



The University of
Nottingham

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School of Health Sciences

Bioscience Workbook:

Basic Science

MSc GEN

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Introduction

We take pride in attracting students into nurse education from a variety of academic backgrounds and interests. For example, students have degrees ranging from English and History to Immunology and Molecular Biology.

This provides a rich mix of knowledge and experience, which can enhance the problem-based learning approach used on the MSc Graduate Entry Nursing (GEN) programme. All of you will have something unique to offer this course and so enhance the learning experience of others.

Nevertheless, we cannot get away from the fact that science subjects such as anatomy, physiology, microbiology, pathology, genetics, epidemiology and behavioural science all underpin nursing practice. This means that from the onset of the course you may be exposed to several different subjects that you have not studied before. This is inevitable on a course that aims to help you learn important topics in both a focused and an integrated way. For instance, you are probably well aware that smoking is known to damage the lungs. This will be explored, not only in relation to public health and individual well-being, but also with regards physical changes that take place in the human body due to smoking. As a student you will learn about lung anatomy and lung function as well as the impact that smoking can have on the lungs and other areas of the human body. At the microscopic level it is evident that the airways are lined with cells that have cilia to help move harmful particles and microorganisms out of the lungs. Smoking damages these cells so that toxins remain in the lungs. But what are cells? What are organisms and what are toxins, never mind the cilia? So many questions already!

In order to understand the normal and abnormal functioning of life, it helps to know what the body is made of. For example, you will need to know what cells are, what they are made of and how they work. From this, the functions of the constituents of cells, for example, proteins and fats can be studied. Proteins carry out many cellular activities, but how are they made and what enables them to function in so many different ways? Organic compounds and inorganic elements all have a role too. Life continues because the body makes use of different types of bonds between these atoms and molecules, for example, covalent and ionic bonds. Changing the environment in which cells work (e.g. by altering the pH) can drastically affect normal function.

Some of the basic science concepts and jargon may be relatively unfamiliar to those of you who have not studied physical science in detail or who have had a break from studying. The aim of this workbook, therefore, is to provide an opportunity before and during the early stages of the course, to familiarise yourselves with some of the more important concepts that underpin the basic and clinical sciences.

How to use this workbook

We hope that by working though this book, you will gain confidence in any unfamiliar territory. This should enable you to concentrate on appreciating, learning and subsequently applying the core biological sciences that underpin nursing practice.

If you use an active approach to the workbook, for example, by completing the exercises, making extra notes, drawing diagrams and/or referring to additional recommended texts, it will help you prepare for further self-managed learning tasks planned for you on the GEN programme. As self-assessment of learning is also an important student activity on the course, we hope that you will try to answer the self-test questions on each topic as you go along and revise any points that you haven't understood. The exercises include online multimedia tutorials. We call these reusable learning objects or RLOs, which are accessed via links to the Internet. These RLOs have text, animation and sound so you will benefit from using earphones or speakers when you work through them. You can link to the on-line tutorials directly when viewing the workbook from your computer. Within each section of the workbook, you will also find information detailing the clinical relevance of each topic so that you can see how the information can be translated into the nursing practice. We suggest you work through the sections in order. Workbook topics 6-9 are more challenging and develop ideas that are introduced in topics 1-5. We will revisit many of the topics briefly in lectures, seminars and workshops as the course progresses.

Throughout, we have highlighted key words for you in ***bold italic*** text when they first appear. These terms are listed on pages 63-65. We will expect you to know the meaning of these terms as soon as is possible for you.

If you have any queries regarding this workbook please contact:
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TOPIC 1: LEVELS OF ORGANISATION IN THE HUMAN BODY

Aim: To enable you to recognise the levels of organisation in the human body.

Learning outcomes. You have completed this section when you can:

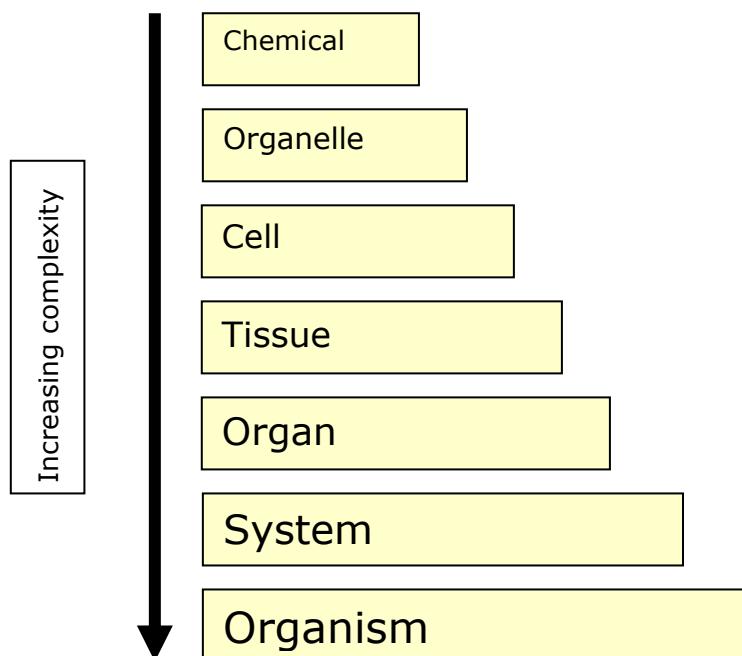
1. Explain the relationship between cells, tissues and organs.
2. Explain that organs work together to form the major body systems.

INTRODUCTION

Like any large company or establishment (the NHS, or a University for example), the body has different levels of organisation. All levels, from chemicals through to complex body systems, work together to maintain the body's homeostatic balance (Link to RLO tutorial at the end of this section). In order to understand the function of organs, body systems and even a whole organism, it is essential to understand the properties of the smallest elements of organisation.

There are **7 levels of organisation** in the human body, outlined in Figure 1.1

Figure 1.1 Levels of organisation in the human body



Topics 2-8 in this workbook will introduce you to the chemical, organelle and cellular components of the human body. But let us start by briefly thinking about how these crucial components come together to form the tissues and organs that make up our body systems and the whole human organism.

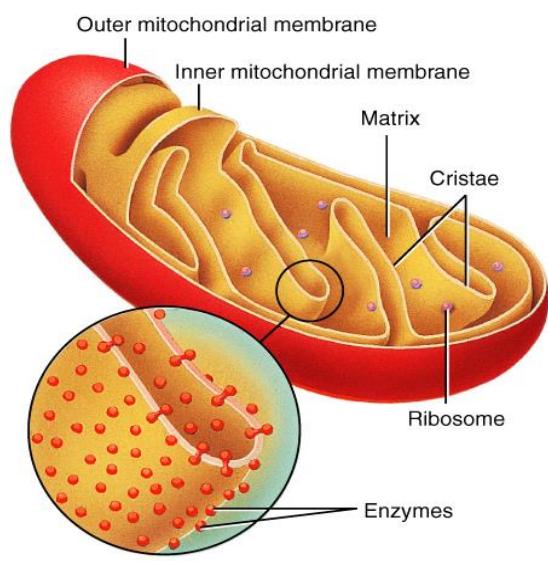
Chemical level

The chemical level is the smallest level that we will consider. Chemicals can combine to form molecules. These molecules can themselves combine to form macromolecules such as lipids and proteins

Organelle level

Chemicals and molecules can be organised into larger units called organelles (topic 2). Organelles such as mitochondria, ribosomes and nucleus can be described as a collection of molecules organised in such a way that they can perform a specific task or function inside the cell. For example, mitochondria produce adenosine triphosphate (ATP) which stores energy for use in the cell.

Figure 1.2 Organelle: structure of a mitochondrion.



Cellular level

Cells are the smallest and most numerous structural units that possess the basic characteristics of life. An average human body contain approximately 1×10^{14} cells! Although all cells have some characteristics in common, such as being surrounded by the **plasmalemma** and containing a single **nucleus**, they specialise or differentiate in order to carry out unique functions. For example, adipocytes (or fat cells) are specialised to enable storage of lipid and myocytes (muscle cells) are specialised to contract under the control of certain stimuli. The structure of a typical mammalian cell can be seen in Figure 2.2.

Tissue level

Tissues represent the next step in the hierarchy of the human body. Despite the body containing trillions of cells, they don't work independently. Cells work together to perform various tasks to keep the body in **homeostasis**. In order for the cells to work together, they form tissues. A tissue is a collection of many similar cells that are specialised to carry out a particular function. There are 4 tissue types in the human body, epithelial, connective, muscle and nervous tissue.

Organ level

Many tissue types come together to form an organ such as the heart or liver. Organs usually have a recognisable shape and are composed of two or more different tissues. For example, the heart contains smooth muscle and cardiac muscle and receives communication from nerves.

System level

The next level of structural organisation is the system level. A system consists of two or more organs that have a common function, or work together in a coordinated way. Systems accomplish tasks that organs would not be able to carry out on their own. For example, the cardiovascular system consists of the heart and blood vessels. Together, these organs transport blood around the body. Sometimes an organ can be part of more than one system.

Organism level

The term organism represents any living individual. This is the upper most organisational level. All the levels we have discussed must work together in order to support the life of an organism (e.g. human being).

Consolidation, further learning and self-assessment on topic 1.

The online tutorials below will help you expand and consolidate your learning on levels of organisation in the human body.

1. <http://www.nottingham.ac.uk/~cczcal/Nursing/homeostasis/homeostasis.html>

2. The link below will take you to a slideshow tutorial that will help you consolidate and extend your knowledge on the topics covered in Section 1 of this workbook.

http://www.rapidlearningcenter.com/biology/Preview/RL204/PT/ANP_CT01_IntroductionToPhysiology.pdf

B. Multiple choice questions (answers are in the appendix). Choose the single best answer from the 5 options for each question.

1.1 Which of the following places levels of organisation in the human body in the correct order commencing from the smallest?

- a. Tissue – system – chemical – cell – organism
- b. Chemical – cell – tissue – system – organism
- c. Chemical – cell – system – tissue - organism
- d. Tissue – cell – organisms – chemical – system
- e. Cell – tissue – chemical – organism - system

1.2 Which of the following is a type of cell?

- a. Lipid
- b. Ribosome
- c. Adipocyte
- d. Cristae
- e. Mitochondrion

1.3 The average human body is estimated to contain...

- a. 1×10^2 cells
- b. 1×10^4 cells
- c. 1×10^8 cells
- d. 1×10^{10} cells
- e. 1×10^{14} cells

1.4 Which of the following terms most closely defines the concept of homeostasis?

a. Conception

b. Balance

c. Disruption

d. Degeneration

e. Development

TOPIC 2: CELL STRUCTURE

Aim: To enable you to understand the structure and function of a human cell.
(On commencing the course you will be given access to an e-learning package that will enable you to explore the human cell further).

Learning outcomes. You have completed this section when you can:

1. Describe the basic structure of the cell including the following sub-cellular organelles: nucleus, membrane, ribosomes, mitochondria, endoplasmic reticulum, Golgi apparatus (Golgi bodies) and lysosomes.
2. Briefly describe the functions of the organelles listed in 1.
3. Explain how molecules move around the body by diffusion, osmosis and active transport (use RLO listed at end of section).

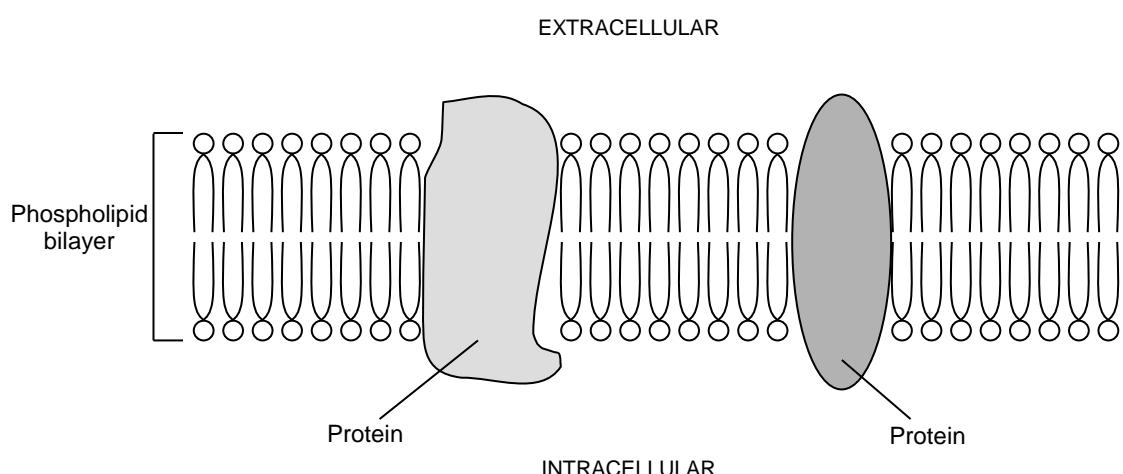
INTRODUCTION

There are approximately 10 million million cells in the human body. These cells are organised into the tissues and organs that perform all of the essential functions we require for life. Despite the fact that various cells have very different sizes, shapes and functions, almost all of them contain the same cellular machinery or **organelles**, enclosed within a cell membrane.

