THE HUMAN CELL

2

UNDERSTAND: KEY CONCEPTS

Before working through this chapter, you might find it useful to watch these external video clips on the human cell.

The URLs for these videos can be accessed via the companion website https://edge.sagepub.com/essentialaandp.

INTRODUCTION TO CELLS (2:54)

CELL STRUCTURE AND FUNCTION (9:06)

LEARNING OUTCOMES

When you have finished studying this chapter you will be able to:

1. Describe the structure and functions of the different components of human body cells
2. Describe the two types of cell division: meiosis for the formation of gametes for reproduction, and mitosis involved in growth and development
3. Identify how different types of body cells are adapted for their different functions and how they interact synergistically

INTRODUCTION

In the previous chapter you were introduced to the systems of the multicellular body which supply the necessary conditions for life. It will make understanding the human body easier if you know rather more about how each cell works and this chapter focuses on the structure and function of the different types of cell in the human body.

The two types of cell division will also be examined:

- **mitosis** for growth and repair of tissues,
- **meiosis** for creation of sperm or ova (gametes) containing half the normal genetic material for formation of the next generation.

Context

During the life story of every individual the balance in the cells of which they are composed goes through various stages. Cell multiplication increases the number of body cells while apoptosis (programmed cell death) reduces this number. Both processes occur throughout life but the balance between them varies and permits normal growth and development.

THE BODIE FAMILY

The Bodie family members are at different stages of the life-cycle. Danielle, the baby, is growing fast with cell multiplication occurring rapidly but apoptosis (programmed cell death) contributing to shaping and reshaping of the body as she moves through infancy and childhood, adolescence and adulthood.

In the younger adults (Thomas (30), Derek (29), Michelle and Margaret (27), Kwame (28)), cell multiplication and cell death are roughly in balance, with a good state of health and physical strength. The older adults (Edward (57), Sarah (55), Hannah and Richard (both 54)), are likely to have moved towards a preponderance of cell death although they are still in general good health. Physical strength and health tends to be maintained in those who undertake regular exercise as Matthew does (45).

The grandparents (George (84) and Maude (77)) are very likely to have more cell death than cell multiplication occurring and their general health and tolerance for activity are probably deteriorating.

While this brief consideration of the Bodies provides some guidance, it is important to recognise the considerable variation between individuals in their physical status through the life span. Person-centred practice requires consideration of individual variation in all aspects of a person.

THE CELL

Introduction

This chapter focuses on the human cell and how it works. However, although not essential, it is interesting to understand where this fits in the wider biological context.

GO DEEPER

Types of living cells

There are three types of living cell, two prokaryotes and the eukaryotes:

Prokaryotes (before nucleus): there are two of these – bacteria and archaea, both of which are single-celled organisms without membrane-bound organelles (small organs) with specialist functions such as a nucleus, mitochondria, etc.:

Bacteria (bacterium – singular) very similar to archaea in size and shape;

Archaea (archaeon – singular) much of its metabolism is more similar to eukaryotes than bacteria.

Eukaryotes: have well-defined membrane-bound nuclei and organelles and form all the multicellular organisms on earth. Lane (2015) has proposed that these developed through endosymbiosis in which these complex cells arose from a unique merger of a bacterium into an archaeon resulting in the first eukaryote from which all others evolved. The bacterium replicated, transferred much of the surplus DNA (genetic material – see later in this chapter) to the host archaeal chromosomes, and developed into the mitochondria. The major benefit is the large amount of Adenosine Triphosphate (ATP) available from the mitochondria thus increasing the energy available and quantity of protein formed.

The human (mammalian) cell is a complex structure able to carry out all the functions required to maintain cell life and also makes its contribution to homeostasis through the activities of the different organelles (small organs) within the cell. Figure 2.1 illustrates a generic cell filled with the liquid cytoplasm and the range of organelles, and surrounded by the cell (plasma) membrane.

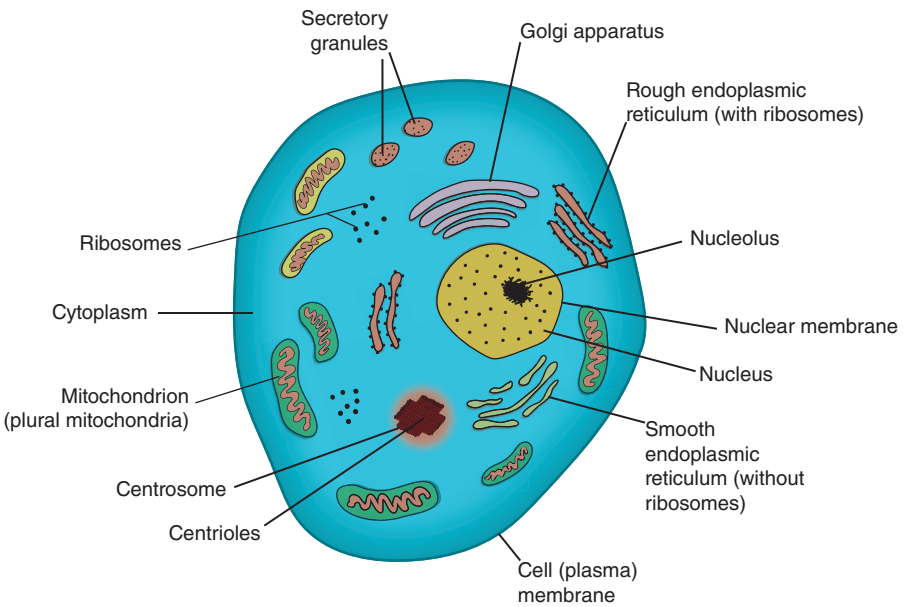

Figure 2.1 A human cell

Table 2.1 identifies the different organelles and their functions within the cells of the body.

The nucleus of the cell is unique to eukaryotes and contains the genetic material of the individual which determines the characteristics of each person. We are going to consider the nucleus first, including how it carries genetic information, and how the cells divide.

THE NUCLEUS

The nucleus is surrounded by a double membrane similar in structure to the cell membrane. The nucleus contains the genetic information which determines the constitution of the body in the 46

chromosomes (23 pairs). The nucleus also contains the nucleolus which is involved in the formation of ribosomes in the nucleus which are then moved out into the cytoplasm of the cell through the nuclear pores.

Table 2.1 The functions of cell organelles

Organelle	Functions
Cell (plasma) membrane (double membrane)	Controls movement of substances, ions and nutrients into, and waste products out of, the cell thus determining composition of cytoplasm (cell contents excluding organelles) Response to external stimuli
Nucleus (double membrane)	Contains genetic information within DNA of chromosomes of the cell; provides the template (RNA) for protein formation. Controls activities of the cell
Nucleolus	Made of protein and RNA and is in the nucleus. Synthesises and assembles ribosomes which leave the nucleus and enter the cytoplasm
Mitochondria (double membrane)	The 'power houses' of the cell. Glucose used as fuel to create ATP for storage of energy which is released when required
Ribosomes	The protein factories of the cell, translate RNA into protein. When loose in cytoplasm, forms proteins for use within the cell
Endoplasmic reticulum Smooth Rough	Directs movements of lipids and proteins through the cell Synthesises lipids and steroid hormones Combined with some ribosomes – synthesises proteins for 'export' *from* the cell
Golgi body (apparatus)	'Packages' proteins within membrane as vesicles, stored, then exported through cell (plasma) membrane
Lysosomes	Contain enzymes which break down unneeded large molecules which are recycled or excreted from cell One type digests foreign bodies such as microbes
Cytoskeleton	Microfilaments and microtubules form an internal framework of the cell allowing movement Centrosome and centrioles: play important role in cell division

Chromosomes

The nucleus contains 44 autosomes (i.e. not sex chromosomes) and two sex chromosomes. Normally each body cell (except ova and sperm – the gametes involved in reproduction) contains the diploid number of 46 chromosomes composed of a haploid set of 23 from each parent.

UNDERSTAND

Diploid: two complete sets of chromosomes.

Haploid: one complete set of chromosomes present in gametes.

UNDERSTAND

The gametes are the specialist cells formed in the reproductive organs which combine at fertilisation to form the zygote. These differ in the two genders:

Female: Ovum (pl. ova);

Male: Spermatozoon (or sperm) (pl. spermatozoa).

