S294 Cell biology

The Open University

Are you ready for S294?

This publication forms part of the Open University module S294 *Cell Biology*. [The complete list of texts which make up this module can be found at the back (where applicable)]. Details of this and other Open University modules can be obtained from Student Recruitment, The Open University, PO Box 197, Milton Keynes MK7 6BJ, United Kingdom (tel. +44 (0)300 303 5303; email general-enquiries@open.ac.uk).

Alternatively, you may visit the Open University website at www.open.ac.uk where you can learn more about the wide range of modules and packs offered at all levels by The Open University.

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Contents

1 Introduction

S294 *Cell biology* explores the structure and function of cells. Themes developed throughout the module include:

- cellular organisation and diversity
- the component molecules of cells and the complex interactions between them
- cellular metabolism and proliferation
- cellular interactions and communication
- experimental techniques used to study cell structure and function
- the application of cell biology in health science and technology.

The study of this module provides a solid foundation on which to build a life science specialism. S294 is one of the compulsory Level 2 modules for BSc (Hons) Natural Sciences (Biology) and BSc (Hons) Health Sciences and is a stepping stone to the Level 3 Biology and Health Sciences modules, particularly S317 and SK320.

If you are intending to study S294, you will want to make sure that you have the necessary background knowledge and skills to be able to enjoy the module fully and to give yourself the best possible chance of completing it successfully. This booklet is intended to help you find out whether or not you are ready for S294.

Please read through these notes carefully, and work through the self-assessment questions (SAQs). You should allow yourself about an hour. This exercise will be useful for *all* prospective students of S294, even for those of you who have already studied other OU science modules and have completed the suggested prior study (see Section 3): working through these notes will serve as a reminder of some of the relevant facts, skills and concepts that you should be bringing with you from earlier study. **If you are coming to S294 without having studied one of the OU modules recommended in Section 3, then it is essential that you establish whether or not your background and experience give you a sound basis on which to tackle the work.**

You shouldn't expect to be able to answer all the SAQs correctly now, but attempting them should allow you to judge (a) whether the module will interest you, (b) the areas where some reading beforehand would be useful and (c) whether you will be able to cope with the intellectual demands of the module.

If, after working through these notes, you are still unsure about whether or not S294 is the right module for you, we advise you to seek further help and advice from the Student Support Team (SST) for Undergraduate Science. Contact details for the SST can be found on StudentHome.

2 Workload on S294

S294 is a conceptually challenging 30 credit module and it is estimated it should require 8-9 hours of study per week over the 30 weeks of the presentation. At Level 2 the depth of knowledge expected is far greater than at Level 1 and studying can be significantly more demanding, at times seeming to take longer than the suggested number of hours. In particular, if you have not completed the recommended prior study (see Section 3), then you will struggle to cope with S294 without spending a lot of extra time covering the Level 1 material on which S294 is based.

If you increase your workload by opting to study more than one Level 2 30 credit module at a time, it may feel as if the workload is more than doubled; particularly as many modules have similar assignment deadlines. The majority of Level 2 modules are assessed by an exam at the end, so revision for multiple modules would also be necessary.

We would therefore strongly recommend that, if you are studying S294, you do not opt to study more than 60 credits in total in one year, particularly if you also have additional commitments on your time, such as working, family etc. Remember that 120 credits is the equivalent of full time study (32-40 hours per week). It may be tempting to attempt to complete your studies in the minimum time possible, but by studying more modules in less time you may end up with results that don't fairly reflect your ability. Many students who take on too many modules at once often end up performing more poorly in terms of results, or have to defer some of their modules.

You can find advice about planning your study time and time management within the 'Study Skills' section in StudentHome. If you would like additional advice about workload, please contact your Student Support Team, details for which can be found on StudentHome.

3 Suggested prior study for S294

We strongly recommend that you have completed an OU Science Level 1 module as S294 assumes you have an understanding of some basic scientific and mathematical concepts and study skills at least equivalent to this level. These modules include: S111 *Questions in Science*; S112 *Science: concepts and practice*; SDK100 *Science and Health* (or the now discontinued SDK125 *Introducing Health Sciences: a case study approach*) and S104 *Exploring Science* (now discontinued). As an alternative, you should, fairly recently, have taken and obtained good marks in modules equivalent to GCE A-level or level 3 vocational qualification standard in science, including biology and chemistry.

We recommend that you revise the essential Level 1 concepts before your study of S294 commences; and to help you do so, the S294 module team has compiled some useful reference materials that you can access through the S294 module website or the Qualification webpages (Biology and Health Sciences Resources: https://learn1.open.ac.uk/course/view.php?id=100146).

