AQA A-Level Biology Year 1 and AS Student Book Answers

Chapter 1: Water and carbohydrates

ASSIGNMENT 1

A1. There should be a straight line graph.

A2. a. 87.5 mg cm^{-3}

A2. b. 4 mg cm^{-3}

A3. 50 seconds

A4. It is very difficult to determine the end point; you may not stop the clock fast enough.

A5. Fructose is also present as wine is made from fruit.

ASSIGNMENT 2

A1. Lactose is a sugar, so water enters by osmosis.

A2. Watery faeces or diarrhoea.

ASSIGNMENT 3

A1. a. Add potassium iodide and look for a colour change from red/brown to blue/black.

b. Add Benedict's solution and heat and look for a colour change from blue to yellow/green/brick-red.

c. First, carry out the reducing sugar test. If this is negative, hydrolyse the sample with dilute hydrochloric acid, neutralise with sodium hydroxide, and then add Benedict's solution and heat. Look for a colour change from blue to yellow/green/brick-red.

A2. a. Sample C had no carbohydrate as it was negative with all tests.

b. Samples B and F were likely to contain sucrose as they were negative for a reducing sugar and positive for a non-reducing sugar.

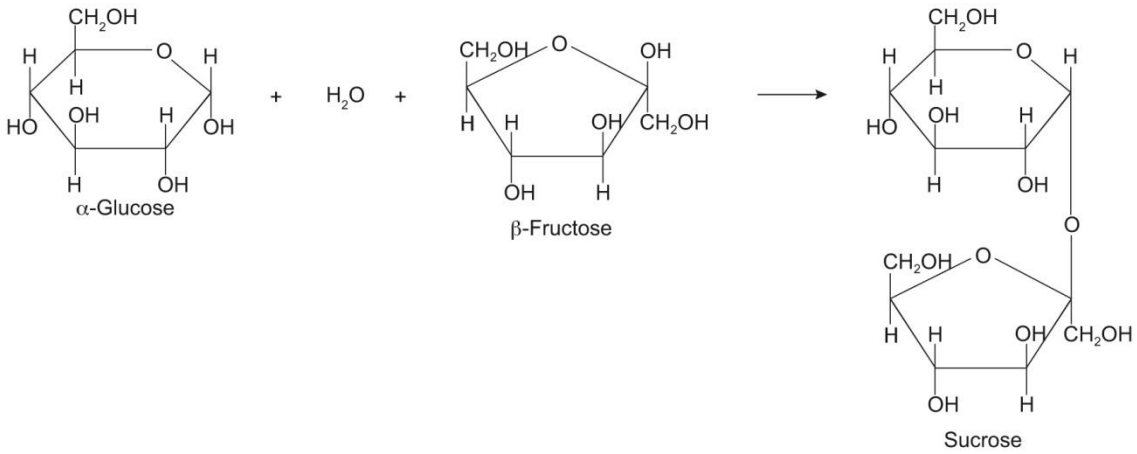
c. Samples C and E would be suitable for someone with lactose intolerance as they were negative for the fermentation test.

PRACTICE QUESTIONS

1. a. Alpha, because the H on carbon 1 is above the ring, and OH is below.

b. $C_6H_{12}O_6$

c.



d. Condensation

2. a. Add Benedict's solution and heat to about 80 °C. Glucose is a reducing sugar, and reduces the Cu^{2+} ions in the copper sulphate in the Benedict's solution to Cu^{+} ions, so the colour changes from blue to brick-red.

b. Use an electronic balance to measure 10 g of glucose. Put this into a 1 dm^3 (1000 cm^3) volumetric flask and add a small amount of distilled water. Dissolve completely. Add more distilled water to exactly the 1000 cm^3 mark.

c. For example, you could make an 8% solution by taking 80 cm^3 of the 10% solution, and then adding 20 cm^3 of distilled water.

Use a similar method to make up solutions of a range of concentrations, say 6%, 4%, 2%, 1% and 0.5%.

d. Measure a known volume of the 10% solution – say 10 cm^3. Add a known volume of Benedict's solution – say 10 cm^3. Note: it is important that there is enough Benedict's solution to react with *all* of the glucose. In other words, the Benedict's must be in excess.

Stand the mixture in a water bath at a steady temperature of 80 °C for a standard length of time, say 10 minutes.

Repeat with each of your other standard solutions. Ensure that each tube is labelled, and stand them in a row so that you can compare their colours with the results from your unknown sample.

e. Repeat the procedure with your unknown solution, using the same volume of solution, the same volume of Benedict's solution, the same temperature and the same time. Compare the results with your standards.

3. a. You could include these points in your answer:

- a polymer made of repeating monomers of α-glucose
- the glucose monomers are linked by 1–4 glycosidic bonds
- there are also 1–6 branches
- the molecule coils into a spiral.

b. These large molecules are insoluble in water, so starch is a good storage substance. The spiral form means that they are compact, again good for storage inside a cell. The α-1–4 glycosidic bonds are easy to break by enzymes, so the starch can be converted to glucose when required for energy.

4. a. i. Total loss after five days at 22 °C is 18 g. The mean rate of loss is therefore 18 ÷ 5 = 3.6 g day^{-1}.

ii. Total loss after five days at 28 °C is 28 g. The mean rate of loss is therefore 28 ÷ 5 = 5.6 g day^{-1}.

b. As temperature rises, the kinetic energy of water molecules increases. This means that water evaporates faster at higher temperatures, and the water vapour will also diffuse more quickly out of the leaf.

c. Water has a high latent heat of evaporation. As the most fast-moving water molecules in the liquid water in the walls of the mesophyll cells escape as gas, the average kinetic energy of the water molecules that are left behind decreases. This makes the cell walls cooler.

Chapter 2: Lipids and proteins

ASSIGNMENT 1

A1. The fatty acids in their molecules do not have charges, so are hydrophobic and so do not dissolve in water; this means they do not affect the osmotic properties of the cell in which they are stored. They have a high proportion of hydrogen and carbon atoms in their molecules, which provide a lot of energy when the molecules are respired.

A2. For example: the thickness of the blubber samples; the freshness of the samples; the site of the body from which they were taken; the temperature at which heat transfer was measured; the temperature at which they were kept before the measurements were made.

A3. They had readings for two variables for each animal sampled. They did not choose the values for any of the readings, so there was no 'independent variable'.

A4. a. The thermal conductivity of the pilot whale blubber is generally greater than that of the sperm whale blubber. This suggests that triglycerides have greater thermal conductivity than long chain alcohol lipids – the triglycerides are less good as thermal insulators.

b. For the pygmy sperm whales, there appears to be a trend that the higher the lipid content, the lower the thermal conductivity. For the pilot whales, there could possibly be a trend in the other direction: the higher the lipid content, the higher the thermal conductivity.

c. More samples could be taken and measured, so that there are more points on the scattergraph. Spearman's rank correlation test or Pearson's linear correlation test could be done to find out if there is a significant correlation between one variable and the other.

ASSIGNMENT 2

A1. Five

A2. Spot A is leucine; B is valine; C is methionine; D is cysteine and E is lysine.

A3. Spots may overlap or merge, e.g. glutamine and lysine.

A4. (Research task) Students should find and present information about photosynthetic pigments.

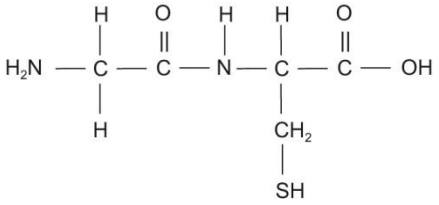
PRACTICE QUESTIONS

1. a. Add a small amount of biuret solution to a solution containing the suspected protein. A purple or violet colour indicates the presence of protein.

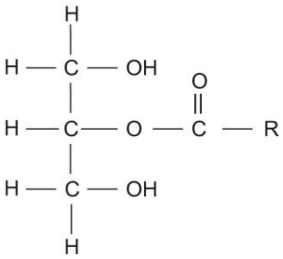
   b. i. Nitrogen

   ii. Condensation

   iii.



2. a.



   b. A polymer is a large molecule made up of a chain of repeating units, called monomers. Triglyceride molecules do not have repeating units, nor are they made up of a long chain.

3. a. The answer could include some or all of the following points: at least one named globular protein (e.g. haemoglobin, an enzyme, insulin) and one named fibrous protein (e.g. collagen, keratin, fibrin); a description of the shape of the molecules of globular and fibrous proteins; reference to the solubility of many globular proteins, and an explanation of why they are soluble, referring to the presence of hydrophilic R groups on the outside of the molecule; reference to why this solubility is important (e.g. allowing the molecules to be transported in blood, allowing them to take part in or catalyse chemical reactions); reference to the structural roles of fibrous proteins, and how the shapes of their molecules suit them to these roles.

   b. Reference to proteins being made up of combinations of 20 building blocks/amino acids, giving rise to many more combinations than carbohydrates which are made solely from sugar/glucose molecules/monomers; and proteins having more complex structures and diverse range of roles within the body.

4. a. P hydrogen bond, Q peptide bond, R ionic bond, S disulfide bridge.

   b. **Primary structure**: only peptide bonds are involved. They link amino acids together into a chain; **Secondary structure**: hydrogen bonds link the R groups of different amino acids together, forming a regular alpha helix or beta sheet; **Tertiary structure**: hydrogen bonds, ionic bonds and disulfide bridges between R groups in different parts of the chain hold the whole chain in a complex 3D shape; **Quaternary structure**: hydrogen bonds, ionic bonds and especially disulfide bridges between R groups in different polypeptide chains hold the whole molecule in a complex 3D shape.

