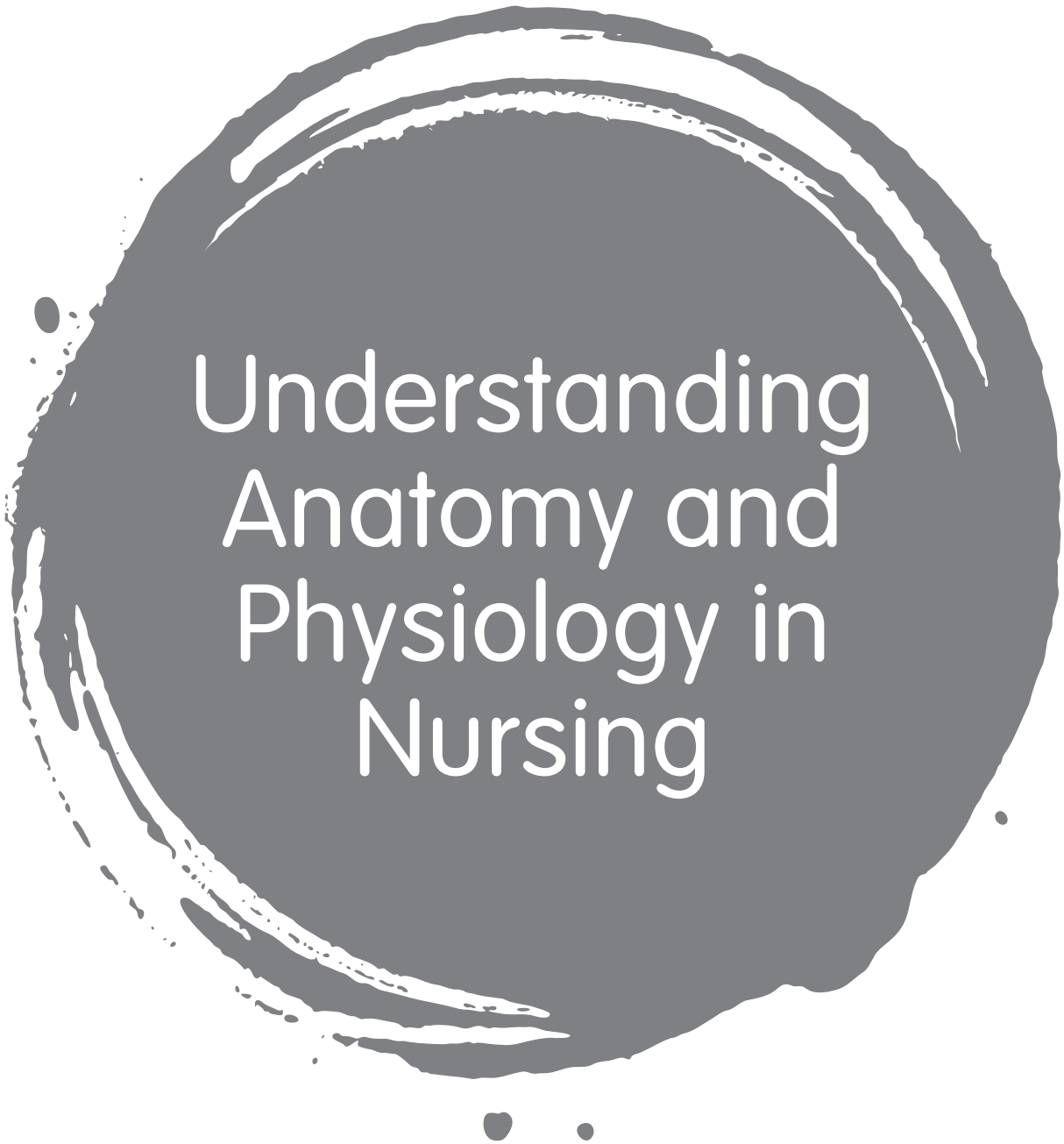

Understanding Anatomy and Physiology in Nursing

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2E

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Contents

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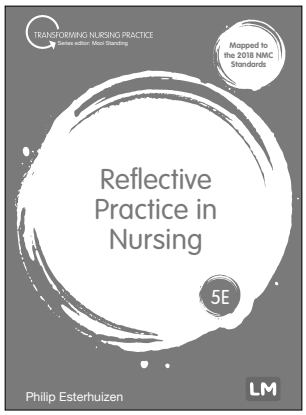

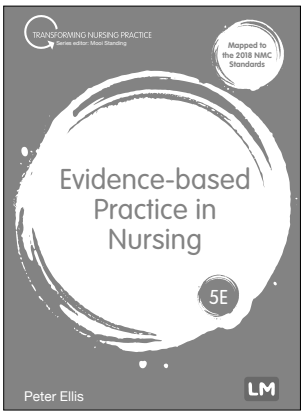

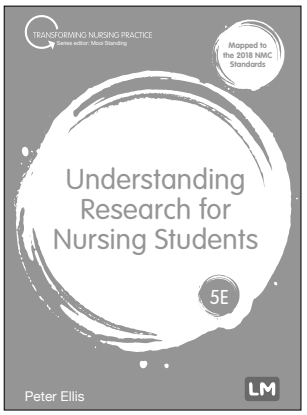

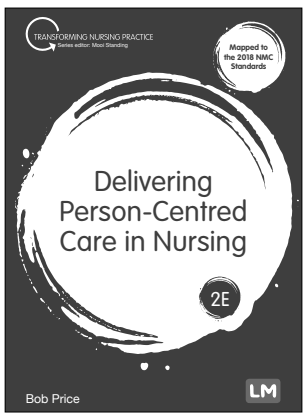

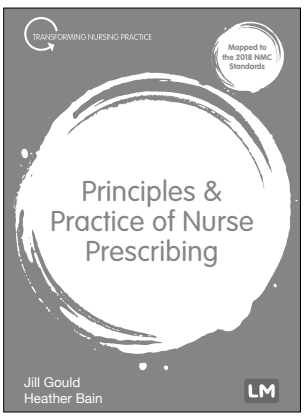

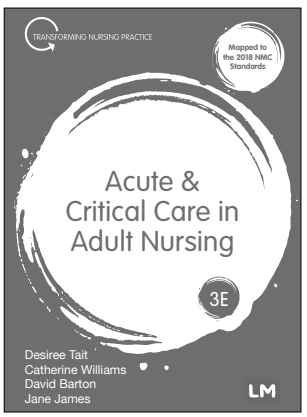

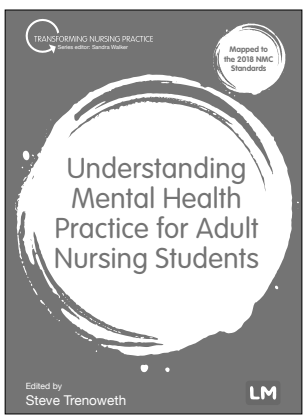

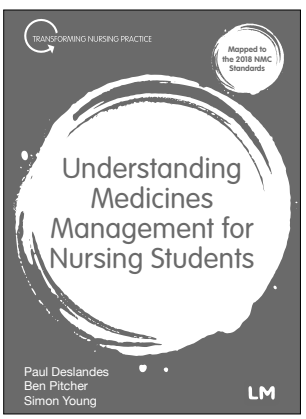

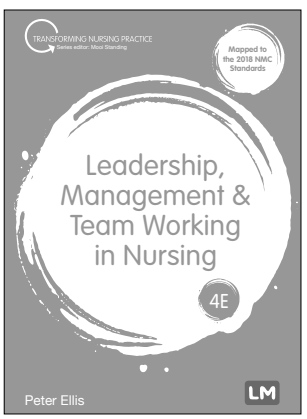

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About the authors

Dr John Knight is Associate Professor in Biomedical Science within the Faculty of Medicine, Health and Life Sciences at Swansea University. For the last 24 years he has taught anatomy, physiology and pathophysiology on a wide variety of professional degree and diploma programmes, including: health and social care, paramedic science, nursing and midwifery. John's first degree is in microbiology; additionally, he holds a PhD in immunology and has over 60 published articles in peer-reviewed journals. His teaching at Swansea University has been recognised by the presentation of two Distinguished Teaching Awards. John has a variety of research interests, including the evolution of immune responses, the physiological effects of ageing and immobility, and the use of virtual reality simulations in the teaching of anatomy and physiology.

Professor Yamni Nigam is a Professor in Biomedical Science (anatomy, physiology and pathophysiology) and a Fellow of the Higher Education Academy, teaching a wide range of health professionals, including nurses and paramedics. Her specialist subjects include digestion, blood, immunology, microbiology, parasitology, wounds (infection and healing) and maggot therapy. Yamni graduated from King's College London and undertook a master's degree in applied Parasitology and Medical Entomology at the Liverpool School of Tropical Medicine. After successful completion of her doctorate, Yamni was offered a lectureship teaching anatomy and physiology at Swansea University. In 2001, she set up the Swansea University Maggot Research Group, focusing on scientific investigations of the medicinal maggot and its role in wound healing. Her love of human anatomy and physiology has persisted, and she continues to write articles to support the learning of these subjects for all health professionals. Yamni is the author of over 80 peer-reviewed articles, book chapters and papers.

Professor Jayne Cutter worked in surgery and intensive care after qualifying as a nurse before becoming a Clinical Nurse Specialist in Infection Control. She spent 15 years in this post before leaving the NHS and joining Swansea University as a lecturer. Jayne's research interests include infection control and pedagogy. Although interested in all aspects of infection prevention and control, Jayne has a particular interest in factors influencing compliance. In 2009 she gained a PhD following a study titled, 'Factors influencing sustaining and reporting inoculation injuries in healthcare professionals undertaking exposure prone procedures'. In April 2015, Jayne was appointed as the Head of the Department of Nursing at Swansea University and became a professor in 2019. She is currently the Head of the School of Health and Social Care in the Faculty of Medicine, Health and Life Sciences. She has been closely involved in developing

the new curriculum at Swansea to meet the new NMC Standards for pre-registration nursing programmes. Jayne currently chairs the all-Wales Pre-Registration Nursing and Midwifery Group and has contributed to the development of all-Wales documentation to support the new NMC Standards. She also currently chairs the Wales Nursing and Midwifery Committee.

Introduction

Nursing is a profession that continually evolves to meet the ever-changing demands of modern healthcare. As a result, the education of student nurses must also evolve so that registrants are equipped to deal with the challenges of being a qualified nurse.