CELLULAR ORGANELLES

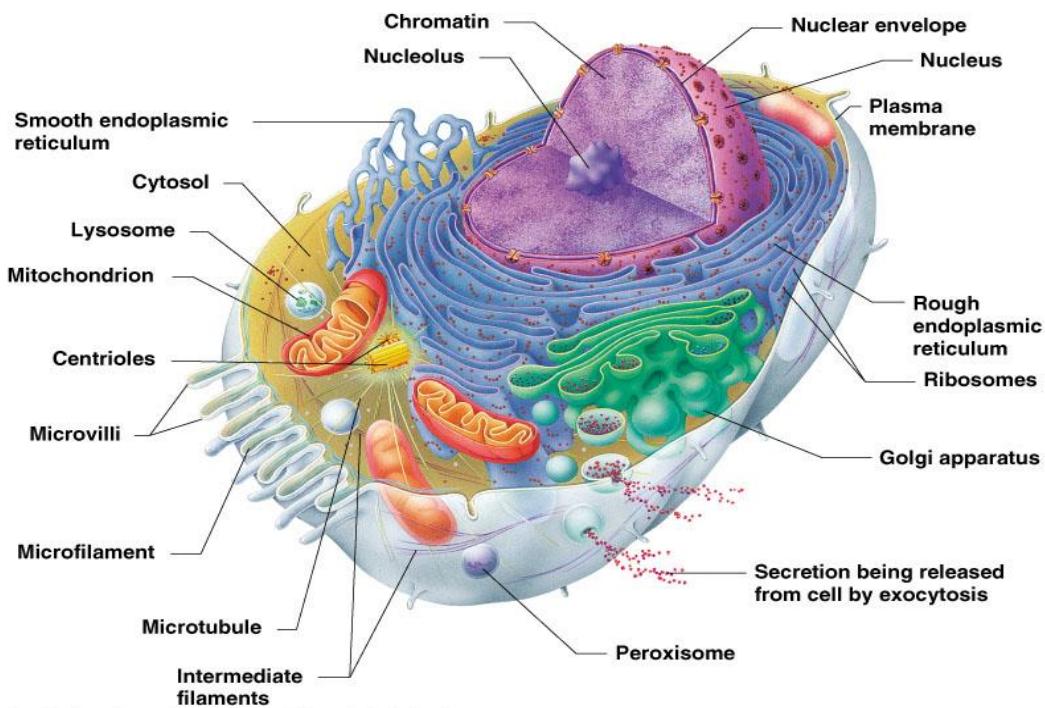
The cell membrane (**plasmalemma**) is composed of a double layer of **phospholipid** molecules with embedded **proteins** (see Figure 2.1). The plasmalemma acts as the barrier between the fluid inside the cell (**intracellular fluid**) and the fluid outside the cell (**extracellular fluid**). The intracellular fluid is also known as the **cytoplasm**. Entry or exit of substances is tightly regulated. The plasmalemma may have some surface specialisations, such as **cilia** (hair-like projections).

Figure 2.1 Structure of the plasmalemma



The cytoplasm contains all of the substances necessary for the various functions of the cell (e.g. growth, movement, secretion, absorption). Within the cell there are numerous organelles, each with a specific function or set of functions (Figure 2.2, Table 2.1).

Figure 2.2 A human cell showing organelles



The **nucleus** is the control centre of the cell. It contains the 'blueprint for life', **deoxyribonucleic acid (DNA)**. Everything that the cell does is controlled by expression of the **genes** (discrete lengths of DNA) that code for proteins (see Topic 6). The nucleus itself is separated from the major intracellular compartment, the cytoplasm, by a **nuclear membrane**.

When genes are transcribed, the **messenger ribonucleic acid (mRNA)** that is produced moves into the cytoplasm and is translated into protein on **ribosomes**. (See Topic 6) As such, ribosomes can be thought of as the manufacturing plants (or more specifically, assembly benches) of the cell. If the protein is destined for export from the cell or is destined for a cell membrane, the ribosome will move to the **endoplasmic reticulum**, an intracellular membrane system.

When such proteins are synthesised, they are 'polished' before final use. Small **vesicles** (lipid bags) bud off from the endoplasmic reticulum, pass to the **Golgi apparatus** where they are modified before being packaged into further vesicles that are exported from the Golgi apparatus.

Table 2.1 Functions of major cellular organelles

Organelle	Major function(s)
Nucleus	Site of most of the cell's DNA; Transcription of DNA into mRNA takes place here.
Ribosomes	Site of translation of mRNA into protein.
Endoplasmic reticulum (ER)	Intracellular membrane system – Rough ER has ribosomes that translate mRNA into proteins destined for membranes in the cell or for transport out of the cell.
Golgi apparatus	Intracellular membrane system that is the site of protein modification that might be needed to achieve its final structure.
Mitochondrion	Major site of energy production in the cell.

Most cellular functions are regulated by proteins that act as biochemical catalysts called **enzymes**. Enzymes can exist in the cytoplasm or in other intracellular spaces such as the Golgi apparatus, the nucleus, or the **mitochondrion**.

The mitochondria are the organelles in which the majority of the cell's energy-storage molecule **adenosine triphosphate (ATP)** is synthesised. One molecule of **glucose** can be used by the cell to yield more than 30 molecules of ATP, which can then be used to power any of the energy-dependent processes in the cell. These can be as diverse as pumping ions out of the cell, cell shortening (contraction) or conversion of one chemical substance into another. The mitochondria can be thought of as the power stations of the cell.

CLINICAL RELEVANCE

Understanding cell structure and function can now help explain some of the damaging effects of smoking. For example, we know that smoking can cause frequent airway infection (bronchitis). This is because smoking damages the cilia on the cells that line the airways. The function of cilia is to keep fluid moving from deep in the lungs to the upper parts of the airways; when the cilia are damaged or lost, this results in

defective clearance of mucus from the airways, meaning that bacteria can accumulate and cause infection.

Consolidation, further learning and self-test exercises on topic 2.

A. The **RLO tutorials** below will help you consolidate your learning on the cell and preview cell division.

1. Labelling the cell

http://www.wisc-online.com/objects/index_tj.asp?objID=AP11403

2. Cell Division

<http://www.nottingham.ac.uk/nmp/sonet/rlos/bioproc/celldivision/index.html>

B. **Multiple choice questions** (Answers are in the Appendix).

Choose the single best answer from the 5 options for each question.

2.1 DNA transcription happens mainly in the:

- a. cytoplasm.
- b. endoplasmic reticulum.
- c. Golgi apparatus.
- d. mitochondrion.
- e. nucleus.

2.2 The major lipid component of the plasmalemma is:

- a. cholesterol.
- b. linoleic acid.
- c. myelin.
- d. phospholipid.
- e. triglyceride.

2.3 The major energy-storage molecule in human cells is:

- a. adenosine diphosphate (ADP).
- b. adenosine monophosphate (AMP).
- c. adenosine triphosphate (ATP).

- d. cyclic adenosine monophosphate (cAMP).
- e. guanosine triphosphate (GTP).

2.4 Translation of mRNA into protein occurs at the:

- a. Golgi apparatus.
- b. mitochondrion.
- c. plasmalemma.
- d. nuclear membrane.
- e. ribosome.

TOPIC 3: ATOMS, MOLECULES, BONDS and IONS

Aim: To enable you to understand the chemical nature of biological systems.

Learning outcomes. You have completed this section when you can:

1. Explain that atoms and molecules are the basic units of matter.
2. Identify the following by their chemical symbol - oxygen, hydrogen, carbon, sodium, potassium, chlorine, nitrogen, calcium, iron, magnesium, iodine and phosphorus.
3. Define with examples the terms electrolyte, cation, anion, and explain their significance to health.

INTRODUCTION

All living beings (including the cells they are composed of) and non-living objects are made up of chemicals. The ancient Greeks recognised that all matter was composed of minute building blocks and although they were not sure of their existence they used the word *atomata* to describe them. Today these building blocks or chemical **elements** are named and given abbreviations based on the first or first and second letter of their Latin or English name. Each element is made of smaller units of matter called **atoms**. For any given element, all atoms are of the same type.

Structure of Atoms

An atom consists of two basic parts - a centrally located **nucleus** and **electrons** that move around the nucleus. The nucleus contains positively charged particles called **protons** and uncharged particles called **neutrons**. Each proton carries one positive charge. The overall effect is that the nucleus is positively charged. Each electron is negatively charged and carries one negative charge. The number of electrons in an element always equals the number of protons and thus the atom is electrically neutral.

The atoms of one element differ from another element predominantly because of the number of protons. For example hydrogen has one proton, helium has two protons and carbon has six protons. The number of protons in an atom is called the **atomic number**. The **atomic mass** is the total number of protons and neutrons in an atom.

Question 3.1. Link to and work through the RLO tutorial below. Check out the periodic table and find the atomic number and atomic mass (to the nearest whole number) of nitrogen, oxygen, phosphorus, sodium and chlorine.

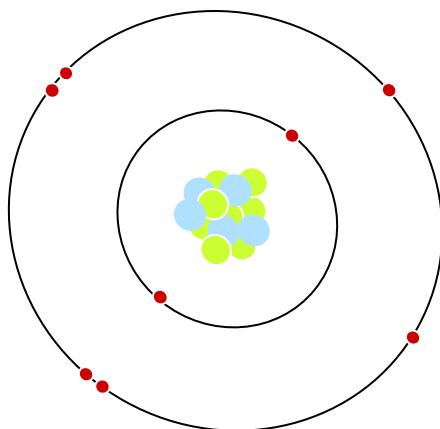
http://www.nottingham.ac.uk/nursing/sonet/rlos/science/body_elements/

Electrons

The electrons concentrically orbit around the nucleus in an organised manner. Each of these orbits is called an **energy level**. The inner energy level only holds 2 electrons and the next, 8. The third energy level can hold up to 18 electrons but can be stable with only 8. The fourth energy level can hold 32 electrons. The energy levels fill with electrons from the innermost outwards and electrons 'pair up' as the energy level fills.

Thus an atom of oxygen (O), which has 8 electrons, would have 2 electrons in the first level and 6 in the second level, with room for 2 more electrons in the second level. The electrons in the second energy level of an oxygen atom exist as two sets of paired electrons and two unpaired electrons (Figure 3.1).

Figure 3.1 Schematic diagram of an oxygen atom. Electrons are represented as small dots orbiting the nucleus in two energy levels.