Chapter 3: Enzymes

ASSIGNMENT 1

A1. Protease enzymes will digest proteins including those in the cell membranes of skin cells.

A2. Enzymes are specific and only a complementary substrate will fit the active site.

A3. Many bacteria will not be killed at this temperature so washed items may not be completely clean although they may look clean.

A4. a. and b.

Factor to control	Why it should be controlled	How it could be controlled
Size of gelatine blocks	Detergent and enzymes will diffuse into blocks at different rates if different sizes	Cut cubes from a solid block/use a cork borer to produce cylinders
Volume of water	To ensure equal concentrations of washing powder	Measure using measuring cylinder
Mass of washing powder	To ensure equal concentrations of washing powder	Weigh using accurate scale
Temperature of water	Higher temperature increases kinetic energy and will speed up reactions	Use a thermostatic water bath at a set temperature
Method of measuring 'digested blocks'	Need to measure both blocks accurately	Weigh blocks before and after
Amount of agitation / no agitation	Agitation would increase rate of collisions	Stir a given number of times or not at all

c. Use more than one block; repeat the experiment; carry out the experiment at a range of different temperatures.

A5. No. The investigation only used blocks of gelatine, and not stains on clothes. It could only demonstrate the ability of each washing powder to digest protein, and did not investigate the general cleaning ability of each powder.

ASSIGNMENT 2

A1. Enzymes are proteins and are made up of amino acids that contain an amino group with nitrogen.

A2. Cellulase will break down cellulose in plant cell walls. Wood contains plant cells so the cellulose will start to digest the wood.

A3. Student should plot suitable graph.

A4. The protease is effective over a much wider range of pH, and will work well in alkaline solutions above pH 7.

A5. The protease inhibitor stops the action of enzymes (proteases) that break up proteins. If a researcher wants a true picture of what proteins are present in the cell, they need to stop the proteins being broken up. If not, they would gain a false picture of the proteins in cells.

REQUIRED PRACTICAL 1

P1. Volumes of solutions used (enzyme and substrate), temperature and pH.

P2. The diameter of the neck of the burette means that the volume is measured more accurately. A gas syringe is designed to accurately measure gas evolved.

P3. a. Use a range of buffer solutions, keeping the enzyme and substrate concentrations constant.

b. Use water baths at a range of temperatures, keeping the enzyme and substrate concentrations constant.

P4. It is difficult to determine the end point accurately. The end point may occur between taking samples.

P5. When using photographic, film the end point may occur between taking samples; it can be problematic determining the end point when using an indicator to observe colour change.

P6. Keep a colour standard to compare with your samples.

ASSIGNMENT 3

A1. COOH

A2. The graphs should be a similar shape to that in Figure 5, but with an optimum temperature of 55 °C for glucose dehydrogenase and 85 °C for hydrogenase.

A3. 60 °C, since glucose dehydrogenase is denatured above this temperature, so the whole process would cease.

A4. Molecules have more kinetic energy so there are more frequent collisions / more enzyme substrate complexes formed.

A5. By using the enzyme cellulase, which is produced by some species of bacteria.

A6. a. 1300%

b. $28 000 000 000

c. Other costs need to be considered, such as fees for waste disposal – getting rid of an industrial waste product.

d. Lower percentage profit since start-up costs would be the same even though not all the gluconic acid could be sold.

e. Energy costs; cost of enzymes.

ASSIGNMENT 4

A1. a. Area of A = 21.21 mm^2, B = 71.48 mm^2, C = 0.00 mm^2 and D = 43.20 mm^2

b. Data should be presented as a bar chart.

c. B and D have a higher concentration of amylase than the standard and C has no amylase.

d. Maltose (and amylase).

A2. Place equal-sized samples of each strain of fungus on starch agar plates. Leave under controlled conditions for a set amount of time. Add iodine solution and measure the size of the clear areas around each strain of fungus.

PRACTICE QUESTIONS

1. a. Hydrogen peroxide was broken down to oxygen and water, and the oxygen was lost as a gas.

b. i. Using a piece of boiled liver rather than fresh. All enzymes would be denatured by boiling, and so would be inactive.

ii. This would be a check that the hydrogen peroxide does not decompose by itself, and would show that it is the enzymes in the liver that are causing the reaction to take place.

c. The rate of reaction is greatest at the start of the reaction, and then gradually decreases until it stops at around five minutes.

d. i. This is the most rapid stage of the reaction, when the concentration of substrate is greatest,

and the main limitation on the rate is the speed at which the catalase can break down and release each hydrogen peroxide molecule with which it forms a temporary enzyme–substrate complex.

ii. There is no change in mass during this time, because all of the hydrogen peroxide has already been broken down.

e. The energy level of the hydrogen peroxide has to be raised before it will decompose. At room temperature, the energy level is not sufficient for most molecules to reach their activation energy. The presence of catalase lowers the activation energy, so this can be achieved even at room temperature.

2. a. In order for a reaction to happen, energy often has to be supplied. The quantity of energy required is called activation energy. Enzymes lower activation energy, enabling reactions to take place at much lower temperatures than is otherwise possible.

b. i. Add iodine in potassium iodide solution. If starch is present, a blue-black colour is produced.

ii. Add Benedict's solution to a solution of the suspected reducing sugar, and heat to about 80 °C. If reducing sugar is present, the blue Benedict's solution will change to green, yellow or red-brown, as a coloured precipitate is produced.

c. i.

	pH		
	4	6	8
Optimum temperature / °C	48	57	54

ii. As temperature increases from 40 to 48 °C, the rate of reaction increases, as shown by the increase in the percentage of starch converted to maltose in 10 minutes. This happens because an increase in temperature means an increase in kinetic energy of the amylase and starch molecules. They are therefore moving more quickly, and collide more frequently.

As temperature increases above 48 °C, hydrogen bonds in the enzyme molecule begin to break, so the enzyme loses its three-dimensional shape. As the active site becomes distorted, it is no longer able to bond with starch. This happens progressively as temperature increases to 67 °C, and at that temperature all enzyme molecules are so denatured that none can bind with starch and no reaction occurs at all.

3. a. Enzyme has active site; Only substrate fits the active site.

b. Allopurinol is a similar shape to xanthine; Allopurinol enters active site / is a competitive inhibitor; Less xanthine binds / fewer enzyme–substrate complexes / fewer uric acid crystals formed / less uric acid formed.

4. a. Phosphate changes shape of TK / changes shape of enzyme / changes the active site; Active site forms/becomes the right shape / can bind to substrate / complementary to substrate / enzyme–substrate complex can form.

b. Faulty TK has functional active site without phosphate; So, faulty TK functional all the time / TK not controlled by phosphate.

c. Non-competitive inhibitor / binds to site other than active site; Causes TK to be in non-functional form / active site not formed / wrong shape / enzyme–substrate complex not formed; So, uncontrolled cell division stopped / slowed / controlled.

5. a. Product is oxygen so volume can be measured; substrate is hydrogen peroxide which cannot be seen / measured.

b. i. Accept any range in which minimum is between 0 and 10 and maximum is between 80 and 90 °C.
ii. Any suitable justification for either end of the range.

iii. e.g. Cannot use temperatures below freezing point / above boiling point, catalase could have an optimum anywhere within this range.

c. i. Use a buffer

ii. Any two of: concentration of catalase; concentration of hydrogen peroxide; source of catalase; time over which oxygen production measured.

6. Reference to active site of enzyme; active site has complementary shape to substrate; so each enzyme is specific for a particular substrate / reaction; reference to primary structure of protein / sequence of amino acids; idea that very large variety of different primary structures possible; because there are 20 amino acids that can be organised in any sequence; idea that primary structure determines tertiary structure; reference to three-dimensional shape of protein; idea that huge variety of primary structures means enzymes with different shapes can be produced.

7. a. It breaks down (hydrogen) peroxide.

b. It is made up of more than one polypeptide chain.

c. Similarities: it is made of four polypeptide chains; it contains haem groups; difference: it has an active site (where hydrogen peroxide can bind).

d. Affected by temperature: hydrogen bonds; affected by pH: ionic bonds.

e. The active site must be a similar shape in all of them, even if the rest of the molecules have different shapes.

f. Idea that it is loss of catalase activity in hair follicles that is responsible for greying of hair; catalase in a pill will be digested / hydrolysed / broken down; to individual amino acids; it is probable that the catalase in the cells in hair follicles is made *in situ*.

g. The reaction is exothermic / reaction increases temperature / reaction releases heat energy; heat causes the liquid to expand, increasing pressure; generation of oxygen gas increases pressure.

Chapter 4: Nucleotides

ASSIGNMENT 1

A1. a. They were easy to obtain and contain a nucleus.

b. It has more phosphorus and different properties.

A2. Chargaff's rule is the evidence for base pairing and was crucial to Watson and Crick.

A3. There is no correct answer to this question. Your answer could look at both sides of the argument, and use the facts you have found to support your final viewpoint. It is important to remember that all scientific discoveries build on work done earlier, so it is never easy to decide on exactly who should be credited with a discovery, but many people do feel that Rosalind Franklin could also have been given a Nobel Prize.

ASSIGNMENT 2

A1. DNA is double stranded, RNA is single stranded; DNA has deoxyribose, RNA has ribose; DNA has thymine, RNA has uracil.

