

# Chapter 1

## Cell and body tissue physiology

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### Key words

- Plasma membrane
- Organelles
- Connective tissue
- Passive transport
- Nucleus
- Cell cycle
- Muscle tissue
- Active transport
- Cytoplasm
- Epithelial tissue
- Nervous tissue
- Bulk transport

## Test your prior knowledge

- What are the three main parts of a human cell?
- Describe the structure and function of a human cell.
- Describe the phases of a cell cycle.
- Make a list of the major cellular organelles.
- Name the four tissue types and explain the differences between them.

## Learning outcomes

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

- Outline the structure and function of a human cell.
- List and describe the functions of the organelles.
- Explain the phases of a cell cycle.
- Explain the cellular transport system.
- Describe the structure and function of epithelial tissue, connective tissue, muscle tissue and nervous tissue.
- Explain the process of tissue repair (inflammation).



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## Introduction

To understand the human body and how it works (and also how it fails to work properly), it is important to understand the anatomy and physiology of the cell. Living organisms show a wide diversity as regards their size, shape, colour, behaviour and habitat. In spite of this, however, there are many similarities between organisms, and this fundamental similarity is known as the 'cell theory'. This cell theory states that all living organisms are composed of one or more cells and the products of cells. Despite the fact that the cells belong to different organisms, and cells within the same organism may have different functions, there are many similarities between them. For example, there are similarities in their chemical composition, their chemical and biochemical behaviour and in their detailed structure.

All cells have many characteristics, but these characteristics can differ from cell to cell, such as:

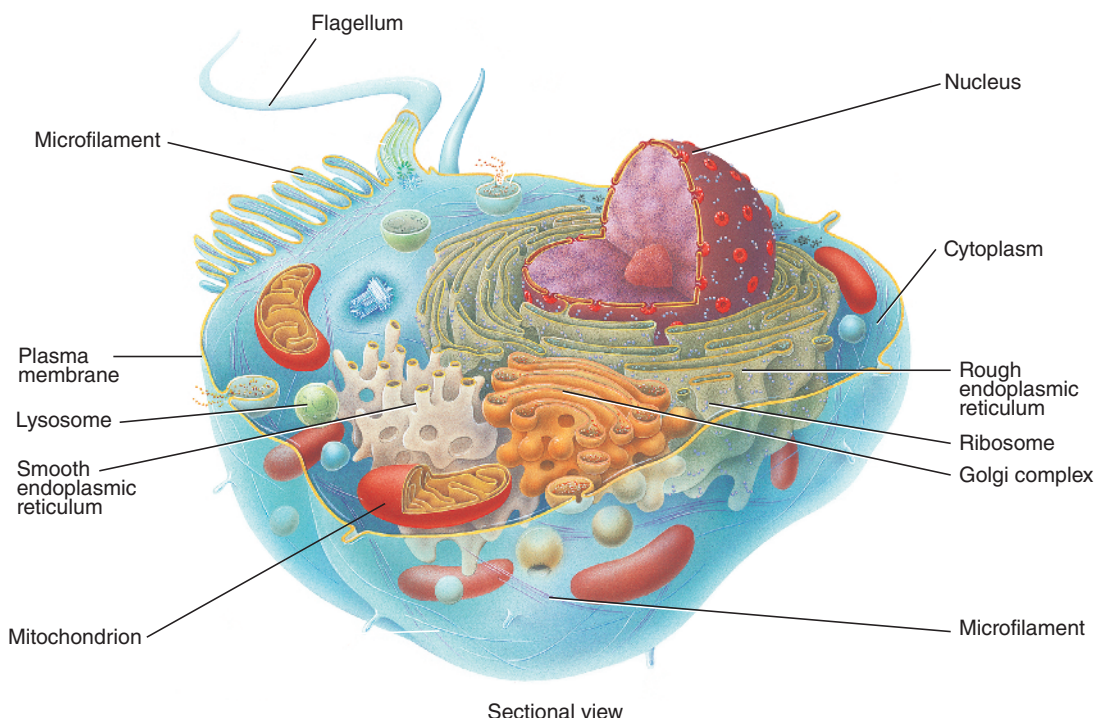
- Cells are able to carry out certain specific functions, i.e. they are active.
- Cells need to consume food to live and to carry out their functions. Although they do not have mouths, they are still able to 'catch' and digest their food and use it for growth and reproduction. The correct term for this is endocytosis – they surround and engulf organisms such as bacteria and digest them.
- Cells can grow and repair.

- Similarly, cells can reproduce themselves. They do this by a process known as simple fission. This means that they reproduce themselves by dividing into two, and then each new cell grows to full size before it divides by simple fission and so on. In other words, cells replicate themselves.
- Like humans, cells can become irritable if something upsets or stimulates them.
- The nutrition that cells take in is also used for the storage and release of energy (just like humans), thus enabling them to grow and repair themselves.
- Similarly, just as humans do not utilise all the food they eat – some of it cannot be used and so is excreted – cells excrete what they do not need or cannot use.
- Just as all humans will eventually die, so will cells. Some have a short life, whilst others survive many years – but eventually they will die.

So, cells are not all that different from humans in many respects. They do what humans do – albeit in different ways.

## Anatomy of the cell

Each cell has a structure that is almost as complex as the human body (Figure 1.1). For example, each cell contains as many molecules as the body has cells. There is no such thing as a typical cell. However, each cell is surrounded by a membrane and contains protoplasm. This protoplasm consists of a nucleus, which is kept separate from the rest of the cell by a nuclear membrane (although the nuclear membrane disappears during the process of cell division), and an opaque substance called cytoplasm (Watson, 2005). The cells themselves consist of water, proteins, lipids, carbohydrates and various ions such as potassium ( $K^+$ ) and magnesium ( $Mg^{2+}$ ). Within the cytoplasm there are also many complex protein structures called organelles.



**Figure 1.1** Simplified structure of a cell.

Cells vary in size from 2 to 20  $\mu\text{m}$ . For example, a lymphocyte (a type of blood cell) is about 8–10  $\mu\text{m}$  in diameter.

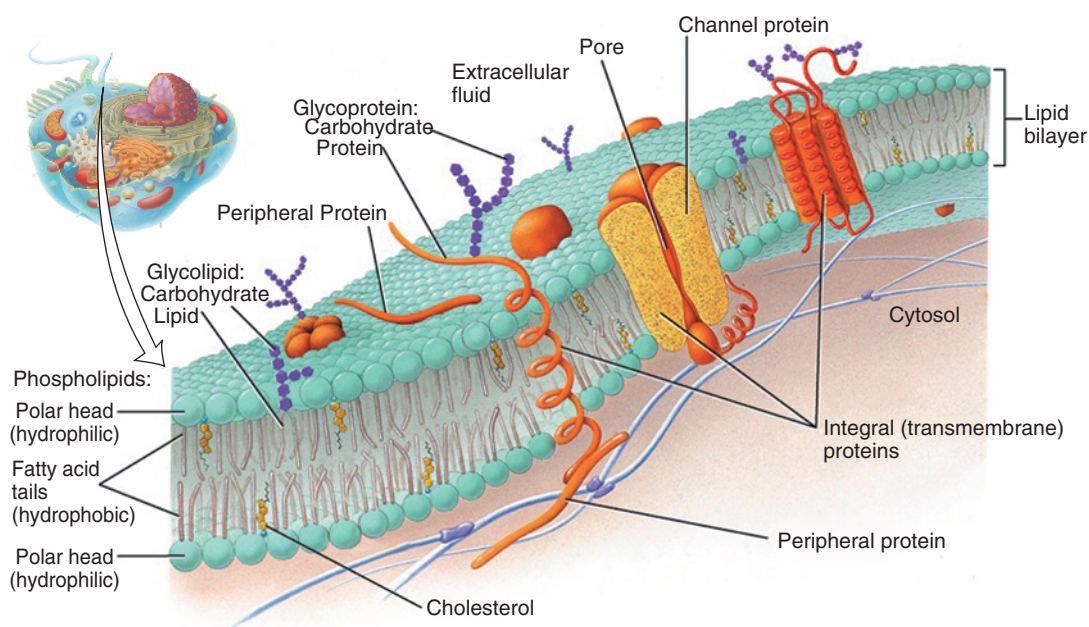
All the cells in the body, apart from those on the surface of the body, are surrounded by a fluid that is known as extracellular fluid (i.e. fluid outside of the cell).

## The cell membrane

The cell membrane can vary from 7.5 to 10 nm in thickness. It acts just like a 'skin' that protects the cell from the outside environment. In addition, it regulates the movement of water, nutrients and waste products into and out of the cell.

The cell membrane is made up of a double layer (bilayer) of phospholipid (fatty) molecules with protein molecules interspersed between them (Figure 1.2). A phospholipid molecule consists of a polar 'head' which is hydrophilic (water loving) and 'tails' which are hydrophobic (water hating). The hydrophilic 'heads' are attracted to water and are found on the inner and outer surfaces of the cell (water is the main component of both extracellular and intracellular environments), whilst the hydrophobic 'tails' are found in the middle of the cell membrane where they can avoid water. These phospholipid molecules are arranged as a bilayer with the heads facing outwards. This means that the bilayer is self-sealing. It is the central part of the plasma membrane, consisting of the hydrophobic 'tails', that makes the cell membrane impermeable to water-soluble molecules, and so prevents the passage of these molecules into and out of the cell (Marieb, 2015). However, if the membrane just consisted of these phospholipid molecules, then cells would not be able to function – within the cell membrane there are also plasma membrane proteins (PMPs), which can be either integral or peripheral.

Some of the integral PMPs are embedded amongst the tails of the phospholipid molecules, whilst others penetrate the membrane completely (Figure 1.2). Subunits of some of these integral proteins can form channels which allow for the transportation of materials into and out of the



**Figure 1.2** The cell membrane.

cell. Other subunits are able to bind to carbohydrates to form receptor sites. These receptor sites are important, as will be discussed in Chapter 3 – Inflammation, immune response and healing.