The Nursing and Midwifery Council (NMC) regulates nurses and midwives in the UK and nursing associates in England. The role of the NMC is to protect the public. To that end, all student nurses enrolled on a programme leading to registration with the NMC have to complete a programme of study informed by the NMC Standards for pre-registration nursing programmes (2018b). According to Article 5 (2) of the Nursing and Midwifery Order (2001) (legislation.gov.uk, 2002), the NMC must identify standards of proficiency required to enter the register. These standards of proficiency are grouped together under seven platforms and two annexes.

The platforms are:

1. *Being an accountable professional*
2. *Promoting health and preventing ill health*
3. *Assessing needs and planning care*
4. *Providing and evaluating care*
5. *Leading and managing nursing care and working in teams*
6. *Improving safety and quality of care*
7. *Coordinating care.*

(NMC, 2018b, page 6)

Annex A focuses on communication and relationship management while Annex B identifies nursing skills and procedures required of a nurse at the point of registration (NMC, 2018b).

The NMC recognises that nurses require a

> *comprehensive knowledge of the sciences on which general nursing is based, including sufficient understanding of the structure, physiological functions and behaviour of healthy and sick persons, and of the relationship between the state of health and the physical and social environment of the human being.*

(NMC, 2018a, page 14)

Table 0.1 Contents mapped to NMC proficiencies (NMC 2019b, pages 7–18, 32–6)

Platform/annexe	Proficiency	Chapter
Platform 1 Being an accountable professional	1.20 safely demonstrate evidence-based practice in all skills and procedures stated in Annexes A and B	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
Platform 2 Promoting health and preventing ill health	2.2 demonstrate knowledge of epidemiology, demography, genomics and the wider determinants of health, illness and wellbeing and apply this to an understanding of global patterns of health and wellbeing outcomes	1, 2, 5, 6, 14
	2.4 identify and use all appropriate opportunities, making reasonable adjustments when required, to discuss the impact of smoking, substance and alcohol use, sexual behaviours, diet and exercise on mental, physical and behavioural health and wellbeing, in the context of people's individual circumstances	3, 4, 5, 7, 8, 11, 13
	2.5 promote and improve mental, physical, behavioural and other health related outcomes by understanding and explaining the principles, practice and evidence-base for health screening programmes	1, 2, 3, 4, 5, 11,13
	2.11 promote health and prevent ill health by understanding and explaining to people the principles of pathogenesis, immunology and the evidence-base for immunisation, vaccination and herd immunity	1, 2, 10
	2.12 protect health through understanding and applying the principles of infection prevention and control, including communicable disease surveillance and antimicrobial stewardship and resistance	1, 7, 10

Platform/annexe	Proficiency	Chapter
Platform 3 Assessing needs and planning care	3.2 demonstrate and apply knowledge of body systems and homeostasis, human anatomy and physiology, biology, genomics, pharmacology and social and behavioural sciences when undertaking full and accurate person-centred nursing assessments and developing appropriate care plans	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	3.5 demonstrate the ability to accurately process all information gathered during the assessment process to identify needs for individualised nursing care and develop person-centred evidence-based plans for nursing interventions with agreed goals	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
	3.11 undertake routine investigations, interpreting and sharing findings as appropriate	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13
	3.12 interpret results from routine investigations, taking prompt action when required by implementing appropriate interventions, requesting additional investigations or escalating to others	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Platform 4 Providing and evaluating care	4.8 demonstrate the knowledge and skills required to identify and initiate appropriate interventions to support people with commonly encountered symptoms including anxiety, confusion, discomfort and pain	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	4.10 demonstrate the knowledge and ability to respond proactively and promptly to signs of deterioration or distress in mental, physical, cognitive and behavioural health and use this knowledge to make sound clinical decisions	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

(Continued)

Table 0.1 (Continued)

Platform/annexe	Proficiency	Chapter
Annex B 1. Use evidence-based, best practice approaches to take a history, observe, recognise and accurately assess people of all ages	1.2 physical health and wellbeing	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	1.2.1 symptoms and signs of physical ill health	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
	1.2.2 symptoms and signs of physical distress	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
	1.2.3 symptoms and signs of deterioration and sepsis	1, 2, 3 ,4, 5, 6, 7, 8,9 10, 11, 12, 13
Annex B 2. Use evidence-based, best practice approaches to undertake the following procedures:	2.1 take, record and interpret vital signs manually and via technological devices	1, 2, 3, 4
	2.2 undertake venepuncture and cannulation and blood sampling, interpreting normal and common abnormal blood profiles and venous blood gases	1, 2, 3, 4, 5, 9,
	2.3 set up and manage routine electrocardiogram (ECG) investigations and interpret normal and commonly encountered abnormal traces	3
	2.4 manage and monitor blood component transfusions	9
	2.6 accurately measure weight and height, calculate body mass index (BMI)and recognise healthy ranges and clinically significant low/high readings	2, 11
	2.7 undertake a whole body systems assessment including respiratory, circulatory, neurological, musculoskeletal, cardiovascular and skin status	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
	2.8 undertake chest auscultation and interpret findings	3, 4
	2.9 collect and observe sputum, urine, stool and vomit specimens, undertaking routine analysis and interpreting findings	3, 9, 11
	2.10 measure and interpret blood glucose levels	5, 9, 11

Platform/annexe	Proficiency	Chapter
	2.12 undertake, respond to and interpret neurological observations and assessments	6
	2.13 identify and respond to signs of deterioration and sepsis	1, 2, 3, 4, 5, 9
4. Use evidence-based, best practice approaches for meeting the needs for care and support with hygiene and the maintenance of skin integrity, accurately assessing the person's capacity for independence and self-care and initiating appropriate interventions	4.1 observe, assess and optimise skin and hygiene status and determine the need for support and intervention	7
	4.8 assess, respond and effectively manage pyrexia and hypothermia	2, 7
5. Use evidence-based, best practice approaches for meeting needs for care and support with nutrition and hydration, accurately assessing the person's capacity for independence and self-care and initiating appropriate interventions	5.1 observe, assess and optimise nutrition and hydration status and determine the need for intervention and support	11
	5.4 record fluid intake and output and identify, respond to and manage dehydration or fluid retention	11
8. Use evidence-based, best practice approaches for meeting needs for respiratory care and support, accurately assessing the person's capacity for independence and self-care and initiating appropriate interventions	8.1 observe and assess the need for intervention and respond to restlessness, agitation and breathlessness using appropriate interventions	4
	8.2 manage the administration of oxygen using a range of routes and best practice approaches	4
	8.3 take and interpret peak flow and oximetry measurements	4

Since the NMC standards were introduced in 2018, the world has experienced the COVID-19 pandemic. During the pandemic, nurses and their fellow healthcare professionals were rightly hailed as heroes. The skills and dedication of the nursing workforce were instrumental in saving lives, relieving symptoms, providing physical and emotional support and planning effective care. To do all these things effectively, a thorough understanding of anatomy and physiology is required. It is not enough to learn how to undertake tasks by rote. Nurses must be able to understand what is happening within the body so that when a patient develops a high temperature during a blood transfusion (Chapter 9) or a person with asthma becomes breathless when exposed to pollen (Chapter 4), for example, they can make an informed decision on the appropriate action to take. In short, unless we understand what is 'normal', we can never truly understand how the disease process affects our minds and bodies, and without this understanding, we cannot deliver appropriate care.

We have specifically written this book to ensure that its readers have the requisite underpinning knowledge and understanding of anatomy and physiology to equip them to assess, plan and deliver safe and effective nursing care. Within each chapter, you will find case studies and activities to encourage you to test and apply your newfound knowledge in relation to 'real-world' situations. We have mapped each chapter against the relevant platforms and the procedures in Annex B to ensure that you have the required knowledge and understanding of anatomy and physiology to meet the NMC Standards for pre-registration nursing programmes (2023) and achieve proficiency in these standards (see Table 0.1).

We are confident that you will find this book invaluable as you navigate your way through your nursing degree. Once you have qualified as a nurse, this book will continue to provide a useful source of reference as you develop your nursing skills even further on the journey from being a novice to an expert (Benner, 1984).

We sincerely hope you enjoy reading this book and wish you every success in your nursing career.

John Knight

Yamni Nigam

Jayne Cutter

Chapter 1 Cellular physiology and histology

Chapter aims

After reading this chapter, you will be able to:

- describe the structure of a typical human cell;
- describe the movement of materials into and out of cells;
- explain how cells can be used to screen for disease;
- provide a description of the major types of human tissue;
- explain the difference between eukaryotic and prokaryotic cells.

Introduction

Case study: Josie – breast cancer

Josie was showering when she noticed a small but hard lump in her right breast. Josie was quickly referred to the local breast screening clinic for further investigation, where ultrasound sonography revealed a dense mass around the size of a large garden pea. The consultant immediately recommended a needle biopsy, which was carried out the same day under local anaesthetic. The tissue collected was sent for histological examination and a week later Josie was diagnosed with breast cancer and her treatment options were discussed.

The collection of a tissue sample from a patient is termed a biopsy. There are many types of biopsy, ranging from the collection of a peripheral blood sample from a finger prick to a more invasive needle or surgical biopsy. As we have seen in Josie's case study, biopsies may be carried out to look for characteristic tissue changes that may be indicative of diseases such as cancer. Biopsies can also be used to check for infection or to monitor a variety of biochemical parameters in patients.

An average adult body is thought to be constructed from around 50 trillion (50 million million) cells, the majority of which have a finite lifespan, and are continually being replaced as they die. This means that most of the tissues and organs of the human body are not static but in a continual state of flux as senescent, aged cells are replaced.

This chapter will begin by examining the structure of a human cell. We will explore how deoxyribonucleic acid (DNA) is organised in the nucleus and the nature of human chromosomes and their use in screening for genetic disease. The individual components of the cytoplasm and structure of the plasma (cell) membrane will be described and mechanisms of transporting materials into and out of cells explored. Once you have a good grasp of cell structure, we will examine how cells are organised into the tissues which are used to construct the human body. Since microbes greatly outnumber human cells, we will examine the nature of bacterial cells which are found colonising the body as part of the microbial biome. To reinforce the key points we will explore the use of cells in detecting disease and examine how certain drugs can target specific cell types to treat disease.

Regions of a cell

Human cells are traditionally split into three distinct regions: the nucleus, the cytoplasm and the plasma (cell) membrane (Figure 1.1).