4 General skills for S294

It is expected that you will already have achieved some degree of competence of the skills listed below, especially those at the beginning of each section. However, during your participation in the module, it is hoped you will refine and develop these skills further and extend your competence to include those towards the end of each list.

Basic study skills

You will have:

- an ability to organise time for study and to pace it (see Section 3 of this document);
- an ability to analyse tasks and plan how to tackle them;
- a willingness to seek help or information when appropriate, and to learn from feedback provided.

Obtaining, evaluating and interpreting information

You will be able to:

- read effectively to distinguish relevant from irrelevant or redundant information and analyse data from scientific text and images;
- locate and consult a range of online module materials (including video, audio and interactive activities) in order to obtain information and clarify complex ideas;
- collate and summarise information in note form;
- synthesise information, including being able to identify arguments and alternative interpretations.

Cognitive skills

You will be able to:

- recognise trends and patterns in data;
- use evidence to support or refute theories and arguments;
- assess the adequacy/limitations of explanations;
- apply knowledge in new contexts, including an ability to recognise associations/relationships, make predictions, extrapolate and interpolate from data;

- use information from current 'News and Views' articles or data from article extracts and link this to specific concepts from the module material;
- interpret this information in the context of the module material.

Writing skills

You will to be able to present information in a range of formats, e.g. essays, reports, short answers to questions, based on information and data abstracted from module materials and scientific texts, in each case keeping to the main points, elaborating where necessary and including figures or making references where appropriate, and ensuring that arguments, ideas and information are presented in a logical sequence.

Collaborative skills

In S294, you need to be able to work as part of a team in a collaborative activity, to share information collected from a variety of sources (websites, review articles, research articles). As a team you should be able to organise distribution of work and tasks, post information to wikis or forums, summarise all information and discuss the key components from the activity within your team and the larger tutor group. The activity will build on collaborative data sharing activities and discussion at Level 1 and will help to develop collaborative working and Library based research skills required at Level 2.

Suggested further reading for skills

Northedge, A. *et al*. (1997) *The Sciences Good Study Guide*, Open University Press. ISBN 0 7492 3411 3.

Northedge, A. (2005) *The Good Study Guide*, Open University Press. ISBN: 0749259744.

Additionally a variety of support relating to general skills is available within the 'Study Skills' section of StudentHome.

Now have a look at the Key concepts (chemical and biological) and Mathematical skills required within S294. You should work through the SAQs to check your level of understanding. Please do also refer to the 'Core concepts for S294' materials that are provided on the S294 module website and on the Qualification webpages (Biology and Health Sciences Resources: https://learn1.open.ac.uk/course/view.php?id=100146).

5 Key concepts for S294

This section outlines some of the essential key concepts with which you should be familiar before you begin your study of S294. Emboldened terms are key words that should help you in your search for relevant background information on a particular topic.

5.1 Chemical concepts

An understanding of chemical concepts underpins many of the processes discussed in S294.

5.1.1 Elements, atoms molecules and compounds

An **element** is a substance which cannot be broken down into simpler components by a chemical reaction. Each element is composed of a single type of **atom**. For example, the element hydrogen consists of hydrogen atoms. Every atom has a **nucleus** at its centre which consists of **protons** and **neutrons**. The nucleus is surrounded by particles known as **electrons**. Protons are positively charged, neutrons have no charge and electrons are negatively charged. Protons and neutrons each have approximately the same mass, whereas the mass of an electron is much smaller, and in fact negligible, for practical purposes. An atom has no overall electrical charge because the number of protons in an atom equals the number of electrons, and so the positive charge of the nucleus is exactly balanced by the surrounding electrons, each of which carries a negative charge equal and opposite to the charge of a proton.

Some common elements exist as diatomic **molecules**, e.g. the gases oxygen (O_2), hydrogen (H_2), nitrogen (N_2) and chlorine (Cl_2), which each contain two identical atoms bonded together by covalent interactions (see next section). Atoms of different elements may combine to form a more complex structure called a **compound**, e.g. sodium chloride (NaCl). In each case, the chemical formula of the compound indicates the relative numbers of the different atoms that combine together in its formation.

SAQ 1

(a) How many atoms of oxygen are there in a molecule of oxygen gas?

(b) What are the relative numbers of the three different atoms, calcium (Ca), carbon (C) and oxygen (O), in the compound calcium carbonate ($CaCO_3$)?