A2. There will be 31% thymine; total A & T = 62%, C & G = 100 – 62 = 38% so, C = 38/2 = 19%, and G = 19%.

A3. DNA runs in opposite directions (structurally) so that one side of the DNA ladder runs in the 5′ to 3′ direction and the other runs from 3′ to 5′. This occurs due to the complementary shape of the base pairs and how they are able to bond together. They can only bond in one direction and that is parallel but in the opposite direction. This is called antiparallel.

A4. When cytosine and guanine pair, they do so with three hydrogen bonds, one more hydrogen bond than adenine and thymine.

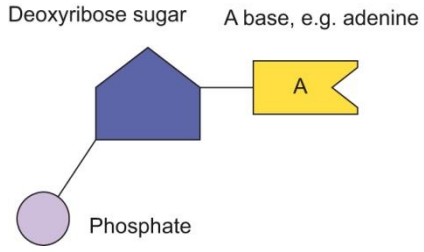
PRACTICE QUESTIONS

1. a. A: deoxyribose B: phosphate C: bases

   b. 3

2. a. Phosphate, a base

   b.



   c.

	Number of bases			
	Adenine	Thymine	Cytosine	Guanine
Strand X	6	2	4	4
Strand Y	2	6	4	4

3. a. Double helix.

   b. By hydrogen bonds between the bases.

   c. It has bases in a fixed sequence, which code for the sequence of amino acids in a protein.

   Adenine can only bond with thymine, and cytosine with guanine, and this complementary base pairing allows DNA to be perfectly replicated.

   The strands can be 'unzipped' (separated) so that the DNA can be copied, or so that complementary mRNA can be built alongside one of the strands.

   Strong phosphodiester bonds hold the sugar–phosphate backbone together, so that DNA is a very stable molecule.

4. a. An isotope of nitrogen that has one more proton than the normal form, ^{14}N, and is therefore heavier.

   b. The bases.

   c. They are heavier, and so settle out at a lower level when centrifuged in a caesium chloride solution.

   d. i. New DNA was produced by semi-conservative replication. Each new molecule therefore contained one strand of 'old' DNA whose bases all contained ^{14}N, and one new strand made from newly produced bases that contained the ^{15}N that had been provided.

   ii. For the second generation, no ^{15}N was provided. New nucleotides were therefore synthesised from the naturally occurring ^{14}N. During replication of the DNA, the two strands in the 'old' molecules – one containing ^{14}N and one containing ^{15}N – separated from each other, and new strands containing ^{14}N were built up against them. Therefore, some of the new molecules contained two strands both with ^{14}N, while the others contained one strand with ^{15}N and the other with ^{14}N.

5. a. The new molecule of DNA contains one strand from the original molecule, and one new one.

   b. i. Adenine always pairs with thymine, while guanine always pairs with cytosine.

   ii. This specific, complementary base pairing ensures that the base sequence on the new DNA exactly matches the base sequence on the original DNA.

   c. Strong phosphodiester bonds, which are covalent bonds, hold the nucleotides together in each strand. The weaker hydrogen bonds, which hold the two strands together, are protected inside the double helix.

6. a. X: phosphate Y: deoxyribose Z: base.

   b. Hydrogen bond

   c. 28% are thymine, so 28% are adenine.

   Therefore 100 – (2 × 28) = 44% are guanine and cytosine.

Therefore 22% are cytosine.

7. a. Each new DNA molecule contains one strand from the original DNA molecule, and one newly synthesised strand.

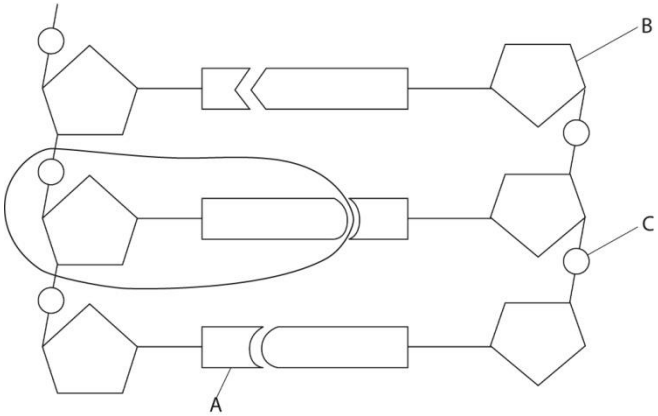
b. i. The DNA formed using ^{15}N is denser than DNA formed using ^{14}N.

ii. In tube C, all the new DNA contains one old strand from the original DNA that contained ^{15}N, and one new strand that was made using ^{14}N from the medium in which the bacteria were kept. This DNA therefore has a density between that of the 'pure ^{15}N' DNA and the 'pure ^{14}N' DNA.

c.

DNA sample	**Percentage of base present**			
	Adenine	Cytosine	Guanine	Thymine
Strand 1	26	32	28	14
Strand 2	14	28	32	26

8. a.



b. i. The sequence of bases codes for the sequence of amino acids that is linked together during protein synthesis. A triplet of three bases codes for one amino acid.

ii. By hydrogen bonds between the bases. There are two hydrogen bonds between A and T, and three hydrogen bonds between C and G.

iii. This protects the bases from interaction with other molecules in the cell, as they are 'hidden' inside the double helix.

9. a. DNA helicase is an enzyme that 'unwinds' part of a DNA molecule, exposing the bases ready for replication or mRNA synthesis.

b.

Sample	Type(s) of DNA molecule present in each sample		
	$^{15}N^{15}N$	$^{15}N^{14}N$	$^{14}N^{14}N$
1	✓		
2		✓	
3		✓	✓

c. i. Cytabarine is a molecule containing cytosine bonded to a sugar. This sugar is not deoxyribose. If cytabarine is present during DNA replication, it could be incorporated into the DNA polynucleotide instead of cytosine, which would not form normal DNA. It could also be a competitive inhibitor of the enzymes involved in DNA replication.

ii. Cancer cells divide very rapidly, and so DNA replication happens much more frequently than in healthy cells.

Chapter 5: Cells

ASSIGNMENT 1

A1. Cyclin stimulates production of another protein that in turn stimulates the replication of the DNA and initiates mitosis.

A2. The second protein breaks down cyclin.

A3. It is over-produced.

A4. It promotes rapid growth of mammary cells.

A5. Finding drugs to block the action of cyclin D1, which could arrest the growth of human breast cancer without harming normal cells.

A6. As with all experiments involving animals, the pain or distress caused by treating the animals must be balanced against the increased life expectancy of humans receiving the treatment tested in this way. Animal rights activists would argue that the experiments should be done using tissues or models, without the use of live animals.

A7. a. Little effect until after 5 µM, then rapid decrease in cell viability to 50 µM.

b. Same type of breast cancer cells, same environmental conditions, inert substance added in place of curcumin.

c. Needs to be tested on animals and human subjects in clinical trials.

REQUIRED PRACTICAL 2

P1. Otherwise cells will be destroyed and not visible.

P2. 0.03 mm or 30 µm.

P3. The eyepiece graticule is a glass disc, fitted into the eyepiece of the microscope. When viewed, a scale can be seen. This scale is fixed and needs to be calibrated depending on the objective lens used. Calibration is done using a stage micrometer, which is a slide or set of slides with accurate measurements etched onto the glass. The eyepiece graticule is matched up with the slide's markers. A calibration factor is calculated by seeing how many divisions the eyepiece graticule is equal to on the micrometer. For example: if the eyepiece graticule has a 100 divisions totalling 1 mm, and this equals 27 divisions on the micrometer, we can calibrate 1 eyepiece division to be 27 µm.

P4. The distribution of cells undergoing mitosis may change in different fields of view.

P5. First, check the light source. Second, remove some dye using a paper towel or similar. Third, draw through some water to dilute the dye if necessary.

P6. Done on lined paper; Cell wall is sketched; Label lines are arrows; Label lines cross; Label lines not drawn with a ruler; Chromosomes are not clearly drawn; No heading; No magnification; Label line for chromosomes does not touch them.

P7. a. $\frac{90}{360} = 0.25$

b.

Stage of cycle	Number of cells	Percentage of cells in stage	Time in stage / minutes
Interphase	270	75.0	1080
Prophase	35	9.7	139.7
Metaphase	30	8.3	119.5
Anaphase	5	1.5	21.6
Telophase	20	5.5	79.2

P8. a. Normal ovary 0.05; cancerous ovary 0.4

b. Mitotic index is much higher in cancerous ovary (eight times higher). This could be used to determine whether further investigations are necessary, or how large a tumour might be.

PRACTICE QUESTIONS

1. a. A: chloroplast B: nucleus C: mitochondrion D: cell wall made of cellulose E: cell-surface membrane F: rough endoplasmic reticulum.

b. Starch.

c. C: Release of energy from organic molecules during respiration, and the synthesis of ATP; D: Support for the cell, for example, preventing it from bursting when water is absorbed by osmosis; E: Control of substances entering and leaving the cell; F: The ribosomes on its surface are the site of synthesis of proteins.

d. An animal would have no cell wall or chloroplasts, nor a large vacuole.

2. a. i. Crista.

ii. The human liver cell uses more energy than the root cell, for example for the synthesis of proteins. Mitochondria produce ATP, which is the energy currency for cells.

iii. The DNA contains the code for the production of some of the proteins (e.g. enzymes) required by the mitochondrion. Ribosomes are the sites on which these proteins are synthesised.

b. The solution is ice-cold to reduce the rate at which any chemical reactions take place that might damage the organelles. The solution is the same concentration as the cytoplasm to avoid any entry or exit of water to or from the organelles by osmosis, which could damage their structures.