The nucleus

In most cells the nucleus is a centrally located structure that is separated from the cytoplasm by the nuclear membrane (nuclear envelope). The region inside the nuclear membrane is called the nucleoplasm and usually has a granular appearance with a denser inner region called the nucleolus. This granular appearance is due to the presence of condensed chromatin which consists of DNA molecules and histone proteins. The histones function as physical spools around which the DNA is wound and stored in a very compact form (Figure 1.2). This spooling of DNA is essential since each cell, which on average is only around 12μm in diameter (12 1/000th mm), has to store around 3m (10ft) of DNA.

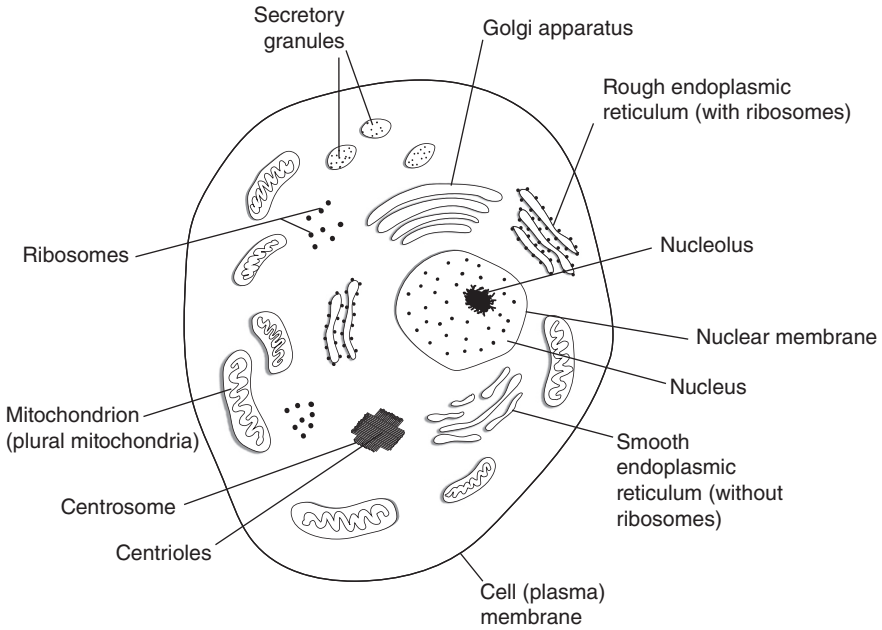

Figure 1.1 Cell structure

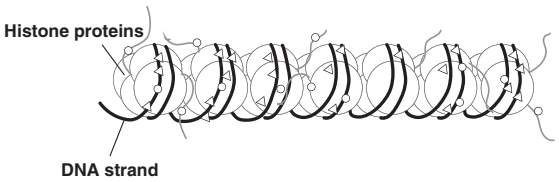

Figure 1.2 Chromatin and the spooling and storage of DNA

Appearance of chromosomes during cell division

When a cell is preparing to divide, highly specialised enzymes called topoisomerases and proteins called condensins act together to fold and twist the DNA into tight coils; this tightly wound-up DNA is much denser and thicker and condenses in the nucleus in the form of threadlike structures which are referred to as chromosomes. To help you visualise how chromosomes appear, attempt Activity 1.1.

Activity 1.1 Reflection

Find a rubber elastic band and two pens. Loop the elastic band around both pens and progressively wind up the elastic tighter and tighter.

What do you notice is happening to the elastic?

There are some possible answers to all activities at the end of the chapter, unless otherwise indicated.

Now that you understand how chromosomes become visible during cell division, we can examine how they can be used to screen for diseases. Nucleated human cells usually have 23 pairs of chromosomes, giving a total of 46, which is referred to as the diploid number (the normal expected number). The only major exceptions to this rule are the sperm and egg cells (ova) which by necessity must have half the diploid number of chromosomes. Half the diploid number in humans is 23 and this is referred to as the haploid number. Having haploid sperm and ova ensures that during fertilisation the diploid number of 46 is restored and the number of chromosomes remains constant down the generations (Chapter 14). Photographs of human chromosomes can be taken during cell division and placed into their ordered pairs according to size; these photographs are called karyographs and reveal the individual's chromosomal make-up, which is referred to as their karyotype.

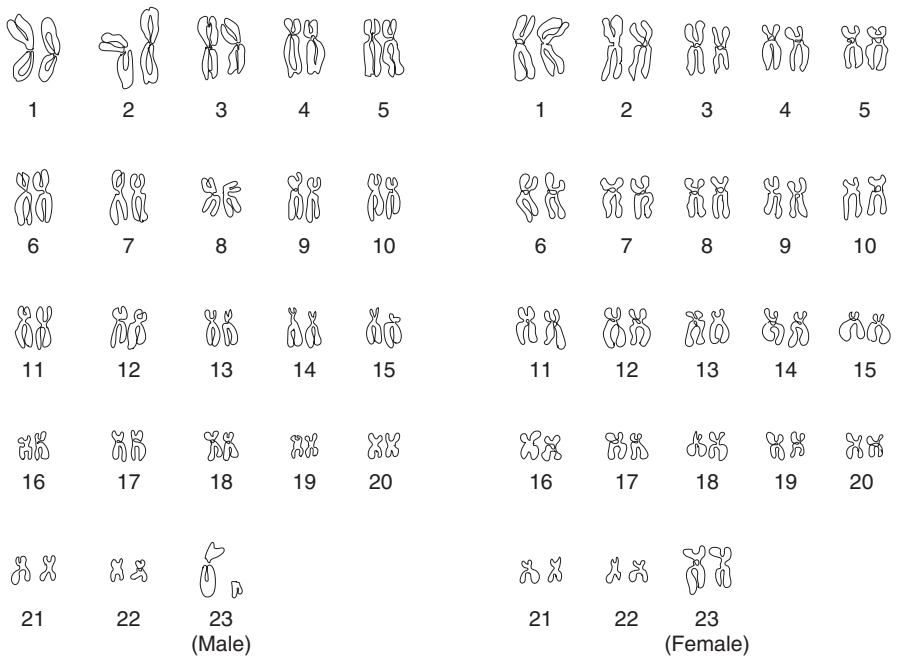

Figure 1.3 Chromosomes and karyotypes

The first 22 pairs of human chromosomes are referred to as autosomes and these appear structurally the same in both males and females (Figure 1.3). The final 23rd pair determines the physical sex of the individual and for this reason these are referred to as the sex chromosomes. Females usually have two XX chromosomes (XX) and males usually have an X and a Y chromosome (XY). However, as we will see in Chapter 14 there are frequently variations in the patterns of sex chromosomes and for this reason not all females are XX and not all males are XY. It is important to understand that the sex chromosomes only determine the biological (birth) sex of the individual and that today it is recognised that gender identity can be very fluid;

frequently the gender that someone feels aligned to may not necessarily reflect their inherited sex chromosomes.

Examining an individual's chromosomes is most frequently carried out before they are born. During pregnancy foetal cells may be collected by procedures such as amniocentesis or chorionic villus sampling. During amniocentesis the amniotic fluid that surrounds the developing foetus is collected; this will contain cells that have become detached from the foetus as it moves. Since the foetus is continually growing, a large number of the cells harvested will be dividing and therefore have chromosomes visible. The process of karyotyping that follows commonly reveals chromosomal abnormalities such as Down syndrome, Klinefelter's syndrome and Turner's syndrome (Chapter 14).

The cytoplasm and cytoplasmic organelles

The cytoplasm is the region between the plasma membrane and the nuclear membrane. It is predominantly composed of the endoplasmic reticulum (ER) which consists of a system of interconnected flattened membranes. In diagrams of the cell (see Figure 1.1) only small portions of the ER are usually shown, but in reality this complex labyrinth-like system occupies a large proportion of the cell. The ER is split into two distinct types: the rough ER has a multitude of tiny, specialised organelles termed ribosomes embedded within its membranes, which are responsible for its characteristic rough, uneven appearance. Ribosomes are the organelles where amino acids are linked together to form proteins according to the instructions encoded in DNA (Chapter 14); for this reason the rough ER is referred to as a region of protein synthesis within cells. The second type of ER is termed smooth ER since it lacks ribosomes; smooth ER is primarily involved in lipid (fat) synthesis. Fats have a multitude of functions within the body including: synthesis of cell membranes, storage of energy, insulation, and cushioning and protecting fragile organs such as the kidneys.

The cytoplasm is an aqueous environment and is filled with a watery fluid called the cytosol. This functions as a mobile medium within cells transporting dissolved sugars for energy, amino acids for protein synthesis and a variety of intracellular chemical signals and growth factors which are involved in coordinating the internal biochemistry and physical activities of the cell.

The Golgi apparatus

The Golgi apparatus is a specialised region of smooth ER resembling a series of crescent-shaped stacked membranes (Figure 1.1). The Golgi is frequently referred to as the cell's packaging and export region since it is involved in preparing material for release from cells. Its key role is refining proteins from the rough ER; this usually involves adding sugar residues to the crude amino acid sequences via a process

termed glycosylation. The refined proteins may be used within the cell or may leave the Golgi in membranous sacs called secretory vesicles which travel to the cell membrane before their contents are discharged out of the cell. Cells that have a secretory role such as those within endocrine glands may each have several well-developed regions of Golgi apparatus; a good example would be the insulin-producing beta cells of the pancreas. The Golgi is also responsible for packaging digestive enzymes required for intracellular digestion into small membrane-bound sacs called lysosomes. These contain over 50 distinct enzymes, including lipases (digest fats), proteases (digest proteins), multiple enzymes to digest carbohydrates and nucleases to digest nucleic acids such as DNA and RNA. These enzymes have several key functions within cells, including: digesting aged cellular organelles, with the products of digestion frequently used to assemble replacements and digesting solid material that has been engulfed by cells, e.g. bacteria trapped by white blood cells (see section on phagocytosis below). When cells come to the end of their functional lives, many undergo a process called programmed cell death (also known as apoptosis). During this process the lysosomes can act as suicide bags, releasing their contents into the cytoplasm and initiating widespread intracellular digestion and ultimately, cellular death.

Mitochondria

Mitochondria are small bean-/boat-shaped cellular organelles (Figure 1.4) responsible for releasing energy within cells. Each mitochondrion consists of an outer smooth membrane and a highly folded inner membrane. The prominent folds of the inner membrane are termed cristae (singular crista) and associated with these folds are the enzymes responsible for cellular respiration.