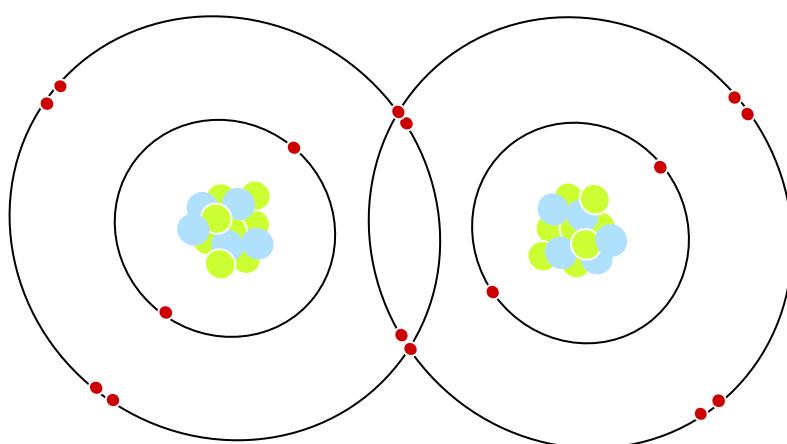
The number of electrons in the outermost energy level determines much of the atom's chemical properties. Atoms attempt to fill their outermost energy levels. Atoms with a full outer energy level, such as helium or neon, are inert. Most other atoms have outer energy levels that are incomplete. This creates opportunities to take on or share electrons. When two or more atoms combine to try to fill their outer energy levels a molecule is formed. A molecule contains two or more atoms of the same element or of different elements. Atoms in a molecule are held together by chemical

bonds, which are a form of potential energy. Chemical reactions are simply the making and breaking of bonds between atoms.

Covalent Bonds

In a **covalent bond**, the atoms do not lose or gain electrons but share pairs of electrons. For example, if the first energy level can hold up to two electrons and hydrogen has only one electron, then a hydrogen atom will have only one electron in its first energy level. Hence, two hydrogen atoms can combine and the two electrons are shared between the atoms. The electrons circle the nuclei of both atoms. The sharing of one pair of electrons is described as a single covalent bond (Figure 2.2). However, two or three pairs of electrons can be shared, forming double or triple covalent bonds respectively. Covalent bonds can form between atoms of the same element or different elements.

Figure 3.2 Sharing of two pairs of electrons between two oxygen atoms, forming diatomic molecular oxygen (written as O_2 or $O=O$, where $=$ denotes the presence of a double bond)



Question 3.2: How many electrons are there in the outer energy shell of a carbon atom and how many other carbon atoms can be joined covalently to a single central carbon atom?

The ability of carbon to form these bonds and create stable compounds is essential for life. Carbon (C), hydrogen (H), oxygen (O), together with nitrogen (N) and phosphorus (P) combined in millions of different ways and account for most biological molecules.

If atoms equally share the electrons, and each atom equally attracts the electrons then this is referred to as a **nonpolar covalent bond**. If, however, there is an unequal sharing of electrons, with one atom attracting the electrons more strongly, then this is referred to as a **polar covalent bond**.

Hydrogen Bonds

Hydrogen bonds occur when a hydrogen atom covalently bonds to an oxygen or nitrogen atom but is also attracted to another oxygen or nitrogen atom. These bonds are weak but if they occur in large numbers they can provide stability as in DNA, for example.

Ionic Bonds

Atoms are electrically neutral because the number of positively charged protons and negatively charged electrons are equal. However, when an atom loses or gains an electron the charge changes. For example, a sodium atom (Na) has one electron in its outer energy level and so it can give up this electron to become an **electron donor**. The atom now has a positive charge and has become a sodium ion (Na^+). Similarly, chlorine (Cl) has 7 electrons in its outer energy level and can pick up an electron to become an **electron acceptor**. In gaining an electron from another element, a chlorine atom becomes negatively charged and becomes a chloride ion (Cl^-). The positively charged sodium ion and the negatively charged chloride ion attract each other. This attraction is called an **ionic bond** and in this example sodium chloride (common salt) is formed.

Question 3.3: How many energy levels do sodium and chlorine have and how many electrons can each level hold?

Atoms that have outer energy levels less than half full (such as sodium) aim to lose electrons and become positively charged ions called **cations**. Similarly atoms with energy levels that are more than half full (such as chlorine) aim to gain electrons and become negatively charged ions called **anions**. Molecules made up of these ions are formed by ionic bonds.

Question 3.4: Which of the following elements found in the body become cations and which become anions? *(circle the correct answer)*

Iodine Anion / Cation

Magnesium Anion / Cation

Potassium Anion / Cation

Calcium Anion / Cation

CLINICAL RELEVANCE

Energy is required to break and make covalent bonds. When we digest food by breaking bonds between atoms in a molecule, the energy released is used to build up other molecules for creating and repairing tissues. Some foodstuffs have a higher calorific value than others, based solely on the number and type of covalent bonds they contain.

A hydrogen atom that has lost its outer electron is a hydrogen ion. Hydrogen ions, which are simply single protons, make solutions acidic. In the stomach a high acid concentration is built up by pumping hydrogen ions into the stomach fluid. Drugs called proton pump inhibitors can reduce the amount of acid being produced - useful if you have painful acid reflux.

Ions in solution are essential for life and many are kept in fine balance by the body. See the section on inorganic elements for further details.

Consolidation, further learning and self-test exercises on topic 3.

A. The **RLO tutorials** below will help you consolidate your learning on atoms, molecules, bonds and ions.

1. Elements that make up the body

www.nottingham.ac.uk/nursing/sonet/rlos/science/body_elements

2. Structure of the Atom

http://www.nottingham.ac.uk/nursing/sonet/rlos/science/atomic_structure

3. Atomic bonding

http://www.nottingham.ac.uk/nursing/sonet/rlos/science/atomic_bonding/index.html

4. Hydrogen bonding

http://www.nottingham.ac.uk/nursing/sonet/rlos/science/hydrogen_bonding/

5. Acids, Alkalies and Bases: An Introduction

www.nottingham.ac.uk/nursing/sonet/rlos/science/acid_base_intro

B Multiple choice questions (Answers are in the Appendix).

Choose the single best answer from the 5 options for each question.

3.5 Which one of the following statements about atoms is **correct**?

- a. An element can contain atoms of different types.
- b. The nucleus of an atom contains protons and electrons.
- c. The atomic mass is the total number of protons in an atom.
- d. The nucleus of an atom contains protons and neutrons.
- e. The number of electrons in an atom is called the atomic number.

3.6 Which one of the following statements about electrons is **correct**?

- a. Electrons are arranged in energy levels around the nucleus.
- b. Electrons move around and collide with the nucleus.
- c. In a triple covalent bond two pairs of electrons are shared.
- d. The first energy level can hold up to 8 electrons.
- e. The second energy level can be filled before the first.

3.7 Which one of the following statements about ionic bonds is **correct**?

- a. An ion that can gain an electron is called an electron donor.
- b. If an atom gains an electron in its outer energy level then it will become negatively charged.
- c. In an ionic bond, electrons are shared between one or more atoms.
- d. One sodium ion will be attracted to 2 chloride ions.

e. Positively charged ions are called anions and negatively charged ions are called cations.

3.8 Which one of the following is a feature of covalent bonds?

- a. A covalent bond cannot be formed between atoms of two different elements.
- b. A covalent bond in a molecule of hydrogen involves sharing 4 electrons.
- c. Carbon can form a covalent bond with 5 hydrogen atoms.
- d. In a covalent bond the atoms share pairs of electrons.
- e. In a nonpolar covalent bond atoms equally attract the electrons.

TOPIC 4: COMMON ORGANIC COMPOUNDS

Aim: To enable you to understand the structure of carbohydrates, proteins, lipids and nucleic acids.

Learning outcomes. You have completed this section when you can:

1. Distinguish between monosaccharides (e.g. glucose and fructose), disaccharides (e.g. lactose and sucrose) and polysaccharides (e.g. starch and glycogen).
2. Identify key proteins within the body and relate their structure to their function.
3. Describe the structure of the following groups of lipids within the body: phospholipids, cholesterol and triglyceride.

INTRODUCTION

There are many different compounds within the body. These can be divided into two groups, organic or inorganic compounds. Organic compounds always contain carbon and hydrogen. They frequently contain oxygen and nitrogen and, sometimes, sulphur and phosphorus. Carbohydrates, lipids, proteins and nucleic acids are all organic compounds.

Carbon is an element that forms covalent bonds quite easily, as its outer energy level is half filled (see topic 3). A carbon atom can form four bonds with other elements. This means that carbon can combine with many different types of atoms to form large molecules of different structures and functions.

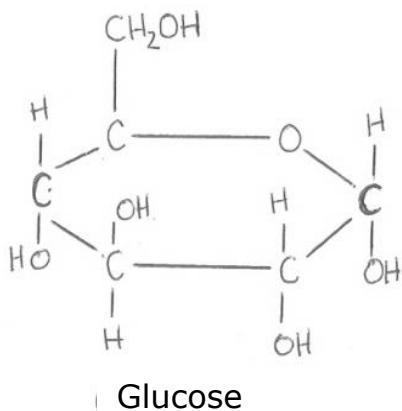
CARBOHYDRATES

Carbohydrates are important to the body. They perform a diverse range of functions. Carbohydrates contain carbon, hydrogen and oxygen usually, but not exclusively, with a ratio of 2 hydrogen atoms to 1 oxygen atom. For example, **ribose** ($C_5H_{10}O_5$), **glucose** ($C_6H_{12}O_6$) and **sucrose** ($C_{12}H_{22}O_{11}$) are all carbohydrates.

Carbohydrates are classified into three groups based on their size:

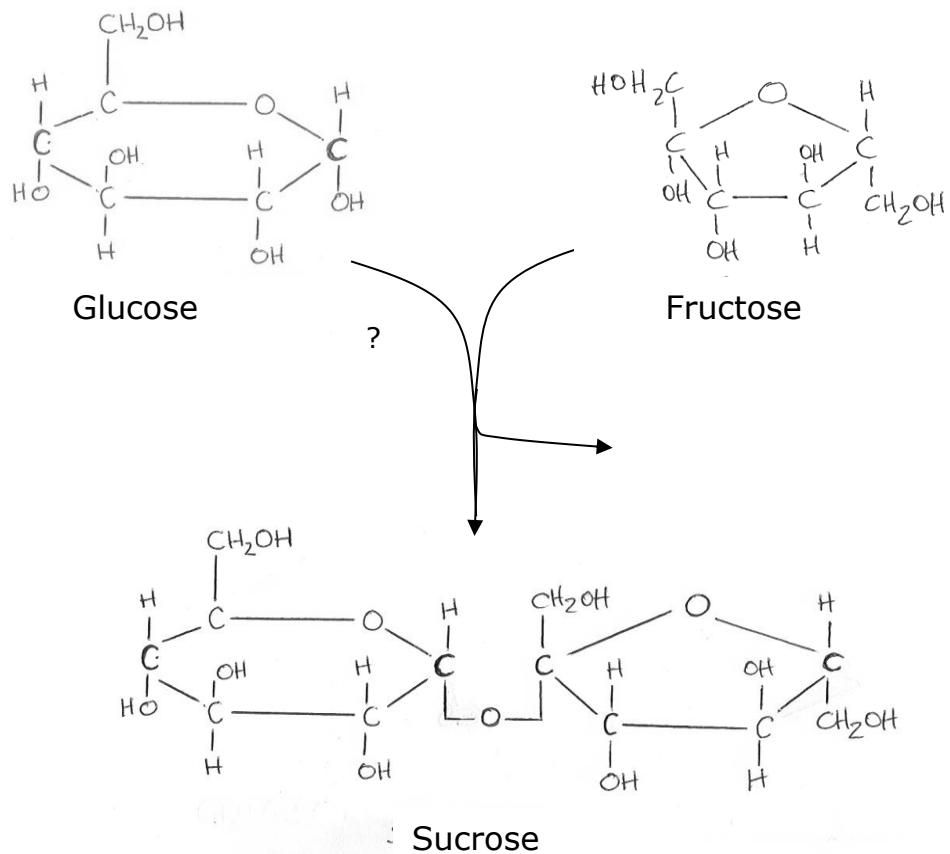
1. **Monosaccharides**; these are simple sugars with 3-7 carbon atoms; an example is glucose, a **hexose** (6 carbons), the main energy supplying molecule (Figure 4.1)

Figure 4.1 The molecular structure of glucose



2. **Disaccharides**; these are two monosaccharides joined chemically. For example sucrose, a disaccharide, is formed when glucose and fructose (both monosaccharides) combine (Figure 4.2):

Figure 4.2 Glucose and fructose combine to form the disaccharide sucrose



Question 4.1: If glucose and fructose are combined as in Figure 4.2, what other molecule would be formed as part of the reaction?

If water is added to disaccharides, they can be broken down (hydrolysed) into smaller and simpler molecules. In the case of sucrose, the products would be glucose and fructose. Another example is the hydrolysis of the disaccharide lactose to produce glucose and galactose.

