S296 Cell and molecular biology

Are you ready for S296?

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1 Introduction

S296 *Cell and molecular biology* explores the structure and function of cells. Themes developed throughout the module include:

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

S296 is one of the compulsory Level 2 modules in the Open University's Biology qualification pathways and is a stepping stone to the Level 3 Biology modules, particularly S317.

To study S296 successfully you need to be sufficiently prepared. The module is delivered online, so you need access to a computer linked to the internet. As well as some basic science knowledge and a good standard of English, you will need numeracy skills from Level 1 study, and an ability to read text that is scientifically technical and understand and prepare data presented in graphical form. Your study will involve you collecting data using on-screen tools such as digital microscopes and other types of interactive experiments. Finally, you will also need enough time to successfully study a 30-credit module – **a minimum of 8 hours per week.**

Are you ready for S296? is a quiz with a set of self-assessment questions, designed to help you decide whether you are sufficiently prepared to start studying this module. When you have completed the quiz, you will be able to decide whether S296 is a sensible choice for you at the present time, or whether you need to engage with some additional preparatory work before starting your studies.

2 Suggested prior study

We strongly recommend that you first complete OU Science Level 1 modules S111 *Questions in Science* and S112 *Science: concepts and practice*, as S296 assumes you have an understanding of basic scientific and mathematical concepts and study skills at least equivalent to this level. 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.

3 Your available study time

S296 *Cell and molecular biology* runs for nine months, starting in October. You will need to find at least 8 hours study time per week. Think now about whether you will be able to find enough time.

Think about your other commitments e.g. paid employment, childcare, hobbies, holidays. You should also take into consideration any other study you have also committed to. For example, studying other OU modules at the same time as S296 to a total of 120 credits would require a total minimum study time of 32 hours a week. We provide breaks in late December and in March or April, but otherwise you will need to keep up to date with your studies throughout the nine-month period, submitting assignments at regular intervals.

Use the grid below to help you decide whether you will be able to find enough time to study S296. Consider your other commitments in a typical week. For each day, enter the amount of time that you are likely to be able to spend in studying, then add them up to give your weekly total.

Remember that you will need to keep up the schedule for nine months, so allow yourself some time off!

Day	Mon	Tues	Weds	Thurs	Fri	Sat	Sun
Hours							
Total							

Given this quantity of study per week, a dedicated study area would be helpful.

4 Computer and web-access

S296 is delivered online via a module website. You will need a computer with reliable internet access to study the module materials and complete your assignments. You will also be offered online tutorials and you will be able to communicate with your tutor and fellow students in our online forums. You will therefore find studying S296 most straightforward if you are the sole or main user of a computer with internet access.

A computing device with a browser and broadband internet access is required for this module. Any modern browser will be suitable for most computer activities. Functionality may be limited on mobile devices and with some older browsers.

Any additional software will be provided or is generally freely available. However, some activities may have more specific requirements. For this reason, you will need to be able to install and run additional software on a device that meets the requirements below.

A desktop or laptop computer with either:

- Windows 7 or higher
- Mac OS X 10.7 or higher.

The screen of the device must have a resolution of at least 1024 pixels horizontally and 768 pixels vertically.

To complete the module assignments, you will also require:

- Word-processing skills and a word processing programme, for example, Microsoft Word (as an OU student, you will have free access to Microsoft Office via Microsoft 365) or Libre/OpenOffice (available as a free download).
- Basic spreadsheet skills and a spreadsheet programme, for example Microsoft Excel or Libre/OpenOffice equivalent. Skills include data entry, basic manipulation and simple graph generation.
- You may need a means of inputting a digital image of hand-drawn graphs or diagrams into a word-processed file, e.g. a scanner, a digital camera or a mobile phone with a camera.
- A calculator.

It may be possible to join some tutorials via a mobile phone with the Adobe Connect app installed. To participate in online tutorials, you may also find it helpful to have:

- A basic headset (earphones and microphone).

5 Self-assessment questions

These questions are intended to help you find out whether you are ready for S296, or if you need to brush up on your knowledge and skills in advance. Answers to the questions are provided at the end of this document.

You should allow yourself about two hours to work through the questions. This exercise will be useful for all prospective students of S296, even for those of you who have already studied other OU science modules and have completed the suggested prior study; working through this information will serve as a reminder of some of the relevant facts, skills and concepts that you should be bringing with you from earlier study.

Please note that you shouldn't expect to be able to answer all the questions correctly now but attempting them should allow you to judge: (a) the areas where some reading beforehand would be useful; (b) whether you will be able to cope with the demands of the module.

As a guide, if you are prepared you ought to get over 80% of the questions correct. If you get less than this, you are strongly advised to prepare for the module with some self-directed study in areas in which you struggled to answer questions correctly. This could be through revising the areas from your previously studied modules, or by using the S296 primer materials.