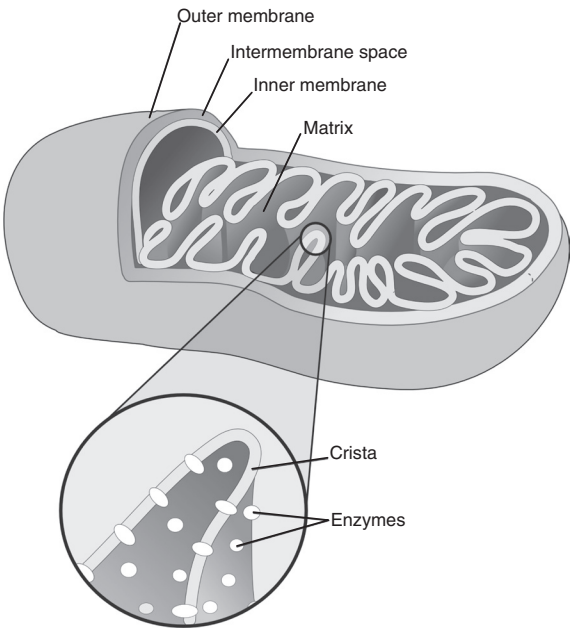

Figure 1.4 Structure of a mitochondrion

Within the mitochondria, glucose, which is derived from carbohydrate-rich foods, is reacted with oxygen acquired by our respiratory system to release energy. This energy is then used to synthesise the energy storage molecule adenosine triphosphate (ATP) from adenosine diphosphate (ADP) and free phosphate. This process results in the production of water and carbon dioxide as waste products. Since these biochemical reactions occur in the presence of oxygen, the process is referred to as aerobic respiration.

$$\text{Glucose } (C_6H_{12}O_6) + \text{Oxygen } (6O_2) \rightarrow \text{Carbon dioxide } (6CO_2) + \text{Water } (6H_2O) + \text{Energy } (38ATP)$$

In theory each molecule of glucose can yield 38 molecules of ATP but in reality this is never achieved, and a yield of around 30 ATPs per glucose molecule is typical. From a nursing point of view the simple equation above tells us something essential about human physiology: to generate the energy necessary to keep us alive we must eat (glucose) and breathe (oxygen). Indeed, a key role that nurses play is in ensuring that their patients receive adequate nutrition and that oxygenation of the blood is maintained.

Glucose is the preferred energy source of most cells, however, when we are deprived of this simple sugar, we can make use of our stored fat reserves. When we attempt to lose weight by going on a calorie-restricted diet, we trigger a process called lipolysis (fat splitting). During lipolysis fat is broken down into its fatty acids and glycerol components. Fatty acids circulate in the blood and are rapidly converted into ketones (also known as ketone bodies) by the liver via a process called ketogenesis. The ketones generated can be utilised by mitochondria as an alternative energy source to glucose ensuring that ATP formation continues, and our cells have the energy to carry out their activities. Ketones have a distinctive fruity aroma; a good example of a ketone is acetone (found in nail varnish remover) which has a strong aroma resembling pear drops. It is important that nurses learn to recognise the distinctive smell of ketones since this smell on a patient's breath or from their urine indicates that they are breaking down their fat reserves; this may be frequently seen in cancer patients who are not eating sufficiently or in patients with poorly managed diabetes.

The glycerol component of fat and the amino acid building blocks of proteins can both be readily converted into glucose by the liver via a process called gluconeogenesis; this literally means the creation of new glucose. Gluconeogenesis ensures that glucose is available to our cells during periods of starvation. In patients with eating disorders such as anorexia nervosa, large amounts of body fat and lean muscle tissue may be utilised as fuel for metabolism. This can lead to significant loss of muscle mass from the major muscle groups resulting in weakness, stick-thin limbs and loss of intercostal muscle mass between the ribs. Patients with chronic anorexia may eventually begin to lose muscle mass from the heart which can lead to heart failure and life-threatening cardiac arrythmias.

If the supply of oxygen is significantly reduced, then aerobic respiration becomes impossible and the cell is forced into anaerobic respiration. This is a far less efficient process that results in only two ATP molecules being produced per molecule

of glucose. The incomplete breakdown of glucose also leads to the accumulation of the metabolic waste product lactic acid (lactate). Many people experience the effects of anaerobic respiration when they participate in hard manual labour or when lifting weights in a gym. When muscles are forced into anaerobic respiration the accumulation of lactic acid is usually experienced as soreness, fatigue and sometimes pain

Centrosomes

Each cell contains a centrally located structure called a centrosome which is essential to the process of cell division. The centrosome consists of two centromeres which are orientated at right angles to each other (Figure 1.1). The role of centromeres is examined in detail when we explore cell division in Chapter 14.

The plasma (cell) membrane

All human cells are surrounded by an outer membrane referred to as the plasma membrane. This has a multitude of functions including: holding the cell together as a discrete intact unit, regulating the movement of materials into and out of the cell, and communication and recognition between cells.

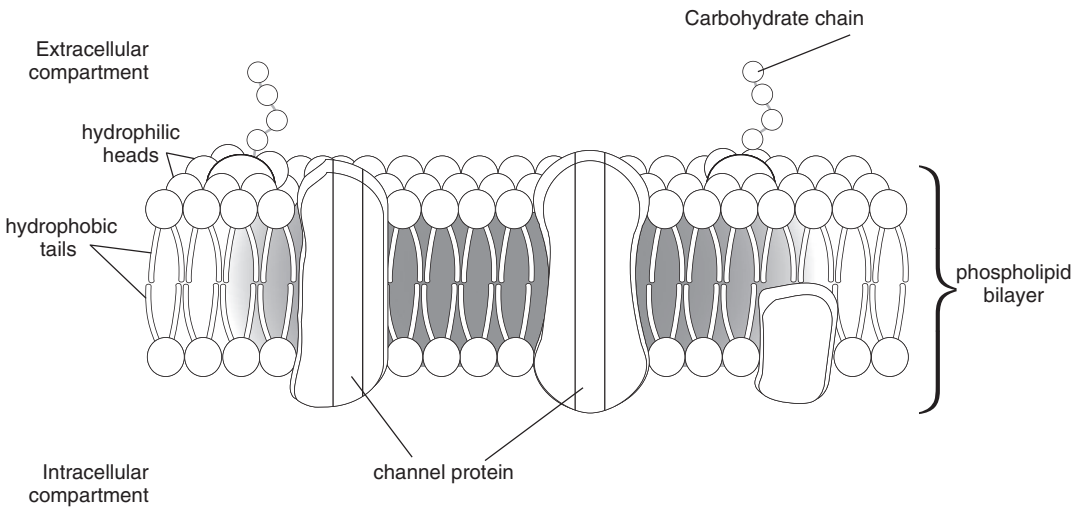

Figure 1.5 Structure of the plasma membrane

The plasma membrane is predominantly composed of a phospholipid bilayer within which are located a variety of proteins (Figure 1.5). Since phospholipid is a fluid, with a similar consistency to vegetable oil, and the denser proteins are positioned throughout its structure, under a microscope it has a mosaic-like appearance, hence the plasma

membrane is frequently referred to as having a fluid-mosaic structure. The phospholipid molecules originate from the smooth ER while the integral proteins initially are synthesised by ribosomes and refined in the Golgi before being transferred to and inserted into the membrane.

The plasma membrane is not a static structure; phospholipid and protein molecules are continually being added and removed depending on the current needs of the cell. The phospholipid bilayer is often referred to as being self-forming. Each phospholipid molecule consists of a hydrophilic (water-loving) head portion and two hydrophobic (water-hating) tails. Since the intracellular compartment of the cell is full of the water-based cytosol and the outside of the cell is surrounded by watery interstitial fluid, the phospholipid molecules naturally form a bilayer as the hydrophobic tails orientate themselves away from the aqueous environments of both the intracellular and extracellular compartments (Figure 1.5).

There are many different types of protein molecules within the phospholipid bilayer, including channel proteins which span the entire width of the membrane and form pores through which materials can enter and leave (see below), and receptor proteins which form three-dimensional pockets into which chemical signals such as hormones can fit.

The glycocalyx

Most of the proteins that are found embedded in the plasma membranes are actually glycoproteins since they have been refined by the addition of sugar (glyco) residues within the Golgi. Some of these sugar residues extend away from the outer surface of the plasma membrane in the form of large polysaccharides and these collectively form a thin shell of sugar around each cell called the glycocalyx (Figure 1.5). The glycocalyx includes a key set of human glycoproteins referred to as the major histocompatibility complex (MHC). These MHC proteins play a vital role in cellular recognition. With the exception of genetically identical siblings, every person has their own set of MHC proteins which uniquely identify their cells as belonging within their body. MHC proteins can cause problems when organs are transplanted since the immune system of the recipient will immediately recognise the cells of the donor organ such as a kidney or heart as being foreign and begin to attack the transplant.

For this reason, most organ transplant patients will require immunosuppressive drugs to help reduce the speed of rejection. Unfortunately, because these medications reduce the patient's natural immune responses, they can increase the risk of opportunistic infections. Even with immunosuppressive drugs, gradually the donated organ is usually rejected and some younger transplant patients may have to undergo several transplants during their lifetime. The only major cells that do not have MHC proteins on their surface are erythrocytes (red blood cells); this is fortunate because it allows for routine blood transfusions of cross-matched blood without the risk of transplant reactions and rejection. To help you understand the potential of transplanted organs to be rejected, explore Jack's case study.

Case study: Jack – organ transplant rejection

Jack is a 32-year-old male who received a donor kidney following several years of renal dialysis. Five months after the transplant, he began to experience flu-like symptoms and was unusually tired. His temperature was slightly raised at approximately 38 °C and he noticed that he was passing less urine than normal. Despite making a good recovery in the immediate post-operative period, Jack began to feel some tenderness over the transplant area. His wife made an appointment for Jack to see his GP who suspected that Jack may be rejecting the transplanted kidney. She contacted the transplant team who admitted Jack to hospital where a renal biopsy confirmed the GP's suspicions. A high-dose steroid drug called methylprednisolone was given for three days and fortunately the rejection process was suppressed. After reviewing Jack's medication and reminding him of the importance of taking his medication as prescribed, the team discharged him home.

Jack's case study highlights the importance of patient vigilance following organ transplants; luckily the rejection of Jack's transplanted kidney was suppressed before major damage to the transplanted organ could occur.

Membrane extensions

The boundary formed by plasma membrane is not uniformly smooth in all cell types; in many cells its structure is drawn out into extensions (also known as membrane projections) which are either static (non-motile) or motile and capable of movement.