Chromosomes differ in size and, when being examined, a cell is prepared so that the chromosomes are spread out in a smear (Figure 2.2a). The individual chromosomes are then cut out, paired up and laid out in order of size as a karyotype (Figure 2.2b) with the 22 pairs of autosomes followed by the two sex chromosomes at the end. The female karyotype has two X chromosomes, while the male has one X and one Y chromosome in each cell. Each pair of autosomes are called homologous chromosomes and are the same size and carry comparable genes for the same characteristics. The genes may not be identical and allele is the term used for an alternative form of the same gene located at the corresponding position on homologous chromosomes.

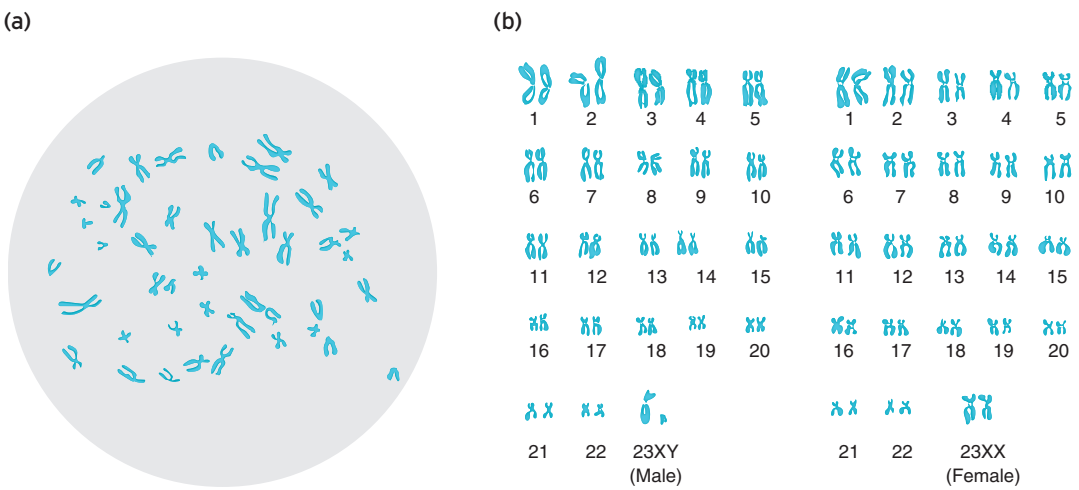

Figure 2.2 The human chromosome (a) Chromosome smear (b) Human karyotype

Deoxyribonucleic acid (DNA)

Chromosomes are composed of Deoxyribonucleic Acid (DNA). DNA acts as the genetic code which provides instructions for the formation of RNA (Ribonucleic Acid) which is transported out of the nucleus and provides a code for the formation of proteins (in collaboration with ribosomes). The proteins may form part of the structure of the cell or the matrix surrounding it, or are enzymes which act as catalysts for the range of chemical reactions in the cell.

Chromosomes are formed of two DNA strands with backbones of alternating sugar (deoxyribose) and phosphate molecules connected by pairs of nitrogen-containing bases (Figure 2.3a), two purine (adenine and guanine) and two pyrimidine (thymine and cytosine); a purine always connects with a pyrimidine. Adenine joins with thymine by two chemical bonds, and guanine connects with cytosine by three chemical bonds. The two chains form a double helix (Figure 2.3b) described by Watson and Crick in 1953.

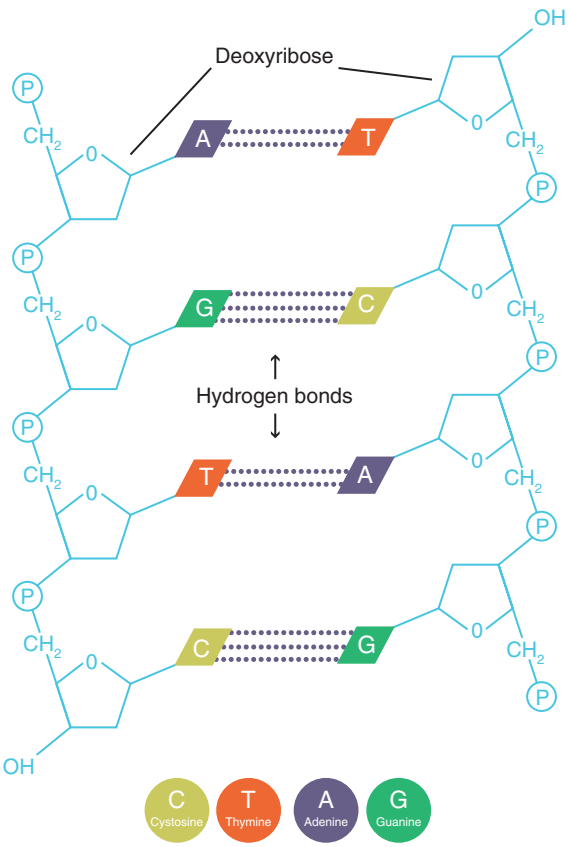

Figure 2.3 (a) DNA structure – The sugar-phosphate backbone and pairing of the nucleotides

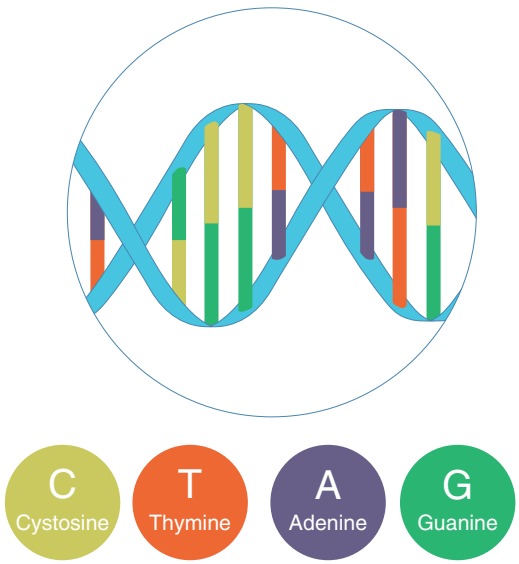

Figure 2.3 (b) DNA structure –DNA helix

In forming the chromosomes shown in Figure 2.3, the DNA helices are further coiled around histones (proteins), and coiled and folded yet further to create the demonstrable thickness of the chromosomes (Figure 2.4).

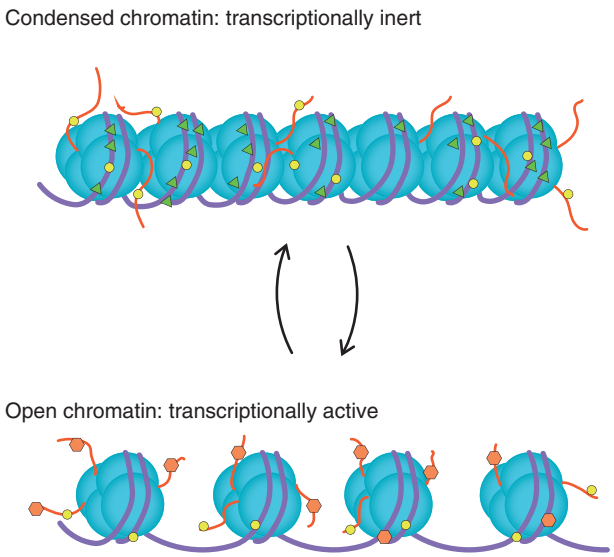

Figure 2.4 Histone modification of DNA activity

GO DEEPER

Cell division and ageing

At the end of each DNA chain is a section called a telomere consisting of a repeated chain of nucleotides (in vertebrates this sequence is TTAGGG). These protect the ends from damage but shorten at each cell division placing a limit on the number of cell divisions that can occur and resulting in ageing (Allsopp et al., 1995). Human foetal cells divide between 40 and 60 times before the telomeres become too short for further division and the cells become quiescent and eventually die. This ageing of the cells correlates with overall ageing of the body. There are certain conditions of premature ageing in which this takes place more rapidly than normal (e.g. progeria).

The enzyme telomerase can lengthen the telomere and result in continued division. This is linked with development of cancer; metastases (i.e. secondary growths) often show telomerase activity (Turnpenny and Ellard, 2007).

Although rare, errors in DNA during cell division can occur and, without repair, it is suggested that 16,000 nucleotide errors could occur in a single cell (Westman, 2006). A number of different repair mechanisms exist to minimise the deleterious effects of such errors.