3. a. i. Metaphase.

ii. Spindle fibres, which are attached to the centromeres of the chromosomes, drag them to the centre of the cell where they line up.

b. i. Telophase.

ii. The chromosomes (each made of a single chromatid now) have arrived at opposite ends of the dividing cell, and now decondense. Nuclear envelopes reform around each group.

c. i. DNA replication.

ii. Prior to mitosis, the DNA in each chromosome is replicated, forming two identical chromatids that remain attached at the centromere. This ensures that when the cell divides by mitosis, each new cell will be genetically identical with the original cell. As the organism grows, more and more genetically identical cells continue to be formed by mitosis.

d. Oncogenes are mutated genes that disrupt the normal control of the timing of the cell cycle. They cause uncontrolled cell division, resulting in the growth of tumours.

4. a. i. D, B, E, A, C

ii. Metaphase

b. Interphase

c. i. Original number of cancer cells = 1×10^6

At week 12, number of cancer cells present = 0.06×10^6.

Percentage of original number of cancer cells = $\frac{(0.06 \times 10^6)}{(1 \times 10^6)} \times 100 = 6\%$

ii. Cancer cells divide more frequently than healthy cells. The chemotherapy drug kills cells that are dividing, and so many of the rapidly dividing cancer cells will be destroyed. Fewer healthy cells are killed, because they divide less frequently.

iii. The interval between cell divisions becomes longer for the cancer cells than for the healthy cells. The increase in the number of cells at each division is less for the cancer cells than for the healthy cells. The number of cancer cells continues to decrease throughout treatment, whereas the number of healthy cells stabilises at about 0.25×10^6.

5. a. i. B

ii. C

b. The quantity of DNA per cell halves during this stage. This happens because the two chromatids making up each chromosome are pulled apart during anaphase, with only one chromatid ending up in each daughter cell.

c. i. At stage B, the quantity of DNA would not increase. The line would remain horizontal.

ii. Cancer cells divide more rapidly than normal cells. As cytarabine stops DNA replication, cells are not able to enter mitosis and cannot divide. This prevents a cancerous tumour from growing or spreading.

6. a. i. Golgi apparatus.

ii. nucleus / nuclear envelope; mitochondrion.

b. This is a mitochondrion, which uses energy stored in organic molecules to synthesise ATP, during aerobic respiration.

c. A transmission electron microscope provides much higher resolution than an optical (light) microscope, and therefore allows small organelles such as mitochondria to be visualised more clearly.

7. a. In a bacterium (a prokaryotic cell), the DNA is in the form of a circular molecule, whereas in a eukaryotic cell, it is a linear molecule. In a bacterium, the DNA is not associated with proteins, whereas in a eukaryotic cell, it is associated with proteins called histones.

b. B is a plasmid; it is a small loop of DNA that often carries genes for antibiotic resistance. C is a ribosome, where proteins are synthesised.

c. D is a cell wall. It is made of a polymer called murein (peptidoglycan), whereas in a plant cell it is made of the polymer cellulose.

d. E is the cell-surface membrane, which controls the entry and exit of substances to and from the cell.

e. Scale bar of 1 μm = 7 mm wide; image of bacterium is 40 mm wide; therefore, actual length = 40 ÷

7 × 1 = 5.7 μm (or calculation with similar measurements).

8. a. DNA helicase unzips the DNA double helix, by breaking the hydrogen bonds between the bases. Free DNA nucleotides then pair up with their complementary bases on each exposed strand; A pairs with T and C with G. DNA polymerase then links the newly placed nucleotides together by forming phosphodiester bonds between the deoxyribose of one nucleotide and the phosphate group of its neighbour. Two new DNA molecules are therefore produced, each one consisting of one old strand and one new one.

b. i. 18 minutes

ii. 9 minutes

iii. Line Y would continue horizontally until the end of metaphase (at 18 minutes) and then drop towards the *x*-axis, reaching the axis at 27 minutes (when anaphase is complete).

c. i. Total number of cells in the sample = (82 + 4 + 5 + 5 + 4) = 100.

Percentage of cells in interphase = 82%.

Therefore time spent in interphase = (82 ÷ 100) × 24 = 19.7 hours.

ii. There would be no visible chromosomes, just chromatin within each nucleus.

iii. Tissue sample **D** was cancerous. At the time of the sample, many more cells were in various stages of mitosis, showing that these cells were dividing more frequently than the cells in tissue sample C. We can calculate the mitotic index for each sample:

Mitotic index for sample C = 18%

Mitotic index for sample D = 55%

Chapter 6: Cell membranes

ASSIGNMENT 1

A1. Surface area of spherical cell = 88 μm^2; Surface area of cylindrical cell = 121 μm^2.

A2. a. 200 μm per second

b. 2 μm per second

A3. a. Approximately 0.4 milliseconds

b. 2–3 milliseconds

A4. The rate of diffusion across the membrane would increase due to an increase in surface area, but the time taken for oxygen to reach the haemoglobin molecules in the centre would increase by a much larger factor.

ASSIGNMENT 2

A1. Sweating involves the loss of both water and salts from the plasma. If these are replaced only by water then the Ψ of the plasma will increase. The Ψ will now be higher than the Ψ of the brain cells, so water will diffuse into these cells causing them to swell.

A2. Yes. Tell the manager that clubbers need to replace salts lost in sweat just like marathon runners, otherwise there is a risk of illness.

REQUIRED PRACTICAL 3

P1. You could remove water.

P2. The skin is impermeable and will affect the rate of osmosis.

P3. To give a larger surface area and so faster water uptake.

P4. 0.25 cm^3 stock solution and 75 cm^3 distilled water.

P5. So there are no ions present which may affect osmosis.

P6. So there is no evaporation.

P7. Because starting masses will not be all exactly the same.

REQUIRED PRACTICAL 4

P1. To make sure pigment from cells damaged by cutting has been removed.

P2. Bigger pieces will contain more pigment and make a darker solution.

P3. Different plants may contain different amounts of pigment.

P4. Plot a graph of independent variable (temperature / solvent concentration) on the *x*-axis against absorbance on the *y*-axis.

ASSIGNMENT 3

A1. a. Diffusion

b. Osmosis

A2. 132 mmol dm^{-3} sodium and 96 mmol dm^{-3} chloride.

A3. Molecules have more kinetic energy so will diffuse faster; prevents cooling of the blood.

A4. To maintain a concentration gradient for faster diffusion.

ASSIGNMENT 4

A1. a. Glucose is taken up by facilitated diffusion and there are still carrier proteins available.

b. Carrier molecules are saturated and become a limiting factor.

A2. a. Magnesium is taken up by active transport. It is beginning to level off as all the carrier proteins become saturated.

b. The concentration of magnesium is higher inside the cells than in the solution.

c. Diffusion is occurring so the rate is proportional to the concentration gradient.

PRACTICE QUESTIONS

1. a. i. Concentration of sucrose solution

ii. Change in length of the potato cylinders

iii. Original dimensions of the potato cylinder; temperature; time of immersion.

b. So that any variation in the changes for the 10 repeats could be noted, and anomalous results ignored. This is a check on the reliability of the results; wide variation suggests that reliability is not good. A mean can be calculated.

c. 0.3 mol dm^{-3} (accept 0.3 or 0.31 mol dm^{-3}, i.e. where ratio is 1.0)

d. i. The water potential of the sucrose solution was greater than that of the potato cells, so water moved into the cells by osmosis, across the partially permeable cell-surface membranes of the cells, down a water potential gradient.

ii. The water potential of the sucrose solution was lower than that of the potato cells, so water moved out of the cells by osmosis, across the partially permeable cell-surface membranes of the cells, down a water potential gradient.

2. a.

Part of membrane	Letter
Channel protein	B
Contains only the elements carbon and hydrogen	D

b. It is fluid because the molecules of which it is made move around, while maintaining contact with one another, as in a liquid. It is a mosaic because the proteins are scattered among the phospholipid molecules, and would look like a mosaic if viewed from above.

c. There is a small but constant increase in the concentration of chloride ions as the temperature is increased from 35 °C to 50 °C. This is because the higher temperatures increase the kinetic energy of the chloride ions, so that they pass more rapidly through carrier proteins in the cell-surface membranes of the carrot cells and escape into the surrounding water, diffusing down their concentration gradient.

As temperatures increase above 50 °C, the increased kinetic energy of the molecules in the cell-surface membranes cause the membrane to lose its integrity. Protein molecules such as the carrier proteins begin to denature, losing their shapes. Phospholipid molecules move so much that spaces open up between them. Both of these changes mean that chloride ions can now move much more freely through the membrane. This explains why there is an increasing concentration of chloride ions in the water as temperature increases.

From about 60 °C and above, there is no change in the concentration of chloride ions in the water. The concentration is now the same as the concentration inside the carrot cells. Although the ions can move even more freely between the carrot cells and the surrounding water as temperature increases, there is no longer a concentration gradient for them, and so no further change is seen.

3. a. Change in concentration of sodium ions in the solution is 10 – 4 = 6 arbitrary units.