5.1.2 Chemical bonding and ions

Atoms can chemically **bond** with other atoms in order to achieve a stable electronic configuration. Bonding can be achieved by either:

(i) transferring electrons (**ionic bonding**) to form positive and negative ions (thus an ion is basically an atom with a net charge, positive or negative, resulting from the overall loss or gain of electrons), or

(ii) sharing pairs of electrons (**covalent bonding**) to form molecules.

Bonds are formed with other atoms using the outermost electrons only. The number of outer or bonding electrons available varies from element to element.

Metals such as sodium (Na), calcium (Ca), magnesium (Mg) and iron (Fe) may form ionic bonds with other atoms by transferring bonding electrons, and so themselves become positively charged ions. The atoms of the element to which the metal transfers electrons become negatively charged ions, and the resulting molecules are electrically neutral overall. Sodium chloride (common table salt, NaCl) is an example of an ionic compound. The sodium ion easily loses one electron to form the positively charged sodium **ion**, depicted as Na^+. The electron lost from sodium is transferred to a chlorine atom, which becomes negatively charged, forming the chloride ion, Cl^-. The ions have equal and opposite electrical charges and attract one another, and it is this electrical attraction that holds salt crystals together. The number of bonds that the atom can form within a molecule is known as its **valency**. For ionic bonding, valency can be considered as the number of electrons gained or lost in the transfer, so the both sodium and chlorine have a valency of 1.

In contrast, the atoms of the gases hydrogen (H_2) and carbon dioxide (CO_2) are examples of covalently bonded molecules in which the bonding electrons are not transferred, but are instead shared between the atoms. Hydrogen, oxygen and carbon, together with nitrogen, are the most important elements involved in the chemistry of the body. In hydrogen, H_2, each hydrogen atom has a single electron which is shared with the other hydrogen atom to form one covalent (electron pair) bond. This is called a single bond and can be depicted as H–H.

In water (H_2O), each hydrogen shares its electron with one electron from oxygen to make a **single bond**. The oxygen atom is able to share two electrons, one with each hydrogen atom, forming two single bonds, depicted as H–O–H.

In oxygen, O_2, each oxygen atom is able to share two electrons with the other oxygen atom. This sharing of two electrons from each atom forms a **double bond**, depicted as O|O. When bonding is covalent, the valency is equal to the number of covalent bonds that an atom forms with the other atoms to which it is joined.

Some atoms are better at attracting electrons to themselves than others; that is, they are more **electronegative**. In some covalent bonds therefore, the shared electrons are attracted to the more electronegative atom, with the result that one end of the bond becomes slightly negative and the other slightly positive. Such covalent bonds are said to be **polar** and molecules containing polar bonds tend to be attracted to each other by weak forces. **Hydrogen bonds** are a specific example of this sort of interaction and are formed between molecules in which a hydrogen atom is attached to an electronegative atom, usually oxygen (O) and nitrogen (N).

SAQ 2

(a) In ionic compounds, potassium forms K^+ ions and calcium forms Ca^{2+} ions. How many electrons do (i) potassium and (ii) calcium use in bonding (i.e. what is the valency of each atom)?

(b) When calcium reacts with chlorine, calcium chloride ($CaCl_2$) is formed, comprising calcium ions and chloride ions (i.e. charged chlorine (Cl) atoms). What is the charge on each chloride ion, and what is the valency of chlorine in $CaCl_2$?

(c) In the covalently bonded molecule carbon dioxide (CO_2), carbon forms a double bond with each oxygen atom. What are the valencies of carbon and oxygen in this molecule?

SAQ 3

(a) Draw a simple representation of a water molecule in which you indicate the polar nature of the bonds.

(b) Draw three or more water molecules to illustrate the hydrogen bonds that exist between them.

(c) Hydrogen bonds, like ionic bonds, are a type of non-covalent interaction that are important in biological processes and assembly of biological complexes. Name two other such non-covalent interactions.

(d) Which type of bond is strongest, a covalent bond or a hydrogen bond?

5.1.3 Chemical reactions

Reactions between various elements and compounds are conventionally written as chemical equations showing the **reactants** on the left-hand side and the **products** on the right-hand side. As atoms are neither created nor destroyed during chemical reactions, the number of atoms of each type present on one side of the equation must be the same as the number of each type on the other side, i.e. the equation must be **balanced**.

In order for a chemical reaction to occur, the reactant molecules must collide with sufficient kinetic energy. Most chemicals reactions do not therefore occur spontaneously at any measurable rate because they cannot overcome this **energy barrier**. A reaction with a large energy barrier can be made possible by introducing a **catalyst**, a substance that increases the rate of a reaction, but is not itself used up during the reaction.