Peripheral PMPs bind loosely to the surface of the cell membrane and so can easily be separated from it. Some of them function as enzymes to catalyse cellular reactions, whilst others are receptors for hormones and other chemicals, or function as binding sites for attachment to other structures (Marieb, 2015).

## Functions

- Endocytosis and exocytosis – the transport of fluids and other matter into and out of the cell.
- Endocytosis is the intake of extracellular fluid and particulate material (small particles) ranging in size from macromolecules to whole cells (e.g. the bacteria engulfed and destroyed by macrophage cells).
- Exocytosis is the bulk transport of material out of the cells.

There are three types of endocytosis:

1. Phagocytosis – involves the ingestion of large particles, even whole microbial cells.
2. Pinocytosis – involves the ingestion of small particles and fluids.
3. Receptor-mediated endocytosis – involves large particles, notably proteins, but also has the important feature of being highly selective.

Endocytosis involves part of the cell membrane being drawn into the cell along with the particles or fluid to be ingested (Figure 1.3). This membrane is then pinched off to form a membrane-bound vesicle within the cell, while at the same time the cell membrane as a whole reseals itself. Inside the cell, the fate of this vesicle depends upon the type of endocytosis involved as well as the material it contains. In some cases, the endocytic vesicle ultimately fuses with an organelle called a lysosome, after which processing of the ingested material can occur. Endocytosis is also the means by which many simple organisms obtain their nutrients.

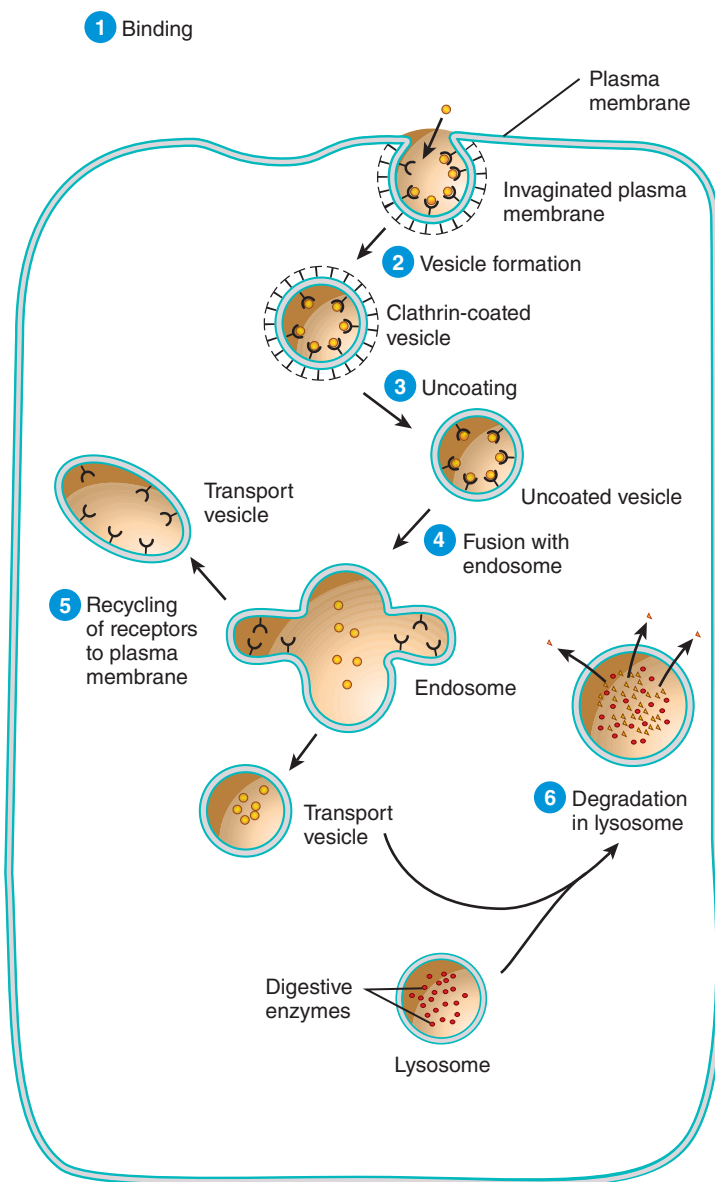
## Transport across the cell membrane

One of the key properties of the cell membrane with regards to transport is its selective permeability. This refers to its ability to let certain materials pass through, whilst preventing others from doing so. This selective permeability is based on the hydrophobicity (water hatred) of its component molecules. Because the phospholipid tails in the centre of the bilayer are composed entirely of hydrophobic fatty acid chains (lipids are fats), it is very difficult for water-soluble (hydrophilic) molecules to penetrate to the membrane interior. The result is a very effective permeability barrier.

However, this barrier can be penetrated, but only by way of specific transport systems. These control what goes into and out of the cell, or what crosses from one subcellular compartment to another. Cell membranes control metabolism by restricting the flow of glucose and other water-soluble metabolites in and out of cells and between subcellular compartments. This is known as compartmentation. The cells store energy in the form of transmembrane ion gradients by allowing high concentrations of particular ions to accumulate on one side of the membrane.

Ions pass from inside to outside of the cell (or the other way round) so that there are more supplies of these ions just outside the cell or inside it and the membrane controls the speed/rate at which these ions pass through the membrane. The controlled release of such ion gradients can be used to:

- extract nutrients from surrounding fluids
- pass electrical messages (known as nerve excitability)
- control cell volume and stop cells bursting from excess fluid.



**Figure 1.3** Endocytosis.

To return to the cell membrane itself, there are four factors that decide the degree of permeability of a membrane:

1. Size of molecules – large molecules cannot pass through the integral membrane proteins, but small ones such as water and amino acids can.
2. Solubility in lipids (fats) – substances that easily dissolve in lipids can pass through the membrane more easily than non-lipid-soluble substances. Lipid-soluble substances include oxygen, carbon dioxide and steroid hormones.

3. If an ion has an electrical charge opposite to that of the membrane, then it is attracted to the membrane and can more easily pass through it.
4. Carrier integral proteins can carry substances across the membrane, regardless of their size, ability to dissolve in lipids or membrane electrical charge.

There are two ways in which substances can move across the membrane: passive or active. Passive processes are:

- diffusion
- facilitated diffusion
- osmosis
- filtration.

Active processes are:

- active transport pumps
- endocytosis
- exocytosis.

A passive process is one in which the substances move on their own down a concentration gradient from an area of higher to one of lower concentration. The cell does not expend any energy on the process. Think of it as rolling down a hill from an area of high altitude to one of lower altitude. Little energy is expended just rolling down a hill.

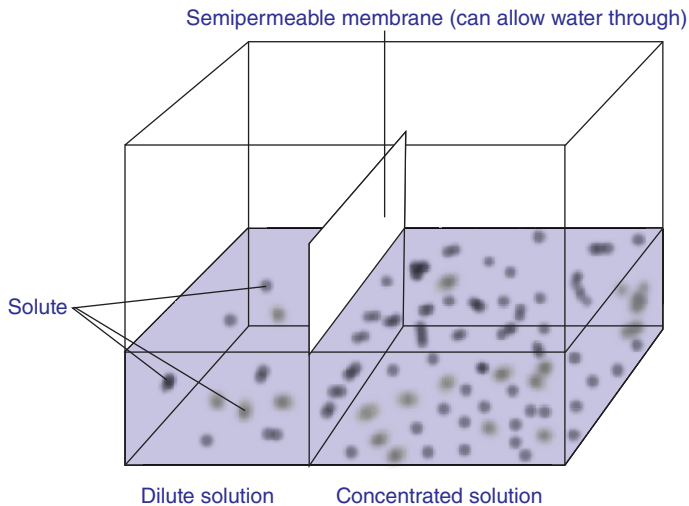
Diffusion is the most common form of passive transport in which a substance of higher concentration moves to an area where there is a lower concentration of that substance (Colbert *et al.*, 2011). This difference between the areas of high concentration and of low concentration is known as a concentration gradient. This process of diffusion is essential for respiration. It is through diffusion that oxygen is transported from the lungs to the blood and carbon dioxide makes the opposite journey from the blood to the lungs (Colbert *et al.*, 2011).

Facilitated diffusion is similar to diffusion, but with one exception. For this process to take place, there needs to be a substance that helps – a facilitator. Glucose is moved using this process. Although glucose can move part of the way through the membrane on its own, it needs something else (a carrier/transport protein) to give it that extra push to get it completely through the membrane (Colbert *et al.*, 2011; McCance *et al.*, 2014).

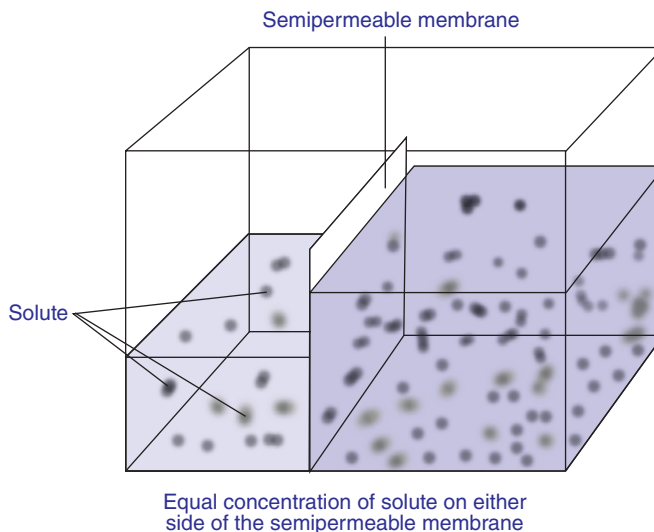
Osmosis is the process in which water travels through a selectively permeable membrane so that concentrations of a substance that is soluble in water (known as a solute) are the same on both sides of that membrane. This is known as osmotic pressure (Figures 1.4 and 1.5). The higher the concentration of the solute on one side of the membrane, the higher the osmotic pressure available for the movement of the water (Colbert *et al.*, 2011).