The chromosomes in the nucleus of the cell contain about 99.9% of the total DNA in the cell and hold information, half from each parent, determining the individual characteristics of the person. The remaining 0.1% of DNA is in the mitochondria (see below) and is concerned with energy metabolism (Chapter 9). Under all normal circumstances this is handed down only from the mother as the spermatozoon

CHAPTER 9

(male gamete) loses its tail and mid-piece (in which the mitochondria are arranged) in the process of entering and fertilising the ovum. Thus all mitochondria in the body develop from those in the ovum.

Protein formation

CHAPTER 8

We have already indicated that the DNA in the chromosomes carries the genetic material that determines the individual's characteristics. It does this by acting as a template for the formation of the proteins of the body from the amino acids, the nutrients absorbed into the body after the breakdown of proteins in the diet (Chapter 8). This determines both structure and function of the components of the body. The process occurs in the two main stages illustrated in Figure 2.5.

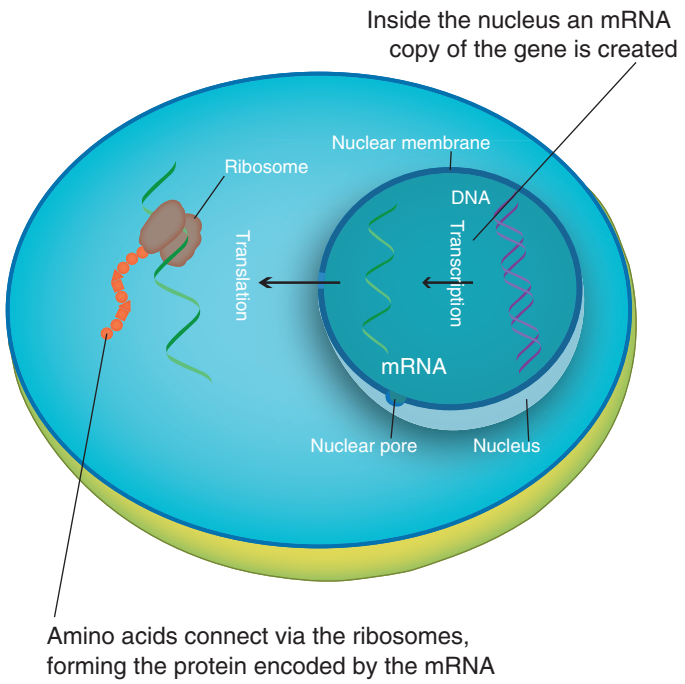

Figure 2.5 Transcription (to RNA) and translation (to proteins)

Transcription of DNA to Ribonucleic Acid (RNA)

The bases within DNA are linked by weak bonds which allow separation of the DNA strands to permit formation of messenger RNA (mRNA) by transcription (Figure 2.6). The RNA is a single-strand molecule similar in structure to DNA except that the deoxyribose is replaced by ribose, and thymine is replaced by uracil. Each base in the RNA is complementary to the base in the DNA.

Translation (to proteins)

The bases in the DNA transcribed into RNA act as a code in which each group of three bases is code for a specific amino acid. The strand of messenger RNA (mRNA) is the template for translation

of this code into a chain of amino acids forming a polypeptide chain which becomes a protein. The mRNA is carried out of the nucleus and joins with a ribosome (see below) in the cytoplasm where the translation takes place (Figure 2.7). Each group of three bases (called a codon) is translated into one amino acid picked up by transfer RNA (tRNA). Figure 2.8 shows the genetic code and illustrates how a number of codons can code for a single amino acid, or can code to stop or start the formation of the chain of amino acids.

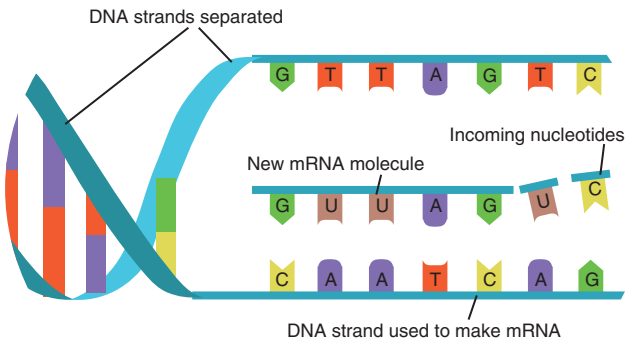

Figure 2.6 Formation of mRNA from DNA

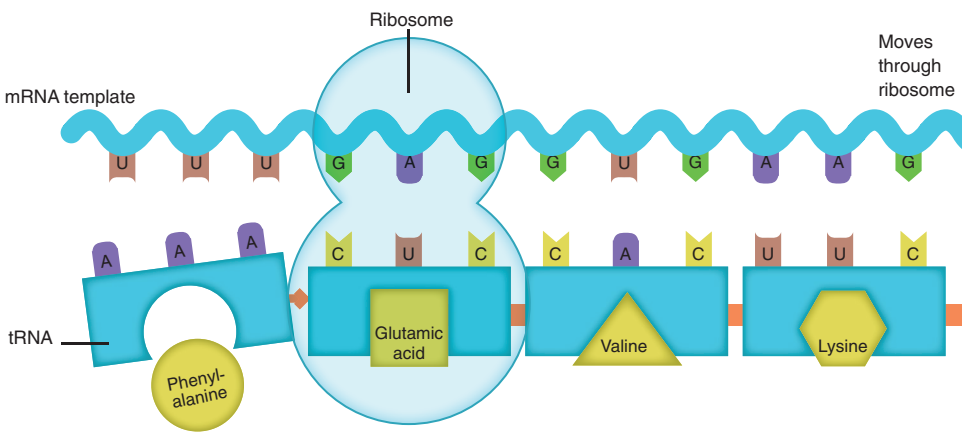

Figure 2.7 Translation of mRNA into polypeptide chain

The nucleolus

The nucleolus is the largest structure in the nucleus of eukaryotic cells. It is composed of proteins and RNA and its main function is to synthesise ribosomes and assemble them for export into the cytoplasm of the cell. It is also involved in how the cell responds to stress.

	U		C		A		G		
U	UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine	U
	UUC		UCC		UAC		UGC		C
	UUA	Leucine	UCA		**UAA****	**Stop Codon**	**UGA****	**Stop Codon**	A
	UUG		UCG		**UAG****	**Stop Codon**	UGG	Tryptophan	G
C	CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine*	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Glutamine	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lysine	AGA	Arginine	A
	AUG	**Methionine (start codon)**	ACG		AAG		AGG		G
G	GUU	Valine	GCU	Alanine	GAU	Aspartate	GGU	Glycine	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glutamate	GGA		A
	GUG		GCG		GAG		GGG		G

Figure 2.8 The genetic code

*Arginine is one example of many amino acids identified by more than one codon

**Codons where amino acids not coded for and translation stops

OTHER ORGANELLES

The cell or plasma membrane is double-layered and the nucleus and mitochondria are covered with similar membranes. Most of the other organelles are surrounded or formed from single-layered membranes.

Cell or plasma membrane

CHAPTER 8

The boundary of each cell is a double-layered lipid membrane, the cell or plasma membrane, composed of phospholipids (fatty molecules with a phosphate group), proteins and carbohydrates arranged in a mosaic structure (Figure 2.9) (Chapter 8 includes the structure of different nutrients). The phosphate ends of phospholipids are attracted to water (hydrophilic) and they face outwards from the cell membrane while the fatty acid tails are water repellent (hydrophobic) and face each other in the centre of the membrane, preventing passage of all but very small molecules.

Some protein molecules are incorporated into one layer of the membrane while some pass through both layers and facilitate transport across the membrane. Proteins compose about 50% of the structure of these membranes, and are particularly important in transport of substances across the cell membrane. Proteins in combination with carbohydrates on the outside of the cell membranes can act as receptors by having a specific binding site where hormones or other substances can link. This initiates other actions in the cell.