3. **Polysaccharides**; these are several monosaccharides joined together. An example of a polysaccharide is **glycogen**, a branching chain of monosaccharides.

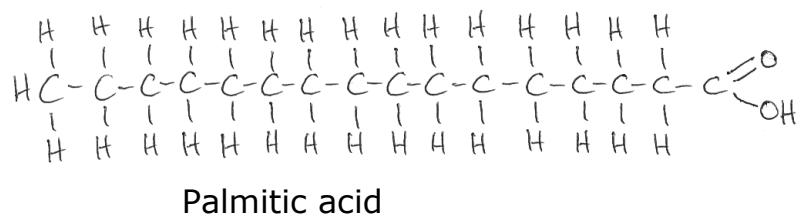
Some 5-carbon sugars (**pentoses**), specifically ribose and **deoxyribose**, are essential in the formation of nucleic acids; you will learn more about this in topic 5.

LIPIDS

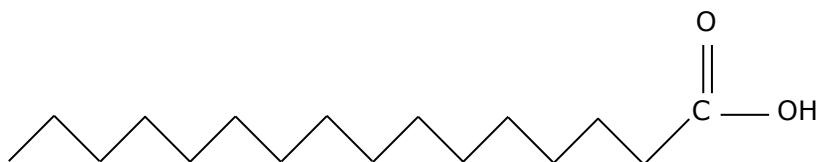
Lipids are made up of carbon, hydrogen and oxygen but do not have the 2:1 ratio of hydrogen to oxygen that is common to carbohydrates. Lipids are usually insoluble in water. Examples of lipids are **triglycerides**, phospholipids, steroids, carotenes, vitamin A and **prostaglandins**. Two are discussed here, triglyceride and prostaglandins.

Triglyceride has two components, **glycerol** and **fatty acids**, which are combined in the ratio of 1 glycerol molecule to 3 fatty acid molecules. The fatty acids that make up triglycerides can be short, medium or long chain fatty acids and they can also be **saturated** (high in hydrogen content with no carbon-carbon double bonds), or **unsaturated** (lower in hydrogen content with some carbon-carbon double bonds). Monounsaturated fatty acids have a single carbon-carbon double bond and polyunsaturated fatty acids have two or more carbon-carbon double bonds.

Figure 4.3 Structure of palmitic acid



or



Q4.2: Is **palmitic acid** a saturated or unsaturated fatty acid?

Triglyceride and fatty acids are important fuel sources for the body, having a higher calorific value per gram (9 calories per gram) than sugars and proteins (4 calories per gram), but they are also important in the synthesis of the constituents of cell membranes.

Prostaglandins (PGs) are membrane-associated lipids produced in all nucleated cells of the body and they influence the function of the cell. The prostaglandins are synthesised from arachidonic acid, which is a polyunsaturated fatty acid.

Prostaglandins can act as local chemical messengers, contributing to such diverse processes as the inflammatory response, dilation and constriction of blood vessels and the regulation of body temperature.

PROTEINS

Proteins are responsible for many activities within the body. For example, they can function as enzymes (speeding up biochemical reactions), antibodies (helping to fight infection) or hormones (acting as intercellular messengers).

Proteins are more complex in structure than carbohydrates and lipids. They contain carbon, hydrogen, oxygen, nitrogen and small amounts of sulphur and phosphorus. The building blocks of proteins are **amino acids**. When two amino acids combine a **dipeptide** is made, when three amino acids combine a **tripeptide** is formed and when a chain of amino acids are combined a **polypeptide** is formed. The bonds between the amino acids in a protein are called **peptide bonds**. There are twenty different amino acids, so protein structure is very variable.

For more on amino acids and protein structure, see topic 7.

NUCLEIC ACIDS

Nucleic acids are also organic compounds. In the body, nucleic acids take the form of DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) and are essential in directing all cellular processes. Nucleic acids are composed of carbon, hydrogen, oxygen, nitrogen and phosphorous. You will learn more about nucleic acids in topic 6.

CLINICAL RELEVANCE

Some knowledge of the structure of organic molecules is essential for healthcare education and practice. For example, it is important to know about the structure, calorific value and biological role of the various foodstuffs that we ingest. An individual may be eating no more than their normal daily calorie requirements, but if a large amount of the calories come from fat, particularly saturated fat, then this can be detrimental to health. Another individual may not be eating enough protein and may become seriously malnourished. Another may eat too much 'rich' food, ingesting too many nucleic acids, and suffer from gout as a result of high levels of uric acid in the blood (from the metabolism of nucleic acids). You will learn more about these topics as you study with us, but it is important to try to grasp these basic facts before you start.

Consolidation, further learning and self-test exercises on topic 4.

A. **RLO tutorials** to help you consolidate your learning.

1. Biomolecules: The Carbohydrates.

http://www.wisc-online.com/objects/index_tj.asp?objID=AP13104

2. Biomolecules: The Lipids.

http://www.wisc-online.com/objects/index_tj.asp?objID=AP13204

3. Biomolecules: The Proteins

http://www.wisc-online.com/objects/index_tj.asp?objID=AP13304

B. **Multiple choice** questions (Answers are in the Appendix).

Choose the single best answer from the 5 options for each question.

4.3 Which one of the following statements about carbohydrates is **incorrect**?

- a. Carbohydrates can be classified into three major groups; monosaccharides, disaccharides and polysaccharides.
- b. Carbohydrates usually contain hydrogen and oxygen atoms in the ratio of 2:1.
- c. Disaccharides are two monosaccharides joined chemically by hydrolysis.
- d. Monosaccharides containing 6 carbon atoms are called hexoses.
- e. Polysaccharides are several monosaccharides joined together through dehydration synthesis.

4.4 Which one of the following statements about lipids is **incorrect**?

- a. Lipids are made up of carbon, hydrogen and oxygen.
- b. Lipids have a 2:1 ratio of hydrogen to oxygen.
- c. Prostaglandins (PGs) are produced from arachidonic acid.
- d. Triglyceride has two components, glycerol and fatty acids.
- e. Unsaturated fatty acids have a lower hydrogen content than saturated fatty acids.

4.5 Regarding proteins, which one of the following statements is **correct**?

- a. Proteins are chains of monosaccharides.
- b. Proteins are synthesised from amino acids by hydrolysis of peptide bonds.
- c. Proteins can act as hormones.
- d. Proteins do not contain nitrogen.
- e. Proteins have the same calorific value as triglycerides.

TOPIC 5: INORGANIC ELEMENTS

Aim: To enable you to understand the properties water, mineral and electrolytes and the function of these within the body.

Learning outcomes. You have completed this section when you can:

1. Explain the important functions of water in the body.
2. Using examples, describe essential interactions of water with electrolytes that are essential to health.
3. Describe some key roles of sodium chloride, potassium, iron and calcium in the body.

INTRODUCTION

In contrast to organic compounds, which contain carbon and hydrogen and mostly contain covalent bonds, inorganic compounds lack carbon, are small in size and usually have ionic bonds. Inorganic compounds are vital to the body. Examples of inorganic compounds include water, many salts, acids and bases.

Water

Water (H_2O) is the most abundant inorganic compound within the body, with 60% of red blood cells, 75% of muscle tissue and 92% of blood plasma being made up of water. Water has many different functions, for example:

Water

1. acts as a solvent
2. can participate in chemical reactions such as those within digestion
3. can absorb and release heat slowly
4. plays an important role in heat evaporation and the cooling of the body
5. acts as a body lubricant, for example, in saliva
6. provides the aqueous environment for chemical reactions to take place in cells

The properties of water depend on the unequal distribution of electrons between the two hydrogen atoms and the oxygen atom. Electrons are displaced towards the oxygen atom and away from the hydrogen atoms, giving the oxygen a slight negative charge and the hydrogens slightly positive charges. This means that water molecules are attracted to each other and to other atoms and compounds.

If inorganic acids, bases or salts are dissolved in water within the body's cells ionisation occurs and they dissociate into ions. These ions are called **electrolytes** because the solution can conduct an electrical current.

Question 5.1: What are the terms for compounds that like water and those that dislike water? Which term applies to fats and oils?

Minerals and electrolytes

Minerals have many roles in the body including: fluid balance; acid-base balance; nerve and muscle functions; providing strength and rigidity for bones and teeth; and as components of enzymes involved in energy metabolism.

Saliva, blood and most other body fluids taste salty because they contain sodium chloride (NaCl). Cells, on the other hand, have a low intracellular concentration of sodium, but a high concentration of potassium. Energy is needed to maintain this difference in the concentration of these ions in the intracellular and extracellular space. Iron is essential for the transfer of oxygen around the body. Lack of iron causes anaemia and symptoms of tiredness, pale skin and shortness of breath on exercise.

Question 5.2: What are good food sources of iron?

Question 5.3: Describe two ways in which iron can be lost from the body.

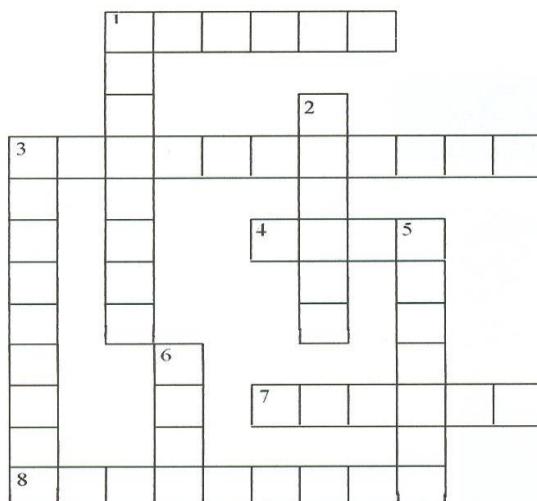
CLINICAL RELEVANCE

Movement of sodium and potassium across cell membranes forms the basis of nerve and muscle function. The ionic concentrations in different compartments control water movement around the body. Blood tests often include measurements of electrolytes.

The body very carefully regulates some minerals, for example, calcium. A low level of ionised calcium in the blood can cause increased nerve excitability and a condition called tetany, with tingling fingers, muscle spasms and convulsions. If the muscles surrounding the larynx are involved, then breathing can be affected. Another metal element that can cause problems if present in too high a concentration is potassium, because this affects the function of the heart.

Some inorganic elements are only required for health in tiny amounts, but if missing cause significant problems. They usually perform an essential role for the function of enzymes, so if not present the enzymes cannot function correctly. Examples are zinc, copper, and selenium. Iodine is essential for the production of thyroid hormone. Lack of iodine in the diet results in goitre (enlarged thyroid gland). This shows as a swelling at the front of the neck. The gland enlarges because it is working too hard to produce the hormone that is required for normal cellular functions.

Crossword. The crossword below is based on the names of some of the most common inorganic elements in the body. Look at the clues and see if you can work out the answers through self directed learning.



Across

1. This inorganic element can be found in vitamin B₁₂ (6)
3. Together with oxygen, this common element forms a group that is used to activate or deactivate many enzymes (11)
4. This element is an essential part of the enzyme carbonic anhydrase, which is important in the transport of carbon dioxide in the blood (4)
7. An extracellular cation in blood that helps maintains water balance (6)
8. A cation which helps maintain the structure of DNA and RNA. It is also abundant in bone (9)

Down

1. An anion in common salt that is important in water movement between cells (8)
2. Vital for production of thyroid hormones by the thyroid gland (6)
3. The major intracellular cation (9)

5. An essential component of bones and teeth, it is required for blood clotting and muscle contraction (7)
6. Plays a key role in the protein haemoglobin which is found in red blood cells (4)

Consolidation, further learning and self-test exercises on topic 5.

