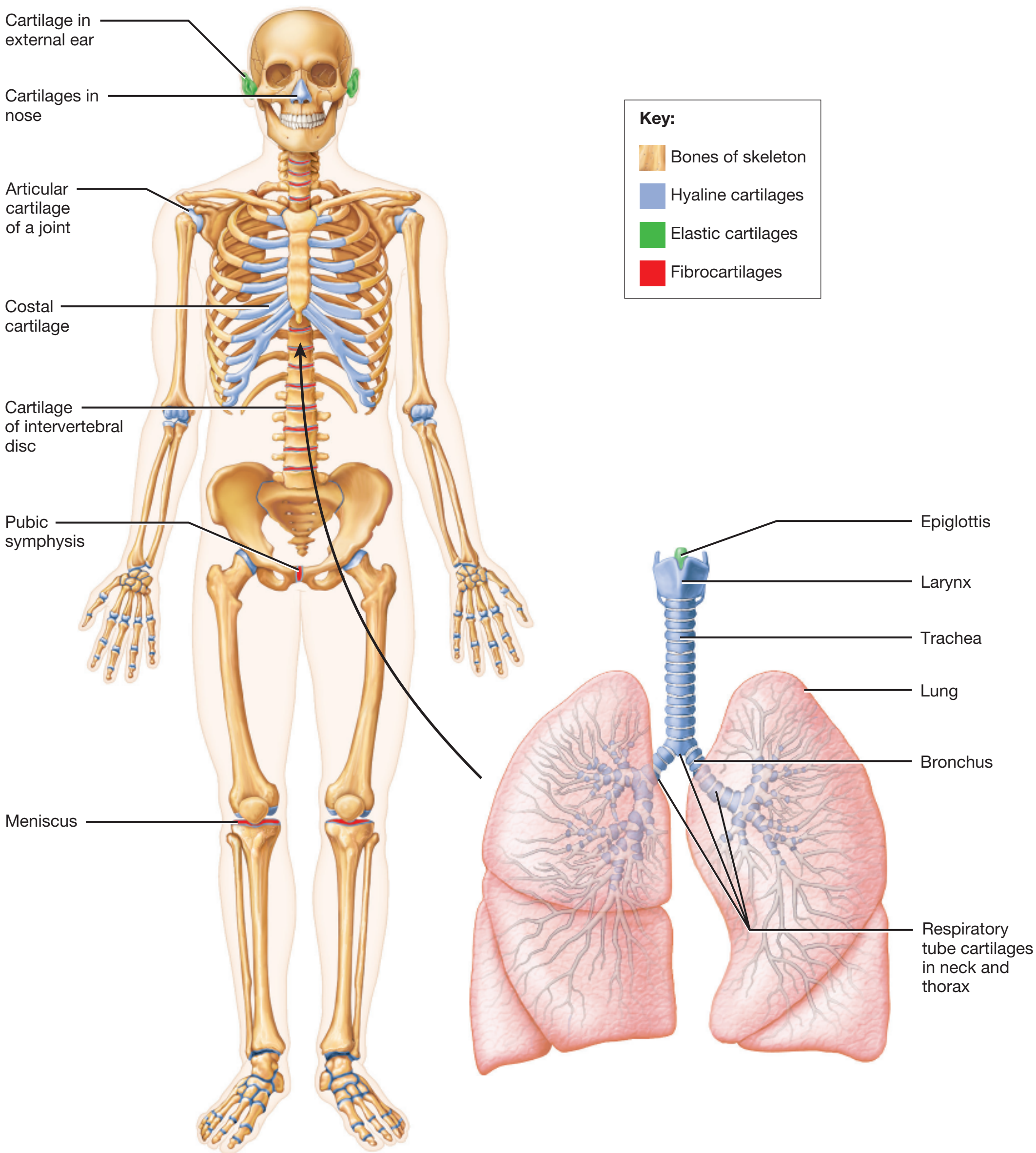

FIGURE 1.13 Where cartilage is found in the body.
Source: Reproduced with permission of Peate & Gormley-Fleming (2015)/John Wiley & Sons.

Areolar tissue

Areolar tissue, the most widely distributed connective tissue, cushions and protects organs, holds them together and has a loose, fibre-filled matrix that provides softness, pliability and a reservoir of water and salts for surrounding tissues.