SAQ 4

(a) During the process of photosynthesis, green plants use atmospheric carbon dioxide (CO_2) and water (H_2O) to produce glucose ($C_6H_{12}O_6$). Balance the left-hand side of the following overall chemical equation for this reaction, so that you have the correct numbers of molecules of the *reactants*.

$?CO_2 + ?H_2O = C_6H_{12}O_6 + 6O_2$

(b) Identify two factors that can increase the rate of collision of reactant molecules and thus speed up a chemical reaction.

5.1.4 Organic compounds, functional groups and biological macromolecules

Organic compounds contain carbon and range from simple hydrocarbons such as methane (CH_4) and ethane (C_2H_6) to the large organic **macromolecules** synthesised by living cells, which typically consist of long chains or rings of carbon with other atoms (usually hydrogen, oxygen and nitrogen) attached. The most common organic macromolecules in living organisms are carbohydrates (sugars), proteins, lipids (fats) and nucleic acids, which cells synthesise by sequentially adding together smaller carbon-containing units.

The properties of organic molecules, and the chemical reactions that take place between them, are determined by the presence of **functional groups** of atoms in the molecule. When organic molecules react together, only the functional group undergoes chemical change. Cells synthesise large biological organic macromolecules by linking together simple monomers in a series of **condensation** reactions, in which two organic molecules are joined together to make a larger, more complex molecule. In protein synthesis, the monomers to be joined are **amino acids** which each have two functional groups: an amino group ($-NH_2$) at one end and a carboxylic acid group (-COOH) at the other. The amino group of one amino acid reacts with the carboxylic acid of another amino acid, with the loss of a water molecule, to form a covalent bond called a **peptide bond**. The joining of two amino acids forms a dipeptide, and sequential addition of many amino acids by condensation forms a long chain called a **polypeptide**. Proteins may be formed from one or more polypeptide chains. Many organisms ingest organic matter, including proteins, and break it down to release energy. This uses a **hydrolysis** reaction (essentially the reverse of condensation) to split the molecules into smaller units by adding water (–H is attached to one section and –OH to the other).

The long carbon chains of proteins spontaneously fold into complex three-dimensional shapes, which are critical for their biological activities. This higher order structure is held together by many weak non-covalent interactions between different parts of the molecule. The four main types of non-covalent interaction involved are hydrogen bonds, ionic interactions, van der Waals forces, and hydrophobic interactions. These types of weak interaction are also involved in the many biological processes in which macromolecules bind specifically but transiently to one another.

SAQ 5

(a) The structure of the amino acid serine ($C_3H_7NO_3$) can be depicted as shown in Figure 3. Draw a ring round its functional group(s).

(b) What are the monomer building blocks of the following examples of macromolecules: (i) globin; (ii) DNA; (iii) cellulose.

(c) What type of bond exists *between* the two separate DNA strands in the characteristic DNA double helix?

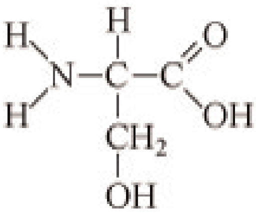

Figure 1 The amino acid serine.

5.1.5 Suggested further reading for Chemical concepts

S111 *Questions in Science:* Topic 1 and Topic 5

S112 *Science: concepts and practice:* 'Material Worlds', 'Why Chemical reactions happen', 'Make me a molecule', 'Energy in Chemistry and Life Sciences', 'Environmental cycles'.

S104 *Exploring science:* Book 4 'The Right Chemistry'.

SDK100 *Science and Health:* Topic 1 Section 6 'Water, Infection and Health'; Topic 2, Section 3 'Water, Salt and Chemical Bonds' and Topic 6 Section 2 'Alcohol's Journey through the Body'.

SDK125 *An introduction to health sciences, a case study approach:* Book 1 'Water and Health in an Overcrowded World' and Book 3 'Alcohol and Human Health'.

5.2 Biological concepts

The essential properties of life are reproduction, growth and metabolism. S294 explores how these processes occur in different types of cell.

5.2.1 Cell structure

At the broadest level, organisms can be divided into two groups on the basis of their cell type: organisms with **prokaryotic** cells include the mainly single-celled Bacteria and Archaea, while those with **eukaryotic** cells include protists, plants, animals and fungi, and are mostly multicellular. While all cells share certain properties, for example they are all bounded by a **membrane**, there are fundamental structural differences between prokaryotic and eukaryotic cells, and between the features of plant, fungal and animal cells.