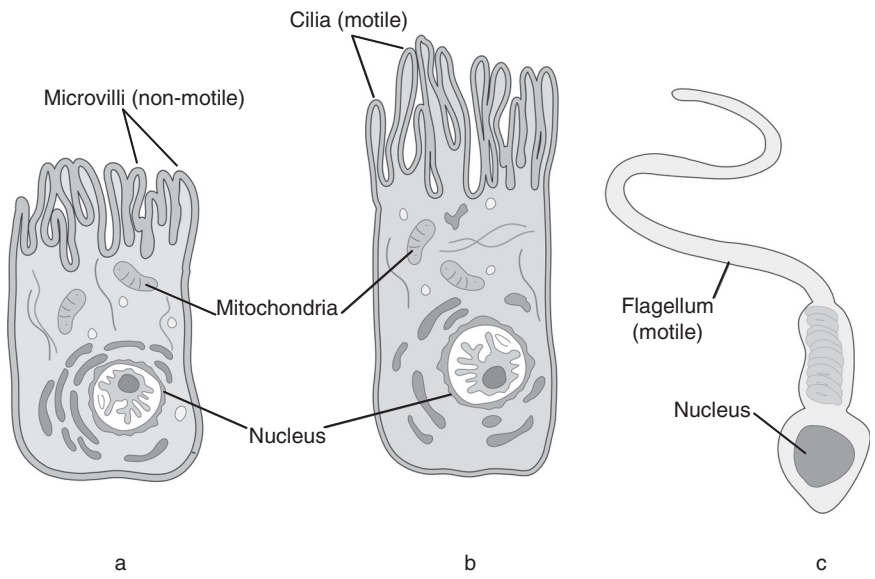

Figure 1.6 Membrane extensions

Cells which play a role in absorption, such as those lining the intestines, increase their surface area through tiny, non-motile extensions called microvilli (Figure 1.6a). These are finger-like extensions of around 1μm in diameter and are usually found covering the entire apical (outer) surface of the cell where they form the so-called brush border.

Some cells such as those lining the airway and fallopian tubes have motile hair-like extensions called cilia extending from their apical surfaces (1.6b). These beat in coordinated waves to allow the movement of extracellular materials e.g. mucus in the airway or an ovum (egg cell) in the fallopian tubes. Cilia are longer than microvilli and can reach lengths of up to 10μm. Cilia are very fragile structures and can be easily damaged by certain infections and exposure to pollutants such as cigarette smoke.

Spermatozoa are the only human cells to possess a motile whip-like extension termed a flagellum (Figure 1.6c). The flagellum is the longest of the membrane extensions at around 50μm and functions to propel the spermatozoan along the female reproductive tract using coordinated, thrashing whip-like movements.

Membrane transport

To stay alive and function optimally, each cell has to take up useful molecules (such as oxygen, water, salts, sugars and amino acids), and eliminate waste products such as carbon dioxide, urea and uric acid. Movement of materials across the plasma membrane is called membrane transport.

Simple diffusion

Since the plasma membrane is a fluid structure consisting predominantly of phospholipid, molecules that are fat-soluble are able to dissolve in the phospholipid bilayer and pass rapidly across by a process called simple diffusion.

Simple diffusion can be defined as:

> *The passive movement of molecules from a region of high concentration to a region of low concentration until an even distribution of molecules (equilibrium) is achieved.*

Gases such as oxygen and carbon dioxide and lipid-based hormones such as steroids, including testosterone and oestrogen, are highly soluble in the fluid phospholipid bilayer and pass readily into and out of cells via simple diffusion. Simple diffusion also occurs rapidly in the lungs with oxygen inspired at high concentration from the atmosphere before diffusing rapidly across the alveolar air sacs into the blood. Conversely, carbon dioxide is at high concentration in the blood and passes across into the alveoli by simple diffusion before being eliminated during expiration. Concepts such as diffusion are often very abstract in nature, so to help consolidate your understanding of this process, attempt Activity 1.2.

Activity 1.2 Team working

Add a small amount of perfume, aftershave or nail varnish remover (acetone) to a piece of tissue and place it in the centre of the room.

What do you notice?

Now that you have had the opportunity of exploring simple diffusion via the diffusion of odours, we can examine a variant of diffusion.

Facilitated diffusion

Since many of the molecules required by cells are water-soluble and not particularly soluble in lipid, they cannot pass across the plasma membrane by simple diffusion. Facilitated diffusion makes use of channel proteins which function as physical passageways to carry molecules across the plasma membrane.

Facilitated diffusion can be defined as:

> *The passive movement of molecules across the plasma membrane from a region of high concentration to a region of low concentration aided (facilitated) by membrane channel proteins.*

Facilitated diffusion is particularly important for getting water-soluble molecules such as sugars, e.g. glucose, into cells. Indeed, as we will see in Chapter 5, when we consume sugar, the hormone insulin is released, which increases the number of channel proteins in our plasma cell membranes, facilitating the movement of sugar from the blood into our cells where it can be used to release energy in the mitochondria.

Active transport

Diffusion only allows movement of molecules from a high to low concentration; sometimes it is necessary to move molecules against their natural concentration gradients, from a low to a high concentration. Moving material against a concentration gradient requires energy. Fortunately, as we have seen above, cells hold a steady stockpile of energy in the form of the energy storage molecule ATP. Many molecules are continually transported across membranes against their natural concentration gradients, including electrolytes such as sodium (Na^+) and potassium (K^+) and amino acids. Since this process utilises channel proteins, it can be regarded as an ATP-powered form of facilitated diffusion and is termed active transport.

Active transport can be defined as:

> *The active movement of molecules against their natural concentration gradients using channel proteins and powered by the energy storage molecule ATP.*

Good examples of active transport are the dedicated ion pumps that maintain the correct balance of ions across cell membranes (Figure 1.7). These pumps play a key role in generating electrical signals termed action potentials, which are essential to the functioning of the nervous system (Chapter 6).

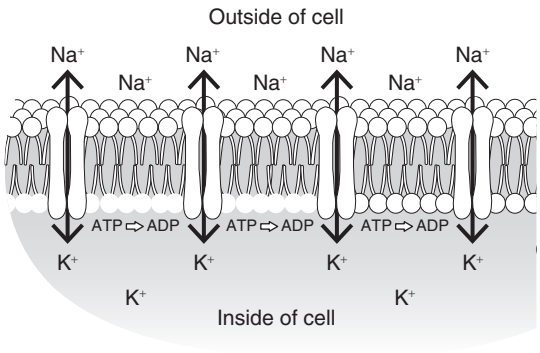

Figure 1.7 Active transport of sodium and potassium

Osmosis

Osmosis is the process by which water passes passively across the plasma membrane.

The classic experiment to help explain osmosis involves taking a vessel such as a beaker and dividing it into two using a semi-permeable material such as cellophane. Into one side of the beaker a solution of sugared water is added, and to the other side pure water is added. If the experiment is left at room temperature for an hour or so then the pure water will gradually move across the selectively permeable cellophane into the side of the

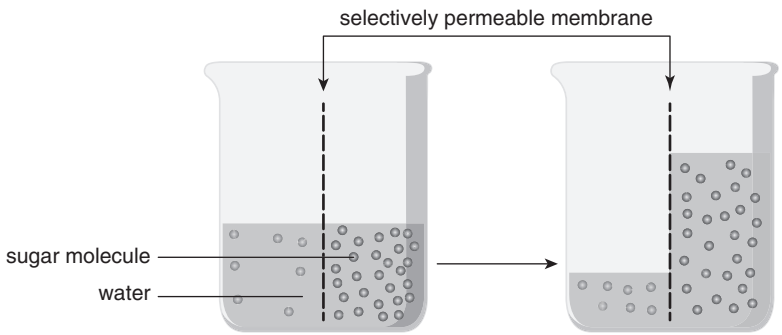

Figure 1.8 The process of osmosis

Source: OpenStax (2013) *Anatomy and Physiology*. Rice University. Available at: https://openstax.org/books/anatomy-and-physiology/pages/preface

beaker containing the sugared water, and the water level on this side of the beaker will begin to rise (Figure 1.8). The cellophane is referred to as being selectively permeable since it has pores that are just large enough to allow the water molecules to pass through but too small to allow the larger sugar molecules through. All human plasma membranes are selectively permeable and behave like the cellophane in this experiment.

Of all the mechanisms of membrane transport, osmosis causes most confusion among students. The reason much of this confusion arises is because there are two common definitions provided for osmosis in textbooks. Although these definitions are worded differently, they are effectively saying the same thing.

Osmosis can be defined as:

> *The movement of water from a region of low-solute concentration to a region of high-solute concentration across a selectively (semi-) permeable membrane.*

Osmosis is also frequently defined as:

> *The movement of water from a region of high water concentration to a region of low water concentration across a selectively (semi-) permeable membrane.*

While both definitions are accurate, the second definition is preferable since it highlights that osmosis is actually the diffusion of water through a selectively permeable membrane.

A nice, simple rule to help remember osmosis is that 'water follows solutes', or in plain English, 'water follows sugar, salt or other dissolved material'.

Knowledge of osmosis is essential for nurses to understand how the kidneys function and to understand water balance. Now that you have an understanding of osmosis and diffusion, read through the therapeutic clinical application to develop your understanding of how this knowledge can be applied to a patient with significant kidney disease.

Therapeutic clinical application

Patients with renal failure may undergo peritoneal dialysis in which a catheter is implanted into the abdomen and glucose-rich fluid (known as the dialysate) is infused via the catheter into the peritoneal cavity. The peritoneum acts as a selectively permeable membrane through which excess fluid (and electrolytes and waste products) are drawn out of the blood and into the dialysis fluid. Peritoneal dialysis may be continuous ambulatory peritoneal dialysis (CAPD) in which the dialysate is infused into the abdomen and retained there for approximately eight hours before being allowed to drain. The process is then repeated two or three times a day. Alternatively, automated peritoneal dialysis (APD) may be used, in which a machine is used to cycle the fluid into and out of the abdomen. This is usually done overnight.

Isotonic, hypertonic and hypotonic

The term isotonic has become more familiar to the general public with the introduction of isotonic sports drinks. Isotonic solutions are at the same or close to the same concentration as the fluid found in human cells. Nurses routinely use isotonic saline solutions to help keep patients hydrated, particularly when they are confined to bed, unconscious or unable to drink fluids normally. To help you understand the nature and composition of isotonic saline when you are on your next hospital placement, attempt Activity 1.3.