Where questions require some extended writing, you should not be surprised if your answer does not correspond to the model answers provided as these may contain some very specific details. Also, some answers offer some further explanation or relevant discussion which you would not be expected to provide.

The questions cover the following areas:

- maths, science notation and graphing skills
- science practical skills
- scientific comprehension skills
- basic chemistry
- basic cell and molecular biology.

5.1 Maths skills, scientific notation, graphing skills

S296 will require you to collect, analyse and report data from various sources, including from investigations you will perform. The following questions will help you gauge your skills in these areas. You should note that there is an online maths skills book available should you need to study this area further.

5.1.1 Numbers and units

Question 1

The decimal number 102.6485 is expressed to four decimal places (i.e. there are four numbers after the decimal point). If 102.6485 is rounded to three decimal places, it becomes 102.649, because the fourth digit after the decimal place (5) is '5 or more' – so the third digit is rounded up from 8 to 9. If the fourth digit had been less than 5, the third digit would not have been rounded up.

(a) Follow the '5 or more' rule to round 102.6485 to:

(i) to two decimal places

(ii) one decimal place.

Numbers can also be expressed according to significant figures. It is frequently more reliable to quote answers from calculation to a specified number of significant figures. In straightforward cases, the number of significant figures is found simply from counting the number of digits. So, a temperature of 16.472 3 °C could be quoted to five significant figures as 16.472 °C, to four significant figures as 16.47 °C, to three significant figures as 16.5 °C and to two significant figures as 16 °C.

(b) Follow these rules to express 102.6485 to:

(i) four significant figures

(ii) three significant figures.

(c) To how many significant figures are each of the following measurements given?

(i) 5.63 m

(ii) 3 567.1 kg

(iii) 0.082 m

(iv) 50.6 m

Question 2

Large numbers (and small numbers) are expressed using powers of 10 rather than writing out all the zeros. If you write 100 as 10^2, the ten (10) is known as the base number and the superscript two (^{2}) is called the power (or exponent). So, 10^2 can also be referred to as 'ten to the power two'.

In scientific notation, a number is written in the form m 10^n, where m, the multiplier, is between 1 and 9. So, 100 (10^2) can be written as 1×10^2 using scientific notation and a large number such as 2 million (2 000 000) therefore can be written as 2×10^6.

(a) Express the following numbers in scientific notation:

(i) 100 000 000

(ii) 35 000

(iii) 95×10^5

(iv) 0.0035

(v) 0.51×10^3

(b) Scientists use units of measurement that have been agreed internationally called SI units.

(i) What is the SI unit (and symbol) for the following quantities: length, mass and time?

(ii) Express 1 gram using scientific notation for the appropriate SI unit of mass (kg).

5.1.2 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.

Question 3

The pie chart shown in Figure 1 shows the relative proportions of different categories of DNA in the human genome.

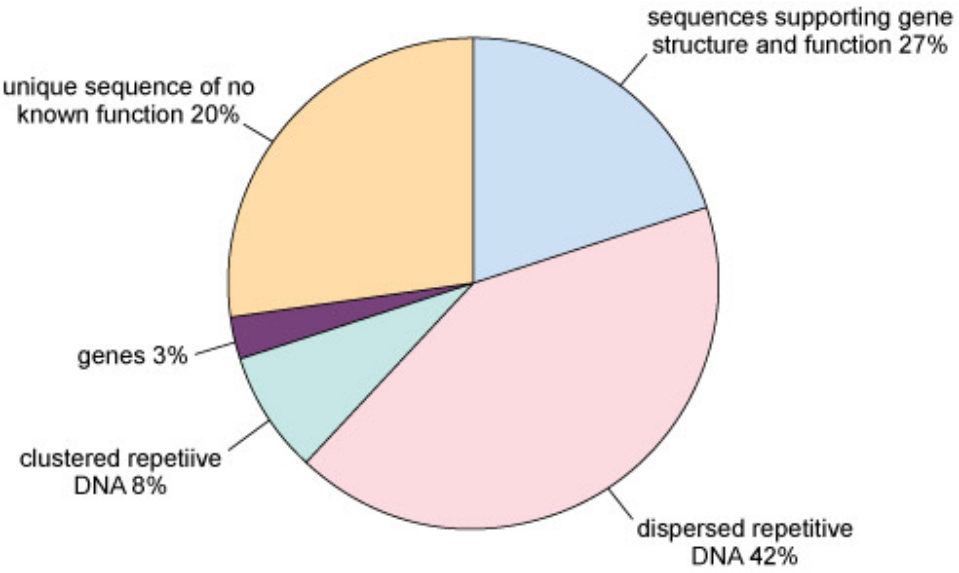

Figure 1 Pie chart representing proportions of DNA sequences in the human genome.