You should also be familiar with the structure, composition and function in cells of a range of biological macromolecules including: polysaccharides, proteins, lipids and nucleic acids.

SAQ 6

(a) The items in the following table describe features of cells. Using ticks and crosses, complete the table for a prokaryotic cell, a eukaryotic animal cell and a eukaryotic plant cell.

Feature	Prokaryotic cell	Eukaryotic animal cell	Eukaryotic plant cell
Contains a nucleus			
Possesses a cell wall			
Contains organelles			
DNA is contained within the nucleus			
Contains chloroplasts			
DNA is free within the cytoplasm			

(b) Briefly describe one function that is associated with the following structures in cells:

(i) chloroplast;

(ii) ribosome;

(iii) mitochondrion;

(iv) cell membrane.

(c) Which type(s) of biological macromolecule performs each of the following functions in cells?

(i) support;

(ii) energy storage;

(iii) catalytic activity;

(iv) carry genetic information;

(v) cell compartmentation.

5.2.2 Genomes, cell division and heredity

The heritable characteristics of an organism are determined by the structure of their **genes**, sections of the DNA **genome** that encode gene products, usually proteins, that form the cell structure and carry out cellular processes. In other words, genes determine the characteristics of the organism. The sequence of the four nucleotide bases (commonly referred to as A, G, C and T) in DNA provides the **genetic code**, which specifies the sequence of the amino acids within the encoded proteins.

In order to multiply, cells must grow and make a copy of their genome in a process known as **DNA replication**. They then undergo cell division to produce two daughter cells each containing one copy of the genome. Prokaryotes divide by the process of binary fission after replicating their DNA. The process in eukaryotes is more complex because the DNA is packaged into a number of individual **chromosomes** which must be replicated and divided equally between the daughter cells in the process of **mitosis** (or **meiosis** in germline cells).

Genetic variation between individuals is brought about from one generation to the next as a result of recombination, the genetic 'shuffling' that takes place as the result of sexual reproduction, and **mutation**, spontaneous changes in the composition of the DNA. The basis for evolutionary change is the operation of **natural selection** upon heritable variation in the genes of organisms. Natural selection ensures that populations of plants and animals evolve; in other words their morphology and their genetic make-up changes over time in response to their changing environment, resulting in the appearance of new species.

SAQ 7

(a) If an interphase cell of a diploid eukaryotic organism has four chromosomes, how many chromosomes will each daughter cell have after it has undergone mitosis (mitotic cell division)?

(b) Match each of the terms (a)–(e) with one of the descriptions (i)–(v) below.

(a) genotype; (b) alleles; (c) heterozygote; (d) phenotype; (e) homozygote.

(i) A eukaryotic individual that has two identical copies of a gene which determines a particular characteristic (or trait).

(ii) The alternative forms (or variants) of a gene.

(iii) An organism's observable characteristics (or traits).

(iv) A eukaryotic individual that has two different forms of a gene which determines a particular trait (or characteristic).

(v) The genetic make-up of an organism.

5.2.3 Metabolism

You should be familiar with the process of **cellular respiration** in which oxygen is used to break down the bonds in carbohydrates – including glucose – releasing energy, and producing carbon dioxide and water. The energy so produced is required to maintain life. Each cell requires energy to synthesise new biomolecules such as DNA and proteins, and to carry out other energy-dependent processes, for example the contraction of muscle cells. The biochemical reactions that break down nutrients (catabolic reactions) and those that use the energy to synthesise new macromolecules from smaller components (anabolic reactions) are all part of a cell's **metabolism**.

SAQ 8

(a) Write down the overall chemical equation for the breakdown of glucose during cellular respiration.

(b) Comment on the relationship between the equation in (a) and the equation for photosynthesis in SAQ 3; is the latter a catabolic or an anabolic process?

5.2.4 Suggested further reading for Biological concepts

S111 *Questions in Science:* Topic 2 and Topic 6

S112 *Science: concepts and practice:* 'Energy in Chemistry and Life Sciences', 'DNA', 'Proteins', 'The Multicellular organism', 'Ecological Interactions'.

SDK100 *Science and Health:* Topic 5 and Topic 7.

SDK125 *An introduction to health sciences, a case study approach:* Book 4 'Screening for Breast Cancer' and Book 6 'Trauma, Repair and Recovery'.

S104 *Exploring science:* Book 5 'Life'.

6 Mathematical skills for S294

You should be able to perform simple calculations and work out percentages. The following basic mathematical skills are also relevant to S294.