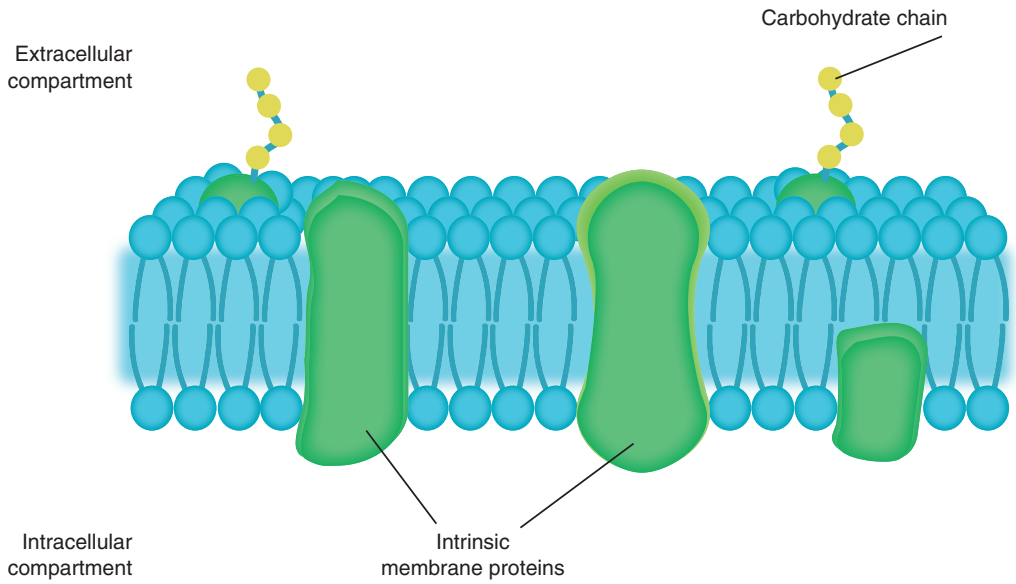

Figure 2.9 Cell membrane

The composition of the cytoplasm (intracellular fluid (ICF)) is very different from that of the Extracellular Fluid (ECF) surrounding it (Table 2.2). The concentration gradient of a substance sets the initial parameter, with substances moving from high to low concentration (Chapter 11). However, the plasma membrane plays a vital role in maintaining the differences between the interior and exterior of the cell through regulating the movement of substances in and out of the cell.

CHAPTER 11

Table 2.2 Ionic composition of cytoplasm (ICF) compared to extracellular fluid (ECF) (these values can vary depending on which type of cell is being looked at and results can vary somewhat in different laboratories)

Element	Ion	ICF	ECF
Sodium	Na^+	15	141
Potassium	K^+	140	4
Calcium	Ca^{2+}	0.0001	2.5
Chloride	Cl^-	8	103
Bicarbonate	HCO_3^-	15	25

Transport across the cell membrane

The cell membrane controls how substances can move in and out of the cell and these are discussed in detail in Chapter 11. They include passive movement, in which molecules pass down a concentration gradient and no energy is required, and active movement, in which energy is required to move molecules against resistance.

- **Carrier proteins** facilitate the movement of specific molecules. These are proteins which pass through the cell membrane, and provide a site recognised by specific molecules which link to it. The protein then changes conformation and releases the molecule on the other side of the membrane (Figure 2.10). The proteins assist movement of substances by what is known as carrier-mediated transport requiring energy.

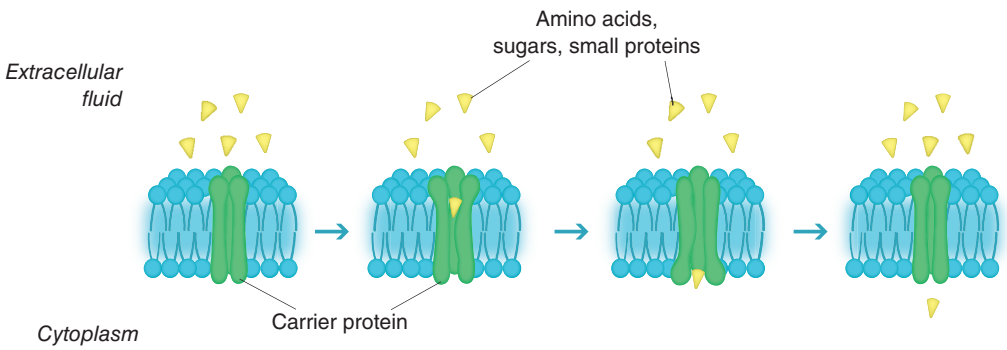

Figure 2.10 Carrier proteins

- **Ion channels** (Figure 2.11) determine the concentration of fluid and inorganic ions (which have a positive or negative charge) within the cytoplasm, including sodium (Na^+), potassium (K^+), chloride (Cl^-), bicarbonate (HCO_3^-) and calcium (Ca^{2+}). The distribution of ions within the Intracellular Fluid (ICF) and outside the cell in the ECF results in an electrical difference across the cell membrane (the electrical potential) with the inside of the cell being more negative than the outside.

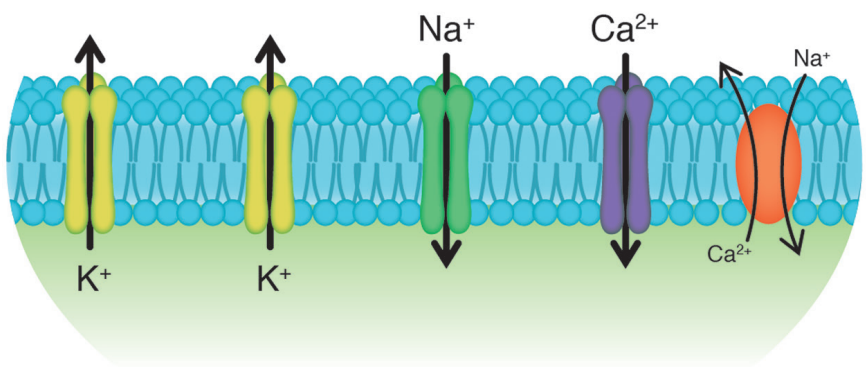

Figure 2.11 Ion channels

- **Exocytosis and endocytosis:** these processes enable large molecules that cannot pass though the cell membrane to move between the ICF and ECF. Endocytosis enables molecules to enter

the cell by engulfing it (Figure 2.12a). Exocytosis enables the contents of a vesicle formed from the Golgi apparatus to fuse with the cell membrane and the contents are released from the cell (Figure 2.12b).

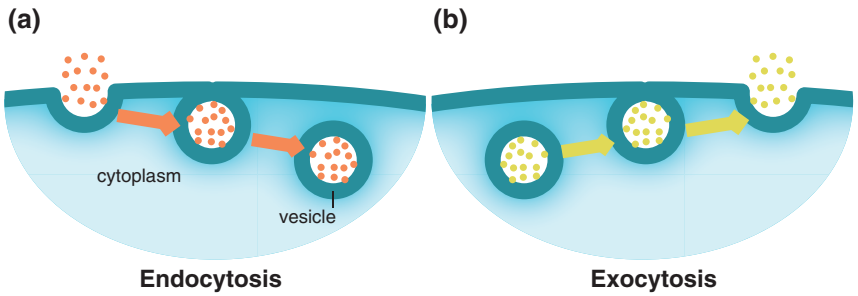

Figure 2.12 Endocytosis and exocytosis

ACTIVITY 2.1: UNDERSTAND

Watch these two short video clips to see endocytosis and exocytosis in action. The URLs for these online videos can be accessed via the companion website https://edge.sagepub.com/essentialaandp.

ENDOCYTOSIS EXOCYTOSIS A (1:54)

ENDOCYTOSIS EXOCYTOSIS B (3.53)

Receptors and the cell membrane

The cell membrane also plays an important role in signalling between cells through the action of receptors. These are proteins embedded in the plasma membrane surrounding the cell, within the cell or in the nucleus which bind to chemicals from outside the cell called ligands. Receptors detect the specific molecules (ligands) to which they are sensitive, for instance a hormone (Chapter 7), neurotransmitter (Chapter 5), small protein, a drug or part of an infectious agent (bacterium or virus), and modify the activity of the target cell.

The receptors modify the activity of the target cells in one of four ways:

1. By opening an ion channel and thus modifying the action potential (i.e. the electrical difference across the membrane) which in nerve cells cause nerve impulses to pass along the cell (Chapter 5). In other types of cell they activate particular cellular processes.
2. By activating a membrane-bound receptor and initiating a particular metabolic pathway.
3. By activating a receptor that activates another protein in the membrane (a G protein). The G protein can have effects on the cell in one of two ways: either through influencing activity of the ion channels or by influencing the concentration of second messengers.
4. By activating an intracellular receptor to adjust the transcription of specific genes.

CHAPTER 5

Receptors are discussed again in Chapters 5 and 7.