Filtration is similar to osmosis, except that pressure is applied in order to 'push' water and solutes across that membrane. The heart is a major supplier of the force that can lead to one type of filtration (renal filtration) as it pushes blood into the kidneys where filtration of the blood can take place (Colbert *et al.*, 2011).

An active process is one in which substances move against a concentration gradient from an area of lower to one of higher concentration. To do this, the cell must expend energy; this is released by splitting adenosine triphosphate (ATP) into adenosine diphosphate (ADP) and phosphate. ATP is a compound of a base, a sugar and three phosphate groups (triphosphate). These phosphate groups are held together by high-energy bonds, which when broken release a high level of energy. Once one of these phosphate bonds has been broken and a phosphate group has been released, that compound now has only two phosphate groups (diphosphate). The released phosphate group in turn joins up with another ADP group, so forming another molecule of ATP (with energy stored in the phosphate bonds), and the whole process continues to recur.



**Figure 1.4** Osmosis.



**Figure 1.5** Osmosis and movement of solute.

The energy is required because the cell is attempting to move a substance to an area that already has a high concentration of that substance. Think again of a hill. When walking up a hill, a lot of energy is expended. Obviously, the higher the concentration already present, the more energy required to move further molecules of the particular substance into that area – the steeper the hill, the more energy is used. For example, cells contain a lot of potassium ( $K^+$ ); therefore, energy is required to transport more potassium through the membrane and into the cell.

Now, to turn to what is inside the cell membrane, starting with the cytoplasm.

## Cytoplasm

Cytoplasm is a ground substance (also known as a matrix) in which various cellular components are found. 'Cyto' means cell, so any word that has 'cyto' in it is to do with cells.

Cytoplasm, itself, is a thick, semitransparent, elastic fluid containing suspended particles and the cytoskeleton. The cytoskeleton provides support and shape to the cell. In addition, it is involved in the movement of structures in the cytoplasm because some cells can change shape, e.g. phagocytic cells (see Figure 1.3).

### Role of cytoplasm

- Chemically, cytoplasm is 75–90% water plus solid compounds – mainly carbohydrates, lipids and inorganic substances, and it is the substance in which chemical reactions occur.
- The cytoplasm receives raw materials from the external environment (such as from digested food) and converts them into usable energy by decomposition reactions.
- As well as the breakdown of raw materials to make energy, the cytoplasm is also the site where new substances are synthesised (produced) for the use of the cell.
- It is the place where various chemicals are packaged for transport to other parts of the cell, or to other cells in the body.
- It is in the cytoplasm that various chemicals facilitate the excretion of waste materials.

## Nucleus

When considering the nucleus, a simple analogy is to think of it as the brain of the cell.

Prokaryotic cells do not have a nucleus, but eukaryotic cells do. Eukaryotic cells are found in animals and plants, whilst prokaryotic cells are very typical of bacteria. In many ways, prokaryotic cells are less complex and often smaller than eukaryotes.

However, not all human cells possess a nucleus. An example of a cell without a nucleus is the red blood cell. Chapter 7 describes the concave shape of the mature red blood cells. This is because the lack of a nucleus means the red blood cell 'collapses in' on itself. Also, just to make it more confusing, some cells can have more than one nucleus, e.g. some muscle fibre cells (see Figure 1.12).

Some facts about the nucleus are:

- The nucleus is the largest structure in the cell.
- It is surrounded by a nuclear membrane. This nuclear membrane has two layers and, like the cell membrane, is selectively permeable.
- The protoplasm within the nucleus is not called cytoplasm – it is called nucleoplasm.
- The nucleus assumes a great responsibility for both mitosis and meiosis (see later).
- Inside the nucleus is found the genetic material, consisting principally of deoxyribonucleic acid (DNA). When a cell is not reproducing, the genetic material is a threadlike mass called chromatin.
- Before cell division, the chromatin shortens, and coils into rod-shaped bodies called chromosomes.
- The basic structural unit of a chromosome is a nucleosome – composed of DNA and protein.
- DNA has two main functions:
  1. It provides the genetic blueprint which ensures that the next generation of cells is identical to existing ones.
  2. It provides the plans for the synthesis of protein by the cell.

- All this information is stored in genes.
- Inside the nucleus are little spherical bodies called nucleoli and these are responsible for the production of ribosomes from ribosomal ribonucleic acid (rRNA).
- In humans, there are 23 pairs of chromosomes in each cell with a nucleus, with the exception of the spermatozoa and ova (sperm and eggs).
- Sperm and ova only have 23 single chromosomes (i.e. one of each).
- The chromosomes are the same for males and females except for one pair – the X and Y chromosomes. It is these chromosomes that determine whether a baby is going to be male or female.

## Mitosis and meiosis

These are the processes by which the cell reproduces itself. Most human cells reproduce asexually by mitosis, but the spermatozoa and ova reproduce by meiosis. Whereas the cells reproducing by mitosis finish up as exact copies of the parent cells with a pair of each of the 23 chromosomes, the cells reproducing by meiosis just finish up with one each of the 23 chromosomes.

### Mitosis

In order for the body to grow, and also for the replacement of body cells that die, cells must be able to reproduce themselves, and in order for genetic information not to be lost, they must be able to reproduce themselves accurately. They do this by cloning themselves. In some organisms, this can occur by simple fission, where the nucleus in a single cell becomes elongated and then divides to form two nuclei in the same cell, each new nucleus carrying identical genetic information. The cytoplasm then divides in the middle between the two nuclei, and so two identical daughter cells result, each with its own nucleus and other essential organelles.

In humans, cell reproduction is a complex process called mitosis, in which the number of chromosomes in the daughter cells has to be the same as in the original parent cell.

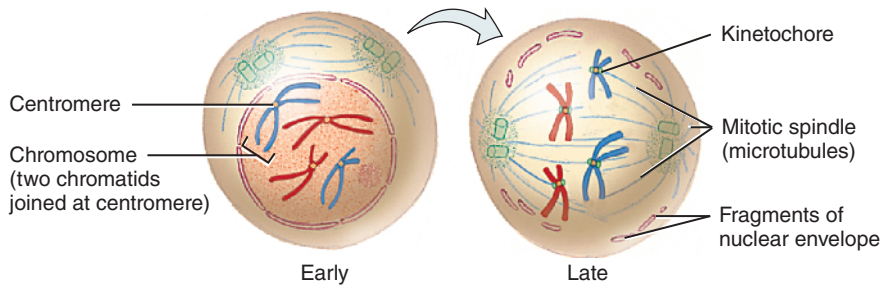
Mitosis can be divided into four stages:

1. prophase
  2. metaphase
  3. anaphase
  4. telophase.
- Before and after it has divided, the cell enters a stage known as interphase – this was thought to be a resting period for the cell, but the cell is actually very busy during this period because it has to get ready for replication.
  - Extra organelles are manufactured by the replication of existing organelles.
  - Also, the cell builds up a store of energy which is required for the process of division.

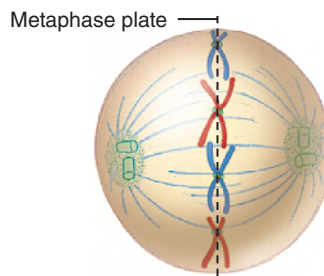
### Prophase

The first stage after interphase is prophase:

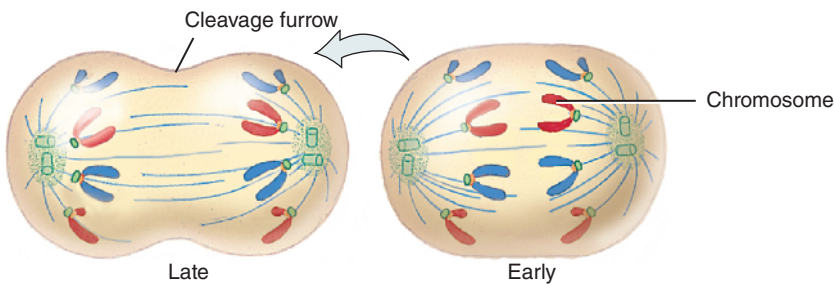
- During prophase (Figure 1.6), the chromosomes become shorter, fatter and more easily visible, and each chromosome now consists of two chromatids, each containing the same genetic information (i.e. the DNA has replicated itself during interphase).
- The nucleolus and nuclear membrane disappear, leaving the chromosomes in the cytoplasm.



**Figure 1.6** Prophase.



**Figure 1.7** Metaphase.



**Figure 1.8** Anaphase.

### Metaphase

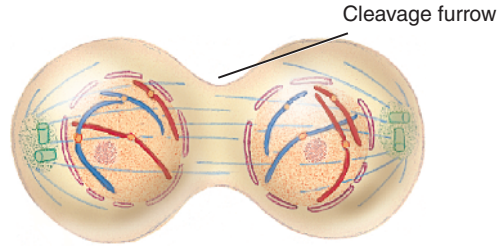
- During metaphase (Figure 1.7), the 46 chromosomes (two of each of the 23 chromosomes), each consisting of two chromatids, become attached to the spindle fibres.

### Anaphase

- During anaphase (Figure 1.8), the chromatids in each chromosome are separated.
- One chromatid from each chromosome then moves towards each pole of the spindle.

### Telophase

- There are now 46 chromatids at each pole, and these will form the chromosomes of the daughter cells.
- The cell membrane constricts in the centre of the cell, dividing it into two cells.