A. An **RLO tutorial** to help you consolidate your learning.

1. Solutions and Electrolytes.

<http://www.nottingham.ac.uk/nmp/sonet/rlos/science/solutions/>

B. **Multiple choice questions** (answers are in the appendix).

5.4 Which of the following describes inorganic compounds?

- a. cannot enter cells
- b. always insoluble in water
- c. large compared to organic compounds
- d. mostly contain covalent bonds
- e. lack carbon atoms

5.5 Which of the following is NOT a function of water?

- a. acts as a solvent
- b. dissolves lipids
- c. cools the body
- d. absorbs and releases heat slowly
- e. participates in chemical reactions

5.6 When inorganic acids, bases or salts are dissolved in water they...

- a. form water molecules
- b. have a neutral pH (7)
- c. become inert
- d. dissociate into ions
- e. form organic compounds

5.7 Water molecules are attracted to each other because of...

- a. an unequal distribution of electrons between hydrogen and oxygen atoms
- b. an unequal distribution of protons between hydrogen and oxygen atoms
- c. an unequal distribution of neutrons between hydrogen and oxygen atoms
- d. there are twice as many hydrogen atoms than oxygen atoms
- e. because of their physical shape

TOPIC 6: DNA – RNA – PROTEIN

Aim: To enable you to understand how DNA acts as a blueprint for the cell.

Learning outcomes. You have completed this section when you can:

- 1 Outline the relationships between DNA, genes and chromosomes.
- 2 Outline the structure and function of DNA and RNA in relation to protein synthesis.
- 3 Differentiate between mitosis and meiosis* (Achieved through RLO).
- 4 Describe the significance of crossover in genetic inheritance (Achieved through RLO).

* You are not be required to identify the different phases of mitosis or meiosis.

INTRODUCTION

Nucleic acids are very large organic molecules that contain carbon, hydrogen, oxygen, nitrogen, and phosphorus. There are two types of nucleic acid:

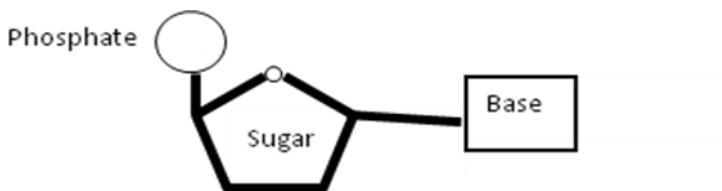
Deoxyribonucleic acid (DNA), and

Ribonucleic acid (RNA)

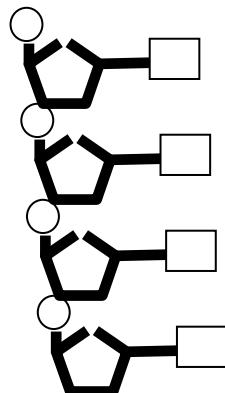
The basic building blocks of nucleic acids are **nucleotides**. A nucleotide is made up of three constituent parts:

1. A nitrogenous base, a ring shaped structure containing atoms of carbon, hydrogen, oxygen and nitrogen. There are four different nitrogenous bases in DNA: **adenine** (A), **thymine** (T), **cytosine** (C), and **guanine** (G). Adenine and guanine have a double ring structure and are referred to as **purines**. Cytosine and thymine are smaller, single-ringed structures and are referred to as **pyrimidines**. An easy way to remember this is that the ones with the letter 'y' in their name (cytosine and thymine) are pyrimidines
2. Deoxyribose, which is a monosaccharide. This sugar contains five carbon atoms and it is thus called a pentose.
3. A **phosphate** group

The parts of a nucleotide molecule are arranged as follows:



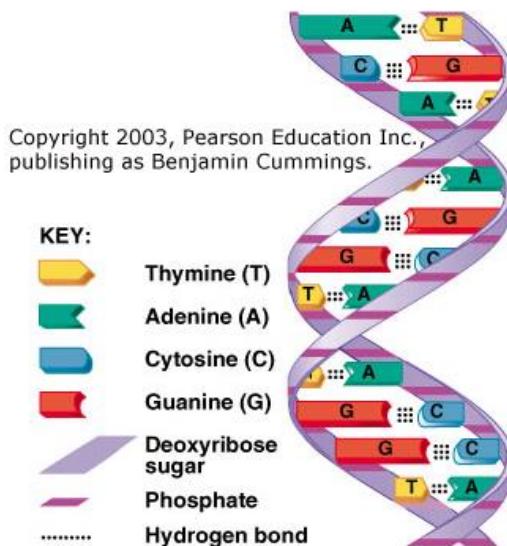
Several nucleotides joined together make a **polynucleotide** chain:



DNA

DNA is the type of nucleic acid that is contained in the nucleus of the cell. This DNA comprises the **genome**. A DNA molecule (Figure 6.1) is made up of two polynucleotide chains.

Figure 6.1 The structure of a molecule of DNA



The two strands of DNA are twisted around each other in a '**double helix**' that is, in some respects, like a spiral staircase. The phosphate and deoxyribose groups are rather like the banisters of the staircase. Paired bases form the steps in the staircase: cytosine always pairs with guanine and adenine always pairs with thymine. The order of bases in the DNA molecule is the '**genetic code**'. Thus a base sequence might be written 5'-TGGTTGCTACA-3' with the complementary (opposite) strand having the sequence 5'-TGTAGCAACCA-3'. When writing a base sequence, the convention is to go from the 5' end to the 3' end of the DNA. The two strands run in opposite directions so that the pairing happens as illustrated in Figure 6.2.

Figure 6.2 Pairing of complementary bases on two strands of DNA

5' TGGTTGCTACA 3'
| | | | | | | |
3' ACCAACGATGT 5'

RNA

RNA is the form of nucleic acid that is involved in **protein synthesis**. There are two main types of RNA that are involved in different parts of this process, **messenger RNA** and **transfer RNA** (also called mRNA and tRNA, respectively). RNA differs from DNA in several ways:

- It is single stranded
- The sugar in the RNA nucleotide is ribose (another pentose monosaccharide)
- RNA does not contain the base thymine, but the base **uracil** (U) instead

Protein Synthesis

Cells synthesise large numbers of diverse proteins, which perform many different functions. They may be enzymes, antibodies or hormones, for example. Genomic DNA contains the genetic instructions for making proteins. Protein synthesis occurs in two steps, **transcription** and **translation**.

Transcription

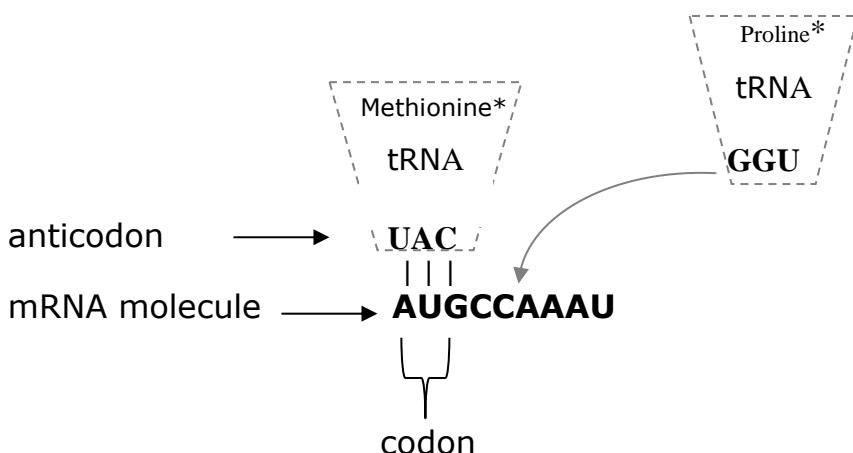
During transcription, the sequence of bases in a part of the DNA is copied (hence 'transcription') in the form of mRNA. The strand of the DNA that carries the genetic code is called the coding strand or 'sense' strand. The double helix strands separate or 'unzip' as the hydrogen bonds that hold the base pairs together break. An mRNA

molecule that has the same sequence as the 'sense' strand of DNA is synthesised, the one exception being the substitution of uracil for thymine. The mRNA then moves out of the nucleus to a ribosome.

Translation

Translation describes the process of synthesising a protein on a ribosome using an mRNA template (Figure 6.2). The building blocks of proteins are amino acids (see topic 7 for details). The various amino acids are chemically bound to specific tRNA molecules. This combination of amino acid and tRNA is known as **aminoacyl tRNA**. Each aminoacyl tRNA can bind to a specific three-base (triplet) sequence on mRNA known as a **codon** (e.g. AUG). The complementary triplet on tRNA (e.g. CAU) is known as an **anticodon**.

Figure 6.3 Codon-anticodon pairing and mRNA translation



*an amino acid

Through base pairing, the anticodon on a specific tRNA binds to the codon of mRNA. This only occurs when the mRNA is attached to a ribosome.

As each tRNA attaches to the mRNA via codon-anticodon pairing, the ribosome moves along the mRNA and the next tRNA and its corresponding amino acid will move into position. The two amino acids are joined by a peptide bond, the tRNA detaches from the mRNA, and the released tRNA can be recycled to pick up another available amino acid molecule. This process continues with the protein chain getting longer (elongation). When the protein is completed, further synthesis is terminated by a **stop codon** on the mRNA (UAA, UAG or UGA). The protein is then released from the ribosome for folding and further post-translational modification.

CLINICAL RELEVANCE

A number of diseases are caused by ***mutations*** in genomic DNA (changes in the sequence of bases) that result in the formation of mRNA that has the 'wrong' sequence, which subsequently leads to the synthesis of proteins that have an incorrect amino acid sequence and do not function properly. One example is sickle cell disease, in which a single nucleotide change in the gene encoding one of the subunits of haemoglobin results in a single mistake in the amino acid sequence of the protein. This causes crystallisation of the haemoglobin in the patient's red blood cells and can result in painful blockage of small blood vessels by the mis-shapen red blood cells. In some cases it can be fatal.

Consolidation, further learning, self-test exercises on topic 6.

A. RLO tutorials to help you consolidate your learning.

1. Protein Synthesis.

http://www.wisc-online.com/objects/index_tj.asp?objID=AP1302

2. Cell Division (initially requires DNA replication)

www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/celldivision

B. Multiple choice questions (Answers are in the Appendix).

Choose the single best answer from the 5 options for each question.

6.1 DNA structure includes:

- a. adenine.
- b. amino acids.
- c. base-pairing between adenine and guanine.
- d. ribose.
- e. uracil.

6.2 Which one of the following statements is **correct**?

- a. Adenine in the DNA template matches a thymine in the mRNA strand.
- b. Cytosine in the DNA template matches an adenine in the mRNA strand.

- c. During transcription, a copy is made of the 'sense' strand of DNA.
- d. During transcription, genetic information encoded within the DNA is copied into a strand of RNA called transfer RNA (tRNA).
- e. The double helix of DNA remains tightly bonded.

6.3 Which one of the following statements is **incorrect**?

- a. Messenger RNA (mRNA) leaves the nucleus after transcription.
- b. Protein synthesis occurs on ribosomes.
- c. RNA does not contain thymine.
- d. The amino acids used in protein synthesis are attached to mRNA.
- e. The process of protein synthesis includes transcription and translation.

6.4 Regarding translation, which one of the following statements is **correct**?

- a. A codon is a triplet of nitrogenous bases on tRNA.
- b. An anticodon is a triplet of nitrogenous bases.
- c. One end of the mRNA binds with an amino acid.
- d. One end of the tRNA binds with two nitrogenous bases.
- e. Protein synthesis is halted by a termination anticodon.

TOPIC 7: AMINO ACIDS AND PROTEIN STRUCTURE

Aim: To enable you to understand the structure of a protein and how this determines its function.

Learning outcomes. You have completed this section when you can:

- 1 Outline the range of functions proteins have in the body.
- 2 Outline the structure and nomenclature of amino acids.
- 3 Describe peptide bonding.
- 4 Describe primary, secondary, tertiary and quaternary protein structures.
5. Outline the role and actions of enzymes.

INTRODUCTION

Proteins are large molecules (macromolecules) that are indispensable to us. They are our body building blocks and have an enormous array of functions, playing a major role in all our body activities, including:

- a) Structural roles (e.g. muscle and nails contain the proteins collagen and keratin, respectively)
- b) Protective roles (e.g. interleukins and immunoglobulins are released to help our body fight infection)
- c) Transport roles (e.g. oxygen and carbon dioxide can be transported in haemoglobin)
- d) Regulatory roles (e.g. most enzymes, which act as catalysts for the biochemical reactions in our bodies, are proteins)
- e) Signalling roles (e.g. hormones such as anti-diuretic hormone, which helps to conserve body water when it is released into the blood stream)

With so many functions, it's not surprising to find that there are thousands of different proteins with distinct structures. However, all proteins are made from chains of amino acids that are strongly held together by covalent peptide bonds. Hundreds of amino acids exist but only 20 are found in the body. All of these amino acids have different chemical structure. When combined in a chain, the structural variety of the amino acids gives proteins an almost endless range of structural (and therefore functional) diversity. Just think of how many words you could make out of 20 different letters, using each letter as many times as you liked, and what their meanings would be.