Major Histocompatibility Complex (MHC)/Human Leukocyte Antigen (HLA)

CHAPTER 13

The Major Histocompatibility Complex (MHC) proteins (known as Human Leukocyte Antigens (HLAs) in humans) are based in the cell membrane and play an important role in protecting against external agents entering the body (e.g. bacteria or viruses) or abnormalities developing in cells (e.g. cancer). The defence of the body depends on the immune system (Chapter 13) being able to recognise the difference between 'self' and 'non-self' cells. The specific body cell proteins involved in this recognition are known as antigens.

During development the foetus develops antigens on its cells which act as markers for the 'self'. However, each cell modifies itself in response to infection or by changes in the cell, becoming, for example, malignant, and binds fragments derived from the breakdown of these pathogens (infective agents). The cells of the body's immune system recognise these not-self antigens and destroy these cells (Chapter 13).

Mitochondria

CHAPTER 9

The mitochondria (singular mitochondrion) are surrounded by a bilipid layer similar to the plasma membrane and they act as the power houses of the cell. They metabolise nutrients to produce ATP (Adenosine Triphosphate) – the energy store of the cell – which is used to power the various cell activities (Chapter 9).

Mitochondria are positioned in cells according to the particular cell function and where energy is required. For example, in a cardiac muscle cell where energy is required all the time, the mitochondria are clustered near the muscle fibres.

Ribosomes

These granules are formed by the nucleolus within the nucleus of the cell and pass through the nuclear pores into the cytoplasm. They are composed of RNA and protein and those that are either loose or in groups within the cytoplasm form proteins for use within the cell. Other ribosomes combine with Endoplasmic Reticulum (ER).

Endoplasmic reticulum (ER)

ER is a cell-wide network of membrane which provides a surface on which lipids and proteins can be formed and transported round the cell.

GO DEEPER

Cellular transport

ER forms transport vesicles to carry the substances formed between the ER, plasma membrane, Golgi apparatus and lysosomes. Special transfer proteins carry the same substances to mitochondria and lysosomes.

- **Smooth ER** is involved in the synthesis of steroid molecules (a type of lipid) in cells where these are produced, and in calcium storage. This is particularly important in muscle cells in which smooth ER is known as sarcoplasmic reticulum.

- **Rough ER** is combined with ribosomes and thus appears rough under the microscope. The ribosomes with the ER form proteins such as enzymes or hormones which are exported from the cell for use elsewhere in the body.

Golgi apparatus or body

The Golgi apparatus is more important and larger in cells which have a secretory role. It is composed of stacks of flattened sacs of membrane which receive proteins and lipids from the ER and package them into secretory vesicles. These are stored and moved to the plasma membrane when needed, and exported by exocytosis.

Lysosomes

These are one of the types of secretory vesicles created by the Golgi apparatus and essentially are bags of enzymes. These break down large molecules that are no longer required into smaller fragments which may be reused or eliminated from the cell. Those in white blood cells contain enzymes which break down microbes.

Cytoskeleton

As indicated in Table 2.1 this forms a framework for the cell and enables movement. The centrosome is the core from which single filaments radiate and enable movement of vesicles and organelles. The centrosome is near the nucleus and has two cylinders, centrioles, at right angles to each other. During cell division these separate and move to opposite poles of the nucleus (see Cell Division below).

CELL DIVISION

From the formation of the zygote, cell division continues to occur throughout life. There are two types of cell division: one which forms the gametes, called meiosis, and the other is mitosis, the cell division involved in growth and development.

Meiosis

Meiosis occurs in relation to reproduction and is the division that occurs to form the gametes – sperm or ova – in preparation for fertilisation and formation of the zygote which develops into the foetus. As already stated, the gamete from each parent normally contains half the full number of chromosomes (i.e. 23:22 autosomes and one sex hormone).

Figure 2.13 shows the stages involved in meiosis. Initially the DNA replicates so that each chromosome in a pair of homologous chromosomes consists of two chromatids. Some of the DNA often swaps over (chromosomal crossover) between the two chromosomes as shown in the different colours in the chromatids in meiosis I. The pairs of chromosomes separate into two daughter cells each with half the original number of chromosomes, but with the sister chromatids remaining together. During meiosis II the chromatids separate into two separate cells so that from the original single cell, there are now four daughter cells. These can all be somewhat different in their DNA structure. These cells then mature into the male sperm or a female ovum with three polar bodies (Figure 2.14) which usually die.

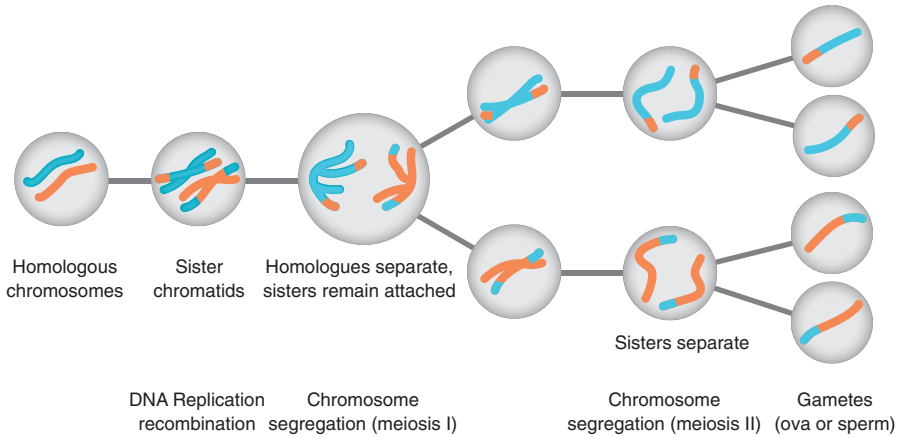

Figure 2.13 Meiosis in formation of gametes

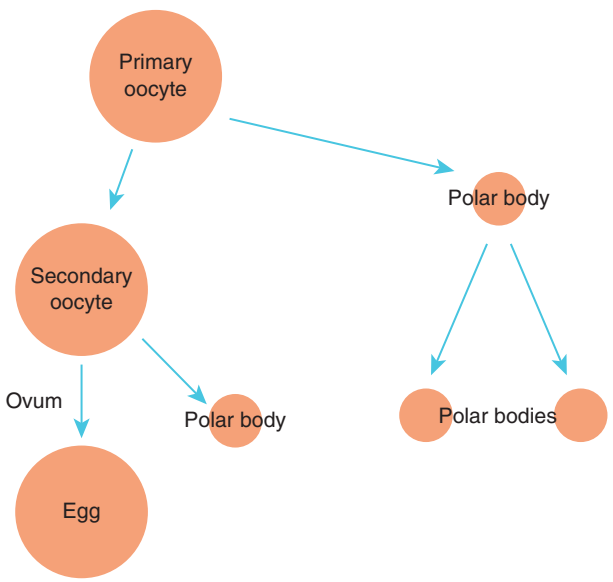

Figure 2.14 Formation of polar bodies

ACTIVITY 2.2: UNDERSTAND

Go online and watch the following video clip to see meiosis in action.

To save time, this external video link can be accessed via the companion website https://edge.sagepub.com/essentialaandp.

MEIOSIS (1:48)

Mitosis

After the merger of the ovum and the sperm in fertilisation, mitosis, the alternative type of cell division, occurs as the embryo grows and differentiates into the different cells and tissues making up the body. Mitosis is when a cell divides into two genetically identical daughter cells. Continued cell division occurs as the body develops through the stages of development discussed in Chapter 17. It also enables tissue repair.

CHAPTER 17

Mitosis consists of five main stages shown in Figure 2.15 and described below.

- **Interphase:** occurs between cell divisions and for most of this time the cells continue to function. During part of this phase, each chromosome duplicates to form two chromatids tightly coiled around each other.
- **Prophase:** the two chromatids become visible. The centrioles separate and go to each end of the cell with the mitotic spindle of microtubules between. The nuclear membrane disappears.
- **Metaphase:** the chromatids line up along the equator of the spindle attached by their centromeres (where the DNA is constricted and the two chromatids join).
- **Anaphase:** the microtubules forming the spindle begin to contract and draw the two chromatids of a chromosome apart to the ends of the cell.
- **Telophase:** The mitotic spindle disappears, the chromosomes reform and the nuclear membrane reforms.