All body cells obtain their nutrients from this tissue fluid, and they also release their waste into it. It is in this area that, following injury, swelling (oedema) can occur because the areolar tissue soaks up the excess fluid, causing it to become puffy (Marieb, 2021).

Adipose tissue

Adipose tissue, commonly known as ‘fat’, consists mainly of fat cells. It forms the subcutaneous layer beneath the skin, insulating the body, protecting against temperature extremes and cushioning organs like the kidneys and eyes.

Reticular connective tissue
This tissue consists of a delicate network of reticular fibres that are associated with reticular cells. It forms an internal framework to support many free blood cells – mainly the lymphocytes – in the lymphoid organs, such as the lymph nodes, spleen and bone marrow.

Blood
Blood, a connective tissue, consists of cells suspended in a non-living fluid matrix called plasma. It transports nutrients, waste, gases and other substances. In children, blood-forming tissues such as bone marrow are highly active, and the immune system matures with increasing white blood cell production to combat infections.

Muscle tissue

There are three types of muscle tissue. These are responsible for helping the body to move and for moving substances around the body. The three types of muscle tissue are:

- skeletal muscle
- cardiac muscle
- smooth muscle.

See Figs. 1.14 and 1.15 for examples of skeletal muscle cells and smooth muscle.

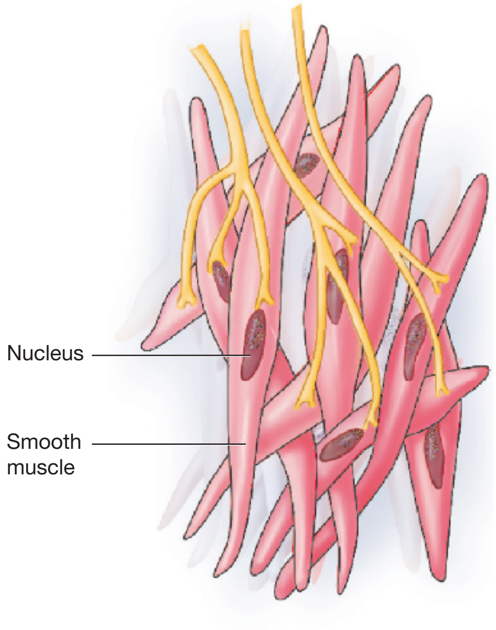

FIGURE 1.15 Smooth muscle.
Source: Peate & Gormley-Fleming (2015)/with permission of John Wiley & Sons.

Skeletal muscle
Skeletal muscle is attached to bones and is involved in the movements of the skeleton. These muscles can be controlled voluntarily and form the 'bulk' of the body – the flesh. The cells of skeletal muscles are long and cylindrical and have several nuclei (Fig. 1.12). In addition, they appear striated (striped). They work by contracting and relaxing, with pairs working antagonistically against each other – i.e., one muscle contracts and the opposite muscle relaxes. So, if the muscles in the front of the arm contract, then the ones at the back relax, which causes the arm to bend.

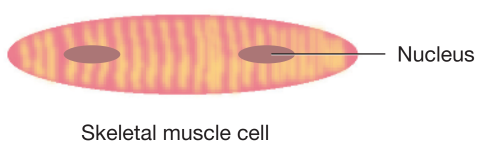

FIGURE 1.14 Skeletal muscle cells.
Source: Peate & Gormley-Fleming (2015)/with permission of John Wiley & Sons.

Cardiac muscle
Cardiac muscle is only found in the heart, and its role is to pump blood around the body. It also achieves this by contracting and relaxing. However, unlike skeletal muscles, cardiac muscle works in an involuntary way – the activity cannot be consciously controlled. The cells of the muscle do not have a nucleus.

Smooth muscle
Also known as visceral muscle, smooth muscle is found in the walls of hollow organs – for example, the stomach, bladder, uterus and blood vessels. Like cardiac muscle, smooth muscle works in an involuntary way. It causes movement in the hollow organs; for example, as smooth muscle contracts, the cavity of the organ constricts – becomes small in volume – and when it relaxes, the organ