Activity 1.3 Evidence-based practice and research

On your next placement take a few minutes to examine the saline drip bags at the side of your patients' beds; pay close attention to the chemical composition specified.

What do you notice?

Now that you understand the composition of isotonic salines, we can explore why these are routinely used in clinical practice.

Human cells are stable in isotonic solutions because the concentrations of dissolved materials (solutes) are equal on both sides of the plasma membrane and so no net movement of water is occurring.

In health, the blood is a near-perfect isotonic medium kept at the same concentration as the cytosol of our cells by a multitude of homeostatic mechanisms. However, in certain diseases human cells can be taken out of their isotonic comfort zone, which can cause damage and, in some circumstances, become life-threatening.

Dehydration

In patients with diabetes the presence of large amounts of sugar (hyperglycaemia) results in the blood becoming too concentrated. Highly concentrated blood is referred to as being hypertonic (too concentrated) to human cells. In hypertonic solutions water will leave the cells of the body by osmosis and move into the blood, and this can lead to progressive dehydration which is a common presenting symptom in patients with undiagnosed or poorly controlled diabetes.

Dehydration caused by not drinking enough fluids or by severe vomiting or diarrhoea will similarly lead to hypertonic blood and loss of water from cells. As cells lose water, their cell membranes become loose and flaccid and may take on a crinkled

appearance; this phenomenon is referred to as crenation. Progressive loss of water from the intracellular compartments can lead to tissues of the body such as the skin becoming noticeably looser, and this can be detected in patients using skin-pinch tests. As well as being a sign of shock, prolonged capillary refill time may also indicate dehydration.

Dehydration is also characterised by the mucous membranes of the body drying out which is why many people wake up with a dry mouth after drinking too much alcohol, which is known to cause dehydration by promoting diuresis (increased urination). A common cause of dehydration in hospital patients is infection with norovirus. To help develop your knowledge of this problem, attempt Activity 1.4.

Activity 1.4 Evidence-based practice and research

An outbreak of norovirus is confirmed on your placement. List the most effective infection prevention and control measures that should be applied to minimise the spread of infection.

Dehydration, such as that experienced in patients following norovirus infection, is very common. More rarely, nurses will encounter patients who have too much water in their body.

Water intoxication (water toxaemia)

Water intoxication can be thought of as the opposite of dehydration and is caused by consuming too much water. It is frequently seen in endurance athletes such as cyclists and marathon runners who may routinely consume large quantities of water at drinking stations along the routes of their races. Occasionally it occurs following the use of recreational drugs such as ecstasy (MDMA), which can induce thirst and upset the normal water balance of the body by reducing urine output. Young babies who are fed on formula milk may also be at risk, particularly in poorer households where the milk powder may be over-diluted to make it last longer.

Consuming large quantities of water dilutes the blood, in effect making it hypotonic and at a lower concentration to the cytosol within cells. The dilution of blood in these patients will also lead to hyponatraemia (low blood sodium). Water will gradually move from the blood into the cells by osmosis, causing the cells to swell. Since all the tissues of the body are composed of cells, during water intoxication all the soft tissues will begin to swell and internal organs will enlarge. Early signs of water intoxication will include headache, nausea and vomiting. In more serious cases, the patient may experience confusion, visual disturbances, drowsiness, breathing difficulties, muscle weakness and cramping.

Since the brain is enclosed within the cranium of the skull, there is minimal space available to accommodate cerebral enlargement, and the intracranial pressure will increase restricting blood flow and reducing cerebral perfusion. As a result, the patient will gradually lose consciousness, commonly slipping into a coma and, unless quickly treated, they will suffer permanent brain damage and may die.

Treatment will be determined by the cause and severity of water intoxication. Firstly, the amount of fluid taken on board must be reduced and excess water expelled. This can be achieved by the administration of diuretics to increase urine output. If the condition has been caused by medication, the patient's medication must be reviewed and the drug causing the problem should be discontinued.

The importance of following the manufacturer's instructions when mixing infant formula must be reinforced and where financial hardship is a contributing factor, parents should be advised on appropriate support networks and benefits that might be available. Sodium levels should be corrected by careful administration of intravenous fluids with a relatively high concentration of sodium. Diuretics will also help increase sodium levels as excess fluid is excreted; however, these have to be used with care as some can cause significant loss of potassium, leading to hypokalaemia (low blood potassium).

Other forms of membrane transport

In addition to allowing the passage of single molecules into and out of the cell, the plasma membrane can allow larger groups of molecules and even solid materials/fluids to enter the cell via endocytosis or leave the cell via exocytosis (Figure 1.9).

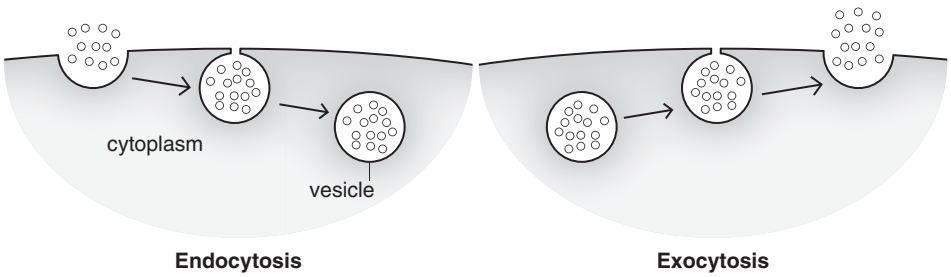

Figure 1.9 Endocytosis and exocytosis: material entering the cell may be either solids or fluid

Phagocytosis

This is the form of endocytosis by which cells can take up solid particulate materials. The term phagocytosis literally means 'cell eating' and is particularly important in the cells of the immune system, which are actively engaged in removing pathogenic material such as bacteria, fungal cells and viral particles. The process of phagocytosis utilises the fluid nature of the plasma membrane. When a pathogen such as a bacterium is

encountered the plasma membrane flows around it, engulfing it and enclosing it in a membrane-bound vesicle. Once internalised within the cytoplasm, the lysosomes produced by the Golgi fuse with the vesicle and discharge their enzymes into its interior, killing the pathogen and initiating intracellular digestion.

Exocytosis

Following the intracellular digestion of solid particulates such as bacteria, waste materials such as components of bacterial cell walls are released from cells by exocytosis (Figure 1.9). This process of exocytosis is also the mechanism by which cells of endocrine glands release their hormones into the blood and neurons release their neurotransmitters into synapses (Chapters 5 and 6).

Pinocytosis

This form of endocytosis allows cells to take up small droplets of fluid from the extracellular environment. The term pinocytosis literally means 'cell drinking', with most cells capable of taking up droplets of the interstitial fluid which surrounds them.

Histology

Histology is the study of biological tissues. A tissue can be defined as a collection of one or more cell types that work together for a common purpose. In the human body tissues can be thought of as the building blocks of organs. As highlighted in Josie's case study at the beginning of this chapter, tissue samples can be collected via biopsy to screen for disease.

Although the human body is incredibly complex, only four major categories of tissue are present: epithelial tissues, connective tissues (e.g. bone, cartilage, blood, adipose tissue and fat), muscle (skeletal muscle, cardiac muscle and smooth muscle) and nervous tissue (neurons and neuroglial cells).

As we move through this list from epithelial tissue through to nervous tissue, there is a gradual increase in complexity, with epithelial tissues regarded as the simplest human tissues and nervous tissue the most highly organised and complex. In this chapter we will only examine the nature of the epithelial tissues since the other tissue types are explored throughout the book.

The nature of epithelial tissue

Epithelial tissues are found throughout the body and have many diverse roles that are typically associated with absorption, protection and secretion. Epithelial tissues are recognisable since they rest on a thin delicate basement membrane (Figure 1.10).

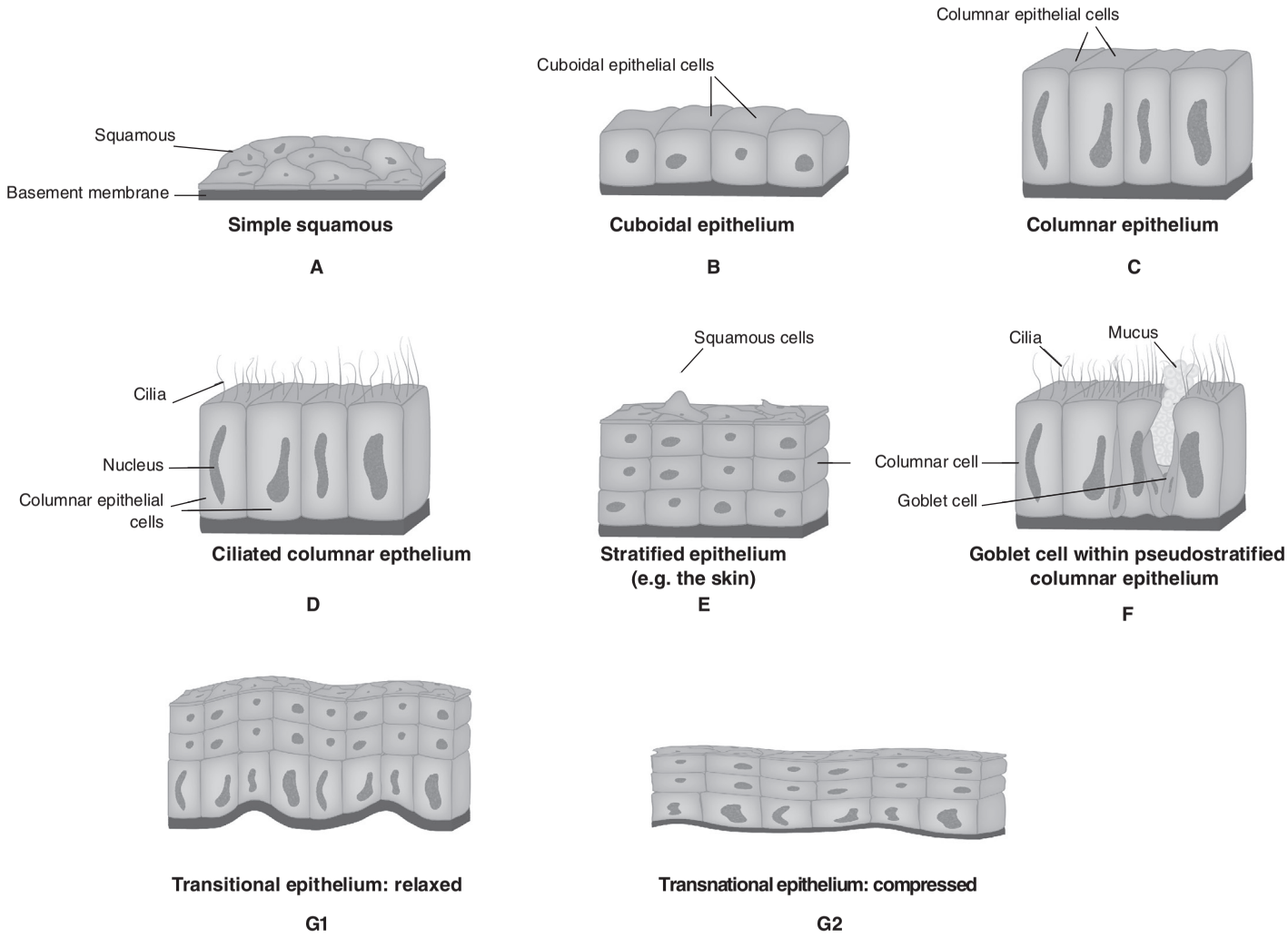

Figure 1.10 Some of the major epithelial tissues

Epithelial tissues can be broadly split into the simple epithelia, which consist of a single layer of cells, and the stratified epithelia, which consist of multiple layers of cells stacked one on top of the other like bricks in a wall.