(a) Which category of DNA in the human genome is the largest?

(b) Which category of DNA in the human genome is the smallest?

(c) Based upon Figure 1, are these statements true or false?

(i) Dispersed repetitive DNA makes up over half of the human genome.

(ii) There are more sequences supporting gene structure and function than there are genes.

(iii) The function of 95% of the human genome is known.

Question 4

The bar chart shown in Figure 2 shows the number of podcasts listened to by students.

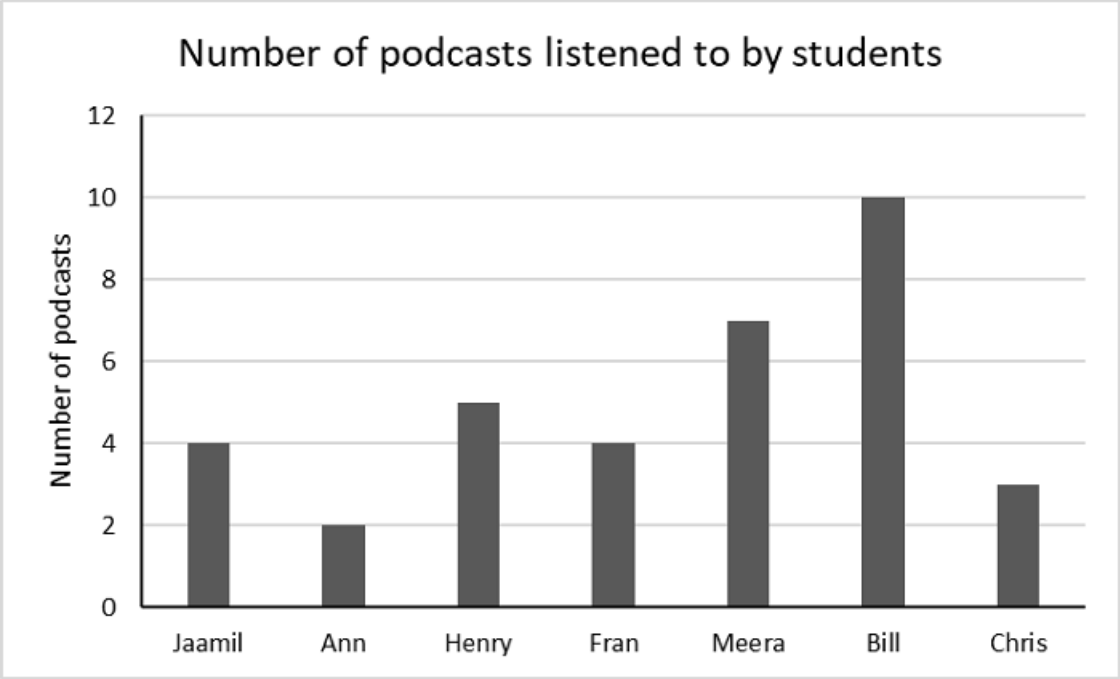

Figure 2 Bar chart showing numbers of podcasts listened to by seven students.

(a) How many podcasts have Ann and Meera listened to between them?

(b) How many podcasts in total have the whole group listened to?

(c) What is the mean number of podcasts listened to by the members of the group?

Question 5

Scatter plots are very useful for seeing whether two variables are associated, i.e. when one variable changes does the other also change? Figure 3 is a scatter plot showing the relationship between deaths among children aged under five years and their access to so-called 'improved' sanitation.

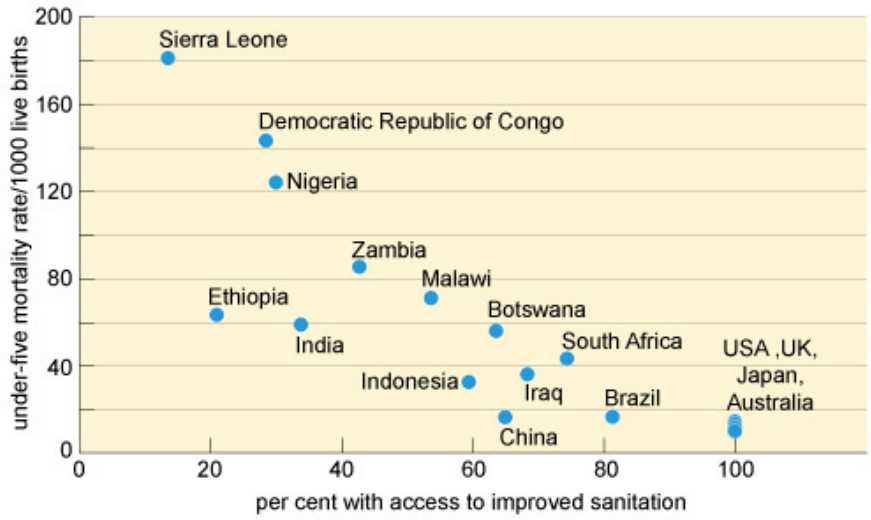

Figure 3 Scatter plot showing relationship between mortality and sanitation in various countries.