Therefore, the rate of uptake = $\frac{6}{30}$ = 0.2 arbitrary units per minute.

b. When cyanide is added, the uptake of sodium ions occurs only for the first 20 minutes. Moreover, this uptake is much less rapid than when no cyanide is present.

c. Respiration produces ATP, which is used to provide energy for active transport. With cyanide present, there is no respiration and therefore no ATP. The initial uptake of sodium ions is by diffusion down their concentration gradient, but once the concentration in the cells equals the concentration of the surrounding water (at 20 minutes), there is no longer a diffusion gradient and no more ions are taken up. With no cyanide, uptake continues by active transport, against a concentration gradient.

4. a. The quantity taken up by one million cells in one hour is a measurable quantity. Fewer cells or a smaller length of time would involve such tiny amounts as to be very difficult to measure.

b. Increase in rate of uptake = 32.5 – 10.7 = 21.8 µg per million cells per hour.

Percentage increase in rate of uptake = $\frac{21.8}{32.5} \times 100 = 67.1\%$

c. i. Imatinib is taken up by the cells at both temperatures even when the concentration outside the cells is at its lowest, suggesting that it can be taken up against its concentration gradient.

ii. At the higher temperature, rate of uptake levels off as the outside concentration increases from 50 to 100 µmol dm^{-3}, suggesting that the number of carrier proteins is now limiting the movement of imatinib into the cells.

5. a. Active transport requires the input of energy by the cell, in the form of ATP, which is hydrolysed to release energy. Facilitated diffusion relies entirely on the kinetic energy of the molecules or ions themselves.

Active transport involves the movement of molecules or ions up their concentration gradient, whereas in facilitated diffusion they move down their concentration gradient.

b. i. This was to determine whether the drug was the cause of the difference in acid secretion, rather than another factor – such as simply taking part in a trial.

ii. The control group would be given a 'dummy' drug (a placebo). Neither group would know whether they were taking the drug or a placebo.

c. The drug immediately reduces acid secretion, causing a fall of approximately 175 cm^3 per hour over a period of three hours. However, it should be noted that even taking the dummy drug causes a fall of about 25 cm^3 per hour, so it could be said that the drug itself is causing a fall of approximately 150 cm^3 per hour. The effect of the drug then gradually wears off, so for the next two hours the rate of acid secretion gradually climbs back towards its starting value.

Chapter 7: The immune system

ASSIGNMENT 1

A1. Two weeks (week 7 to week 9)

A2. 56 units (from 9 to 65)

A3. The blood will still contain memory cells, each produced by clonal selection from the original B cells that were stimulated by the vaccination. Even when the plasma cells that secrete antibodies have died out, memory cells remain. These can quickly divide to produce new plasma cells if stimulated again by the same antigen.

ASSIGNMENT 2

A1. All children attend school; no special arrangements need to be made by parents.

A2. a. Data presented as a bar chart.

b. There may be infection with HPV but this may not be the cause of cancer; not all people will be tested for HPV; HPV may have caused cancer but be no longer present.

c. 82.95%

A3. Cancer takes many years to develop.

A4. Boys will gain little themselves from the HPV vaccination, although it may offer some protection against cancer of the penis (see the table). It could therefore be argued that it is wrong to subject boys to a vaccination that is designed to help someone else, not the person who is being vaccinated. Whether or not this is an appropriate line to take depends on whether there is any potential harm that could come to a boy because he is vaccinated with HPV. You may like to research this issue further by searching on-line, and find out what is recommended in different countries such as the USA and the UK.

ASSIGNMENT 3

A1. Health care systems in West Africa were probably not good enough to detect a new disease. It was not until the virus had spread to the USA that the disease was recognised. (Even then, it took some years before the cause of the disease was understood.)

A2. Viruses that infect animals could be transferred to humans when they have close contact with the tissues of these animals. Most viruses are not able to infect more than one species, but if a mutation occurs then a virus from an animal may become able to infect a person. The frequent contact of people with fresh meat from wild animals in this region increases the chances of this happening.

A3. The answer will depend on the evidence that is found. Try to contain clear reference to biological evidence (e.g. DNA base sequences), and emphasise that it is not possible to draw firm conclusions because we do not have complete records of all cases; evidence is circumstantial.

ASSIGNMENT 4

A1. Over-use of antibiotics leads to an increase in the number of antibiotic-resistant bacteria, leading to difficulty in treating illnesses caused by the resistant bacteria.

A2. Data plotted as a bar chart

A3. a. Study A – largest number of participants.

b. A, C and D, since no placebo was used.

A4. There was very little difference between treating with antibiotics, symptomatic treatment and placebo.

A5. Since a majority of parents ask for antibiotics, their efficiency should be investigated. However, there is no information as to whether parents gave their informed consent to their children taking part in a trial. Since colds are rarely serious, giving some children the placebo is not likely to disadvantage them.

PRACTICE QUESTIONS

1. a. i. B lymphocytes with receptors that bind to a particular antigen are stimulated, and divide rapidly to form a clone of cells. Some of these become plasma cells, and secrete large quantities of antibodies. The antibodies bind to the antigens; if these are on the surfaces of bacteria, they may cause the bacteria to clump together. Macrophages then take in the bacteria by phagocytosis and destroy them.

ii. Macrophages place antigens from cells that they have destroyed in their cell-surface membranes (antigen presentation). This is also done by cells infected with viruses. T cells that recognise these antigens divide to form a clone of cells. Some of these cells are cytotoxic cells, which bind with the antigens and destroy the cells to which they are attached. Others are T helper cells; these secrete cytokines, which stimulate the activity of macrophages and B cells.

b. i. The regions near the end of the light chains have a specific shape, which can bind with a specific antibody.

ii. The amino acid sequence near the end of the light chain is variable, so that different antibodies can be produced that will bind with different antigens.

They are globular proteins, which are small enough to be soluble, and therefore can spread to all parts of the body in blood and tissue fluid.

c. i. Monoclonal antibodies are identical antibodies, all secreted by the same clone of plasma cells.

ii. For example, a monoclonal antibody that binds with a receptor on a type of cell that is causing illness (e.g. a cancer cell) can be linked to a drug that kills the cells. This ensures that the drug kills only the required cells, not other cells that do not carry this receptor.

2. a. Antigens from the 'flu virus diffused into the agar from well **A**, and antibodies from the human volunteer diffused from well **C**. The antibodies caused the antigens to clump together, or agglutinate.

b. The plasma from the volunteer contains antibodies against several different strains of the 'flu virus. This is indicated by the fact that several different precipitation lines, at different distances from wells **B** and **C**, have formed. This suggests that different antigens and antibodies diffused at different speeds, meeting in different places.

3. a. Mean amount of antibody before vaccination = 0.05 arbitrary units

mean amount of antibody after vaccination = 0.73 arbitrary units

increase = 0.73 – 0.05 = 0.68 arbitrary units

so, percentage increase = $\left(\frac{0.68}{0.05}\right) \times 100 = 1360\%$.

b. Both groups of children came from the same country, in which we are told that measles is common. The difference must therefore be due to chance selection of the children in the group. More of the children in the group to be given MV + MMR had previously been exposed to the measles virus.

4. a. Pathogens, by definition, cause disease. If a person cannot mount an effective immune response against a pathogen, then the pathogen can reproduce in the body. Large populations of a pathogen cause harm that can be fatal.

b. i. Once inside a host cell (in this case, T lymphocytes), the virus may be hidden and not come into contact with the molecules contained in the vaccine.

ii. The vaccine is designed to bind to particular antigens from the virus. If these antigens change, then the vaccine will not be able to bind and will have no effect.

c. All of the vaccines contain material derived from HIV. It is possible that they could cause a real infection, damaging T lymphocytes and allowing opportunistic infections from other pathogens to take hold.

Chapter 8: Exchange with the environment

ASSIGNMENT 1

A1. a. Manatee: $r = 0.375$, $h = 4$

area = $(2 \times \pi \times 0.375 \times 4) + (2 \times \pi \times 0.375^2) = 10.31\ m^2$

Walrus: $r = 0.5$, $h = 3.5$

area = $(2 \times \pi \times 0.5 \times 3.5) + (2 \times \pi \times 0.5^2) = 12.57\ m^2$

Elephant: $r = 1$, $h = 3$

area = $(2 \times \pi \times 1 \times 3) + (2 \times \pi \times 1^2) = 25.13\ m^2$

b. volume = $\frac{\text{mass}}{\text{density}}$

Manatee: $1000\ kg \div 1000\ kg\ m^{-3} = 1.0\ m^3$

Walrus: $1700\ kg \div 1000\ kg\ m^{-3} = 1.7\ m^3$

Elephant: $5000\ kg \div 1000\ kg\ m^{-3} = 5.0\ m^3$

c. Manatee: 9.4 ÷ 1.0 = 9.4 : 1

Walrus: 12.57 ÷ 1.7 = 7.4 : 1

Elephant: 25.13 ÷ 5.0 = 5.0 : 1

d. The walrus, because it has the smaller surface area to volume ratio. This as an advantage because the walrus lives in arctic water and will lose less heat. The larger surface area to volume ratio of the manatee is an advantage in warmer climates as it allows the manatee to lose heat more easily.

A2. In water: water molecules are much closer together than the molecules in air, so conduction of heat is more rapid.

ASSIGNMENT 2

A1. When the spiracles are closed, the carbon dioxide concentration in the tracheae increases. When the spiracles open, the concentration of carbon dioxide in the tracheae is greater than that in the burrow, so carbon dioxide will diffuse more rapidly out of the insect's body.