The simple epithelia

Simple squamous epithelium

The term squamous means resembling the scale of a fish, therefore squamous cells are described as being thin and flat in appearance (Figure 1.10A). This tissue is found in multiple locations within the body, including the alveolar walls of the lung, endothelial lining of blood vessels and capillary walls, and lining the major serous membranes and serous layers of organs.

Since the cells of squamous epithelium are so thin and flat they are perfectly adapted to locations where simple diffusion takes place such as the alveoli of the lungs. Their thinness also imparts elasticity to the alveolar wall, allowing inflation of the lungs when air is inspired.

From a surface (apical) view, squamous epithelial cells have an appearance that resembles crazy paving, and for this reason this tissue is also commonly referred to as pavement epithelium. Many of the body's internal membranes, such as the parietal peritoneal membrane which lines the abdominopelvic cavity, the pericardial membranes that surround the heart and the pleural membranes that surround the lungs, have a layer of squamous epithelial cells associated with them. These membranes are referred to as serous membranes since their resident squamous cells secrete a thin watery fluid called serous fluid.

This fluid is very slippery and acts as a natural internal lubricant within the body, reducing friction between the visceral organs during bodily movement. Many of the body's internal organs such as the outer layers of the gut (serosa) and the uterus (perimetrium) also have a thin serous layer composed of squamous cells; these layers are collectively referred to as the visceral peritoneum which contributes further to the secretion of this internal lubricant. When major body cavities are opened during surgery this serous fluid is clearly visible as a glistening shiny surface coating the internal organs. The abdominopelvic cavity usually contains around 25–50ml of lubricating serous fluid. If pathogens are introduced, e.g. as a result of a perforated ulcer or burst appendix, they can replicate rapidly and lead to a painful and life-threatening inflammation of the peritoneal cavity called peritonitis. Signs and symptoms of peritonitis include: severe abdominal pain that is worse with movement, fever, nausea, increased breathing and heart rate, and potentially reduced blood pressure, particularly if the patient is entering a state of shock. It is usually diagnosed by taking a sample of fluid from the abdominopelvic cavity to identify the presence of pathogens and treated using intravenous antibiotics. Many patients with advanced liver disease, e.g. as a result

of alcoholic liver cirrhosis, can develop ascites; this is a condition where much larger quantities of serous fluid (up to a litre or more) are produced, leading to visible distension of the abdomen. Ascites can cause discomfort, varying degrees of abdominal pain, weight gain and breathing issues. It can be treated by reducing salt in the diet and by using diuretic medications to increase urine volume and fluid loss. If this is not effective the excess fluid may have to be drained off at regular intervals.

Simple cuboidal epithelium

This consists of a single layer of cube-shaped cells (Figure 1.10B) and is found forming the walls of the kidney tubules where it plays a key role in regulating the composition of the urine. Within the brain are specialised ciliated cuboidal epithelial cells called ependymal cells which produce the cerebrospinal fluid (CSF) which surrounds the brain and spinal cord. The cilia which extend from the apical surface of these cells beat in coordinated waves and help ensure the directional flow of the CSF (Chapter 6).

Simple columnar epithelium

This consists of a single layer of tall, thin, column-shaped cells (Figure 1.10C) found forming the mucosal lining of many areas of the gastrointestinal tract. These relatively thick cells allow gradual absorption of nutrients across the gut into the blood. A specialised ciliated columnar epithelium (Figure 1.10D) is located in the lining of the fallopian tubes; here the cilia beat in coordinated waves, playing a key role in transporting ova from the ovaries to the uterus.

Stratified epithelium

Stratified squamous epithelium

This consists of several layers of thin, flat cells (Figure 1.10E). The epidermis, which forms the outer layer of the skin, is composed of a stratified squamous epithelium. The initial layer of cells that resides on the basement membrane is actually cube-shaped and continually dividing by mitosis. This acts as a germinal layer and is the origin of all the cells above. As new cube-shaped cells are pushed up through the layers, they are compressed and flattened by the cells immediately above, gradually taking on their characteristic thin flat squamous appearance. These epidermal cells progressively accumulate the tough, dense protein called keratin. This makes the epidermal layer very strong, but keratin accumulation displaces and disrupts the internal cytoplasmic components of the cell so that they can no longer perform basic functions such as a cellular respiration. As a result of this the cells at the surface gradually begin to die.

This means that the outer layer of the epidermis is composed of entirely dead skin cells which gradually slough off and flake away from the surface. There are examples

of stratified cuboidal epithelium found surrounding developing ovarian follicles and stratified columnar epithelium found lining the male urethra, and these are discussed further in subsequent chapters.

Pseudostratified epithelium

Lining the nasal cavity, trachea and upper portions of the bronchial tree is a specialised ciliated epithelium. This is composed of a combination of tall column-shaped cells and smaller cells squashed between. This gives the false appearance of a tissue that is stratified (multilayered). The term pseudostratified (which literally means falsely layered) is often used to describe this tissue. In reality, all the cells within this tissue are in contact with the basement membrane and so pseudostratified epithelium is actually a specialised simple epithelium (Figure 1.10F).

Transitional epithelium

The bladder is lined by an elastic stratified epithelium with cells that change shape according to the volume of urine currently stored. When the bladder is full, the pressure exerted by the urine compresses this tissue and the cells take on a thin, flat, squamous appearance (Figure 1.8G2). As the bladder empties, the cells become progressively less compressed, gradually adopting a cuboidal and then a columnar appearance (Figure 1.10G1).

Prokaryotic cells

Cells which contain their DNA within a nuclear membrane are referred to as eukaryotic cells. The cells which make up the bodies of animals (including humans), plants and fungi are all eukaryotic. Human erythrocytes (red blood cells) lose their nucleus as they mature; this loss of the nucleus allows more haemoglobin molecules to be packed into the cell, improving the efficiency of oxygen transport. However, since erythrocytes are derived from nucleated cells, they are still eukaryotic in origin.

Unlike eukaryotic cells, bacterial cells do not have their DNA enclosed within a nuclear envelope and are referred to as prokaryotic cells.

Prokaryotic cells typically have other key differences from eukaryotic cells; most are surrounded by a thick, robust cell wall which allows them to survive in fluctuating environmental extremes of temperature, pH and dryness (Figure 1.11). A key feature of bacteria is that they are able to replicate incredibly fast, for example, some species of Clostridium (which can cause food poisoning) can replicate as fast as every ten minutes. This allows huge populations to be generated in relatively short periods of time; in the human body this can have disastrous consequences, particularly if bacteria gain access to the blood.

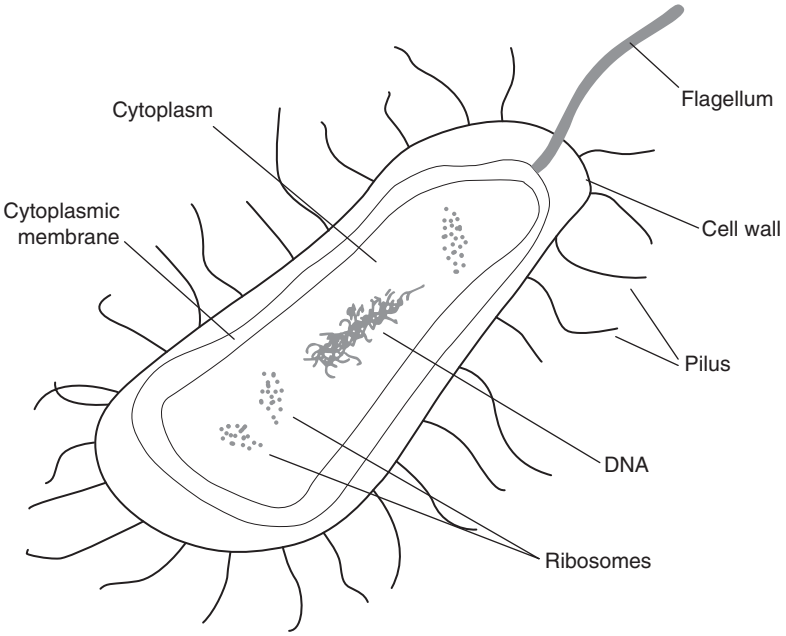

Figure 1.11 Structure of prokaryotic cells

Sepsis is often defined as an overwhelming life-threatening infection. It is more common than myocardial infarction (MI) (heart attack) and kills more people in the UK than breast, bowel and prostate cancer combined. Sepsis is more common in the very old and very young whose immune systems are in decline or not fully developed, while patients on immunosuppressive medications such as certain steroids are also at increased risk (Knight and Hore, 2018).