(a) In Sierra Leone, where fewer than 20% of under-fives have access to improved sanitation, what is the mortality rate?

(b) How would you describe the pattern made by the data points (the dots) in Figure 3?

(c) Is access to improved sanitation high or low in countries with high under-five mortality rates? Pick a country to illustrate your answer.

Question 6

The association between two variables is often shown graphically using simple data points.

How would you describe the relationship between predators and their prey in the three data sets shown in Figure 4(a–c)?

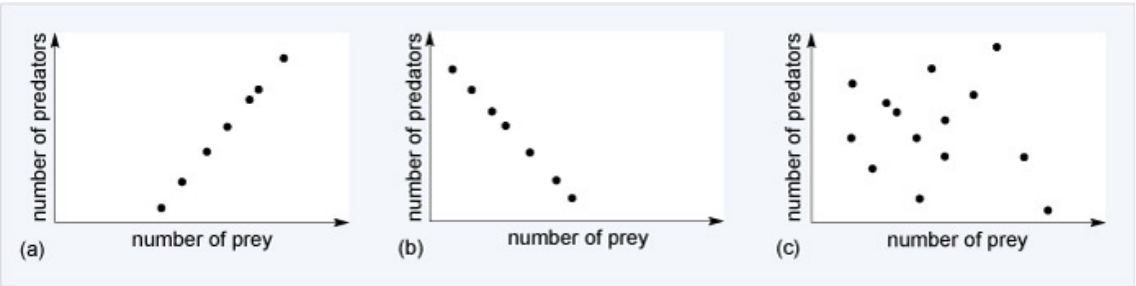

Figure 4 Graphs illustrating three different types of relationships (a–c) between two variables.

5.2 Science practical skills

The ability to ask well-designed scientific questions and address them in a safe, ethical manner is a key skill for science-related subjects.

Question 7

To understand a complex experiment, it is essential to appreciate the variables that contribute to the result.

(a) Give definitions for dependent, independent and controlled variables.

(b) Which axis of a graph would be used for the independent variable, and the dependent variable?

Question 8

Before beginning an investigation, a hypothesis is needed. Hypotheses are predictions that can be tested by experiment or observations. Statistical hypothesis testing can be applied to data to determine whether a true difference exists between two groups. Scientists are required by this procedure to put forward a so-called null hypothesis in the first instance. This is a hypothesis of no difference.

The hypothesis for an investigation into the effect of aspirin on blood glucose levels is that taking aspirin will decrease blood glucose levels. What would be the null hypothesis for this investigation?

Question 9

Laboratory record keeping is an essential part of all scientific investigations. As a scientist, you have a responsibility to clearly evidence how you achieved the results you are reporting. Comprehensive laboratory notes on methods enable you and equally importantly, others, to replicate your experiment. Memory can be very unreliable and having a written record of methods and results enables you to return to the data later on.

List at least four things that should be recorded as a part of a scientific investigation.

5.3 Scientific comprehension skills

As a part of S296, you will be reading scientific reports and using scientific information from web-based resources. Whilst you do not need to be familiar with these at the start of the module, a reasonable level of scientific comprehension is required. These questions will allow you to assess areas of your ability to comprehend a piece of scientific writing. Read the following article:

> **Stem cells appear to repair tissue damage caused by bowel disease**
>
> Gut stem cells appear to be able to repair tissue damage due to inflammatory bowel disease in tests on mice, according to a team of researchers from the Cambridge Stem Cell Institute at the University of Cambridge, and BRIC, the University of Copenhagen, Denmark. The findings may pave the way for patient- specific regenerative therapies for inflammatory bowel diseases such as ulcerative colitis.
>
> Writing in the journal Cell Stem Cell, the team described looking at developing intestinal tissue in a mouse embryo and finding a population of stem cells that were quite different to the adult stem cells that have been described in the gut. The cells were actively dividing and could be grown in the laboratory over a long period without becoming specialized into the adult counterpart. Under the correct growth conditions, however, the team could induce the cells to form mature intestinal tissue. When the team transplanted these cells into mice with a form of inflammatory bowel disease, within three hours the stem cells had attached to the damaged areas of the mouse intestine and integrated with the gut cells, contributing to the repair of the damaged tissue.
>
> "We found that the cells formed a living plaster over the damaged gut. They seemed to respond to the environment they had been placed in and matured accordingly to repair the damage," observed R. Kim Jensen, a Wellcome Trust researcher and Lundbeck Foundation fellow, who led the study. "One of the risks of stem cell transplants like this is that the cells will continue to expand and form a tumour, but we didn't see any evidence of that with the immature stem cell population from the gut."
>
> Cells with similar characteristics were isolated from both mice and humans, and the team were also able to generate similar cells by reprogramming adult human cells (induced pluripotent stem cells) and grown them in the appropriate conditions.
>
> "We've identified a source of gut stem cells that easily expanded in the laboratory, which could have huge implications for treating human inflammatory bowel diseases. The next step will be to see whether the human cells behave in the same way in the mouse transplant system, and then we can consider investigating their use in patients," added Dr. Jensen.
>
> Gale Academic OneFile (2013) 'Stem cells appear to repair tissue damage caused by bowel disease', *Transplant News,* 23(12), p. 5. Available at: https://link.gale.com/apps/doc/A357760610/AONE?u=tou&sid=AONE&xid=fbc fe255 [Accessed 9 March 2023].

Question 10

(a) Where do the cells under discussion come from?

(b) What do the researchers observe when cells are transplanted into mice with a form of inflammatory bowel disease?

(c) In which journal was the original research published?

(d) What is the risk of stem cell transplants identified by Dr Jensen?

5.4 Knowledge of key concepts for S296

These questions will allow you to assess areas of your core knowledge and understanding of underlying principles important for S296.

5.4.1 Chemistry concepts

An understanding of chemical concepts, including molecules and compounds, chemical bonding, and chemical reactions, underpins many of the processes discussed in S296.

Question 11

(a) How many atoms of oxygen are there in a molecule of oxygen gas (O_2)?

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

Question 12

(a) 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 how many electrons does chlorine use in bonding (i.e. what is the valency of chlorine) in $CaCl_2$?

(b) 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?

Question 13

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

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

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

Question 14

(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.

5.4.2 Biology concepts

These question address some of the key biology processes and concepts relevant to S296.

Question 15

Cellular respiration is the process in which oxygen is used to break down the bonds in glucose, releasing energy, and producing carbon dioxide and water. The energy released in the form of ATP is required to maintain life. 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.

(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 Question 14. Is photosynthesis a catabolic or an anabolic process?

Question 16

What are the monomer building blocks of the following examples of macromolecules:

(a) Globin

(b) DNA

(c) cellulose.

Question 17

The information needed to synthesise proteins is stored in the base sequence of double-stranded DNA. Although DNA has a relatively simple structure, its four nucleotides provide a powerful coding language – a means of storing and passing on information. The key to understanding the structure of DNA and how it functions in the cell lies in the interaction between the bases in each strand. Along the length the double helix, each base makes a specific pairing with a corresponding base in the other strand. These interactions are known as base pairing.

In Figure 5 below, which of the bases on the right would pair with the bases in the DNA strand on the left to form a double stranded segment of DNA?

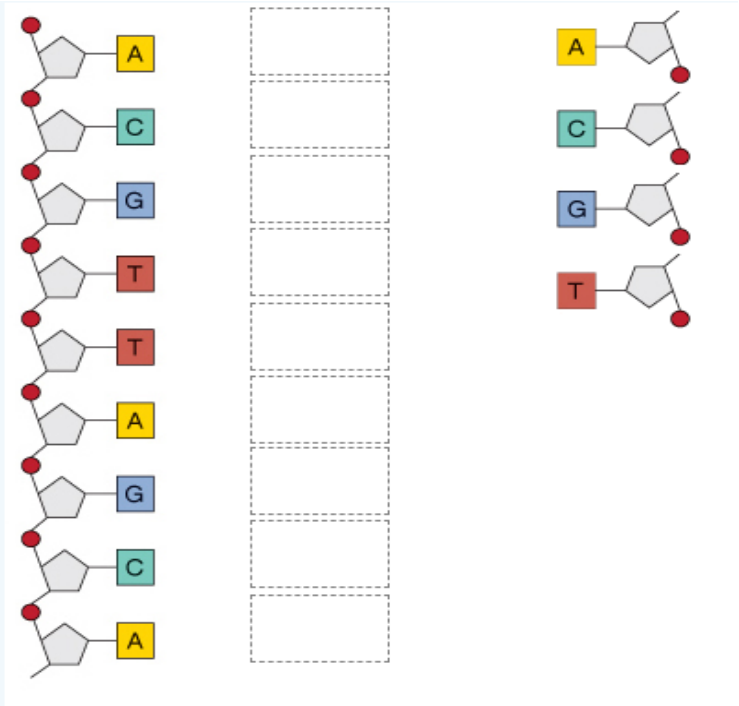

Figure 5 On the left is a DNA strand with nine nucleotides, with bases coloured pink (T), yellow (A), blue (G) and green (C) in random order. On the right are listed the four different types of bases that can be paired with the DNA strand.