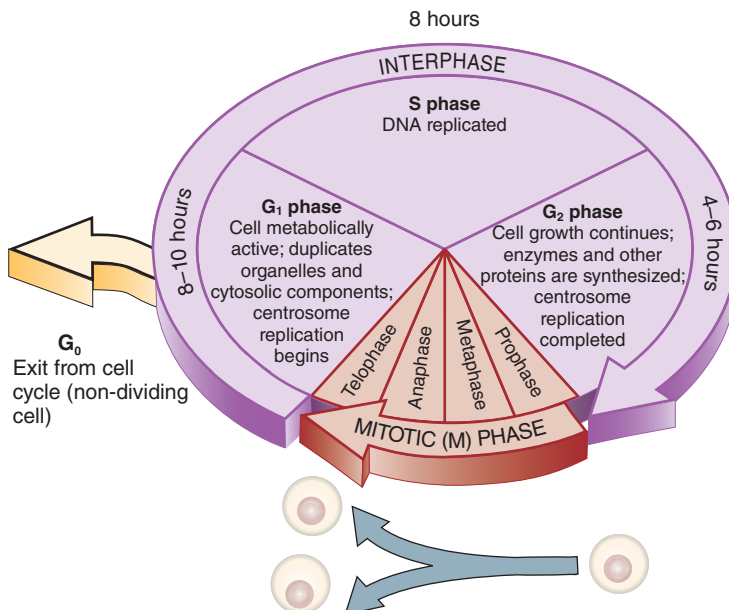
**Figure 1.9** Telophase.

- The nuclear spindle disappears, and a nuclear membrane forms around the chromosomes in each of the daughter cells (Figure 1.9).
- The chromosomes become long and threadlike again, and are very difficult to see.

Cell division is now complete, and the daughter cells themselves enter the interphase stage in order to prepare for their replication and division.

### Cell cycle

Looking now at the cell cycle (Figure 1.10) and supposing that one full cycle represents 24 hours, then the actual process of replication (mitosis) would only last for about 1 hour out of those 24 hours. The rest of the time, the cell is undertaking the replication of its DNA. It also has to produce two of everything that is in the cell. In addition, it has to go through the process of obtaining and digesting nutrients so that it has the raw materials for this duplication, as well as the energy required in order to carry out various functions of the cell.



**Figure 1.10** Cell cycle.

**Table 1.1** Stages of meiosis.

| First meiotic stage | Second meiotic stage |
|---------------------|----------------------|
| Prophase I          | Prophase II          |
| Metaphase I         | Metaphase II         |
| Anaphase I          | Anaphase II          |
| Telophase I         | Telophase II         |

**Meiosis**

During the reproduction of humans, the egg is penetrated by a sperm, which then releases its DNA to combine with the DNA of the egg, so that the resulting embryo has two copies of each of the 23 chromosomes in nucleated cells. If the sperm and eggs had two copies of each chromosome (like other cells), the resulting fusion and developing embryo would have four copies of each chromosome. This means that the next generation would have four copies of each chromosome. The generation after that would have eight copies, and so on. This is obviously not practical, so the sperm and eggs undergo a process known as meiosis to ensure that the resulting embryo will only carry two copies of each chromosome in each cell with a nucleus.

For descriptive purposes, meiosis can be divided into eight stages (not the four of mitosis). However, they have the same names, but are known as either I or II (Table 1.1). As with mitosis, these phases are continuous with one another. However, there are differences as well as similarities between mitosis and meiosis.

*First meiotic stage*

*Prophase I*

- This is similar to prophase in mitosis.
- However, instead of being scattered randomly, the chromosomes are arranged in 23 pairs. For example, the two chromosome number ones will pair up, as will the two chromosome number twos.
- Within each pair of chromosomes, genetic material may be exchanged between the two chromosomes.
- It is these exchanges that are partly responsible for the differences between children of the same parents.
- This process is called ‘gene cross-over’.

*Metaphase I*

As in mitosis, the chromosomes become arranged on the spindles at the equator. However, they remain in pairs.

*Anaphase I*

One chromosome from each pair moves to each pole, so that there are now 23 chromosomes at each end of the spindle.

*Telophase I*

The cell membrane now divides the cell into two halves, as in mitosis. Each daughter cell now has half the number of chromosomes that each parent cell had.

### Second meiotic stage

- The cells produced by the first meiotic division now divide again.
- Prophase II, metaphase II, anaphase II and telophase II are all similar to their equivalent stage in mitosis, with the exception that the DNA has not been replicated before prophase II, so there are only 23 single chromosomes in each of the granddaughter cells.

### Fusion of the gametes

- When the gametes, each with 23 chromosomes, fuse together, a cell known as a zygote with 23 paired chromosomes (i.e. 46 in all) is formed.
- One chromosome in each pair comes from the mother and one from the father.
- The zygotic cell then divides (by mitosis) many times to form the embryo.

## The organelles

All cells contain many organelles (little organs).

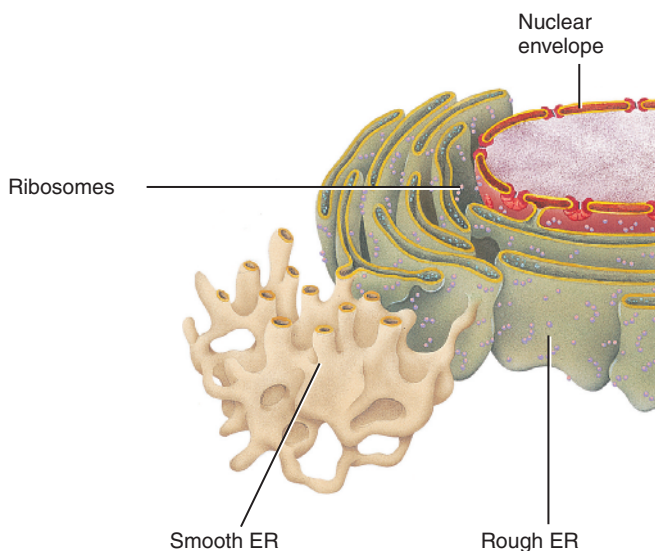
### Endoplasmic reticulum

It is believed that the endoplasmic reticulum (ER; Figure 1.11) is formed from the nuclear membrane.

The ER consists of membranes that form a series of channels (called cisternae) dividing the cytoplasm into compartments. The cisternae are concerned with the transport of materials, primarily proteins. The alteration or addition of proteins for export from the cell can occur within the cisternae. They also contain a number of enzymes of importance in cell metabolism, such as digestive enzymes, enzymes involved in the synthesis of steroids, and enzymes responsible for a variety of reactions leading to the removal of toxic substances from the cell (McCance *et al.*, 2014). The ER present in liver cells has a role in drug detoxification.

There are two types of cisternae:

1. granular (rough) ER – associated with ribosomes
2. agranular (smooth) ER – free of ribosomes.



**Figure 1.11** Endoplasmic reticulum (ER).

Granular ER is particularly well developed in cells that actively synthesise (produce) and export proteins. Agranular ER is found in steroid hormone secreting cells, such as the cells of the adrenal cortex or the testes. Ribosomes include tiny particles of RNA on which the synthesis of proteins needed by the cell takes place, and they are formed in the nucleoli.

## Golgi apparatus

The Golgi apparatus is a collection of membranous tubes and elongated sacs – actually flattened cisternae stacked together. It plays a part in concentrating and packaging some of the substances that are made in the cell, e.g. lysosomal enzymes. The complex also plays a part in the assembly of substances for secretion outside of the cell. Secretory cells (such as those found in the mucous membrane) have many Golgi stacks, whereas non-secretory cells have few Golgi stacks per cell.

Proteins for export from the cell are synthesised on the ribosomes, and then travel through the ER to the Golgi vesicles (a vesicle is a fluid-filled sac). Vesicles leaving the Golgi fuse with the cell membrane by the process of exocytosis. The contents of the vesicles are then exported out of the cell. In addition, the Golgi is itself involved in the formation of glycoproteins.

## Lysosomes

Lysosomes are organelles bound to the membrane and contain a variety of enzymes. Lysosomes have a number of functions:

- Digestion of material taken up by endocytosis, e.g. pathogenic organisms.
- Breakdown of cell components, e.g. during embryological development, the fingers and toes are webbed – the cells between the toes and fingers are removed by the lysosomal enzymes. After a baby's birth, the uterus, which weighs around 2 kg at full term, is invaded by phagocytic cells that are rich in lysosomes – these reduce the uterus to its non-pregnant weight of about 50 g within about 9 days.
- In normal cells, some of the synthesised proteins may be faulty – lysosomes are responsible for their removal.
- Contribute to hormone production, e.g. thyroxine – a hormone affecting a wide range of physiological activities, including metabolic rate.

It is important that lysosomes do not rupture and release their contents inside living cells; otherwise the lysosomal enzymes would start to digest the cell. In certain degenerative diseases, such as rheumatoid arthritis, enzymes released by the breakdown of lysosomes from macrophages may be a significant factor by attacking living cells and tissues.

## Peroxisomes

Peroxisomes are organelles similar in structure to lysosomes, but are much smaller. They are particularly abundant in liver cells. They contain several enzymes that are toxic to body cells. The role of peroxisomes in cells appears to be one of detoxification of harmful substances, such as alcohol and formaldehyde. More importantly, they 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 and Hoehn, 2015).

## Mitochondria (single = mitochondrion)

Mitochondria (often known as the power houses of the cell) consist of three membranes. The inner membrane has many folds that increase the surface area available for chemical reactions to occur. This process is collectively known as internal respiration. The mitochondrial matrix (the space surrounded by the inner membrane) contains enzymes of the

tricarboxylic acid (TCA) cycle, as well as enzymes involved in fatty acid oxidation. The inner membrane is of the same thickness as the outer membrane and is responsible for oxidative phosphorylation. The mitochondria themselves are often found concentrated in regions of the cell associated with intense metabolic activity.

By using ATP, the mitochondria are able to generate the energy needed by the cell for it to function by converting the chemical energy contained in molecules of food. The production of ATP requires the breakdown of food molecules, and it occurs in several stages, each requiring the appropriate enzyme. An enzyme is a protein that can initiate and speed up a chemical reaction (it acts as a catalyst). The enzymes in the mitochondria are stored in the membranes in the required order so that the reactions occur in the correct sequence. This is very important, as it would be disastrous if the chemical reactions occurred out of sequence.

Mitochondria are self-replicating – just like the cells. DNA that is incorporated into the mitochondrial structure controls the replication process.