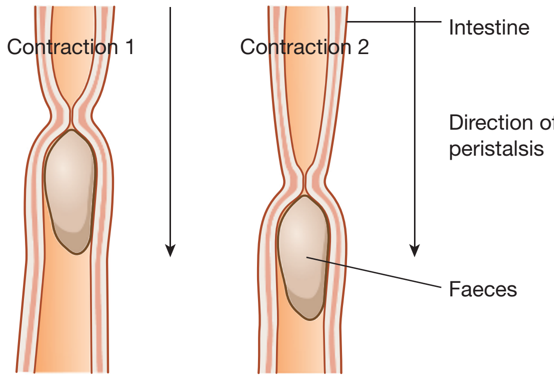

FIGURE 1.16 Peristalsis.
Source: Reproduced with permission of Peate & Gormley-Fleming (2015)/John Wiley & Sons.

becomes larger in volume (dilates). This allows substances to be propelled through the organ in the right direction, for example, faeces in the intestine. As smooth muscle contracts and relaxes, it forms a wave-like motion (peristalsis) to push the faeces through the intestines to the rectum (see Fig. 1.16).

Nervous tissue

Nervous tissue is concerned with control and communication within the body by means of electrical signals. The neurone (Fig. 1.17) is the main type of cell found in nervous tissue.

All neurones receive and conduct electrochemical impulses around the body. The structure of neurones is very different from that of other cells. The cytoplasm is found within long processes or extensions; some in the leg are more than a metre long. These neurones receive and transmit electrical impulses very rapidly from one to the other across junctions (known as synapses). Synapses also allow electric impulses to pass from neurones to muscle cells. The total number of neurones is fixed at birth and cannot be replaced if lost or damaged (McCance & Huether, 2022). Although the number of neurones is fixed, the development of the nervous system continues throughout childhood. In particular, the process of myelination – where nerve fibres are coated in an insulating layer to increase transmission speed – is ongoing during infancy and early childhood, supporting improvements in coordination, motor skills and cognitive development.

In addition to neurones, nervous tissue includes some cells known as neuroglia (supporting cells). These

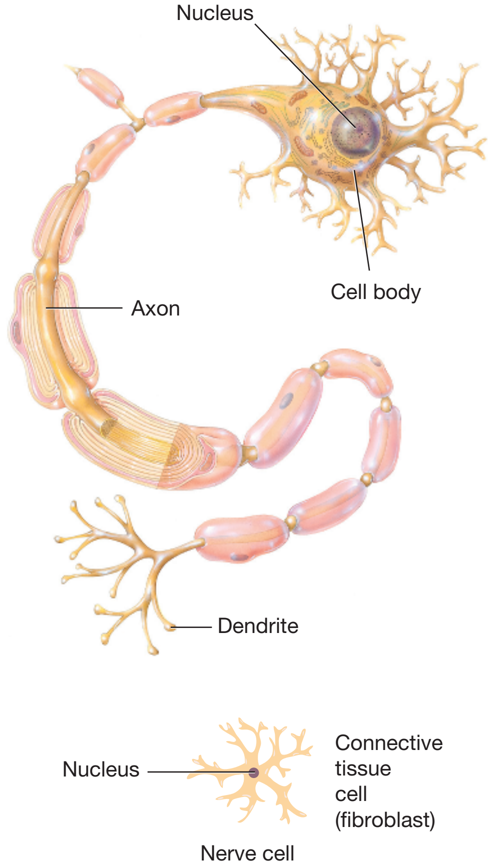

FIGURE 1.17 Nerve cell.
Source: Peate & Gormley-Fleming (2015)/with permission of John Wiley & Sons.

cells insulate, support and protect the delicate neurones. The neurones and supporting cells comprise the structures of the nervous system, namely:

- brain
- spinal cord
- nerves.

Tissue repair

The many tissues of the body are always at risk of injury or disease. Inflammation is the body's immediate reaction to tissue injury or damage because when this occurs, it stimulates the body's inflammatory and immune responses to spring into action so that the healing process can begin almost immediately. In children, tissues generally have greater plasticity and healing capacity than in adults. This means that many injuries, particularly to skin, bone and muscle, heal more quickly and with less scarring. This regenerative advantage gradually decreases with age.

Conclusion

This chapter has examined the building blocks of the human body: cells and tissues. Understanding cells and their functions is key to understanding how the body works. Cells form tissues, which build the body's structures, systems and organs. The rest of the book will explore these systems and organs, their functions and potential disorders.

Test your knowledge

1. How many primary tissue groups are there?
2. What is the difference between an exocrine and an endocrine gland?
3. What is the function of muscle tissue?
4. Discuss the two main classifications of cells: the prokaryotes and eukaryotes.
5. Each cell is surrounded by a membrane, what is the function of this membrane?

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