Question 18

Complete the following description of how genetic information in DNA is copied and used to synthesis protein by inserting the appropriate word or phrase into [a]–[f].

> The DNA base sequence of a gene is copied into RNA during the process of [a]. During this process, the bases pair between DNA and RNA along similar lines to the process that occurs in double-stranded DNA, with the exception that the thymine base (T) in DNA is replaced by a [b] base in the messenger RNA (mRNA). Once complete, the mRNA is then exported from the nucleus to the cytoplasm to be used as a template to synthesise proteins. The synthesis of proteins is called [c] and occurs on specialist components within the cell that are called [d]. Each amino acid incorporated during synthesis is coded by three RNA bases that together are referred to as a [e]. Amino acids are joined together covalently into a chain by a covalent bond often referred to as a [f] bond.

Question 19

Complete each of statements A–C about protein structure by selecting a definition from the list (1–3) and a diagram of its structure from Figure 6 below.

A. The primary structure of a protein is (choose from 1–3) and is commonly represented as (choose from a, b or c)

B. The secondary structure of a protein is (choose from 1–3) and is commonly represented as (choose from a, b or c)

C. The tertiary structure of a protein is (choose from 1–3) and is commonly represented as (choose from a, b or c)

1. formed by the folding of the alpha helices and beta pleated sheets to form a 3D structure.
2. the sequence of amino acids in a polypeptide chain.
3. the formation of alpha helices and beta pleated sheets.

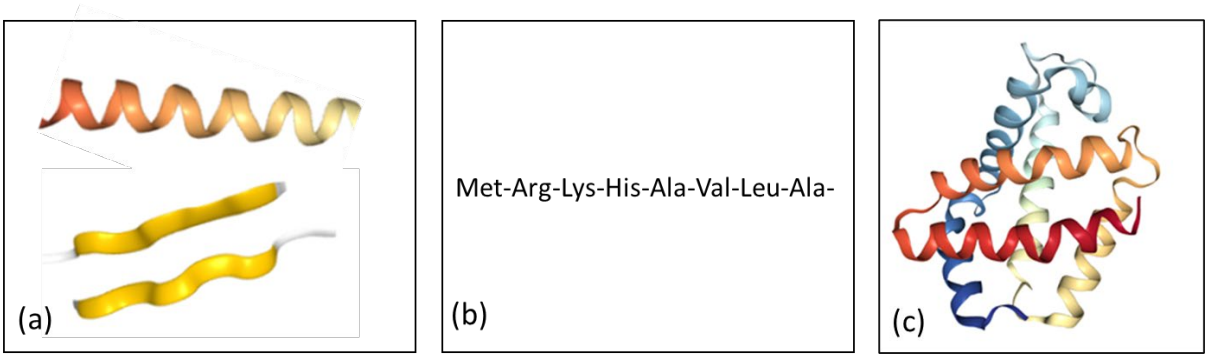

Figure 6 Different ways of representing the structure of a protein. [From RCSB Protein Data Base PDB ID:1Y9B, PDB ID:3NI3, and PDB ID:1H97].

Question 20

(a) Complete the following table using ticks and crosses to indicate which features are characteristics of 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 within a nucleus			
DNA is 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.

Question 21

The cell cycle refers to the cycle of growth and division whereby one cell becomes two. This involves the replication and exact partitioning of the chromosomes, and division to form two new daughter cells.

(a) The two main parts of the cell cycle are interphase and M phase. Interphase consists of three subphases: G1, S, and G2. Which one of the following statements describes the events that occur during S phase?

A. The cell divides into two daughter cells.

B. The DNA within the cell is replicated producing two complete copies.

C. The cell enters a state of quiescence.

(b) Name the two main processes that occur during the M phase of cell division:

(i) the process in which the nucleus divides

(ii) the process in which the cytoplasm divides.

Question 22

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 cell structure and carry out cellular processes. The basis for evolutionary change is the operation of natural selection upon heritable variation in the genes of organisms.

Match each of terms A–E with one of the descriptions (1)–(5) below.

A. genotype

B. alleles

C. heterozygote

D. phenotype

E. homozygote.

1. A eukaryotic individual that has two identical copies of a gene which determines a particular characteristic (or trait).
2. The alternative forms (or variants) of a gene.
3. An organism's observable characteristics (or traits).
4. A eukaryotic individual that has two different forms of a gene which determines a particular trait (or characteristic).
5. The genetic make-up of an organism.