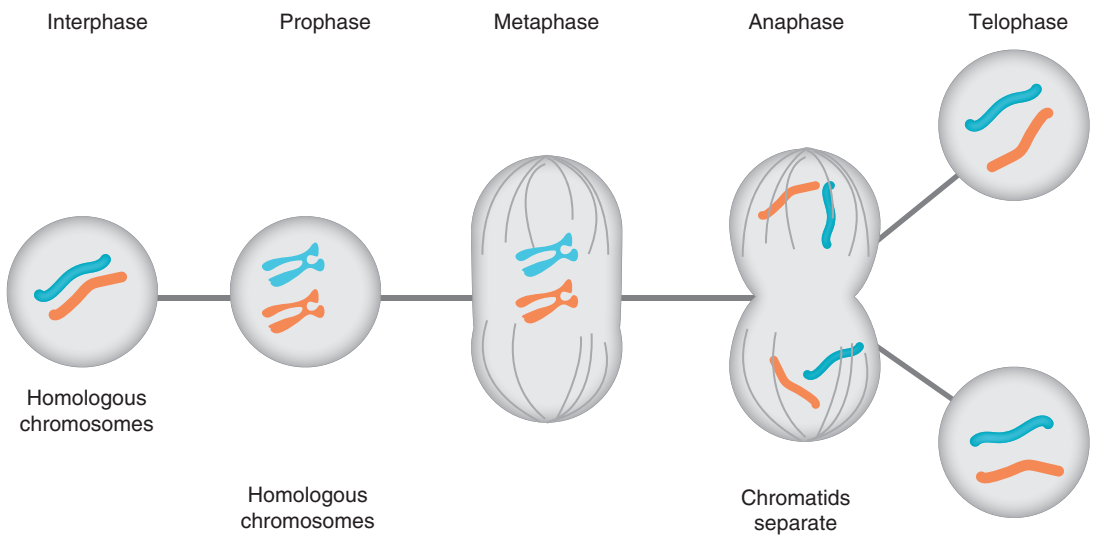

Figure 2.15 Mitosis

The original cell then divides into two daughter cells by the division of the cytoplasm and cell membrane and may re-enter the cell cycle. However, many specialised cells remain in interphase and undergo no further cell division.

ACTIVITY 2.3: UNDERSTAND

Watch this online video clip about mitosis.

To save time, you can access the video link via the companion website https://edge.sagepub.com/essentialaandp.

MITOSIS (6:10)

TYPES OF BODY CELLS

Introduction

Following fertilisation, the cells initially created have the potential to differentiate into any type of body cell – they are known as stem cells and, while most become fixed as a particular type of cell, some retain their flexibility and continue in certain tissues as stem cells. Cells with the ability to develop into any of the cells which make up the body are known as pluripotent stem cells (e.g. embryonic stem cells); those which are more limited but able to form more than one cell type are known as multipotent (e.g. adult stem cells and cord blood cells).

All body cells contain the same set of instructions, the DNA, but the expression of those genes is altered to produce the different types of cell. Differentiation is not thought to involve loss of DNA but occurs by modifying the expression of genes either through epigenetic changes to the DNA (Chapter 3) or by environmental factors extrinsic to the cell such as specific small molecules, secreted proteins from other cells, temperature and oxygen. The changes in gene expression can turn genes on or off or adjust the level of transcription of RNA and formation of proteins (Ralston and Shaw, 2008).

Cell differentiation produces five main types of body cell within the different tissues of the body:

- Blood and lymph,
- Connective tissue,
- Nervous tissue,
- Muscle tissue,
- Epithelial tissue.

Nervous and muscle tissue are both excitable tissues.

Blood and lymph

These differ from the other tissues in that the cells are not combined to form solid structures but are dispersed and transported in liquid. Table 2.3 outlines the major information about formation and functions of these tissues, which are sometimes included as connective tissues.

The cells within these systems are formed from pluripotent stem cells, originally present in the embryo and capable of forming any type of body cell, which create the two multipotent stem cells from which the range of blood cells are formed (Figure 2.16).

Table 2.3 Components of blood and lymph

	Constituent	Formation	Function
Blood		Carried in blood vessels: arteries, capillaries and veins	Transport medium
	Plasma	Water containing ions, plasma proteins, nutrients and waste products	Supplies all organs and tissues Carries nutrients, waste products, blood gases, blood cells
	Erythrocytes (red blood cells)	Formed in bone marrow, require iron and vitamin B_{12}. Have no nucleus. Life span 120 days	Transport O_2 to cells of the body, and some CO_2 to the lungs in haemoglobin of red blood cells (RBC)
	Platelets (thrombocytes)	Cell fragments, formed in bone marrow	Initiate haemostasis (blood clotting)
	Leucocytes (white blood cells)	Formed in bone marrow or lymphoid tissue	See below
Lymph		From tissue fluid from plasma, carried in lymphatic vessels. Returns fluid to blood circulation	
	Lymphatic fluid	Clear fluid formed in the tissues	Transports substances between blood and body cells Carries leucocytes
	Leucocytes		Combat infection, foreign bodies, malignant cells
	Agranulocytes: Monocytes	Formed in bone marrow	Phagocytic – engulf bacteria
	Lymphocytes	Formed in bone marrow, lymphoid tissue, thymus, spleen	Produce antibodies (B Lymphocytes)
	Granulocytes: Basophils	Formed in bone marrow	Produce histamine and heparin
	Eosinophils		Congregate at inflammation, antihistamine properties
	Neutrophils		Phagocytic, become macrophages when migrate to tissues

All organs of the body are supplied with blood through the circulation (Chapter 12). Fluid from the blood enters the tissue spaces to provide the cells with the necessary nutrients and remove waste products. Some of the tissue fluid re-enters the circulation via the capillaries. Excess tissue fluid enters the lymph channels, passes through lymph nodes where it acquires additional lymphocytes, and returns to the circulation at the subclavian vein (Chapters 12 and 13).

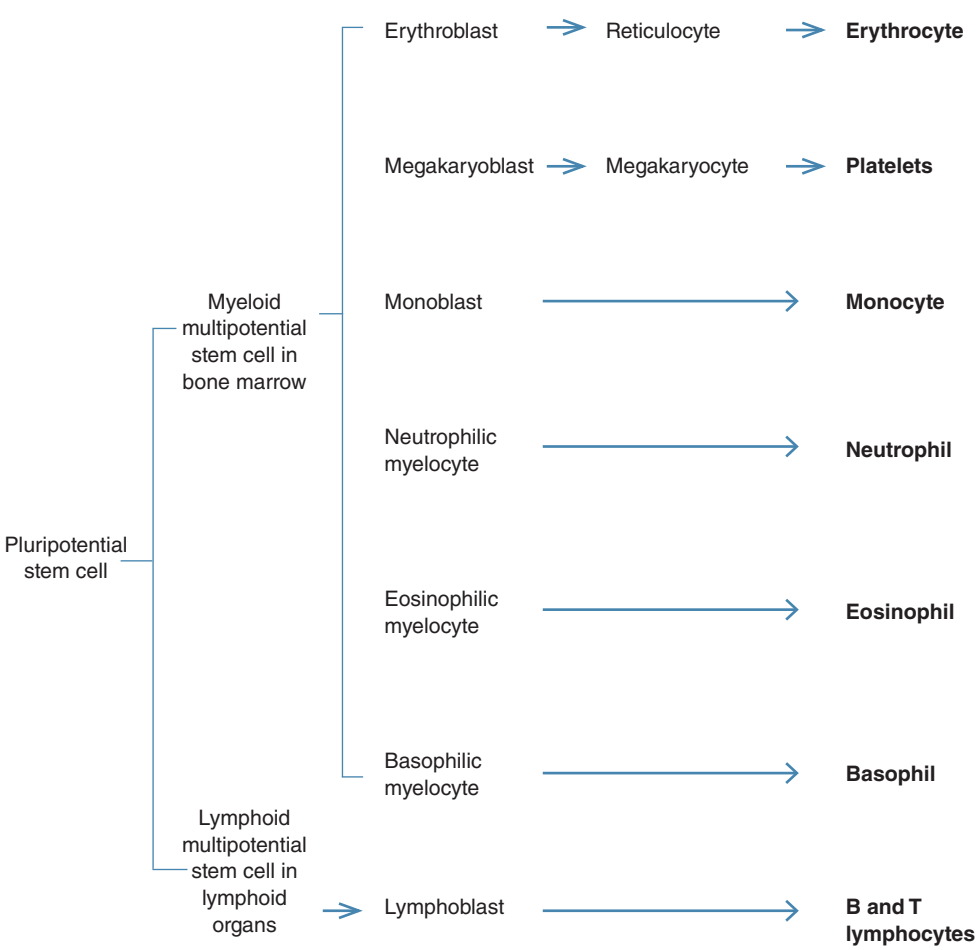

Figure 2.16 Formation of blood cells

Adapted from Pocock and Richards (2009)

Connective tissue

These tissues are also known as structural tissues as they provide structural support for the organs of the body. They vary considerably in appearance but all consist of cells, inter-cellular substance (matrix) and fibres, the last two being manufactured by the cells. The cells in connective tissue are much more spread out than in other tissues and there is considerably more matrix than in other tissues. The matrix and fibres vary according to the type of tissue and its function, major functions being structural support, protection, transport and insulation. The types of cells in connective tissue are given in Table 2.4.