A2. a. There is a correlation between spiracle opening and water loss in both DGC and cyclic gas exchange. In continuous gas exchange, the rate of water loss is almost constant.

b. Overall, the data appear to show a correlation between spiracle opening and water loss, supporting the hypothesis that spiracle closing is a water-conserving mechanism.

c. Higher metabolic rates require more oxygen and continuous gas exchange constantly supplies oxygen, whereas DGC only supplies oxygen every few minutes, which is insufficient for a high metabolic rate.

ASSIGNMENT 3

A1. The partial pressure of oxygen in air decreases with altitude.

A2. Diffusion of gases is much slower in liquids than in air.

A3. Allowing body processes to adapt to changed conditions.

A4. Shortness of breath, mental confusion and inability to walk.

A5. The higher pressure it provides simulates low-altitude conditions.

ASSIGNMENT 4

A1. Smoking, blood pressure, plasma cholesterol, age, sex.

A2. Male smoker age 60+ with high blood pressure and high plasma cholesterol.

A3. Risk = 20–40%; therefore, between 100 and 200 men. If non-smokers, risk = 10–20%; therefore, 50–100 men.

A4. None of the factors has a direct cause–effect relationship with heart disease, only an association. Therefore, only statistical links exist.

A5. Risk factors will change over 10 years; Smoking is not quantified; Other risk factors are not considered.

A6. Numerous governments have, for example, placed restrictions on how and where cigarettes and tobacco are marketed, packaged and sold, and restrictions on where and when people can smoke.

PRACTICE QUESTIONS

1. a. Villus

b. The villi provide a large surface area, which increases the rate at which soluble nutrients can be absorbed. The thin walls of the villi and the blood capillaries close to their surfaces reduce the diffusion distances for nutrients.

2. a. The thin walls of the capillary and the alveolus (each only one cell thick), and their close association with each other, reduces the diffusion distance for oxygen and carbon dioxide. The narrowness of the lumen of the blood capillary ensures that red blood cells are brought very close to the capillary wall, again reducing the diffusion distance for oxygen into the red blood cells.

b. This is a layer of moisture, which prevents the cells lining the alveolus from drying out. It contains surfactant, which prevents the walls of the alveoli from sticking together.

c. Deoxygenated blood, high in carbon dioxide, constantly flows into the capillary. Fresh air, containing a relatively high concentration of oxygen and a relatively low concentration of carbon dioxide, is moved into the alveolus by breathing movements. This ensures that the concentration of oxygen in the alveolus is greater than in the blood being brought to it, and vice versa for carbon dioxide.

4. a. Hydrolysis

b. They are too large to be able to fit into carrier proteins and pass through the cell-surface membrane.

c. The microvilli on the epithelial cells are destroyed by the immune response. This greatly reduces the surface area across which absorption can take place.

d. They are different from the molecules that the immune system recognises as 'self'. They therefore act as antigens.

e. Is it safe? That is, does it cause any harm to the people that are taking it? Does it work? That is, does it reduce the symptoms of coeliac disease?

5. a. *M. inflatus*: $\frac{(20 \times 10)}{8.9} = 22.5 : 1$

E. wahlbergi: $\frac{(73 \times 10)}{76.0} = 9.6 : 1$

L. angolensis: $\frac{(72 \times 10)}{76.9} = 9.4 : 1$

b. *M. inflatus:* $\frac{\left(0.13 \times 10^4\right)}{8.9} = 146 : 1$

E. wahlbergi: $\frac{\left(2.7 \times 10^4\right)}{76.0} = 355 : 1$

L. angolensis: $\frac{\left(1.5 \times 10^4\right)}{72} = 208 : 1$

c. Although the insectivorous bat, *M. inflatus*, has a relatively longer intestine, it has a smaller intestinal surface area to body mass ratio. This is because the two fruit bats have microvilli which are much longer than those of the insectivorous bat, and therefore each villus has a greater surface area. This outweighs the greater number of villi per unit surface area found in the insectivorous bat than in the two fruit bats (3.1×10^{12} in *M. inflatus*, 1.2×10^{12} in *E. wahlbergi* and 1.0×10^{12} in *L. angolensis*).

d. The final digestion of proteins and carbohydrates takes place on the surface of the microvilli, where enzymes are present on the surfaces of the membranes. By the time proteins reach the small intestine, most will already have been digested to dipeptides, so it is possible that the remainder of the digestion can be done quite rapidly, without the need for a large surface area on which this digestion can take place. On the other hand, fruit is made up of cells with cellulose cell walls, which are difficult to digest. Perhaps the final breakdown of nutrients released from these cells requires more enzymes and more time, both of which could be achieved through having a larger surface area where the enzymes can work. Fruit bats, like all herbivores, also need to eat larger quantities of food than carnivores (such as the insectivorous bats) each day in order to obtain enough nutrients, and having a larger intestinal surface area would maximise the quantity of nutrients that can be digested and absorbed at any one time.

Chapter 9: Mass transport

ASSIGNMENT 1

A1. a. Stroke volume = $5.25 \div 45 = 0.117$ dm^3.

b. The average adult has a lower stroke volume than an athlete since regular exercise increases the volume of the heart chambers

A2. a. The athlete has a slightly higher cardiac output at rest, but a much higher cardiac output during exercise.

b. Cardiac reserve of the average adult = $21 - 5 = 16$ dm^3 min^{-1}.

Cardiac reserve of athlete = $30 - 5.25 = 24.75$ dm^3 min^{-1}.

c. Regular exercise increases the cardiac reserve as the cardiac muscle becomes larger and stronger, and the peripheral resistance to blood flow is reduced because of the development of peripheral circulation in the muscles.

A3. a. Greater cardiac output increases blood flow to the active tissues.

b. Increased capillary networks in the muscles increase gaseous exchange.

c. Improved capillary networks in the lungs, increased lung volume and better ventilation improve gaseous exchange in the lungs.

ASSIGNMENT 2

A1. The digestive system.

A2. The digestive system.

A3. 8300 cm^3 per minute

A4. a. Slow then rapid increase.

b. Steady decrease.

c. Rapid increase then steady decrease.

A5. a. Brain needs a constant supply of glucose for respiration so no change in blood flow.

b. Skeletal muscle uses more glucose for respiration during exercise so blood flow increases.

ASSIGNMENT 3

A1. It ensures that as much oxygen as possible reaches the tissues during the time it takes the body to produce new red blood cells.

A2. a. Increased level of oxygen displaces the carbon monoxide from the red blood cells.

b. In smoke inhalation, lung tissue is damaged so there is less gas exchange. Increased oxygen gives a steeper concentration gradient in those alveoli still able to carry out gas exchange.

A3. It forces nitrogen bubbles back into the blood where they can be transported to lungs and exhaled.

A4. a. As oxygen is released at the tissues, the oxygen present in the plasma combines with haemoglobin to increase its percentage saturation.

b. When the blood pigment is foetal haemoglobin; oxygen shortage (for example: at altitude, in anoxic mud).

REQUIRED PRACTICAL 5

P1. To avoid damaging the aortic (semilunar) valve.

P2. To enable the xylem to be seen easily.

P3. It may be carrying a range of pathogens and/or parasites that could be harmful to humans.

ASSIGNMENT 4

A1. The stomata are at the bottom of folds in the leaf, where there is a high humidity because of slower removal of water vapour molecules by air currents. The hairs reduce the flow of air, increasing the humidity at the leaf surface. Both of these make the water potential of the air less negative, reducing the rate of diffusion of water molecules.

A2. Screwing up reduces the surface area from which transpiration could occur. Many stomata will be on the inside of the curves, resulting in a higher internal humidity and protection from air currents.

A3. Smaller leaves give a smaller surface area and fewer stomata, both of which will reduce the rate of transpiration, but some photosynthesis can still take place.

A4. Some roots are nearer the surface of the soil, so any rainfall will reach them quickly. Some roots go very deep, in case there is any water deep in the soil. Other roots grow towards moisture trapped under stones.

ASSIGNMENT 5

A1. a. siemens per metre, S m^{-1}

b. It is much quicker and simpler to do. It measures all ions present. A different quantitative chemical test would be needed for each ion.

c. Given both ions and water.

A2. The temperature there is higher, resulting in a greater transpiration rate.

A3. a. 620 + 30 = 650 cm

b. The warmer the temperature, the more growth, but fresh water at Besor increased the rate of growth compared with the brackish areas.

c. The difference was probably due to the different ratio of Na^+ to Ca^{2+} in the water.

A4. a. The leaves at Neot grew rapidly, reaching maximum size by May. Leaves at Besor grew more slowly, but reached the same size as those from Neot by June.

b. The difference was probably due to the warmer spring at Neot.

ASSIGNMENT 6

A1. The carbon dioxide containing ^{14}C was used in photosynthesis to make glucose, which was then converted to sucrose for transport in the phloem. This sucrose contained the radioactive ^{14}C, and moved down the phloem, which is situated in a ring just below the surface tissues of the stem.

A2. a. ^{14}C was lost rapidly from the leaf for the first hour and a half, and then more slowly and steadily until 11 hours.

b. ^{14}C is lost because some of it becomes incorporated into sucrose, which is moved out of the leaf and translocated in phloem. The initial sharp drop probably indicates ^{14}C that was not 'fixed' in photosynthesis; instead, the carbon dioxide simply diffused out of the leaf without being used.

A3. a. Group A: In 11 hours, 100 – 50 = 50% of the ^{14}C was lost.

So mean rate of loss = 50 ÷ 11 = 4.5% loss per hour.