## Cytoskeleton

The cytoskeleton is a lattice-like collection of fibres and fine tubes in the cytoplasm, and it is involved in the cell's maintenance and alteration of its shape as required.

There are three components of the cytoskeleton:

1. microfilaments
2. microtubules
3. intermediate filaments.

### Microfilaments

Microfilaments are rod-like structures, 6 nm in diameter, consisting of a protein called actin. In muscle, both actin (thick) and myosin – another protein (thin) are involved in the contraction of muscle fibres. In non-muscle cells, microfilaments help to provide support and shape to the cell, and also assist in the movement of cells as well as movement within the cells.

### Microtubules

Microtubules are relatively straight, slender, cylindrical structures that range in diameter from 18 to 30 nm. They consist of a protein called tubulin. Microtubules, like microfilaments, help to provide shape and support for cells. They also provide conducting channels through which various substances can move through the cytoplasm, and assist in the movement of pseudopodia.

### Intermediate filaments

Intermediate filaments range in diameter from 8 to 12 nm and also help to determine the shape of the cell. Examples of intermediate filaments are neurofilaments found in the nerve.

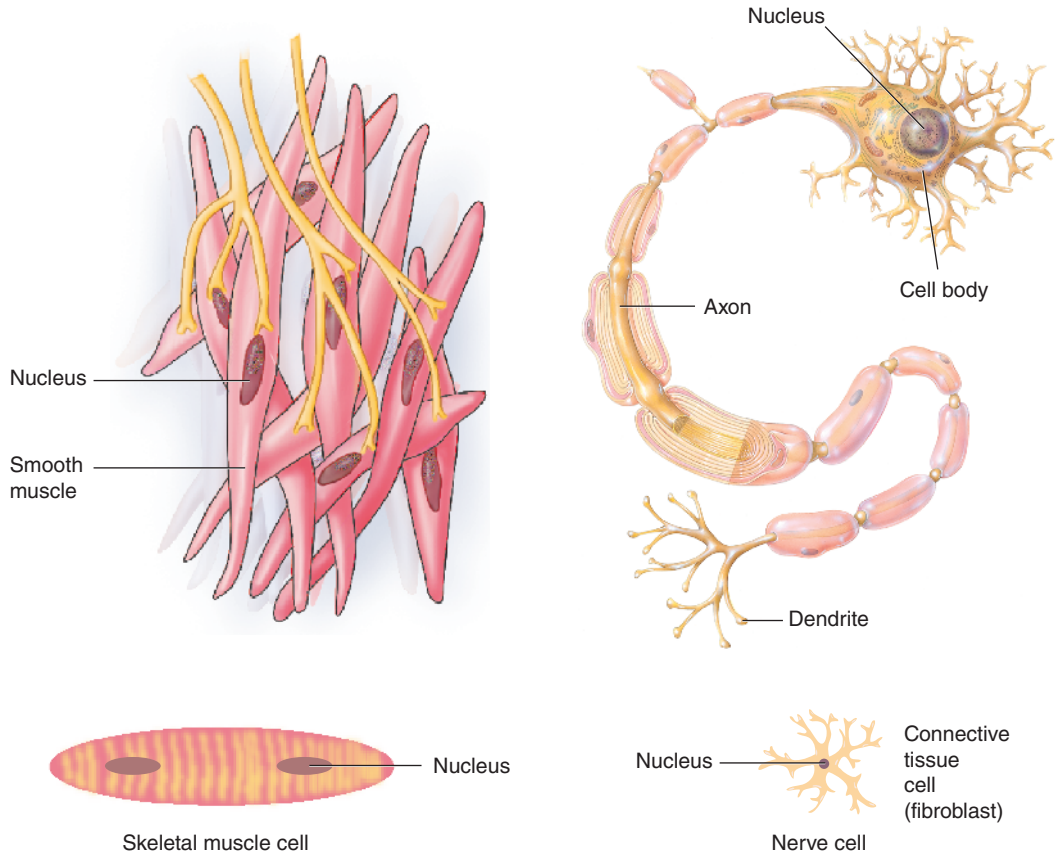
## Centrioles, cilia and flagella

### Centrioles

Centrioles are found in most animal cells and are cylindrical structures. They are composed of nine sets of microtubules arranged in a circular pattern. They are involved in cell reproduction.

### Cilia and flagella

Cilia and flagella extend from the surface of some cells and can bend, thus causing movement. In humans, cilia generally have the function of moving fluid or particulates over the surface of cells. Ciliated cells of the respiratory tract move mucus that has trapped foreign particles over the surface of respiratory tissues. A flagellum is usually a much larger structure than a cilium and is often used like a tail to propel the cell forward. The only example of a cell in the human body with a flagellum is the sperm, where the flagellum acts as a tail and propels the sperm towards the ova.



**Figure 1.12** Types of cells.

## Types of cells

Figure 1.12 illustrates some of the cells that make up certain tissues.

## Tissues

A human begins as a single cell – the fertilised egg. As soon as fertilisation takes place, the egg divides continuously. However, these cells do not divide endlessly and haphazardly. They divide and grow together in such a way that they become specialised, e.g. muscle cells, skin cells, cells of the lens of the eye and blood cells (Marieb, 2015). Cells group together to become tissues. Tissues are basically groups of cells that are similar in structure and generally perform the same functions (McCance *et al.*, 2014). There are four primary types of tissues:

1. epithelial
2. connective
3. muscle
4. nervous.

Most organs of the body contain all four types of tissue. All four have distinct functions that help to maintain homeostasis. For instance:

1. Epithelial tissue is concerned with 'covering'.
2. Connective tissue is concerned with 'support'.
3. Muscle tissue is concerned with 'movement'.
4. Nervous tissue is concerned with 'control' (Wheeldon, 2016).

Specialised cells form themselves into tissue in one of two ways. The first way is by mitosis. Cells formed as a result 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 of cells will all be of the same type and have the same function – they will become tissue. For example, epithelial cell sheets (such as skin) are formed as a result of mitosis (McCance *et al.*, 2014).

The second way involves the migration of specialised cells to the site of tissue formation and then assembling there. 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 *et al.*, 2014). This movement of cells is known as chemotaxis. Chemotaxis is discussed in detail in Chapter 3, but put simply, it is the 'movement along a chemical gradient caused by chemical attraction' (McCance *et al.*, 2014).

## Epithelial tissue

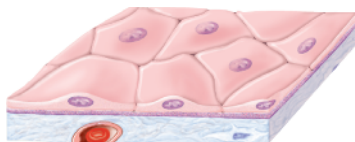
Epithelial tissue lines and covers areas of the body, as well as forming the glandular tissue of the body. So, the exterior of the body is covered by one type of epithelial tissue (the skin), whilst another type of epithelial tissue lines some digestive system organs, such as the stomach and the small intestines, and the kidneys. In effect, epithelial tissue covers most of the internal and external surfaces of the body.

Epithelial tissue is classified into two ways:

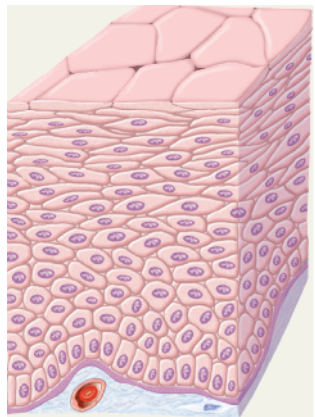
1. by the number of cell layers:
  - simple – where the epithelium is formed from a single layer of cells (Figure 1.13).
  - stratified – where the epithelium has two or more layers of cells (Figure 1.14).
2. shape:
  - squamous
  - cuboidal
  - columnar.

Simple epithelial tissues are most concerned with absorption, secretion and filtration, but because they are usually very thin, they are not involved in protection.

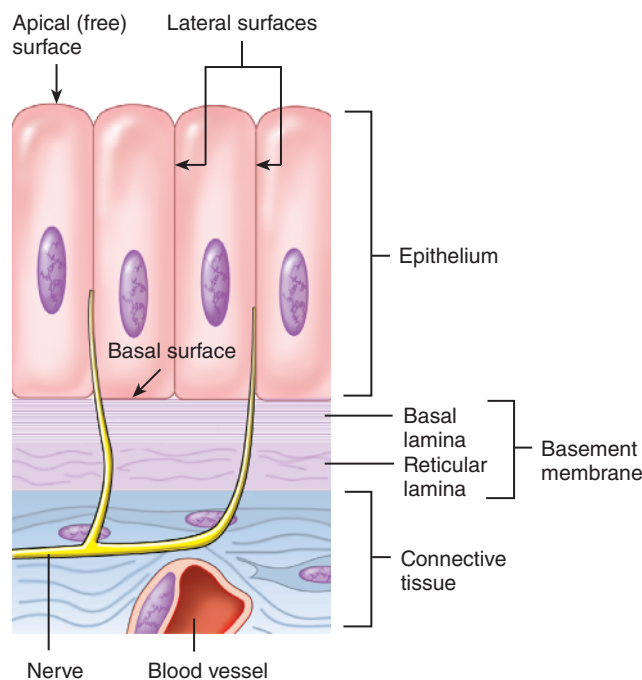
Simple squamous epithelium rests on a basement membrane (basal layer). The basement membranes provide a layer of cells that supports and separates epithelial tissue from underlying connective tissue. Squamous epithelial cells fit very closely together to form a thin sheet of tissue. It is this type of epithelial tissue that is found in the alveoli of the lungs and the walls of capillaries. Rapid diffusion of filtration can take place through this very thin tissue. Oxygen and carbon dioxide exchange takes place through the epithelial tissue lining



**Figure 1.13** Simple epithelium.



**Figure 1.14** Stratified epithelium.



**Figure 1.15** Epithelial cells classified according to shape.

the alveoli of the lungs, whilst nutrients and gases can pass through the epithelial tissue from the cells into and out of the capillaries. In addition, simple squamous epithelial cells form serous membranes that line certain body cavities and organs (Wheeldon, 2016).