The different tissues which these cells can form are specified in Table 2.5.

Table 2.4 Cells in connective tissue

Cells	Description	Function
Fibroblasts: large flat cells	Produce extracellular matrix and fibres: Collagen – minimal stretch coarse fibres in wavy bundles Elastin – fine branching elastic fibres	Major role in tissue repair
Adipocytes: vary in size and shape	Singly or grouped in most connective tissues abundant in adipose tissue	Major energy store as fat in adipose cells
Macrophages: irregular shape	Some fixed, some mobile. Phagocytic – engulf and digest cell debris, bacteria, foreign bodies	Part of immune system
Leucocytes: white blood cells	Small numbers in healthy connective tissue	Raised numbers in infection
Mast cells: like basophils	In loose connective tissues and fibrous capsule of some organs, around blood vessels	Histamine, heparin, etc., released after damage

Table 2.5 Connective tissues

Type of tissue	Subtypes	Description
Loose (areolar) connective tissue	Most generalised type	Connects and supports other tissues through elasticity (elastin fibres) and tensile strength (collagen fibres)
Adipose tissue	• White adipose tissue	Is 20–25% of (non-obese) body under skin, stores fat around kidneys and other organs, acts as insulation and energy store
	• Brown adipose tissue	Has substantial blood supply. Maintains body temperature by producing considerable heat
Dense connective tissue	• Fibrous tissue	Bundles of collagen fibres with little matrix. Forms ligaments to bind bones together. Protective covering for: bones, some organs (e.g. kidney, brain) Muscle sheaths (or fascia) become tendons (Chapter 15)
	• Elastic tissue	Can stretch and recoil, few cells, much elastic tissue secreted by fibroblasts in organs which need to stretch or change shape (e.g. blood vessels, lungs, trachea)
Lymphoid tissue	Or reticular tissue	See Chapter 13. Internal protection: immune system
Cartilage	• Hyaline cartilage	Solid and smooth bluish-white matrix, cells in small groups Flexible, supportive and smooth for movement at joints: ends of long bones, costal cartilages join ribs to sternum, parts of airway
	• Fibrocartilage	Contains dense collagen fibres (see above) within matrix like hyaline cartilage. Tough and flexible: intervertebral discs, in knee, hip and shoulder joints, forms ligaments joining bones
	• Elastic fibrocartilage	Consists of yellow elastic fibres in solid matrix. Supports and maintains shape (e.g. lobe of ear)
Bone	• Compact bone	A very dense hard tissue (Chapter 15)
	• Cancellous (spongy) bone	A spongy bone tissue (Chapter 15)

Adipose tissue

Adipose tissue has long been known as an energy source for the body and as having an important role in maintaining body temperature. Adipose tissue is composed of adipocytes, specialist cells that store fat. There are two types of adipose tissue, white and brown. White fat contributes to temperature regulation by reducing heat loss, and brown fat, with a considerably greater blood supply, produces heat through metabolism. The recognisable deposits of brown fat are particularly important in maintaining body temperature in babies as they generate heat and until fairly recently were not thought to exist in adults.

GO DEEPER

Brown adipose tissue

It has now been confirmed that precursor cells for brown adipose tissue are present in the supraclavicular regions (and possibly in other areas) of adults and that, under cold conditions, these can convert into active brown adipose tissue. Lean men or those working in cold conditions have more brown fat than those not working in such conditions, or those who are obese or overweight (Lee et al., 2011, 2014).

CHAPTER 7

White adipose tissue is more prevalent in adults and also acts as an endocrine organ secreting the hormone leptin which influences food intake by reducing appetite and fat storage (Chapters 7 and 9). Interestingly, we never lose adipocytes, we only regulate the amount of fat stored in them. If there is too much fat for the number of adipocytes, we replicate adipocytes to increase available storage.

CHAPTER 9

Cartilage

Cartilage is firmer than other connective tissues with fewer cells (chondrocytes) within a substantial matrix. Details of the three types are given in Table 2.5 and they vary due to the presence or absence of particular fibres (Figure 2.17).

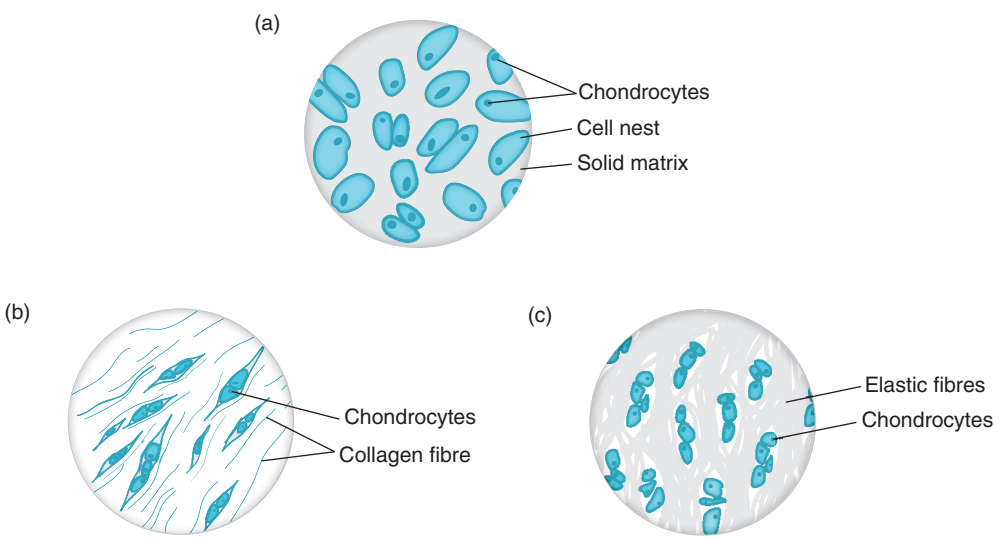

Figure 2.17 Cartilage: (a) hyaline, (b) fibrocartilage and (c) elastic fibrocartilage

Bone

Bone is the main component of the skeleton and the detailed structure of bone and its repair following injury are discussed in Chapter 15. The main functions are to provide the basic framework of the body, protection of organs within spaces in the skeleton, and formation of blood cells.

CHAPTER 15

Nervous tissues

Nerve and muscle are both excitable tissues meaning that the cells respond to chemical, electrical or mechanical stimulation. Nerve cells respond by transmitting a nerve impulse to carry instructions to or from the central nervous system (Chapter 5). Muscle cells respond by contracting (Chapter 15).

CHAPTER 5

Muscle tissue

There are three types of muscle tissue – details are given in Table 2.6. They are discussed in relation to the systems with which they are concerned in the following chapters:

- **Striated:** Chapter 15 – Musculoskeletal System;
- **Non-striated:** Chapter 8 – Gastrointestinal Tract;
- **Cardiac:** Chapter 12 – Cardiovascular and Lymphatic Systems.

Table 2.6 Types of muscle tissue

	Skeletal muscle	Smooth muscle	Cardiac muscle
Location	Attached to the bones or the skin (facial muscles only)	Found in the walls of hollow visceral organs and blood vessels	Located in the walls of the heart
Appearance	Single, long cylindrical cells	Single, narrow, rod-shaped cells	Branching chains of cylindrical cells
Nucleus	Multiple nuclei; peripherally located	Single nucleus, centrally located	Single nucleus, centrally located
Striations	Yes	No	Yes
Neural control	Voluntary (and involuntary reflexes)	Involuntary	Involuntary
Function	Body movements	Moving food through digestive tract, emptying urinary bladder, changing blood vessel diameter, etc.	Pumping blood through the blood vessels

Epithelial tissue

These tissues cover the body and line cavities, organs and hollow organs, and line glands. Their main functions are:

- protection of organs from damage such as dehydration or the effect of chemical agents or trauma;
- secretion;
- absorption.