6 Answers to self-assessment questions

Question 1

(a) Answers: (i) 102.65; (ii) 102.6

(b) Answers: (i) 102.6; (ii) 103

(c) Answers: (i) Three significant figures; (ii) Five significant figures; (iii) Here there are only two significant figures because initial zeros do not count. These initial zeros tell you only about the size of the number, and not about the precision to which it is known. The first significant digit in this value is the 8. (iv) There are three significant figures here, since the zero in the middle of a number does count as a significant figure in the same way as the other digits.

Question 2

(a) Answers: (i) 1×10^{8}; (ii) 3.5×10^{4}; (iii) 9.5×10^{6}; (iv) 3.5×10^{-3}; (v) 5.1×10^{2}.

(b) Answers: Length (metre, m); mass (kilogram, kg) and time (second, s).

(c) The kilogram (kg) is the SI unit of mass. As 1 kilogram contains 1000 g, 1 gram = 1×10^{-3} kilograms i.e. one thousandth of a kilogram. Therefore, 1 g = 1×10^{-3} kg.

Question 3

With pie-charts, the sizes of the areas for each category ('slice') is used to represent the relative quantities, so using this guide, the largest and smallest can be determined visually.

(a) Dispersed repetitive DNA.

(b) Genes.

(c) Answers

(i) False

(ii) True

(iii) False

Question 4

The height of each of the vertical bars for each student indicates how many podcasts they have listened to, which is indicated using the scale on the vertical axis.

(a) Ann has listened to two podcasts and Meera has listened to seven podcasts, so between them they have listened to nine podcasts.

(b) 35 podcasts have been listened to by the whole group.

(c) The mean value is obtained by dividing the total number of podcasts listened to by the number of students, so $35 \div 7 = 5$ podcasts.

Question 5

(a) Reading the vertical axis gives a value of about 180 deaths per 1000 live births in Sierra Leone. It is important to include the 'per 1000 live births' as this is a component of the rate.

(b) You may have said something like 'the data points slope downwards, from top left to bottom right of the diagram'.

(c) Access to improved sanitation is low in countries with high under-five mortality rates. We picked Sierra Leone, which has the highest under-five mortality rate and the lowest access to improved sanitation – but you could have chosen other examples. The reverse is also true: access to improved sanitation is high in countries with low under-five mortality rates; for example, the UK, USA, Australia and Japan all have very low under-five mortality and very high (almost 100%) access to improved sanitation.

Question 6

(a) There is a positive association between predator number and prey - the increase in one variable is associated with an increase in the other.

(b) There is a negative association between predator number and prey- the number of prey increases as the number of predators decreases.

(c) There appears to be no relationship or association between the two variables.

Question 7

(a) Dependent variable: A measured quantity, the value of which depends on the value chosen for another quantity (the independent variable). For example, if an investigator selected children of certain ages and measured their heights, then height would be the dependent variable.

Independent variable: A quantity, the value of which is chosen by the investigator For example, if an investigator selected children of certain ages and measured their heights, then age would be the independent variable, and height the dependent variable

Controlled variable: Potential variables that are held constant to make the results of the experiment intelligible. Controlled variables can affect experimental outcome just as the independent variables do, so they are held constant to ensure that the effects observed are caused by the changes made to the independent variable.

(b) On a graph, the dependent variable is plotted on the y axis and the independent variable is plotted on the x axis.

Question 8

The null hypothesis for the investigation would be that taking aspirin has no effect on blood glucose levels.

Question 9

Some things that should be recorded as part of a scientific investigation include:

- The date
- What was done and why (the research question and hypotheses)
- How it was done (the method and equipment used)
- What happened (the results of the experiment(s) including any measurements, observations and other data collected)
- Any data analysis and interpretation that was carried out
- Any unexpected occurrences, such as equipment or handling error.

Question 10

(a) Developing intestinal tissue in a mouse embryo.

(b) The stem cells attached to the damaged areas of the mouse intestine, integrate with the gut cell and contribute to repair of the damaged tissue.

(c) Cell Stem Cell.

(d) Formation of a tumour from the transplanted stem cells.

Question 11

(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.

Question 12

(a) 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.

(b) 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.

Question 13

(a) 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 7.

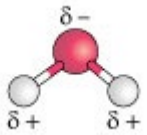

Figure 7 Representation of the chemical structure of a water molecule showing the polar nature of the covalent bonds (red = oxygen atom; white = hydrogen atom).