Simple cuboidal epithelial tissue consists of one layer of cells resting on a basement membrane. However, because cuboidal epithelial cells are thicker than squamous epithelial cells, they are found in different places of the body and perform different functions. This epithelial tissue is found in glands, such as the salivary glands and the pancreas, as well as forming the walls of kidney tubules and covering the surface of the ovaries (Marieb, 2015).

Simple columnar epithelium (Figure 1.15), whilst being composed of a single layer of cells, is made up of a single layer of quite tall cells that, like the other two types, fit closely together.

This epithelial tissue lines the entire length of the digestive tract from the stomach to the anus and contains goblet cells. Goblet cells produce mucus, and those simple columnar epithelial tissues that line all the body cavities that are open to the body exterior are known as mucous membranes (Marieb, 2015).

Stratified epithelial tissue, unlike the simple epithelial tissue, consists of two or more cell layers. Because these stratified epithelial tissues have more than one layer of cells, they are stronger and more robust than the simple epithelia. This means that a primary function of stratified epithelia is protection.

Stratified squamous epithelial tissue (Figure 1.14) is the most common stratified epithelium in the human body, and it consists of several layers of cells (Marieb, 2015). Although this epithelial tissue is called squamous epithelium, in actual fact, it is not made up entirely of squamous cells. It is the cells at the free edge of the epithelial tissue that are composed of squamous cells, whilst those cells that are close to the basement membrane are composed of either cuboidal or columnar cells. Squamous epithelium is found in places that are most at risk of everyday damage, including the oesophagus, the mouth and the outer layer of the skin (Marieb, 2015).

Stratified cuboidal epithelial tissue only has two cell layers and is fairly rare in the human body, only being found in the ducts of large glands. The same can be said of the stratified columnar epithelial tissue.

There is a fourth type of epithelial tissue, known as transitional epithelium. This is a highly modified stratified squamous epithelium and it forms the lining of just a few organs/structures – all of which form part of the urinary system – the urinary bladder, the ureters and part of the urethra. This type of tissue has been modified to cope with the considerable stretching that these organs undergo. So, when one of these organs or structures is not stretched, the tissue has many layers with the superficial (those in the top layer) cells being rounded and looking like domes. However, when distended with urine, the epithelium becomes thinner, the surface cells flatten and they become just like squamous cells. These transitional cells are able to slide past one another and change their shape, allowing the wall of the ureter to stretch as a greater volume of urine flows through. Similarly, it allows for more urine to be stored in the bladder (Marieb, 2015).

## Glandular epithelium

Glandular epithelial tissue is found within glands. According to Marieb (2015), a gland consists of several cells that make and secrete a particular product.

Two major types of glands develop from epithelial sheets:

1. exocrine glands
2. endocrine glands.

Exocrine glands have ducts leading from them, and their secretions empty through these ducts to the surface of the epithelium. Examples of exocrine glands include the sweat glands, the liver and the pancreas.

Endocrine glands, on the other hand, do not possess ducts. Instead, their secretions diffuse directly into the blood vessels that are found within the glands. All endocrine glands secrete hormones. These glands include the thyroid, the adrenal glands and the pituitary gland.

## Connective tissue

Connective tissue is found everywhere in the body and it connects body parts to one another. It is the most abundant and widely distributed of all four primary tissue types. It varies considerably in structure and has four main functions:

1. protection
2. support

3. binding together other tissues (Marieb, 2015)
4. acting as storage sites for excess nutrients (McCance *et al.*, 2014).

However, the most common structure and function of connective tissue is to act as the framework on which the epithelial cells gather in order to form the organs of the body (McCance *et al.*, 2014).

There are several common characteristics of connective tissue. One is that there are few cells in the tissue, but surrounding these few cells there is a great deal of what is known as extracellular matrix. This extracellular matrix is composed of ground substance and fibres and it varies in consistency from fluid to a semisolid gel. The fibres are made up of fibroblasts – one of the connective tissue cells, and are of three types:

1. collagen (white) fibres
2. elastic (yellow) fibres
3. reticular fibres.

Collagen fibres have great strength, whilst elastic fibres can stretch and then recoil. The reticular fibres form the internal 'skeleton' of soft organs such as the spleen.

The ground substance is composed largely of water plus some adhesion proteins and large polysaccharide molecules, and it is these adhesion proteins that serve as a glue that attaches the connective tissue cells to the fibres. The change of consistency within the ground substance from fluid to a semisolid gel depends upon the number of polysaccharide molecules that are present. An increase in polysaccharide molecules causes the matrix to move from being a fluid to being a semisolid gel. The ground substance can store large amounts of water, so it serves as a water reservoir for the body (Marieb and Hoehn, 2015).

Connective tissue forms a 'packing' tissue around organs of the body (very much like the packing that can surround a delicate object in a parcel in transit) and so protects them. It is able to bear weight and to withstand stretching and various traumas, such as abrasions. There is a wide variation in types of connective tissue, e.g. fat tissue is composed mainly of cells and a soft matrix. Bone and cartilage have very few cells but do contain large amounts of hard matrix and that is what makes them so strong (Marieb, 2015).

There are also variations in the blood supply to the tissue. Although most connective tissues have a good blood supply, there are some types, e.g. tendons and ligaments, that have a poor blood supply, whilst cartilage has no blood supply. That is the reason why these structures heal very slowly when they are injured – often a broken bone will heal much quicker than a damaged tendon or ligament (Marieb, 2015).

## Bone

Bone is the most rigid of the connective tissues and it is composed of bone cells surrounded by a very hard matrix containing calcium and large numbers of collagen fibres. Because of their hardness, bones provide protection, support and muscle attachment (Marieb, 2015).

## Cartilage

Cartilage, which is not as hard, but is more flexible than bone, is found in only a few places in the body, e.g. hyaline cartilage that supports the structures of the larynx. It attaches the ribs to the sternum and covers the ends of the bones where they form joints (Marieb and Hoehn, 2015). Other types of cartilage include fibrocartilage which, because it can be compressed, forms the discs between the vertebrae of the spinal column, and elastic cartilage where some degree of elasticity is required, e.g. in the external ear.

## Dense connective tissue

Dense connective tissue forms strong, stringy structures such as tendons (which attach skeletal muscles to bones) and the more elastic ligaments (that connect bones to other bones).

at joints). Dense connective tissue also makes up the lower layers of the skin (known as the dermis). These tissues have collagen fibres as the main matrix element, with many fibroblasts found between the collagen fibres (Marieb, 2015). These fibroblasts are the cells that are involved in the manufacture of the fibres.

### *Loose connective tissue*

Loose connective tissue is softer and contains more cells, but fewer fibres, than other types of connective tissue (with the exception of blood). There are four types of loose connective tissue:

1. areolar tissue
2. adipose tissue
3. reticular tissue
4. blood.

#### *Areolar tissue*

Areolar tissue is the most widely distributed connective tissue type in the body. It is a soft tissue that cushions and protects the body organs that it surrounds. It helps to hold the internal organs together. It has a fluid matrix that contains all types of fibres which form a loose network, so giving it its softness and pliability. It provides a reservoir of water and salts for the surrounding tissues. All body cells obtain their nutrients from this tissue fluid and also release their waste into it. It is also in this area that, following injury, swelling can occur (known as oedema) because the areolar tissue soaks up the excess fluid just like a sponge does, causing it to become puffy (Marieb and Hoehn, 2015).

#### *Adipose tissue*

Adipose tissue is commonly known as 'fat' and is actually areolar tissue in which there is a preponderance of fat cells. It forms the subcutaneous tissue which lies beneath the skin where it insulates the body and can protect it from the extremes of both heat and cold (Marieb and Hoehn, 2015). In addition, adipose tissue protects some organs, such as the kidneys and eyeballs.

#### *Reticular connective tissue*

Reticular connective tissue consists of a delicate network of reticular fibres that are associated with reticular cells (similar to fibroblasts). 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 (Marieb and Hoehn, 2015).

#### *Blood*

'Blood, or vascular tissue, is considered a connective tissue because it consists of blood cells, surrounded by a non-living, fluid matrix call blood plasma' (Marieb and Hoehn, 2015). Blood is concerned with the transport of nutrients, waste material, respiratory gases (such as oxygen and carbon dioxide), as well as many other substances throughout the body.

### *Muscle tissue*

There are three types of muscle tissue and these are responsible for helping the body to move, or to move substances within the body:

1. skeletal muscle
2. cardiac muscle
3. smooth muscle.

#### *Skeletal muscle*

Skeletal muscle is attached to bones and is involved in the movement of the skeleton. These muscles can be controlled voluntarily and form the 'bulk' of the body (the flesh). The cells of skeletal muscle are long, cylindrical and have several nuclei. In addition, they appear striated

(have stripes). They work by contracting and relaxing, with pairs working antagonistically, i.e. one muscle contracts and the opposite muscle relaxes. So, for example, if the muscles in the front of the arm contract and the ones at the back of the arm relax, then the arm bends.

### Cardiac muscle

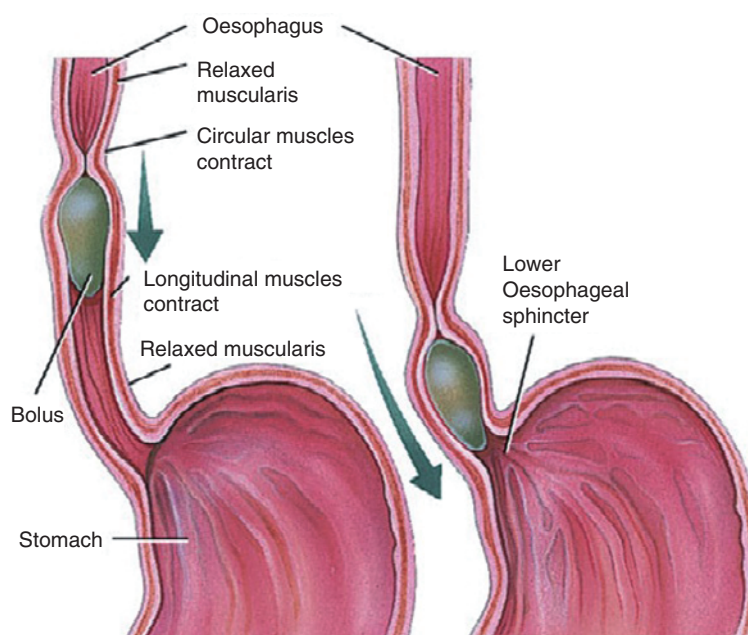
Cardiac muscle is only found in the heart and it pumps blood around the body. It does this by contracting and relaxing, just like skeletal muscle, and it appears striated. However, unlike skeletal muscles, it works in an involuntary way – the activity cannot be consciously controlled. The cells of cardiac muscle do not have a nucleus.