6.1 Scientific units and scientific notation (powers of ten)

All measured quantities must have units associated with them. The current generally accepted system for units is the SI (Système International d'Unités) system, in which all units are related to seven base units with specific abbreviations. Of these, the three you will meet most commonly are: length measured in metres (m), time measured in seconds (s) and mass measured in grams (g). The distance between two cities is generally measured in kilometres (km), and 1 kilometre = 1000 metres. Since cells are rarely large enough to be observed with the naked eye, their size is generally measured in micrometres (μm) and 1 micrometre = one millionth of a metre (1/1000 000 m or 0.000 001 m).

Scientific data may therefore be presented in a very wide range of magnitudes of numbers. For instance, life is now thought to have arisen some 4000 000 000 years ago, whereas bacteria are generally less than 0.000 001 m in diameter. It is clearly inconvenient to express values in such a cumbersome form. A much more manageable form recognises that large numbers are generated by multiplying several tens together. The number of tens is indicated by a superscript. Thus:

$10 = 10^1$, $100 = 10^2$, $1000\,000 = 10^6$, etc.

The time when life arose can therefore be expressed as: 4×10^9 years ago.

Numbers less than 1 can be expressed in an analogous fashion, for example:

$0.1 = 10^{-1}$, $0.001 = 10^{-3}$, $0.00001 = 10^{-5}$.

Thus, the diameter of a bacterial cell can be expressed as 10^{-6} m.

Numbers that are not exactly divisible by ten are written down in scientific notation in the form ($a \times 10^b$) by ensuring that the value 'a' is between one and ten. For example the circumference of the Earth is 40 075 km, which in scientific notation is 4.0075×10^4 km.

You should be used to using decimal numbers, where the decimal places represent a fraction of one, e.g. 0.1 is a 1/10th, 0.01 is a 1/100th. Calculations using a calculator often result in a value with a great many decimal places. You will sometimes be asked to 'round' the value to fewer decimal places. For example, if you want to round 0.168 8573 to two decimal places, you would check the third decimal place and see that the figure you want is closer to 0.17 and not 0.16. So the answer to two decimal places that is most accurate is 0.17.

Preciseness is very important in scientific measurements, so as well as rounding values, in science it is often appropriate to give a decimal value to an appropriate number of **significant figures**, which is the number of digits that you can justify in terms of any uncertainties in the measurement. For example, you would say that the value 23.4 is quoted to three significant figures and the value 23.45 mm to four significant figures – usually this means the last digit is somewhat inaccurate, but you will be confident about the preceding digits. Where there are zeros in the number, *leading* zeros are not significant, so the value 0.023 is quoted to two significant figures. However, zeros *between* or *after* other digits do count, so the value 203.4 is quoted to four significant figures, while the value 23.40 is also quoted to four significant figures. Numbers in scientific notation can also be expressed to a significant figure, e.g. the value 1.4×10^{10} is quoted to two significant figures.

SAQ 9

(a) The *Vibrio cholerae* bacterium that causes cholera is 1.9 μm in length. Convert this into the equivalent length in metres using scientific notation.

(b) How many significant figures are there in each of the following measurements: (i) 1.970; (ii) 0.0012; (iii) 2.88×10^6?

(c) The circumference of the moon is 10 916 000 m. Write this in scientific notation, giving your answer to four significant figures.

6.2 Graphical information

The significance of trends in data is often seen more clearly when it is presented in graphical form. You will be expected to interpret and to draw conclusions from information presented in different graphical formats, including tables, bar charts and line graphs.

SAQ 10

Figure 5 is a graph showing how the surface temperature at Milton Keynes varied over a 24-hour period (14 July 1996).

(a) At what times did the maximum and minimum temperatures occur?

(b) What was the percentage increase in temperature between 12.00 and 18.00 h? Give your answer to two significant figures.

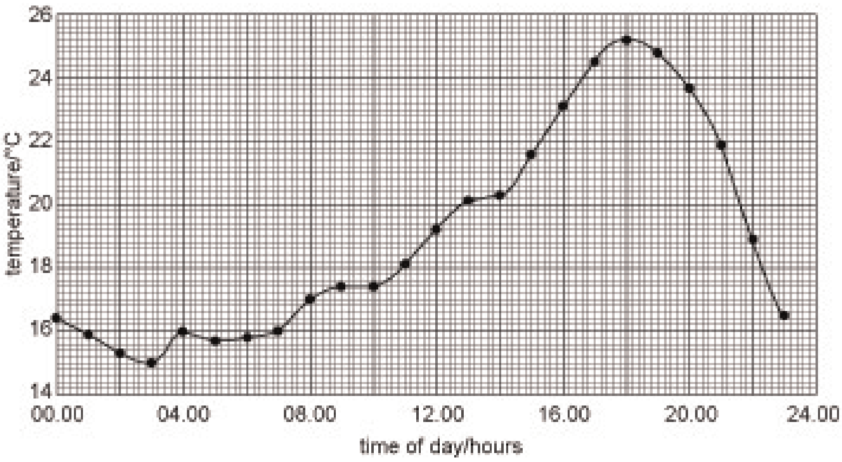

Figure 2 A graph showing how the surface temperature at Milton Keynes varied over a 24-hour period (14 July 1996).