(b) Figure 8 shows the hydrogen bonding (represented as dashed lines) between water molecules

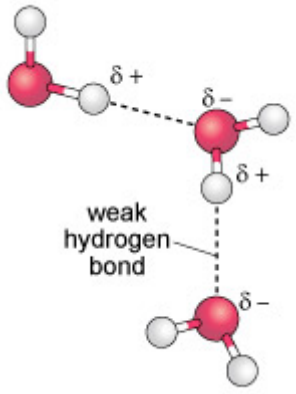

Figure 8 Hydrogen bonding between three water molecules (red = oxygen atom; white = hydrogen atom).

(c) Covalent bonds are stronger than hydrogen bonds.

Question 14

(a) The balanced equation is:

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

$(6 \times C, 12 \times O) + (12 \times H, 6 \times O) = (6 \times C, 12 \times H, 6 \times O) + (12 \times O)$

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

Question 15

(a) The overall equation for cellular respiration is:

$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$ (although in fact this process in cells takes place in a number of enzyme-catalysed steps).

(b) The equation is the reverse of the equation representing photosynthesis in the answer to Question 14, which shows the biosynthesis of glucose from carbon dioxide and water and is an anabolic process (building large complex molecules from smaller ones).

Question 16

(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).

Question 17

Along the length of a strand within a double helix of DNA, each base makes a specific pairing with a corresponding base in the other strand. These interactions are known as base pairing, for which there are very precise rules:

- T pairs only with A
- C pairs only with G

These pairs are called complementary base pairs, so applying these rules the double stranded segment of DNA would be as shown in Figure 9.

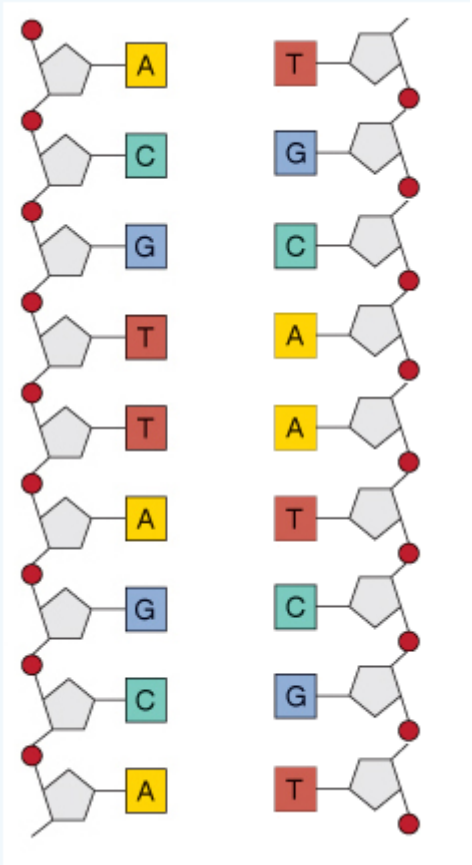

Figure 9 Segment of double-stranded DNA showing base-pairs.

Question 18

(a) transcription

(b) Uracil (U)

(c) translation

(d) ribosomes

(e) codon

(f) peptide

Question 19

A= 2 and (b); B= 3 and (a); C= 1 and (c).

Question 20

(a) Completed table

Feature	Prokaryotic cell	Eukaryotic animal cell	Eukaryotic plant cell
Contains a nucleus	X	✓	✓
Possesses a cell wall	✓	X	✓
Contains organelles	X	✓	✓
DNA is within a nucleus	X	✓	✓
DNA is within the cytoplasm	✓	X	X

(b) Answers:

(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 controls the passage of molecules in and out of the cell.

Question 21

(a) B The DNA within the cell is replicated producing two complete copies.

(b) Answer: (i) mitosis and (ii) cytokinesis.

Question 22

The matches between the terms and the descriptions are as follows:

A is (5)

B is (2)

C is (4)

D is (3)

E is (1).

Acknowledgements

Grateful acknowledgement is made to the following sources:

Figure 6: Images from the RCSB PDB (rcsb.org) of:

PBD ID:1Y9B: Binkowski, T.A., Hatzos, C., Quartey, P., Moy, S., Joachimiak, A. (To be published) 'Conserved hypothetical protein from Vibrio cholerae O1 biovar eltor str. N16961'.

PBD ID:3NI3: Khakshoor, O., Lin, A.J., Korman, T.P., Sawaya, M.R., Tsai, S.C., Eisenberg, D., Nowick, J.S. (2010) 'X-ray crystallographic structure of an artificial beta-sheet dimer', *J Am Chem Soc*, 132: 11622–11628.

PDB ID:1H97: Pesce, A., Dewilde, S., Kiger, L., Milani, M., Ascenzi, P., Marden, M.C., Van, M.L., Vanfleteren, J., Moens, L., Bolognesi, M. (2001) 'Very high resolution structure of a trematode hemoglobin displaying a Tyrb10-Tyre7 Heme Distal Residue Pair and high oxygen affinity', *J Mol Biol*, 309: 1153.