### Smooth muscle

Also known as visceral muscle, smooth muscle (see Figure 1.12) is found in the walls of hollow organs, e.g. the stomach, bladder, uterus and blood vessels (hence 'visceral' because these organs are also known as 'viscera'). Smooth muscle has no striations, and like cardiac muscle it works in an involuntary way. Smooth muscle causes movement in the hollow organs, i.e. as it contracts, the cavity of an organ becomes smaller (constricted) and when it relaxes the organ becomes larger (dilated). This allows substances to be propelled through the organ in the right direction, e.g. faeces in the intestines. Because smooth muscle contracts and relaxes slowly, it forms a wavelike motion (known as peristalsis) that pushes, in the case of the intestines, the faeces through the intestines (Figure 1.16).

### Nervous tissue

Nervous tissue is concerned with control and communication within the body by means of electrical signals. The main type of cell that is found in nervous tissue is the neuron (see Figure 1.12). All neurons receive and conduct electrochemical impulses around the body. The structure of neurons is very different from that of other cells. The cytoplasm is found within long processes or extensions – some in the leg being more than a metre long. These neurons receive and transmit electrical impulses very rapidly from one to the other across synapses



**Figure 1.16** Peristalsis.

(junctions). It is at the synapses that the electrical impulse can pass from neuron to neuron, or from a neuron to a muscle cell. The total number of neurons is fixed at birth, and cannot be replaced if they are damaged (McCance *et al.*, 2014).

In addition to the neurons, nervous tissue includes cells known as neuroglia-supporting cells. These supporting cells insulate, support and protect the delicate neurons. The neurons and supporting cells make up the structures of the nervous system:

- the brain
- the spinal cord
- the 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 tissue injury or damage does occur, this stimulates the body's inflammatory and immune responses to spring into action so that the healing process can begin almost immediately.

There are four major signs and symptoms of an inflammatory response (Nairn and Helbert, 2002):

1. pain
2. swelling
3. heat
4. redness.

There may also be nausea, sweating, a raised pulse, a lowered blood pressure and even a loss of consciousness. These symptoms are the body's response to the pain and to shock.

Inflammation is usually initiated by damage to a cell. Following this damage, three simultaneous processes occur:

1. Mast cell degranulation – mast cells are tissue cells which contain granules in their cytoplasm. These granules are similar to, but smaller than, the granules found in basophils in the blood. These granules contain, amongst other substances, histamine which, during the process of degranulation, is released into the tissues. It causes some inflammatory symptoms and works with the two other processes listed here to provide full inflammatory symptoms.
2. The activation of four plasma protein systems – these systems are the complement, clotting and kinin systems, and immunoglobulins (antibodies). The complement system activates and assists inflammatory and immune processes. It also plays a major role in the destruction of bacteria. The clotting system traps bacteria that have entered the wound and also interacts with platelets to stop any bleeding. The kinin system helps to control vascular permeability, whilst immunoglobulins help in the destruction of bacteria.
3. The phagocytic cells move to the area of damage in order to phagocytose bacteria or any other non-self debris in the wound.

A typical inflammatory response to injured tissue is:

- Arterioles near the injury site constrict briefly, followed by vasodilation which increases blood flow to the site of the injury (redness and heat).
- Dilation of the arterioles at the site increases the pressure in the circulation, which increases the movement of plasma proteins and blood cells into the tissues in the area, so causing oedema (swelling).

- The nerve endings in the area are stimulated, partly by pressure (pain).
- The clotting and kinin systems, along with platelets, move into the area and block any tissue tears by commencing the clotting process.
- Phagocytes and lymphocytes move into the area and start to destroy any infectious organisms found there and remove pus.
- These blood cells remain in the area until tissue regeneration (repair) takes place – known as resolution.

Thus, inflammation can be summed up as the presence of:

- vasodilation – redness/heat
- vascular permeability – oedema
- cellular infiltration – pus
- thrombosis – clots
- stimulation of nerve endings – pain.

## Conclusion

This chapter has looked at the building blocks of the human body, namely the cells. Cells are extremely complicated parts of the body, but an understanding of them and their functions is important in order to understand how the human body itself functions. Cells form tissues, which then form all the structures, systems and organs of the body. Therefore, it is necessary to also have an understanding of tissues. The remainder of this book will look at the various systems, structures and organs of the body – how they function as well as what can go wrong with them.

## Test your knowledge

- How does the cell membrane control metabolism?
- Explain briefly the differences between phagocytosis, receptor-mediated endocytosis and pinocytosis.
- How does the process of cellular reproduction ensure that there are only 46 (23 pairs) chromosomes in a foetus?
- Describe the function of connective tissue.
- Briefly explain the roles of the four plasma protein systems in the process of tissue repair.

## Activities



Here are some activities and exercises to help test your learning. For the answers to these exercises, as well as further self-testing activities, visit our website at [www.wiley.com/go/fundamentalsofappliedpathophysiology3e](http://www.wiley.com/go/fundamentalsofappliedpathophysiology3e)

## Fill in the blanks

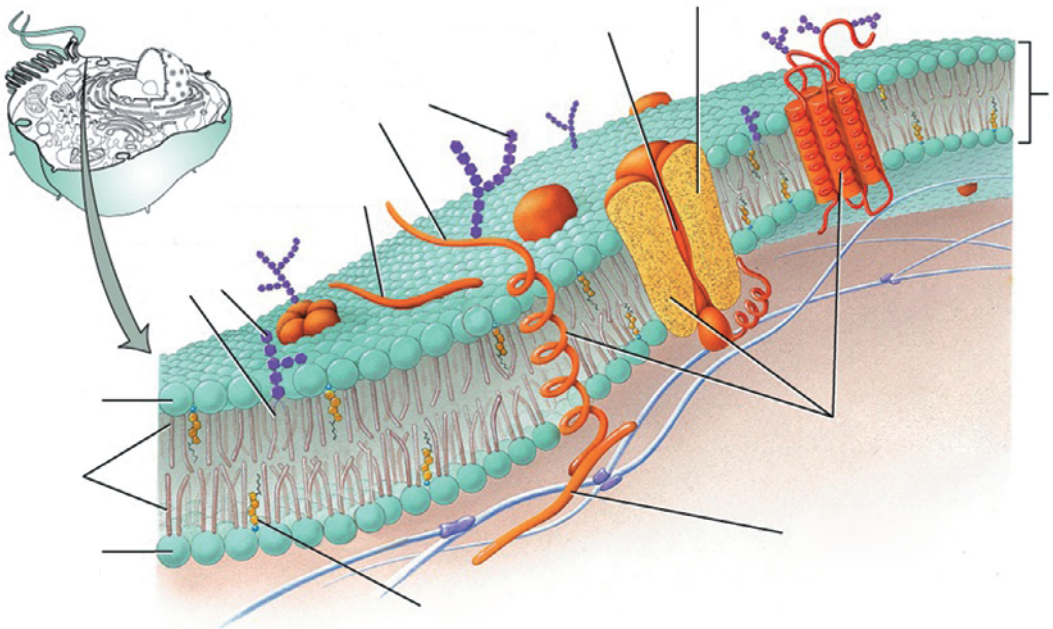
Connective tissue \_\_\_\_\_ body parts to one another. In addition to binding and storage its other main functions are \_\_\_\_\_ and \_\_\_\_\_. Connective tissue cells are surrounded by a collection of substances referred to as the \_\_\_\_\_, which is composed of \_\_\_\_\_ and fibres. There are three types of fibre found in connective tissue. The \_\_\_\_\_ fibres provide strength, whereas elastic fibres are able to \_\_\_\_\_ and \_\_\_\_\_. \_\_\_\_\_ fibres form the internal \_\_\_\_\_ of \_\_\_\_\_ such as the spleen. There are several types of connective tissue. \_\_\_\_\_ is the most rigid, whereas \_\_\_\_\_ is more flexible. Dense connective tissue consists of stringy structures called \_\_\_\_\_, which attach \_\_\_\_\_ to bone. Loose connective tissue is much softer and comes in four main forms, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.