6.3 Suggested further resources for Mathematical skills

The Open University modules Y033 *Science, Technology and Maths Access Module* and S154 *Science starts here*.

Maths resources are also available in the 'Study skills' section of StudentHome.

Other publications:

Northedge, A. *et al*. (1997) *The Sciences Good Study Guide*, Open University Press. ISBN: 0749234113.

Northedge, A. (2005) *The Good Study Guide*, Open University Press. ISBN: 0749259744.

Jordan S. *et al*. (2012) *Maths for Science*, Oxford University Press. ISBN: 0199644969.

7 Answers to self-assessment questions

SAQ 1

(a) The subscript ‘2’ in O_2 indicates that there are two oxygen atoms.

(b) The symbols for calcium and carbon have no subscripts, so there is only one atom of each. However, the symbol for oxygen has the subscript ‘3’, so there are three atoms of oxygen indicated in the chemical formula. The relative numbers of atoms indicated by the chemical formula is therefore 1 calcium: 1 carbon: 3 oxygen.

SAQ 2

(a) (i) The potassium ion carries only a single positive charge (+), implying that only one electron has been transferred, therefore potassium has a valency of 1. (ii) The calcium ion carries two positive charges (2+), implying that two electrons have been transferred, therefore calcium has a valency of 2.

(b) The charge on the calcium ion is 2+, so two electrons have been transferred to chlorine atoms to form chloride ions. Calcium chloride contains twice as many chloride ions as calcium ions so each chloride ion must have received one of the electrons. Therefore, each chloride ion that is formed carries a single negative charge, 1–, written as Cl^-, and so the valency of chlorine must be 1.

(c) In CO_2, carbon forms two covalent double bonds, so two of its bonding electrons pair with two electrons on each of the two oxygen atoms. Carbon therefore has a total of four bonding electrons, so it has a valency of 4, while oxygen has a valency of 2.

SAQ 3

(a)

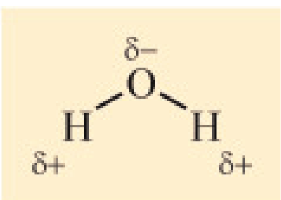

Figure 3 Representation of the chemical structure of a water molecule showing the polar nature of the covalent bonds.

The polar nature of a covalent bond is conveyed by using δ+ (delta with a plus sign) to indicate the atom carrying the partial positive charge and δ- (delta with a minus sign) to indicate the atom carrying the partial negative charge. In water, the O atom is more electronegative than the H atoms, hence the polarity of the covalent bonds, as represented in Figure 3.

(b)

See Figure 4; hydrogen bonds are usually represented by dashed lines between the participating electronegative atom in one molecule or group and the participating H atom (with its partial positive charge) in the other molecule or group. [Note that the direction of the hydrogen bond is the same as that of the covalent bond between the participating H atom and the O atom to which it is covalently attached.]

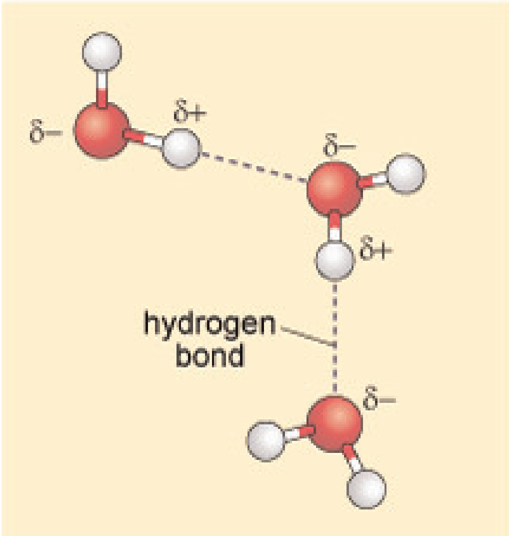

Figure 4 Hydrogen bonding between three water molecules (red = oxygen atom; white = hydrogen atom).