Symptoms of sepsis vary according to the age of the patient. According to the UK Sepsis Trust, the signs of sepsis in an adult include:

1. '***S**lurred' speech or confusion*
2. ***E**xtreme shivering or muscle pain*
3. ***P**assing no urine (in a day)*
4. ***S**evere breathlessness*
5. ***I**t feels like you're going to die*
6. ***S**kin mottled or discoloured.*

In children, sepsis should be suspected if the child:

1. *Is breathing very fast*
2. *Has a 'fit' or convulsion*
3. *Looks mottled, bluish, or pale*

4. *Has a rash that does not fade when you press it*
5. *Is very lethargic or difficult to wake*
6. *Feels abnormally cold to touch.*

A child under five may have sepsis if he or she:

1. *Is not feeding*
2. *Is vomiting repeatedly*
3. *Has not passed urine for 12 hours.*

(UK Sepsis Trust, 2019)

Since sepsis is life-threatening and so common, it is essential that nurses learn to recognise some of the key features of this medical emergency early in their training. To help develop your knowledge, read through Mary's case study.

Case study: Mary – sepsis evidence-based practice

Mary is 72 and has become extremely unwell over the last 24 hours. She has become increasingly breathless and is expectorating green sputum. She was seen by her GP who sent her into her local hospital as an emergency admission. On admission, Mary was fully conscious and alert but slightly confused. Her temperature was 38 °C, her heart rate was 125, her blood pressure 110/58, respiratory rate 26 breaths per minute and oxygen saturation 92 per cent on room air. Mary's vital signs were recorded using the NEWS 2 (National Early Warning Scoring) system (Royal College of Physicians, 2017) and her total score was calculated as 11. Any score of 7 or above should trigger an emergency response by a clinical team with experience in caring for critically ill patients.

Mary was seen by the critical care outreach team and transferred to the High-Dependency Unit where the Sepsis Six Pathway (Sepsis Trust, 2019) was initiated: oxygen was administered, blood cultures were taken, intravenous antibiotics were commenced and a urinary catheter was inserted to measure Mary's urine output accurately. Serial lactates were checked. A raised serum lactate (> 4mmol/L) is associated with a significantly increased mortality rate. Lactate levels rise during sepsis from both aerobic and anaerobic sources as well as reduced lactate clearance. Mary gradually recovered and was able to return home two weeks after her admission.

Mary's case study highlights that although sepsis is immediately life-threatening, if it is recognised early and treatment initiated quickly, even elderly patients can recover.

Not all bacteria are pathogenic or harmful; indeed, some are essential to human survival and health. Bacteria are found in huge numbers within and on the surface of the human body where, together with other microorganisms, they form the microbial biome (also known as the microbiome). It has been estimated that there are around 23 times more bacterial cells associated with the human body than human cells, and although it has been known for a long time that certain bacteria such as those found in the colon play key roles such as synthesising vitamin K (a key clotting factor), the complex roles of the microbial biome are still poorly understood.

Cells as targets for drugs

Virtually, all drugs used by nurses exert their effects at a cellular level. A good example would be synthetic insulin that is used to control the blood sugar levels of patients with diabetes mellitus. Synthetic insulin mimics the naturally produced insulin of the pancreas, stimulating human cells to take up glucose from the blood. Human cells are able to recognise each other using the glycoproteins embedded in their cell membranes; these protein markers can also allow drugs to target specific cell types within the body. To conclude this chapter, we will return to Josie, who was recently diagnosed with breast cancer.

Case study: Josie revisited – breast cancer evidence-based practice

Josie was fortunate to detect the lump in her breast while the tumour mass was small and quickly underwent surgery (lumpectomy) to remove the cancerous tissue. Following histological examination, it was determined that the malignant cells forming Josie's tumour expressed the human epidermal growth factor receptor 2 (HER2). Drugs that block this receptor such as Herceptin have recently become available, which provides a new tool for treating breast cancer.

Herceptin can slow the growth of breast tumour cells and when used in early breast cancer can reduce the risk of recurrence. Josie was relieved to be told by her consultant that since her tumour mass was small, chemotherapy would not be required and since beginning her Herceptin treatment six months ago tests have revealed that Josie is currently free of the disease.

Targeted drugs such as Herceptin are revolutionising the treatment of many forms of cancer, with new targeted therapies continually being developed and made available.

Now that you have completed the chapter, attempt the multiple-choice questions in Activity 1.5 to assess your knowledge.

Activity 1.5 Multiple-choice questions

1. DNA is found wrapped around
   a) Histamine
   b) Histone protein
   c) Myosin protein
   d) Keratin protein
2. The region of a cell primarily involved in protein synthesis is
   a) The smooth endoplasmic reticulum
   b) The lysosomes
   c) The plasma membrane
   d) The rough endoplasmic reticulum
3. The diploid number of human chromosomes is
   a) 46
   b) 23
   c) 48
   d) 52
4. Release of energy within the mitochondria in the presence of adequate oxygen is referred to as
   a) Anaerobic respiration
   b) Aerobic respiration
   c) Glycosylation
   d) Gluconeogenesis
5. Which of the following is *not* a function of the Golgi apparatus?
   a) Production of lysosomes
   b) Preparing material for export out of the cells
   c) Refining of crude proteins from the rough endoplasmic reticulum
   d) Production of mitochondria
6. Which of the following commonly results in dehydration?
   a) Vomiting
   b) Poorly controlled diabetes
   c) Not drinking enough fluid
   d) All of the above
7. Cells will show crenation when placed in a
   a) Hypertonic solution
   b) Isotonic solution
   c) Hypotonic solution
   d) All of the above

8. Water intoxication can cause death because
   a) Soft organs will rapidly become dehydrated
   b) Swelling of the brain raises the intracranial pressure, reducing blood flow
   c) Excess water increases movement of glucose into the blood
   d) Blood pressure will rise rapidly
9. The elastic tissue found lining the bladder is
   a) Simple columnar epithelium
   b) Simple cuboidal epithelium
   c) Pseudostratified epithelium
   d) Transitional epithelium
10. Which of the following tissues forms the walls of each alveolar air sac?
   a) Stratified columnar epithelium
   b) Stratified cuboidal epithelium
   c) Simple squamous epithelium
   d) Simple cuboidal epithelium

Chapter summary

Human cells have three major regions, called the nucleus, the cytoplasm and the plasma membrane. The nucleus is the control centre of the cell and is the location of DNA. When cells divide, the DNA condenses to form chromosomes, which can be visualised and counted. Human cells (with the exception of sperm and ova) have the diploid number of chromosomes (46). Deviations from this diploid number can result in chromosomal disorders such as Down syndrome.

The cytoplasm of the cell consists of the rough endoplasmic reticulum which is an area of protein synthesis and the smooth endoplasmic reticulum which is responsible for the synthesis of lipids (fats). The cytoplasm is also the location of organelles including: mitochondria, which release energy from molecules such as glucose, and the Golgi apparatus, which prepares and packages material for export.

The plasma membrane which surrounds the cell is composed predominantly of a phospholipid bilayer in which there are a variety of proteins that function as channels and receptors. The plasma membrane holds the cell together, controls what enters and leaves the cell and plays key roles in signalling and recognition between cells.

Cells are grouped together in organised collections termed tissues; these include epithelial, connective, muscle and nervous tissue, which are used to construct the internal and external organs. The human body also hosts a diverse community of microorganisms which are collectively referred to as the microbial biome or microbiome.

Activities: Brief outline answers

Activity 1.1 Reflection (page 9)

As you wind the elastic up tighter and tighter it will begin to fold and loop over itself and progressively become thicker. This process is termed supercoiling and a similar happens to DNA as cells begin to divide.

Activity 1.2 Team working (page 18)

Eventually the whole room will start to smell of the aroma as the material evaporates into the room and begins to diffuse in the air from a region of high concentration (the tissue) to a region of low concentration (the room), until an even distribution occurs.

You may have noticed a similar phenomenon when somebody boards a bus with strong-smelling deodorant and eventually everyone on the bus becomes aware of the smell as the deodorant diffuses through the air.

Activity 1.3 Evidence-based practice and research (page 21)

Most saline drips will state 0.9 per cent NaCl which is isotonic to human cells.

Activity 1.4 Evidence-based practice and research (page 22)

Effective infection prevention and control measures include:

- Hand wash with soap and water following the World Health Organization's 5 Moments.
- Wear gloves and aprons for contact with vomit, faeces or contaminated equipment or environment.
- Source isolation preferably in a single room with en-suite facilities or cohort nursing with designated toilets or commodes.
- Specimens of faeces should be sent for microbiological examination.
- Polymerase chain reaction (PCR) tests which detect the presence of norovirus nucleic acid are the preferred tests.
- Decontamination of spillages promptly and increase frequency of environmental cleaning first with detergent and water followed by a 1000ppm solution of a chlorine-releasing disinfectant.
- Reduce unnecessary movement of patients.
- Discharge home is allowed but transfer to nursing homes should be delayed until the patient has been asymptomatic for 48 hours. Transfer to other wards must only be allowed according to urgent clinical need and following a risk assessment.
- Contaminated linen should be placed in an alginate bag before being placed in a red linen bag and sent to the laundry.
- Waste must be correctly sorted and the appropriate coloured bag used.
- Non-essential visitors must be excluded, e.g. hairdressers and newspaper trolleys.
- All patients' visitors must be informed of the outbreak and advised to wash their hands thoroughly on leaving the ward. In some cases visiting may be discouraged but in the case of terminally ill patients, children, vulnerable adults and those for whom visiting is an essential part of recovery, visiting should be allowed.
- Any staff who become unwell should stay off sick until they have been asymptomatic for 48 hours.
- All patient areas must be thoroughly cleaned at the end of the outbreak. This should include laundering of curtains, and steam cleaning of soft furnishings should be considered.

Activity 1.5 Multiple-choice questions (pages 32–3)

1) b, 2) d, 3) a, 4) b, 5) d, 6) d, 7) a, 8) b, 9) d, 10) c

Further reading

Cook, N et al. (2021) Chapter 2: The Human cell, in *Essentials of Anatomy and Physiology for Nursing Practice,* 2nd edition. London: Sage Publications Ltd.

A textbook to develop your knowledge of human anatomy and physiology that is aimed specifically at nurses.

Knight, J and Andrade, M (2018) Genes and chromosomes 1: Basic principles of Genetics. *Nursing Times*, 114(7), 42–5.

A gentle overview of how DNA is organised and the nature of chromosomes.

Tortora, G and Derrickson, B (2023) Chapter 3: The Cellular Level of Organization, in *Tortora's Principles of Anatomy and Physiology* (16th edition). New York: John Wiley & Sons.

In-depth coverage of human anatomy and physiology.

Useful websites

www.medicalnewstoday.com/articles/320878.php

A simple overview of cell structure and function.

www.kenhub.com/en/library/anatomy/introduction-to-histology

An overview of histology, including real tissue sections as viewed under a microscope.