There are numerous types of epithelium (Table 2.7) but they share certain characteristics:

- Cells are tightly joined together by specialist cell-to-cell junctions to form a continuous sheet called epithelium (pl. epithelia);
- These cells lie on a basement membrane of connective tissue fibres which supports and separates the epithelium from the underlying tissue;
- Continual cell division takes place to replace any dead and damaged cells, which occur as skin and gut lining are continually abraded;
- The epithelial sheets enable transport of substances in a particular direction either into or out of the compartment as functionally necessary.

Table 2.7 Epithelial tissues of the body

	Type of Tissue	Position in Body/Function
Simple epithelia	Squamous (pavement): exchange of small molecules between compartments	Walls of lung alveoli Endothelium of blood vessels
	Cuboidal (cubical)	Small collecting ducts in kidney
	Columnar: secretion or absorption	Large collecting ducts of kidney Lining of small intestine
	Ciliated: waft materials along surface	Lining of Fallopian tubes and respiratory tract
Stratified epithelium	Pseudostratified columnar ciliated	Lines upper airways
	Stratified squamous: waterproof and keratin barrier to bacteria	Epidermis of skin
	Transitional	Bladder lining
Glandular epithelium	Goblet cells: secrete mucus	Epithelial surface of airways and gut
	Endocrine: secretions enter bloodstream	Hormones (e.g. thyroxine, insulin)
	Exocrine: secretions via duct onto surface	e.g. salivary and sweat glands and intestinal lining
Serous membranes	Double layer loose areolar connective tissue lined with simple squamous epithelium Serous fluid between two layers	Pleura, pericardium, peritoneum

A range of epithelial tissues and glands are illustrated in Figure 2.18. These include single layer and multiple layer tissues including transitional epithelium which lines the bladder and can stretch to allow increased storage of urine. The figure of the stratified epithelium of the skin shows how the outer layers become thinned and then fall away. The glandular epithelium consists of unicellular or multicellular glands. Goblet cells secrete mucus, a slippery substance which lubricates the tissues of mucous membranes. The multicellular glands can secrete a number of different substances including sebaceous or intestinal seceretions.

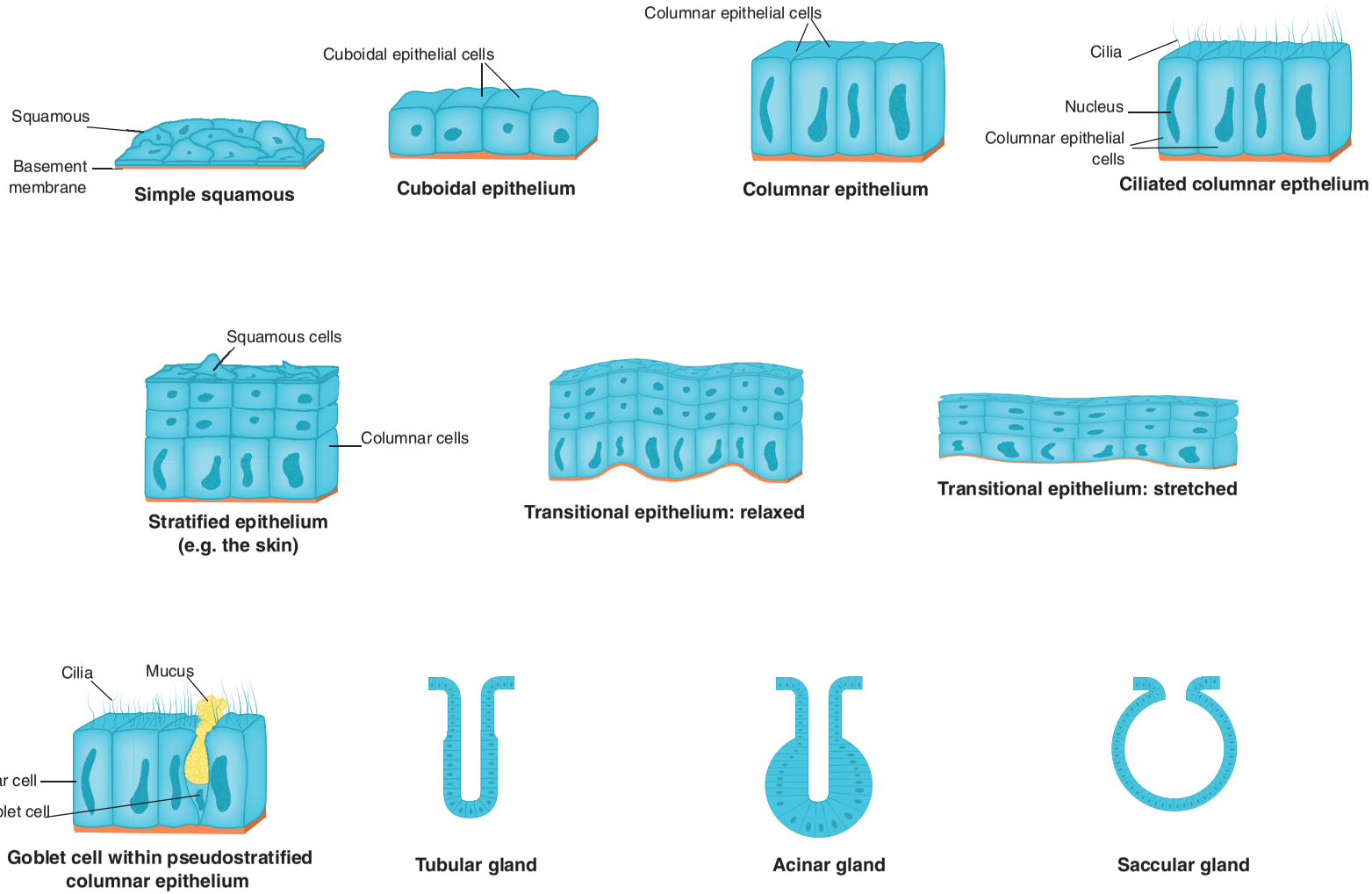

Figure 2.18 Epithelial tissues and glands

UNDERSTAND

Mucus (noun): viscous, slippery substance secreted as a protective lubricant coating cells and glands of the mucous membranes.

Mucous (adjective): means containing, producing, or secreting mucus.

CONCLUSION

This chapter has provided the foundation about human cells and how they work, multiply and differentiate into different types of cell which you can refer back to while you learn about the systems in which these cells function in later chapters. In relation to person-centred practice, this chapter provides some of the basic knowledge for you to understand how the human body works, and how that relates to psychological well-being.

Key points

- Understanding the structure of the human cell and how it works will help you to understand the human body as a whole.
- There are two types of cell division:
  - Meiosis occurs to prepare the gametes with the haploid number of chromosomes. When a sperm fertilises the egg the zygote then has the diploid number of chromosomes and further cell division is mitosis.
  - Mitosis forms two identical daughter cells and is the key to growth and development and is linked with cell differentiation to form the different types of cells and tissues forming the body: blood and lymph, connective tissue, nervous and muscle cells, epithelial cells.
- Understanding the function of the different cells of the body and how they interact synergistically will enable you to understand their contribution to homeostasis.

REVISE

This chapter and the previous one provide an underpinning for the remaining chapters in this book, so it is important to ensure that you have a good understanding of the content. In revising this chapter, it is useful to work through from the beginning. The areas to revise are as follows:

1. All the cell organelles and their functions, including transport across the cell membrane, DNA and RNA.
2. Meiosis – cell division for gamete formation; Mitosis – cell division for growth and repair.
3. The different types of cells and tissues: blood and lymph, connective, nervous and muscle (excitable) tissues, epithelial tissues.
4. The role of apoptosis in human development and functioning.
5. How this knowledge can be used in achieving person-centred practice.

CHAPTER 2

In order to help you revise, consider the following questions, answers for which can be found by visiting https://edge.sagepub.com/essentialaandp. Test yourself by revising the chapter first, and then answering

these questions without looking at the book. Afterwards compare your answers with the text and with the notes you made. Did you miss anything in your notes? Here are the questions:

1. Identify the different organelles in the human body and state their functions.
2. Outline the stages of mitosis and meiosis.
3. Identify the five types of human cells, outline the different variants within each group and clarify their functions.

For additional revision resources visit the companion website at: https://edge.sagepub.com/essentialaandp.

- Revise key terms with interactive flashcards
- Test yourself with multiple-choice questions
- Access the glossary with audio to hear how complex terms are pronounced
- Print out or download the key points from the chapter for quick revision
- Explore recommended websites suitable for revision.

CHAPTER 2

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