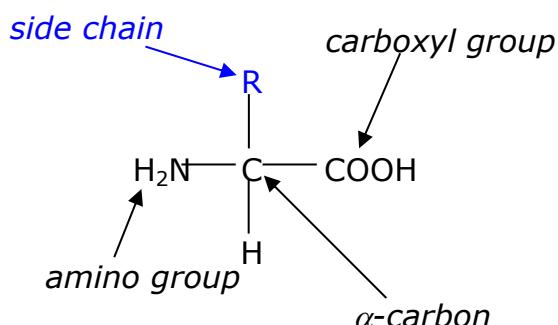
The names of the 20 amino acids are abbreviated using two systems; a three-letter system where, for example, the amino acid glycine is denoted Gly and a single-letter system where glycine is denoted G.

Amino acid structure

All amino acids have four common parts (Figure 7.1):

1. an alpha-carbon atom
2. an ***amino*** group (-NH₂)
3. a ***carboxyl*** group (-COOH)
4. a side chain, specific to each amino acid, denoted 'R'

Figure 7.1 General structure of amino acids



The side chain is the part of the molecule that varies between amino acids. For example, in glycine 'R' is a hydrogen atom but in serine 'R' is CH₂OH (Figure 7.1).

Peptide bonding

When a protein is being synthesised on a ribosome (see topic 6), the amino acids being carried on transfer RNA (tRNA) join in a sequential manner, the order of amino acids being determined by the codons on the messenger RNA (mRNA). A peptide bond is formed between the carbon of the carboxyl group of one amino acid and the nitrogen of the amino group of the next amino acid. Proteins can therefore exist as dipeptides (two amino acids joined) or more commonly polypeptide chains of hundreds of amino acids in length. The more amino acids, the greater the weight of the molecule and the more complex the peptide is in terms of structure.

Protein organisation

Proteins are organised on 4 levels:

1. Primary structure

This is the unique sequence of the amino acids bonded together by the covalent bonds in a polypeptide chain and it makes each protein structurally and functionally distinct as there are so many possibilities. Mutations in DNA can cause alterations in this sequence, which has implications for function (see topic 6).

2. Secondary structure

This refers to the twisting or folding of the polypeptide chain as a consequence of hydrogen bonding (see topic 3) at regular intervals along the polypeptide back bone. Commonly, bonding between the amino acid residues in the same chain cause the peptide to twist clockwise (an alpha-helix). Some polypeptide chains, such as keratin, can also form sheets when chains that run side-by-side bond (β -pleated sheets), or even, as in the case of collagen, twist strongly like entwined ropes (triple helices). The secondary structure can therefore be informative about possible protein functional integrity.

3. Tertiary structure

This refers to the 3-dimensional shape of all functional proteins and is the result of side chain interactions that cause each protein chain to fold up into a crystalline structure. Weak hydrogen, ionic or hydrophobic bonds or strong covalent disulphide bridges (which link adjacent cysteine amino-acids) cause the proteins to have distinctive irregular shapes. The unique tertiary structure helps to determine how the protein will function. Thus the amino acid sequence and folding of the protein give it a distinctive shape and it is this shape that is essential in determining function.

4. Quaternary structure

This occurs when 2 or more polypeptide chains are bonded together weakly or strongly, as before, so that they function together as a single unit. For instance the respiratory pigment haemoglobin consists of 4 polypeptide globin chains (2 alpha and 2 beta) which have related amino acids and similar tertiary structures. This means that haemoglobin can carry four molecules of oxygen (O_2), one on the haem group in each of its four globin chains.

Denaturation of proteins

Proteins can be denatured. This is a process whereby the protein unravels and the specific secondary, tertiary or quaternary structure is lost, rendering the protein useless. Denaturation occurs when the protein is exposed to an excessive large change in its expected environment such as changes in temperature, **pH** or electrolyte concentration. Think of an egg when it is fried! The protein albumin in the egg whitens and hardens up permanently. For this reason, homeostatic regulation of temperature, pH and electrolyte concentration is vital to our normal body function.

Proteins as enzymes

Many proteins act as enzymes. Enzymes are **catalysts** (i.e. they speed up a chemical reaction) for biochemical reactions in the body. Enzymes are specific for the reactions that they catalyse; the shape of the protein confers the ability to catalyse a given reaction. The protein may be folded in such a way that it forms a 'binding pocket' for the **substrate** of the reaction and another area of the protein nearby may then chemically alter the substrate to form the **products** of the reaction. The action of enzymes is sometimes said to mimic a '**lock-and-key**' where the shape of the enzyme is ideally suited to the chemical structure of the substrate for the reaction, but not the products. In this way a substrate can be bound and chemically altered, but the products of the reaction are readily released.

Enzymes catalyse many different types of reactions and the type of reaction that a given enzyme catalyses places the enzyme in a particular class. For example, enzymes that split adenosine triphosphate (ATP) are known as **ATPases** (the name of an enzyme is often derived from adding the suffix -ase to the name of the molecule (or substrate) that it acts upon and/or the type of reaction that it catalyses). Another example is **lipases**, which digest triglycerides (a type of lipid).

Question 7.1: Complete the table below on enzyme classes and their actions.

Enzyme class	Enzyme Action
Amylases	
	Remove carboxyl groups from molecules
DNA polymerases	
Lipases	Digest triglycerides
	Remove phosphate groups from molecules
Proteases	
RNA polymerases	

Altering the activity of enzymes and other proteins

Enzymes work best (have optimal activity) at a certain temperature, pH and in certain electrolyte concentrations. With some exceptions (e.g. **proteases** in the stomach), most enzymes in our bodies work best at around 37°C and close to physiological pH of 7.4.

CLINICAL RELEVANCE

A number of different factors affect protein structure. These factors may be genetic; mutations in the genes encoding a particular protein may alter its primary structure so that its overall structure is abnormal in affected individuals. One example is the disease cystic fibrosis in which affected individuals have mutations or deletions in the gene encoding a membrane-transport protein, which results in abnormal amino acid sequence and therefore abnormal function of the protein. People with cystic fibrosis do not digest and absorb their food well, are prone to lung infections and have reduced life expectancy.

The factors may also be metabolic; electrolyte imbalance or altered body pH can have detrimental effects on protein function. This is why it is important to maintain acid-base balance in the body, a topic you will be introduced to in topic 8 of this workbook.

Consolidation, further learning, self-test exercises on topic 7.

A. **RLO tutorials** to help you consolidate your learning.

1. Amino acid structure

<http://www.johnkyrk.com/aminoacid.html>

2. Illustrates protein denaturation using frying an egg as an example

<http://www.sumanasinc.com/webcontent/animations/content/proteinstructure.html>

3. Enzyme action and the hydrolysis of sucrose (note: enzyme action relies on its protein shape. If becomes denaturised, it cannot catalyse the reaction).

http://highered.mcgraw-hill.com/sites/0072507470/student_view0/chapter25/animation_enzyme_action_and_the_hydrolysis_of_sucrose.html

B. **Multiple choice** questions (Answers are in the Appendix).

Choose the single best answer from the 5 options for each question.

7.2 Which of the following is an amino acid?

- a. Fructose
- b. Palmitic acid
- c. Methionine
- d. Glycerol
- e. Glycogen

7.3 Which of the follow best describes the role of enzymes?

- a. Fight infection
- b. Transport gases
- c. Structural component of skin
- d. Catalyse biochemical reactions
- e. Send signals to regulate biological process

7.4 Which of the following is **NOT** a protein?

- a. Anitdiuretic hormone
- b. Prostaglandin-E₁
- c. Haemoglobin
- d. Interleukin-1
- e. Keratin

TOPIC 8: ACIDS, BASES & pH

Aim: To enable you to understand pH, acids and bases.

Learning outcomes. You have completed this section when you can:

1. Define acids and bases in terms of chemical structure and properties
2. Outline the principle of the pH scale.
3. Describe how carbonic acid / bicarbonate ions help to regulate blood pH.

INTRODUCTION

Enzymes and chemical reactions in the body work best in particular environments.

This is particularly true with respect to the acidity of the body fluids. Acidity is a measure of the concentration of free hydrogen ions (H^+) in the solution.

It is vitally important for the body to try to maintain the hydrogen ion status to avoid detrimental, potentially life-threatening effects.

Acids

Acids are chemical substances that ionise in water to release (donate) H^+ ions. Weak acids do not dissociate easily but strong acids ionise nearly completely in solution. For instance, hydrochloric acid (HCl) ionises nearly completely to release one H^+ and one Cl^- ion:



Bases (alkalis)

Bases are substances that accept free H^+ ions and remove them from the solution. Like acids, there are strong and weak bases. Bicarbonate ion (HCO_3^-) and dihydrogen phosphate ($H_2PO_4^-$) are examples of weak bases that do not readily accept protons. In nursing you may find that the terms **alkalis** and bases are used interchangeably.

An alkali mainly refers to the salt form of a base that produces one or more hydroxyl ions (OH^-) upon ionisation when it dissolves in water. For instance sodium hydroxide

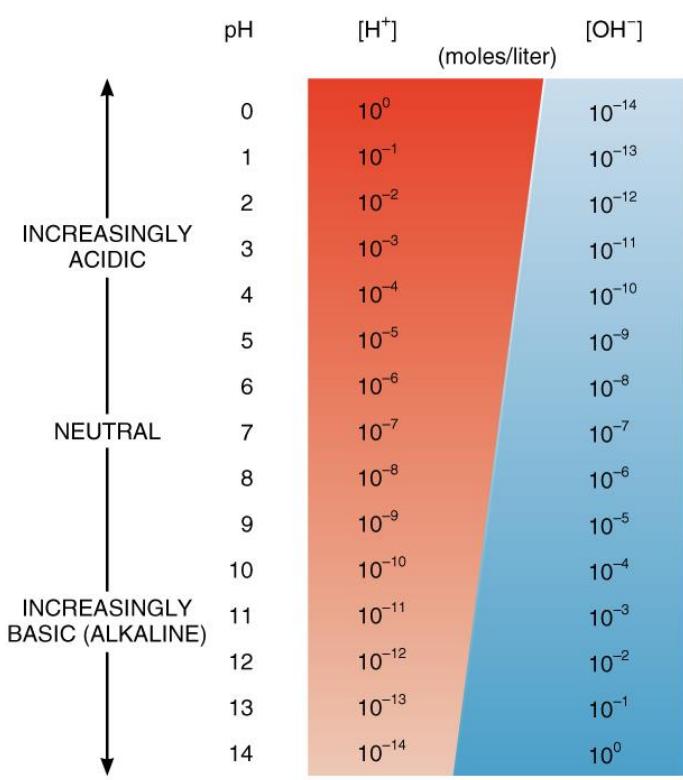
(NaOH, or caustic soda) is a strong alkali. It completely dissociates in solution and can be harmful.

Acidic and alkaline solutions

The pH scale

The pH scale (Figure 8.1) is a series of numbers from 0 to 14 to help quantify the concentration of free H^+ ions in a solution. Pure water dissociates into 10^{-7} mol/L H^+ ions and an equivalent concentration of OH^- ions at 25°C. It is regarded as neutral and so pH 7.0 lies in the middle of the scale. Acidic solutions have a pH less than 7.0 and a higher concentration of free H^+ ions than pure water. Alkaline solutions have a pH more than 7.0 and have a lower concentration of free H^+ ions than pure water.

Figure 8.1 The pH scale



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As the pH scale is a **logarithmic scale**, a 10-fold increase or 10-fold decrease in free H^+ ion concentration is required for a 1 unit change in pH. For instance, if the free H^+ ion concentration of a 1 nmol/L (1×10^{-9} mol/L) solution increased 10 fold to 10 nmol/L (1×10^{-8} mol/L), its pH would be 8.0 and would have moved towards the acidic range of the scale. On the other hand, if the same solution (pH 8.0) was diluted by adding water, this would make it less alkaline, and decrease the pH of the solution towards 7.0.