(c) Van der Waals forces and hydrophobic interactions are other non-covalent interactions that are important in biological processes and assembly of biological complexes.

(d) Covalent bonds are stronger than hydrogen bonds.

SAQ 4

(a) The balanced equation is:

$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$

(6 × C, 12 × O) + (12 × H, 6 × O) = (6 × C, 12 × H, 6 × O) + (12 × O)

(b) The rate of collision of molecules can be increased by increasing the concentration of the molecules, or increasing the temperature which gives the molecules more kinetic energy, so they move faster and interact more often.

SAQ 5

(a) Figure 5 shows the functional groups of serine.

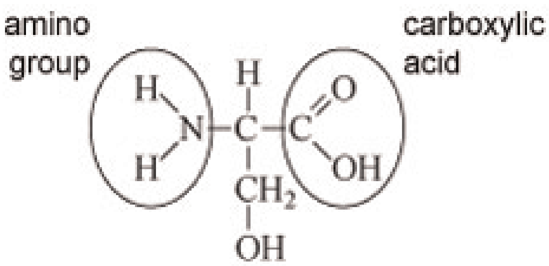

Figure 5 Serine showing functional groups.

(b) (i) globin is a protein, so the monomers are amino acids; (ii) DNA is a nucleic acid, so the monomers are nucleotides; (iii) cellulose is complex carbohydrate; a polysaccharide, so the monomers are monosaccharides (more specifically, glucose).

(c) Non-covalent hydrogen bonds between the nucleotides of the two DNA strands help to maintain the double helical structure.

SAQ 6

(a)

Feature	Prokaryotic cell	Eukaryotic animal cell	Eukaryotic plant cell
Contains a nucleus	✗	✓	✓
Possesses a cell wall	✓	✗	✓
Contains organelles	✗	✓	✓
DNA is contained within the nucleus	✗	✓	✓
Contains chloroplasts	✗	✗	✓
DNA is free within the cytoplasm	✓	✗	✗

(b) These functions are:

(i) In higher plants, chloroplasts are the site of photosynthesis, the process that converts carbon dioxide into organic compounds using the energy from sunlight.

(ii) Ribosomes are the site of protein synthesis in cells.

(iii) Mitochondria (plural of mitochondrion) provide the cell with energy; they convert energy released from the breakdown of nutrients into a useful chemical form.

(iv) The cell membrane is a selectively permeable barrier between the interior of the cell and the outside environment; it allows the control of the passage of molecules in and out of the cell.

(c) These biological macromolecules are:

(i) Fibrous proteins (e.g. collagen) and fibrous polysaccharides (e.g. cellulose) both provide support.

(ii) Polysaccharides, such as starch and glycogen, and lipids (in particular triacylglycerols) serve as energy stores.

(iii) Globular proteins called enzymes have catalytic activity.

(iv) Nucleic acids carry genetic information.

(v) Membranes separate the cell into compartments (both surrounding and within organelles, such as those making up the mitochondria), and lipids (in particular phospholipids) and proteins are the main molecular components of cellular membranes.

SAQ 7

(a) The daughter cells will also each have four chromosomes, because mitotic cell division involves replication of the cell's DNA, which is then divided between the two daughter cells such that each daughter receives one copy of the parental chromosomes.

(b) The matches between the terms and the descriptions are as follows: (a) (v);(b) (ii); (c) (iv); (d) (iii); (e) (i).

SAQ 8

(a) The overall equation for cellular respiration is:

$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$

(although in fact this process actually takes place in a number of steps).

(b) The equation is the reverse of the equation representing photosynthesis in the answer to SAQ 3, which shows the biosynthesis of glucose from carbon dioxide and water and is an anabolic process (building large complex molecules from smaller ones).

SAQ 9

(a) 1.9 μm is 1.9×10^{-6} m.

(b) (i) four (including the final zero); (ii) two (not including the leading zeros); (iii) three.

(c) 1.092×10^7 m.

SAQ 10

(a) The maximum temperature (25.2 °C) was measured at 18.00 (6.00 p.m.) and the minimum temperature (15.0 °C) was measured at 03.00 (3.00 a.m.).

The increase in the temperature between 12.00 and 18.00 hours was 6 °C (25.2 °C - 19.2 °C). The percentage increase in temperature was therefore 6/ 19.2 × 100% = 31% to two significant figures.

8 And finally...

We hope that this diagnostic booklet has given you a good idea of what to expect in S294 and how studying this module is essential for progressing your Level 2 studies as well as helping you to develop the skills required for Level 3. We trust that you have found it interesting and we look forward to welcoming you to the module.