Group B: In 11 hours, 100 – 45 = 55% of the ^{14}C was lost.

So mean rate of loss = 55 ÷ 11 = 5.0% loss per hour.

b. Group B was kept at a higher temperature, so the kinetic energy of all molecules was higher. This could increase the rate at which the reactions of photosynthesis took place, so the ^{14}C would be incorporated more rapidly into sucrose. It could also increase the rate at which the labelled sucrose was incorporated into the phloem.

A4. a. In the Group C plants, the loss of ^{14}C from the leaf took place much more slowly, but followed a similar pattern to Group B.

b. The Group B plants had developing fruits, which would use a lot of sucrose, and this could cause more rapid translocation of sucrose from the leaves (source) to the fruits (sink).

A5. They could measure the time taken for radioactivity to reach points on the stem at measured distances from the leaves. Speed could then be calculated using the formula speed = distance ÷ time.

PRACTICE QUESTIONS

1. a. i. 0.4 s

ii. One complete beat takes 0.8 s.

So in 60 s there are 60 ÷ 0.8 = 75 beats.

Heart rate is 75 beats per minute.

iii. Blood flows out when the pressure in the left ventricle is greater than the pressure in the aorta.

This occurs between 0.15 s and 0.4 s, so the total time is 0.4 – 0.15 = 0.25 s.

b. The pressure in the right ventricle.

c. Training increases the volume of the heart, so the stroke volume increases. To maintain the same cardiac output with a greater stroke volume, heart rate decreases.

2. a. At low partial pressures of oxygen, the haemoglobin of species A is more saturated with oxygen than the haemoglobin of species C. This allows it to absorb and transport oxygen even in the environment in which it lives, where oxygen is in short supply, so its tissues are able to carry out aerobic respiration.

b. The disadvantage of having a dissociation curve to the left is that this haemoglobin does not give up its oxygen until it is in a very low partial pressure of oxygen. Species B's curve lies to the right of species A, showing that the haemoglobin gives up its oxygen more readily to respiring tissues, where oxygen concentration is relatively low. This ensures that the active tissues have enough oxygen for aerobic respiration.

3. a. The speed of flow decreases steadily as the blood flows through the aorta, large arteries and small arteries, because as the blood gets further from the heart, the pressure that is forcing the blood through the

blood vessels gradually lessens. As it enters the arterioles, the pressure drops greatly, because the total cross-sectional area of the arterioles is greater than that of the arteries.

b. Arteries have elastic tissue in their walls, which allows the arteries to stretch as a pulse of high-pressure blood flows into them, and then recoil as the pressure reduces between heart beats. This elastic recoil helps to raise the pressure a little between beats.

c. The function of capillaries is to allow easy exchange of substances between the blood and the tissues. They are very narrow, so their contents are brought close to the tissues, reducing diffusion distances. Their walls are only one cell thick, and there are small gaps between the cells in their walls, and also (in some capillaries) fenestrations within these cells.

d. The lumen of the vein is wider than the lumen of the artery, so the same volume of blood passes through in the same amount of time, even though it is travelling more slowly than in the artery.

4. a. aorta

b. The right ventricle has only to push blood to the lungs, whereas the left ventricle has to provide much more pressure to force the blood all around the rest of the body.

c. Valve A: atrioventricular valve (bicuspid or mitral valve); Valve B: semilunar valve.

d. In order to make comparisons, it is best to calculate each figure as a percentage of the number of patients who received the hearts.

Type of artificial heart	Information recorded two years after artificial heart implanted		
	% of patients surviving without replacement of artificial heart	% of patients surviving but who required repair or replacement of artificial heart	% of patients who died
X (119 patients)	52	11	37
Y (58 patients)	12	41	47

This clearly shows that type X was much more successful than type Y. Only 12% of patients survived without needing their artificial heart replaced, compared with 52% for type Y. The percentage of patients who needed repair or replacement was four times higher for type Y than for type X. Overall, 10% more patients survived with heart type X than with heart type Y.

5. a. i. It is made up of several tissues, which work together to form a structure with a particular function.

ii. They are smooth muscle fibres, which can contract steadily and strongly for long periods without tiring. These muscles can contract to constrict the arteriole and reduce blood flow through it. For example, the arterioles supplying capillaries near the skin surface constrict when it is cold.

b. i. It reduces diffusion distances for substances such as oxygen and carbon dioxide.

ii. It gives more time for blood to be close to the tissues, allowing more exchange of substances between them.

c. Normally, the water potential of blood in the venous ends of capillaries is quite low, because of the dissolved plasma proteins. This enables water to move back into the blood from the tissue fluid by osmosis, down its water potential gradient. If there are not enough plasma proteins in the blood, then the water potential may not be low enough for this to happen, so water remains in the tissue fluid.

6. a. i. The volume of water absorbed remains steady and low between midnight and 0800, and then increases steadily up to a maximum or 22 cm^3 during the four-hour period between 1200 and 1600. The volume of water transpired follows a similar pattern, with the difference that there is an increase between 0400 and 0800. The volumes of water transpired are lower than those absorbed between midnight and 0400, but become greater for the rest of the time period until 1600. For example, between 1200 and 1600, there is 8 cm^3 more water transpired than absorbed.

ii. Transpiration is low at night, as stomata are closed and temperatures are low. As the sun rises and air temperature increase, stomata open to allow the entry of carbon dioxide for photosynthesis, so water vapour can now diffuse easily out of the leaf and transpiration rates increase.

Water absorption by the roots is very dependent on transpiration rate, because this is what provides the force to pull water up the xylem. Hence water absorption follows a similar pattern to transpiration rate.

b. Water evaporates from the surfaces of the mesophyll cells and diffuses out of the leaf. This reduces the water potential in the leaf, causing water to move out of xylem vessels in the leaf, down its water potential gradient, into the leaf cells. Water molecules are attracted to one another by hydrogen bonds, and this holds

the water column in the xylem together by cohesion. Thus transpiration causes a tension pulling the water column up through xylem vessels, and cohesion prevents the column from breaking.

7. a. Open the tap.

b. Ensure everything is airtight. Ensure the air bubble is on the scale before starting to take measurements. Ensure there is no air bubble blocking the cut end of the stem.

c. Not all of the water absorbed is lost in transpiration; some is used for other purposes, such as increasing the volume of growing cells, or in photosynthesis.

d. There is a positive relationship between the number of leaves removed and the reduction in mean rate of water uptake. The removal of two leaves reduces the mean uptake by values ranging from 0.01 to 0.04 cm^3 per minute. This occurs because the loss of leaves reduces the surface area from which transpiration can take place, and therefore reduces the 'pull' of water up through the xylem vessels.

Chapter 10: DNA and protein synthesis

ASSIGNMENT 1

A1. a. Without the complete DNA some enzymes / proteins would not be coded for, so development would not proceed.

b. DNA cannot be obtained from protein.

c. Mammalian red blood cells do not contain nuclei.

A2. a. Because the nucleus contains crocodile DNA.

b. Nutrients

A3. Obtaining a complete sample of DNA; providing the correct nutrients and conditions to mimic the whole dinosaur egg.

ASSIGNMENT 2

A1. The ER will transport proteins to the Golgi body for modification for export.

A2. They have ribosomes similar to those found in prokaryotes.

A3. a. 8

b. 6

A4. X = Ala; Y = Met; Z = Val

PRACTICE QUESTIONS

1 a.

Base sequence on coding strand of DNA	C	G	T	T	A	C
Base sequence on mRNA	G	C	A	A	U	G

b. i. The DNA coding strand contains introns and exons. All of these are originally used to make a pre-mRNA strand, but the introns are then discarded, and only the exons are used to make the mature mRNA.

ii. 870 ÷ 3 = 290

A sequence of three bases, called a codon, codes for one amino acid.

c. mRNA is a linear strand, while tRNA is coiled up into a clover-leaf shape with base pairing holding parts of the strand together.

tRNA has three exposed bases, called an anticodon, whereas all the bases on mRNA are exposed.

tRNA has an amino acid binding site, but mRNA does not.

2. a. i. The molecule is made up of a chain of repeating units.

ii. C: hydrogen bonds

D: deoxyribose

E: phosphate

iii.

Name of base	Percentage
Thymine	34
Cytosine	16
Adenine	34
Guanine	16

b. i. 3 × 51 = 153

ii. Only the sequences of bases making up the exons will be used to code for amino acids. The remainder, which make up introns, are not used to make the mature mRNA.

3. a. i. C, B, E, F, A, D

ii. Nucleus

iii. A, D and F

b. i. The anticodon UAA will pair with the codon AUU on the mRNA strand. So this tRNA will carry isoleucine.

ii. The mRNA codon for threonine is ACC, and this will be built up against the base sequence TGG on the DNA coding strand.

4. a. AGC, TTC

b. Each tRNA molecule has three exposed bases, an anticodon, which is able to pair complementarily with the codons of mRNA exposed on a ribosome. The anticodon of the tRNA determines which amino acid it can be loaded with, so each tRNA brings a specific amino acid to the ribosome, and holds it in place so that a peptide bond can be formed between it and the next amino acid.

c. The triplet base sequences in the DNA are:

TAC AAG GTC GTC TTT GTC AAG

There are two AAGs, so this triplet must code for Phe.

There are three GTCs, so this must code for Gln.

We are told that Met begins the sequence, so this must be coded for by TAC.

This leaves TTT to code for Lys.