Different body fluids may have a different pH

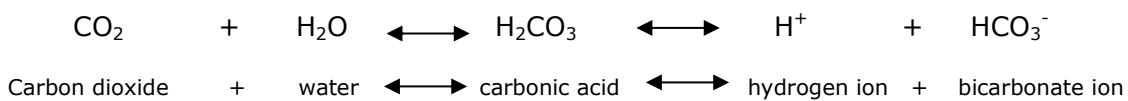
Each body fluid usually has a very narrow range of acceptable levels of pH because most biological processes work best at a given pH (see Topic 7 for the importance of pH for enzyme function).

The pH range that is compatible with life is 7.0 to 7.7 (a 5-fold difference in $[H^+]$).

Our bodies are continuously producing acids; for instance, :

(1) During exercise lactic acid is produced by our cells.

(2) The carbon dioxide we produce during respiration generates carbonic acid when dissolved in water:



In the body, the formation of **carbonic acid** from carbon dioxide and water is catalysed by the enzyme carbonic anhydrase, which is present in red blood cells and some other cell types. Having high levels of carbon dioxide in the blood can lead to acidification of the blood. This can happen if someone develops any form of respiratory failure where insufficient amounts of carbon dioxide are being exhaled.

It is obviously important that the H^+ concentration is regulated to prevent deleterious effects on function. In fact if any pH change caused by a clinical condition is not corrected, this can have serious consequences and can lead to coma and even death.

Fortunately, our body uses various mechanisms including chemical buffers (such as bicarbonate ions (HCO_3^-)) and the respiratory and renal systems to try to protect against such changes in pH. However, despite the efforts of our homeostatic mechanisms, some clinical conditions can lead to changes in pH that could be detrimental to health.

CLINICAL RELEVANCE

In some clinical conditions, the pH of the blood changes so that it falls outside the normal range of 7.35-7.45. In uncontrolled diabetes mellitus, in which blood glucose levels are higher than normal, a lack of insulin (the hormone that helps transport glucose into cells) or a lack of response of the cells to insulin can mean that diabetic patients start to produce ketone bodies in an effort to meet the metabolic demands of their tissues. The ketone bodies are acids (acetoacetic acid and 3-hydroxybutyric acid) that, if produced in large amounts, can cause **acidosis** (ketoacidosis) and can

lead to confusion and behavioural changes. When the pH of the blood falls below 7.35, the body tries to compensate for the acid-base imbalance by increasing breathing (hyperventilation) so that more carbon dioxide is exhaled (remember that carbonic acid can be produced from carbon dioxide and water so that removing carbon dioxide helps remove some acid and therefore some H^+ ions from the system). If the ketoacidosis continues, the kidneys can try to excrete more H^+ ions. However, if the cause of the acidosis is not corrected, this can eventually lead to coma and even death. If blood pH rises above 7.45, the person is said to be in **alkalosis**, which can sometimes be more dangerous than being in acidosis.

Consolidation, further learning and self-test exercises on topic 8.

A. **RLO tutorials** below will help you consolidate your learning on acids, bases and pH.

1. Acids, Alkalies and Bases: An Introduction

http://www.nottingham.ac.uk/nmp/sonet/rlos/science/acid_base_intro/index.html

2. Acids, Alkalies and Bases: Further Application

http://www.nottingham.ac.uk/nmp/sonet/rlos/science/acid_base_further_app/

3. Clinical Skills – Intracellular and Extracellular Buffers

<http://www.nottingham.ac.uk/nmp/sonet/rlos/placs/buffers/>

B. **Multiple choice question** (Answers are in the Appendix).

8.1 If urine has a pH of 6.35, blood has a pH of 7.40 and bile has a pH of 7.60, which one of the following statements is **correct**?

- a. Blood is more acidic than urine.
- b. Blood is more acidic than water.
- c. Bile is more acidic than blood.
- d. Urine is more acidic than blood.
- e. Urine is more alkaline than bile.

8.2 When acids ionise in water they release...

- a. sodium ions
- b. bicarbonate ions
- c. chloride ions
- d. hydrogen ions
- e. hydroxyl ions

8.3 When bases ionise in water they accept...

- a. sodium ions
- b. bicarbonate ions
- c. chloride ions
- d. hydrogen ions
- e. hydroxyl ions

8.4 A solution that has free hydrogen ions at a concentration of 10^{-5} would have a pH of...

- a. 1.0
- b. 2.5
- c. 5.0
- d. 7.5
- e. 10.0

TOPIC 9: SI UNITS, PREFIXES, SIZE AND CONCENTRATION

Aim: To enable you to understand The Standard System of Measurements (SI units) used in healthcare.

Learning outcomes. You have completed this section when you can:

- 1 Define units used within the Standard System of Measurements for weight, length, volume and concentration.
- 2 Give examples that link SI prefix and Scientific notation.
3. Define the following terms: solution, mole, molarity.

INTRODUCTION

In a healthcare setting, you will be surrounded by many different units and ways of expressing length, mass, concentration, temperature, pressure, etc. In most cases there are several different ways of expressing the same thing. For example, concentration may be expressed in grams per litre or in moles per litre. In the last 50 years or so, the way in which such parameters are expressed has become more standardised. It's important that you know something about the ways in which a particular parameter might be expressed so that you are less likely to make a mistake when administering the correct dose of a drug to a patient, for example.

In 1960 a standardised system of measurement, *Le Système International D'unités* (or SI system), was launched. **SI units** are now used in most countries of the world.

SI units are based on 7 standardised units of measurement. Each SI unit has a standard abbreviation, given here in brackets.

Unit	Parameter measured
metre (m)	Length
kilogram (kg)	Mass
mole (mol)	Amount of substance
second (s)	Time
ampere (A)	Electrical current
kelvin (K)	Thermodynamic temperature
candela (cd)	Luminous intensity

The last three SI units (A, K and cd) are rarely, if ever, used in nursing and medicine, so concentrate on the first four.

SI units can be combined to give other units of measurement. For example, speed is measured in metres per second (m/s) and volume in cubic metres (m^3); these are **SI-derived units**.

Question 9.1: Using the information above, which of the following is the most commonly used SI-derived unit to express the concentration of a substance in solution?

- a. g/kg
- b. g/m^3
- c. mol/L
- d. mol/m
- e. mol/m^3

Prefixes

In chemistry, physics, biology and healthcare science we rarely come across unitary values. For example, red blood cells have a diameter of approximately 0.000007 m and there are approximately $5,000,000,000,000$ red blood cells in a litre of normal blood. If this were the only way of expressing such large or small numbers, scientific and healthcare-related textbooks would be much larger than they are today.

Thankfully, SI units can have prefixes or special symbols that precede the unit. These prefixes allow us to make multiples of the original units.

Here are some commonly used prefixes (with their symbols in brackets)

Prefix	Meaning	Scientific notation
femto (f)	one thousand million millionth (0.00000000000001)	1×10^{-15}
pico (p)	one million millionth (0.000000000001)	1×10^{-12}
nano (n)	one thousand millionth (0.000000001)	1×10^{-9}
micro (μ)	one millionth (0.000001)	1×10^{-6}
milli (m)	one thousandth (0.001)	1×10^{-3}
centi (c)	one hundredth (0.01)	1×10^{-2}
deci (d)	one tenth (0.1)	1×10^{-1}
deca (da)	ten (10)	1×10^1
hecto (h)	one hundred (100)	1×10^2
kilo (k)	one thousand (1,000)	1×10^3
mega (M)	one million (1,000,000)	1×10^6
giga (G)	one thousand million (1,000,000,000)	1×10^9

It is important to remember that milli stands for one thousandth and not for one millionth. The prefix milli comes from the French word 'mille' or 1,000.

Using these prefixes obviates the need to write long numbers (and count zeros). For example, red blood cells, which have a diameter of seven one millionths of a metre are said to have a diameter of 7 μm (sometimes called 7 microns). There are approximately 5 million million red blood cells in a litre of normal blood, but this is usually expressed a 5×10^{12} cells/litre.

Question 9.2: How is 10 μm expressed in **scientific notation**?

Size of cells and organisms

A human hair is about 0.1 mm wide. The table below compares the size of some cells, bacteria and viruses to the width of a human hair using SI measurement of length.

Structure / organism	Actual size
Human hair	0.1 mm
Monocyte	0.02 mm
Red blood cell	7 μ m
<i>Mycobacterium tuberculosis</i>	3 μ m
<i>Escherichia coli</i>	2 μ m
Adenovirus	90 nm
HIV	80 nm

Concentration

Concentration is a measurement of how much of a substance is mixed with another substance; this usually refers to the amount of **solute** that is dissolved in a **solvent**. Although we usually think of a solute as a solid that is added to a solvent, the solute could be a dissolved gas.

A **solution** becomes more concentrated if more solute is added or the solvent is reduced. If more solvent is added or the solute is reduced a solution becomes more dilute.

A **mole** of a substance is the quantity of the substance whose mass in grams is the same as its formula weight. Thus a mole of carbon will weigh 12 g. A mole of sodium chloride weighs approximately 58 g (as the atomic mass of sodium and chlorine are 23 and 35 respectively). One mole of a substance will contain approximately 602,214,150,000,000,000,000 'particles' of the substance.

Question 9.3: How would 602,214,150,000,000,000,000,000 be expressed in scientific notation?

Molarity is one method of expressing concentration. The molarity of a solution refers to the numbers of moles of a given substance per litre (L) of solution and is expressed

as mol/L or M. Be careful not to confuse mega with molarity, since both (unhelpfully) are represented by a capital 'M'.

CLINICAL RELEVANCE

Here are two examples of the importance of units in medicine:

A nurse who interprets a full blood count will have information on the number of red blood cells per litre of the sample, but will also be presented with results like packed cell volume (the haematocrit or Hct), mean cell volume (MCV), mean cell haemoglobin content (MCH) and mean cell haemoglobin concentration (MCHC). Although these measurements are clearly related to one another, they can be affected differently by different disease states. The nurse needs to understand the meaning of each measurement and be aware of the different units.

As another example, imagine the case of a nurse who is given a vial containing 20 mL of a drug at a concentration of 5 mg/mL and is asked to administer the drug at a dose of 50 µg/kg to a patient weighing 70 kg over a 2 hour period.

In order to do this safely and correctly, the nurse would first of all have to work out how much drug to administer. In this case, the nurse would have to administer 3.5 mg of the drug ($50 \mu\text{g}/\text{kg} \times 70 \text{ kg} = 3,500 \mu\text{g} = 3.5 \text{ mg}$). This amount of drug is present in 0.7 mL (700 µL) of the solution in the vial ($0.7 \text{ mL of } 5 \text{ mg/mL} = 3.5 \text{ mg}$), so the nurse might have to add 0.7 mL of the stock to an intravenous drip and administer the whole amount over a period of 2 hours.

It's complicated, isn't it? But we hope you'll agree that it's worth getting it right. Ensure that you're familiar with these concepts as soon as is possible after you commence on the GEN course. However, you will be given guidance and tutorial support to help you practice and develop your maths skills throughout the programme.

Consolidation, further learning, self-test exercises on topic 9.

A. RLO tutorials to help you consolidate your learning.

<http://www.nottingham.ac.uk/nursing/sonet/rlos/science/solutions/>
http://www.nottingham.ac.uk/nursing/sonet/rlos/ebp/si_units/index.html

B. Multiple choice questions (Answers are in the Appendix).

9.4: Match the (numbered) measurement to the (lettered) unit. Each unit can only be used once:

1. Hct (haematocrit)
a. fL
2. MCV (mean cell volume)
b. pg/cell
3. MCH (mean cell haemoglobin)
c. g/dL
4. MCHC (mean cell haemoglobin concentration)
d. %

Choose the single best answer from the 5 options for the next four questions.

9.5 A patient's fluid intake could be measured in:

- a. joules (J).
- b. kilograms (kg).
- c. litres (L).
- d. volts (V).
- e. watts (W).