Choose from:

Blood; Reticular; Stretch; Support; Areolar; Cartilage; Connects; Collagenous; Skeleton; Tendons; Adipose; Extracellular matrix; Protection; Ground substance; Recoil; Skeletal muscle; Reticular; Bone; Soft organs

## Label the diagram

Using the list of words supplied, label the diagram:



Glycolipid (carbohydrate lipid); Glycoprotein (Carbohydrate protein); phospholipid heads; Integral transmembrane protein; Peripheral protein; Fatty acid tails

# Word search

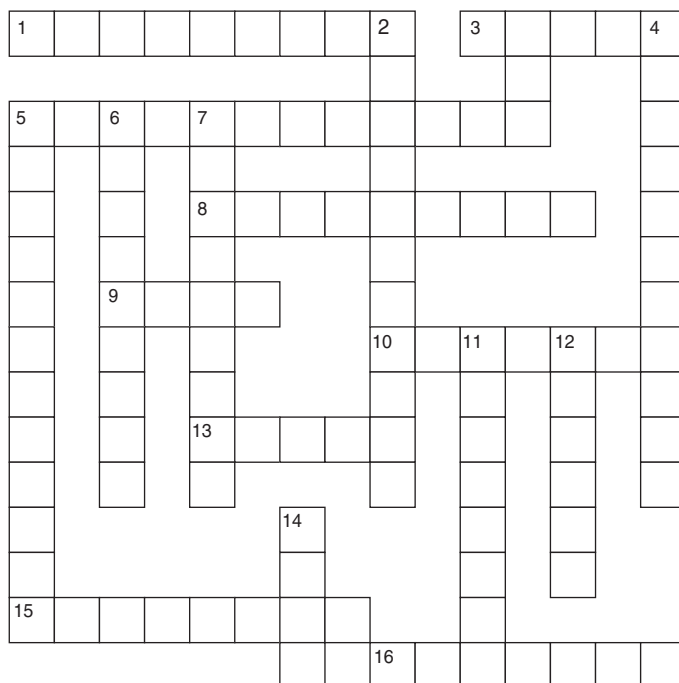
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|                 |              |              |
|-----------------|--------------|--------------|
| Epithelial      | Muscle       | Osmosis      |
| Plasma membrane | Lysosome     | Exocytosis   |
| Organelles      | Bone         | Cytoplasm    |
| Connective      | Mitochondria | Ribosome     |
| Nucleus         | Flagella     | Cytoskeleton |
| Cell cycle      | Prophase     | Tissue       |

## Crossword

Complete the crossword below



### Across

1. Basic functional unit of a cell (9)
3. Adipose and blood are examples of this type of connective tissue (5)
5. The powerhouse of the cell (12)
8. The fibres that form the internal skeleton of internal organs (9)
9. One of the classic signs of inflammation (4)
10. The passive movement of water (7)
13. \_\_\_\_\_ apparatus (5)
15. The secretion of these glands empty through ducts to the surface of epithelium (8)
16. The most widely distributed connective tissue type in the human body (7)

### Down

2. Term used to describe process by which cells ingest foodstuffs and infectious micro-organisms (11)
4. Rough \_\_\_\_\_ reticulum (11)
5. Cells that collectively are concerned with movement (6,6)
6. Fourth stage of mitosis (9)
7. Type of connective tissue that has no blood supply (9)
11. The outer covering of a cell (8)
12. Substance that is dissolved in a solution (6)
14. Biological unit of heredity (4)

## Glossary of terms

**Active transport** the process in which substances move against a concentration gradient from an area of low concentration to one of higher concentration. It requires the release and use of energy.

**Active transport pump** also known as a sodium pump, this is situated in the plasma membrane and uses the energy produced by the ATP reaction to pump sodium ions ( $\text{Na}^+$ ) out of the cell and potassium ions ( $\text{K}^+$ ) into it.

**Adenosine diphosphate (ADP)** found inside cells, it helps to produce ATP during reactions which produce cellular energy and is itself formed from ATP at a later stage. It is this continual synthesis and breaking down of ADP and ATP that produces the energy.

**Adenosine triphosphate (ATP)** a compound of an adenosine molecule with three attached phosphoric acid molecules. Essential for the production of cellular energy.

**Amino acid** the building block of proteins. The type of protein that is produced depends upon the number and types of amino acids that are used to construct it.

**Carbohydrate** an organic compound that is composed of carbon, hydrogen and oxygen. Sugars (including glucose) and starch are carbohydrates. They are very important as an energy store.

**Carrier/transport protein** a small molecule that helps in the movement of ions across a cell membrane.

**Catalyst** a substance that speeds up a reversible chemical reaction. Enzymes are catalysts.

**Chemical reaction** a reactions in which molecules are formed, changed or broken down.

**Chromatid** one of the two strands of chromatin. Two identical chromatids form a chromosome after nuclear reproduction.

**Chromatin** the material which forms chromosomes. It consists of DNA and proteins.

**Chromosomes** tightly coiled chromatin. This is the form in which the genetic material of all cells is organised.

**Concentration gradient** the gradient that demonstrates the difference between an area of high concentration and one of low concentration of a substance.

**Cytoplasm** collective name for all the contents of the cell, including the plasma membrane, but not including the nucleus.

**Deoxyribonucleic acid (DNA)** found in the nucleus, it contains all the genetic information of an organism.

**Diffusion** the passive movement of molecules or ions from a region of high concentration to one of low concentration until a state of equilibrium is achieved.

**Endocytosis** the general name for the various processes by which cells ingest foodstuffs and infectious micro-organisms.

**Enzyme** a protein that speeds up chemical reactions.

**Eukaryotic cell** a cell that normally includes, or has included, chromosomal material within one or more nuclei.

**Exocytosis** the system of transporting material out of cells.

**Extracellular fluid** the fluid outside of the cell and bathes the body's cells.

**Extracellular matrix** found in connective tissue, this is non-living material that is made up of ground substance and fibres. It separates the living cells found in this tissue.

**Facilitated diffusion** similar to diffusion, this requires the help of another substance – a carrier protein – for the process to take place (i.e. a facilitator).

**Fibre** are any long, thin structures. The body contains many of them, including nerve fibres and muscle fibres.

**Fibroblast** the most common connective tissue cell and only found in the tendons. It is responsible for the production and secretion of extracellular matrix materials.

**Gene** the smallest physical and biological unit of heredity that encodes for a molecular cell product.

**Genetic material** mainly DNA (deoxyribonucleic acid) that contains genetic information.

**Glucose** also known as dextrose, it is the principal sugar found in the blood. It is essential for life. An absence can lead to diabetes, coma and even death.

**Glycoprotein** a protein linked to carbohydrates.

**Goblet cell** a mucus-secreting cell found in epithelial tissue.

**Ground substance** the part of the extracellular matrix (found in connective tissue) that is composed mainly of water, with some adhesion proteins and large polysaccharide molecules.

**Hormone** a chemical messenger that is linked to the endocrine system, and that has a physiological control over the function of cells or organs other than those that created it.

**Inorganic substance** a compound that does not contain carbon (e.g. water).

**Internal respiration** the use of oxygen by cells in the enzymatic release of energy from organic compounds. This is known as aerobic respiration. Anaerobic respiration does not require oxygen, but does require a substance such as nitrate or iron to do the same job as oxygen (accept electrons during the chemical reaction). Only human cells with mitochondria can undertake aerobic respiration.

**Ion** an atom or group of atoms that carries either a positive or a negative electrical charge.

**Lipid** an energy-rich organic compound that is soluble in organic substances such as alcohol and benzene.

**Lysosome** an organelle within the cell that is an important part of the cell's digestive system because it secretes lysosyme and other similar enzymes, which are very important in the phagocytosis of micro-organisms.

**Lysosyme** a bacteria-destroying enzyme found in lysosomes, sweat, tears, saliva and other bodily secretions.

**Meiosis** the process by which the gametes (spermatozoa and ova) are reproduced.

**Membrane** the outer covering of a cell and of a nucleus within a cell.

**Metabolism** the collective name for all the physical and chemical processes occurring within a cell/living organism, but often referring only to reactions involving enzymes.

**Metabolite** a substance involved in the process of metabolism – either to cause it, assist it or occurring as a result of the process.

**Mitosis** the process by which cells (other than the gametes) are reproduced by simple division of the nucleus and the cell itself.

**Neuroglia-supporting cell** a cell found in nervous tissue; its role is to support the delicate neurons by insulating, supporting and protecting them.

**Nuclear membrane** the outer shell of the nucleus within the cell.

**Nucleolus** a small spherical body found in the cell nucleus that is involved in the production of ribosomes.

**Nucleoplasm** the protoplasm found within the nucleus.

**Nucleosome** the basic structural unit of a chromosome.

**Organelle** a structural and functional part of a cell that acts like human organs to fulfil all the needs of the cell so that it can grow, reproduce and carry out its functions.

**Osmosis** the passive movement of water through a selectively permeable membrane from an area of high concentration of a chemical to an area of low concentration.

**Osmotic pressure** the pressure that must be exerted on a solution to prevent the passage of water into it across a semipermeable membrane from a region of higher concentration of solute to a region of lower concentration of solute.

**Oxidative phosphorylation** the process by which energy released during aerobic respiration and is linked to the production of adenotriphosphate (ATP).

**Passive transport** the process by which substances move on their own down a concentration gradient from an area of high concentration to one of lower concentration. No cellular energy is required for this process.

**Phagocytosis** the method by which cells ingest large particles, including whole micro-organisms.

**Pinocytosis** the method by which cells ingest small particles and fluids.

**Prokaryotic cell** the opposite of eukaryote cell; their DNA/RNA is not contained within a discrete nucleus. They are generally very small bacteria for example.

**Protoplasm** the collective name for everything within the cell, including the cytoplasm, nucleus and the organelles, as well as the plasma membrane.

**Ribosomal ribonucleic acid (rRNA)** a highly selective method by which the cell is able to ingest large particles (particularly proteins).

**Receptor site** also known as membrane receptor molecule. This is a protein on the membrane of cells that is able to receive certain other proteins that match them (e.g. hormones and antibodies).

**Receptor-mediated endocytosis** involved in the translation of the genetic material encoded in DNA into proteins. It works in conjunction with ribosomes and messenger RNA (mRNA) and transfer RNA (tRNA).

**Ribosome** an organelle found in cytoplasm that plays a major role in the synthesis of proteins from RNA.

**Selective permeability** the ability of the cell membrane to allow only certain substances to pass into or out of the cell.

**Simple fission** the asexual reproduction of cells by means of division of the nucleus and the cell body.

**Solute** a substance that is dissolved in a solution.

**Transmembrane ion gradient** the gradient in the concentration of ions on either side of a plasma membrane. It is involved in the production of cellular energy.

**Tricarboxylic acid cycle** also known as the Krebs cycle. This is an aerobic pathway that occurs in the mitochondria and is necessary for the production of energy there.

**Vesicle** a spherical space within the cell cytoplasm that is involved in the storage and transfer of substances for the cell.

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