9.6 The prefix milli can be abbreviated to:

- a. m.
- b. M.
- c. mi.
- d. ml.
- e. μ .

9.7 A patient is prescribed 1 thousandth of a gram of a drug. An alternative way of writing the dose is:

- a. 10×10^{-2} g.
- b. 1 mg.
- c. 1 Mg.
- d. 0.1 μ g.
- e. 1 μ g.

9.8 A patient is prescribed 0.005 litre of a liquid medication. An alternative way of writing the dose is:

- a. 5 decilitres.
- b. 5 microlitres.
- c. 0.05 mL.
- d. 5 mL.
- e. 50 mL.

Topic 10: BODY SYSTEMS

While you are studying on the GEN programme, you will learn six subject areas related to nursing practice - one of which is biological science. You will study the subject areas side-by-side in the context of case studies during problem based learning.

Considering biological science, you will use each case study as a learning platform to first develop your understanding of normal anatomy and physiology, and then building on this, learn about the altered anatomy and physiology (or pathophysiology), pharmacology (i.e. medicines and administration), physiological measurements/tests that relate to each scenario.

From this you will see that it would be very beneficial to have undertaken some preliminary reading/revision on the anatomy and physiology of human body systems during the period before starting on the course, in addition to the basic science presented in this work book. In particular, if you have not studied human biology before (e.g. as a single subject to GCSE/A-level) we strongly recommend that you undertake some self-managed study during this period in order to familiarise yourselves with the vocabulary, components, anatomical layout, basic functions of each body system and some key physiological concepts.

Most human biology text books would be helpful to you. However, you may find the following workbook particularly useful:

Waugh A, Grant A (2010). **Ross and Wilson: Anatomy and Physiology Colouring and Workbook (3rd Ed)**. Churchill Livingston, London.

This can be used in conjunction with any appropriate human biology text book or with its companion text book:

Waugh A, Grant A (2010). Ross and Wilson: **Anatomy and Physiology in Health and Illness (11th Ed)**. Churchill Livingston, London.

Please note. We are not stipulating that you purchase text books, many public libraries carry excellent resources and some colleges allow day passes to their libraries.

Here is a list of the body systems and some basic physiological concepts along with RLO tutorials that will help guide and consolidate your preliminary reading/revision:

<http://www.innerbody.com/htm/body.html>

1. The cardiovascular system

http://www.wisc-online.com/objects/index_tj.asp?objID=NUR1403

http://www.wisc-online.com/objects/index_tj.asp?objID=AP12504

http://www.wisc-online.com/objects/index_tj.asp?objID=OTA1304

2. The respiratory system

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/ventilation/index.html>

3. The integumentary system (skin)

http://www.wisc-online.com/objects/index_tj.asp?objID=AP12204

http://www.wisc-online.com/objects/index_tj.asp?objID=COS1303

4. The immune system

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/inflam/>

5. The nervous system

http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/brain-anatomy/?f_title=Structures+of+the+brain&submit2=Go+to+RLO

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/synapse/>

http://www.wisc-online.com/objects/index_tj.asp?objID=COS1903

http://www.wisc-online.com/objects/index_tj.asp?objID=AP11704

6. The endocrine system

<http://www.vivo.colostate.edu/hbooks/pathphys/endocrine/>

7. The digestive system

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/liveranatomy/index.html>

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/liverphysiology/index.html>

<http://www.vivo.colostate.edu/hbooks/pathphys/digestion/index.html>

8. The urinary system

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/kidneyanatomy/index.html>

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/kidneyphysiology/index.html>

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/gfr/>

9. The musculo-skeletal system

10. The reproductive system

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/menstrual1/index.html>

<http://www.vivo.colostate.edu/hbooks/pathphys/reprod/index.html>

11. Basic concepts: homeostasis; osmosis; diffusion; pressure

<http://www.nottingham.ac.uk/nursing/sonet/rlos/science/osmosis/index.html>

<http://www.nottingham.ac.uk/nursing/sonet/rlos/science/pressure/home.htm>

<http://www.nottingham.ac.uk/~cczcal/Nursing/homeostasis/homeostasis.html>

<http://www.nottingham.ac.uk/nursing/sonet/rlos/bioproc/gradients/index.html>

Preview of core biology textbooks on MSc GEN

We are not suggesting that you purchase text books at this stage, but for your information the following are core biology texts that will be available for recommended reading during your studies on the GEN course:

Blows WT (2012) *The Biological Basis of Nursing: Clinical Observations* (2nd Ed). Routledge, London.

Blows WT (2010) *The Biological Basis of Nursing: Mental Health*, Routledge, London.

MacGregor J (2008) *Introduction to the Anatomy and Physiology of Children*, Routledge, London.

Marieb E. N (2012) *Essentials of Human Anatomy and Physiology* (10th Ed). Pearson Education, CA.

Tortora G.J. and Derrickson B.H. (2011). *Principles of Anatomy and Physiology*. John Wiley & Sons (13th Ed).

Waugh A, Grant A (2010) Ross and Wilson: *Anatomy and Physiology in Health and Illness* (11th Ed). Churchill Livingston, London.

APPENDIX

Answers to questions

Topic 1

- 1.1 b
- 1.2 c
- 1.3 e
- 1.4 b

Topic 2

- 2.1 e
- 2.2 d
- 2.3 c
- 2.4 e

Topic 3

3.1

Element	Atomic number	Number of neutrons	Atomic mass
Nitrogen	7	7	14
Oxygen	8	8	16
Phosphorus	15	16	31
Sodium	11	12	23
Chlorine	17	18	35

3.2 Carbon has 4 electrons in the outer energy shell. This could contain 8 electrons. Hence 4 other carbon atoms could share electrons with one carbon atom.

3.3 Both sodium and chlorine have 3 levels. The first level contains 2 electrons, the second 8 and the third level can hold up to 18 electrons. When sodium loses an electron to become a sodium ion it then only has 2 energy levels and a positive charge.

3.4 Iodine is found as iodide (an anion), magnesium, potassium and calcium are cations.

3.5 d

3.6 a

3.7 b

3.8 d

Topic 4

4.1 A molecule of water (H_2O) is released during this type of reaction, which is called dehydration synthesis.

4.2 Palmitic acid is a saturated fatty acid; there are no carbon-carbon double bonds in the molecule.

4.3 c

4.4 b

4.5 c

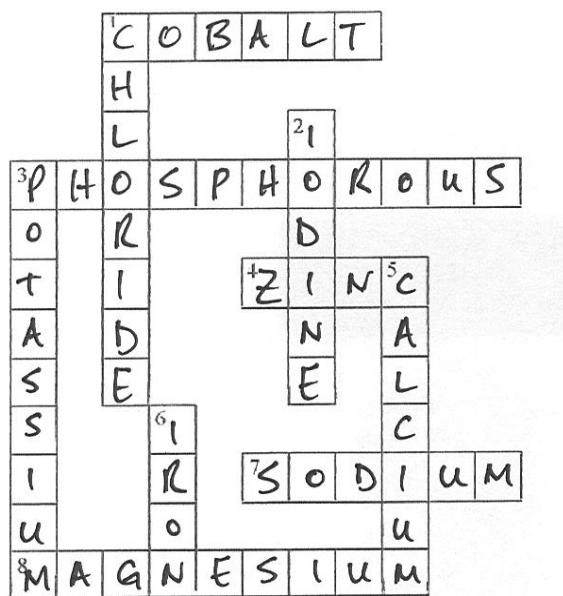
Topic 5

5.1 Compounds that like (have an affinity for) water are known as **hydrophilic** and those which dislike water are known as **hydrophobic**. Fats and oils are hydrophobic and do not dissolve in water.

5.2 Iron is found in red meat, liver, beans and spinach. Iron is better absorbed from meat sources. Some foodstuffs can inhibit absorption, for example, high bran foods.

5.3 Iron is lost when blood is lost, so any situation where chronic blood loss occurs will deplete body iron stores. Examples are haemorrhage from peptic ulcers, haemorrhoids and intestinal parasites. Women can have low iron levels because of blood loss during menstruation or during pregnancy when the iron is transferred to the foetus.

Crossword answer:



5.4 e

5.5 b

5.6 d

5.7 a

Topic 6

6.1 a

6.2 c

6.3 d

6.4 b

Topic 7

7.1

Enzyme class	Action
Amylases	Digest polysaccharides such as starch
Carboxylases	Remove carboxyl groups from molecules
DNA polymerases	Make DNA from deoxyribonucleotides
Lipases	Digest triglycerides
Phosphorylases	Remove phosphate groups from molecules
Proteases	Digest proteins
RNA polymerases	Make RNA from ribonucleotides

7.2 c

7.3 d

7.4 b

Topic 8

8.1 d

8.2 d

8.3 d

8.4 c

Topic 9

9.1 $10 \mu\text{m} = 1 \times 10^{-5} \text{ m}$. Scientific notation takes the form $y \times 10^z$, where y is a number between 1.0 and 9.99 (recurring) and z is any integer (a positive or negative whole number). So it would be incorrect to say that the scientific notation for $10 \mu\text{m}$ is $10 \times 10^{-6} \text{ m}$.

9.2 602,214,150,000,000,000,000,000 is expressed as 6×10^{23} in scientific notation. This number is also known as **Avogadro's number** or the Loschmidt number.

9.3

1. d. Hct is expressed as a relative figure or as a percentage (e.g. 0.45 or 45%, meaning that 450 mL of the blood sample is cells).
2. a. MCV is expressed in femtolitres (fL).
3. b. MCH is expressed in picograms (pg) per cell or in femtomoles (fmol) per cell.
4. c. MCHC is expressed in grams per decilitre (g/dL). It can also be expressed in millimoles per litre (mmol/L or mM).

9.4 c

9.5 a

9.6 b

9.7 d

Key Words

Throughout this workbook we have highlighted key words that we will expect you to know the meaning of soon after you commence on the course. Take the opportunity now to read this list and ensure that you understand what these terms mean. You should be able to find definitions for most of these in this workbook or in any healthcare-related dictionary.

acid
acidosis
adenine
adenosine triphosphate (ATP)
alkali
alkalosis
amino
amino acid
aminoacyl tRNA
anion
anticodon
atomic mass
atomic number
atom
ATPase
Avogadro's number
base
carbohydrate
carbon dioxide
carbonic acid
carboxyl
catalyst
cation
centi (c)
chiral centre
cilia
codon
concentration
covalent bond
covalent modification
cytoplasm
cytosine
deci (d)
deoxyribonucleic acid (DNA)
deoxyribose
dephosphorylation
dextro- (D)
dipeptide
disaccharide
disulphide bridge
double helix
electrolyte
electron acceptor
electron donor
electron
element
endoplasmic reticulum
energy level
enzyme
extracellular fluid
fatty acid
femto (f)
gene
genetic code
genome
giga (G)
glucose
glycerol
glycogen
Golgi apparatus
guanine
hexose
homeostasis

hydrogen bond	peptide bond
hydrophilic	pH
hydrophobic	phosphatase
inorganic	phosphate
intracellular fluid	phospholipid
ionic bond	phosphorylation
isotope	pico (p)
kilo (k)	plasmalemma
kilogram (kg)	polar covalent bond
kinase	polynucleotide
laevo- (L)	polypeptide
lipase	polysaccharide
lipid	primary structure
lock-and-key hypothesis	product
logarithmic scale	prostaglandins
mega (M)	protease
messenger RNA (mRNA)	protein synthesis
metre (m)	protein
micro (μ)	proton
milli (m)	pyrimidine
mineral	quaternary structure
mitochondrial DNA	ribonucleic acid (RNA)
mitochondrion	ribose
molarity	ribosomal RNA (rRNA)
mole (mol)	ribosome
monosaccharide	saturated fatty acid
mutation	scientific notation
nano (n)	second (s)
neutron	secondary structure
nonpolar covalent bond	SI units
nuclear membrane	SI-derived units
nucleic acid	solute
nucleotide	solution
nucleus (atomic)	solvent
nucleus (cellular)	stereoisomer
organelle	stop codon
organic	substrate
pentose	sucrose

tertiary structure	triglyceride
thymine	tripeptide
transcription	unsaturated fatty acid
transfer RNA (tRNA)	uracil
translation	vesicle

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