The amino acid sequence is therefore: Met, Phe, Gln, Gln, Lys, Gln, Phe

Chapter 11: Genetic diversity

ASSIGNMENT 1

A1. Haploid

A2. Mitosis

A3. Excystment

A4. a. Increase in temperature / light / nutrients.

b. Decrease in temperature / light / nutrients.

ASSIGNMENT 2

A1. 0% of Native Americans have blood group B.

A2. a. No. For example, Nigerian and Japanese people both have 23% with Group B, but their skin colour differs. On the other hand, both Nigerians and native Australians have black skin, but the percentage with group B is quite different.

b. The black population derives from people of West African ancestry, such as Nigerians, whereas the white population is largely European in origin, where the proportion of group B is around 9%.

A3. a. They probably migrated from somewhere with a low proportion of group B in the population, such as from the population in Siberia.

b. Information from DNA analysis, e.g. from comparing mutations in genes that code for substances such as haemoglobin.

A4. Mitochondria are found in the egg; sperm only donate nuclear DNA.

REQUIRED PRACTICAL 6

P1. Lawn plate.

P2. To prevent contamination.

P3. Add 1 cm^3 of solution C to 9 cm^3 of distilled water, and then 1 cm^3 of this new solution to 9 cm^3 distilled water.

P4. So you are less likely to culture pathogens.

PRACTICE QUESTIONS

1. a. i. H on either spore Y, spore X or a gamete.

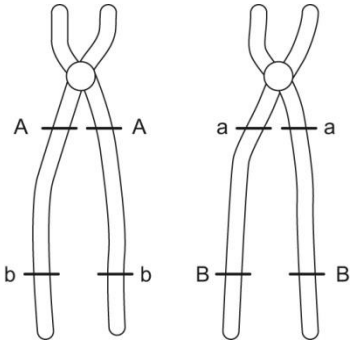
ii. D on zygote.

iii. M on the arrow from the zygote to spore Y.

b. i. The spore is still haploid, so it has been produced by mitosis from cells of the algal body. Mitosis does not introduce genetic variation.

ii. Spore Y has been produced from a diploid zygote by meiosis. Meiosis brings about genetic variation, through independent assortment and crossing over. The algal body may therefore have a different set of alleles than the original algal body that produced the gametes.

2. a.



b. i. Ab and aB

ii. AB and AB

c. Gene mutation; this is a change in the base sequence of DNA, which can produce new alleles of a gene.

Random fertilisation; this is the chance that any male gamete can fuse with any female gamete, bringing together different combinations of alleles.

3. a. A gene mutation is a change in the sequence of bases in a DNA molecule. A chromosome mutation is a change in the number or structure of chromosomes in a cell.

b. If base C is substituted for base G, only the triplet GGC will change. Subsequent triplets will be unaltered, so all but one of the amino acids in the polypeptide chain that is made when this gene is translated will be the same, and the protein may function normally.

If the base G is lost, then that triplet and all the ones that follow will be changed. This will change all the amino acids in the protein from then on, which is likely to produce a non-functioning protein.

c. During meiosis in either a testis or an ovary, two chromosome 21s went into one cell and none into another. This is called non-disjunction. It resulted in one gamete getting two copies of chromosome 21. When this gamete fused with another, normal, gamete with one chromosome 21, a zygote with three copies

was formed. This then divided by mitosis, so that each cell in the developing embryo had three copies of the chromosome.

4. a. The resistant variety first arose in 1989. The percentage of this form then increased exponentially up to 1997, although there was a brief drop in 1995 and 1996. Since 1997, the percentage has increased much more slowly and appears to be levelling off.

   b. Perhaps the antibiotic vancomycin began to be used more regularly in or just before 1989. Natural, random mutations in individual bacteria made one or more of them resistant to vancomycin. In environments where this antibiotic was used, the resistant bacterium would have a better chance of survival than normal bacteria, and so this one would reproduce more successfully, producing a whole population of bacteria with the mutation for resistance. This is an example of directional selection, and it continued to favour the survival of resistant bacteria throughout the time period shown in the graph.

   However, the percentage of resistant bacteria never rose above 30%. This may be because many bacteria were not exposed to vancomycin – e.g. they grew in people who were not treated with this antibiotic. There was no advantage to them in having the mutation, so normal bacteria survived and reproduced successfully.

   c. There are always ethical issues when treating two populations of patients differently. In this case, if the different antibiotic works more successfully than vancomycin, then it is not justifiable to give this only to the intensive care patients and not to others. However, there may be unknown risks in using the different antibiotic, in which case it is not ethical to 'experiment' with it on the intensive care patients. Potential benefit and potential risk need to be weighed up carefully, using all information available.

5. a. The greater the number of breeding pairs, the smaller the mean number of eggs per year. The relationship is not linear.

   b. i. There are many possibilities, for example:

   The quantity of food available to the female – if she is short of food, she may not be able to lay as many eggs.

   The age of the female – young and very old females may not be able to lay as many eggs as those at the height of their reproductive capabilities.

   ii. There will be an optimum range of the number of eggs in terms of the likely survival of young. Very high numbers of eggs will make it less likely that the parents will be able to provide enough food for the young birds, and so few if any will survive to be old enough to reproduce. Very low numbers of eggs will mean that the parents produce fewer young overall. Both of these occurrences will reduce the number of young produced by a particular set of parents, and therefore reduce the chance of their alleles being passed on to the next generation, in comparison with birds producing a number of eggs nearer the centre of the range. This is stabilising selection.

6. a. Isoniazid prevents the formation of mycolic acids, because it inhibits the enzyme that catalyses the conversion of substrates to the fatty acids that are needed to form mycolic acids. This will prevent the formation of cell walls. The bacterial cell wall is important in providing a strong outer covering to the cell. Without a strong cell wall, when the bacterium takes up water and the volume of the cell increases, there is nothing to prevent it from bursting.

   b. The enzyme that catalyses the production of fatty acids in humans may be different from the one found in bacteria. Another possibility is that enzyme B, which converts isoniazid to an active form, is not found in humans.

   c. The mutation would change the sequence of bases in the DNA coding for the enzyme. This could change the sequence of amino acids in the enzyme, which would affect its 3D shape, preventing its active site from binding with its substrate.

   d. The use of isoniazid could cause any individual bacterium that happens to have a mutation conferring resistance, to have a better chance of surviving and reproducing. These resistance mutations often occur in plasmids, which can be transferred between bacteria, even ones of different species. Thus, a selection pressure on one species that results in the growth in the number of individuals with resistance could cause this resistance to spread to a different species.

Chapter 12: Taxonomy and biodiversity

ASSIGNMENT 1

A1. Evaporation is reduced close to the hedge. Evaporation reduces because moisture is not dispersed by the wind, so humidity close to the soil increases, thus decreasing the diffusion gradient. Therefore less moisture is lost from the soil. The temperature is increased near the hedge because the cooling effect of evaporation is reduced.

A2. At about 14 m from the hedge.

A3. The hedge may shade the crop, reducing photosynthesis. There may also be competition for mineral ions and water from the roots of the hedge.

A4. The area below the curve for yield showing an increase is greater than the area above the curve showing a decrease.

A5. The wind may not blow consistently from the same direction.

A6. Hedges provide a different habitat for organisms, so many different species can live there that would not be able to live in the field. The more species diversity of plants there is in the hedge, then the more species of animals and fungi will live there. Hedges therefore greatly increase species diversity.

ASSIGNMENT 2

A1. 1, 6, 10, 14, 17, 18, 19 and 20.

A2. These amino acids are likely to have important functions in maintaining the structure of the cytochrome c molecule (for example, by forming bonds with other amino acids) or in the way in which it interacts with other molecules. If a mutation occurs that changes one of them, then perhaps that organism does not survive, so the new allele is not passed on.

A3. Between the chicken and the fruit fly, based on the amino acids at positions 11, 12 and 13.

A4. There are various possible quantitative analyses that could be made. A simple one is to count the number of differences between humans and each species, which might indicate how closely we are related to each one. If we want to look at relationships between all of the species, we could construct a table like this, in which the numbers are the number of differences in the amino acids between each pair of species:

	Human					
Human		Pig				
Pig	3		Chicken			
Chicken	3	2		Fruit fly		
Fruit fly	6	4	5		Wheat	
Wheat	10	9	10	9		Yeast
Yeast	11	10	11	9	9	

This would indicate that humans, pigs and chickens are all relatively closely related, with only two or three differences between each of them. This matches their classification, because all of them are vertebrates. Fruit flies are less closely related to any of them, with four, five or six differences, which makes sense because fruit flies belong to a different phylum (arthropods). Wheat is very different from humans, pigs, chickens and fruit flies, with nine or ten differences from each of them; this matches the classification of wheat into a different kingdom (plants rather than animals). Yeast is very different from all the other organisms in the table, with 9, 10, or 11 differences; again, this matches classification, as yeast is a fungus and therefore in a different kingdom from both wheat and all the animals.

ASSIGNMENT 3

A1. a. Mean length 37.7 mm; height 15.0 mm; Mode length 34.5 mm; height 14.0 mm; Median length 36.4 mm; height 14.0 mm.

b. SD length = 8.98; height 5.90.

A2. Data plotted as a scattergraph.

A3. Positive correlation between shell length and height.

ASSIGNMENT 4

A1. a. Measuring observable characteristics is relatively easy. It can be done in the field or in a laboratory without any specialist equipment, and can be done quickly and cheaply. However, observable differences may not correlate with genetic differences, because the environment also has an effect on many characteristics.

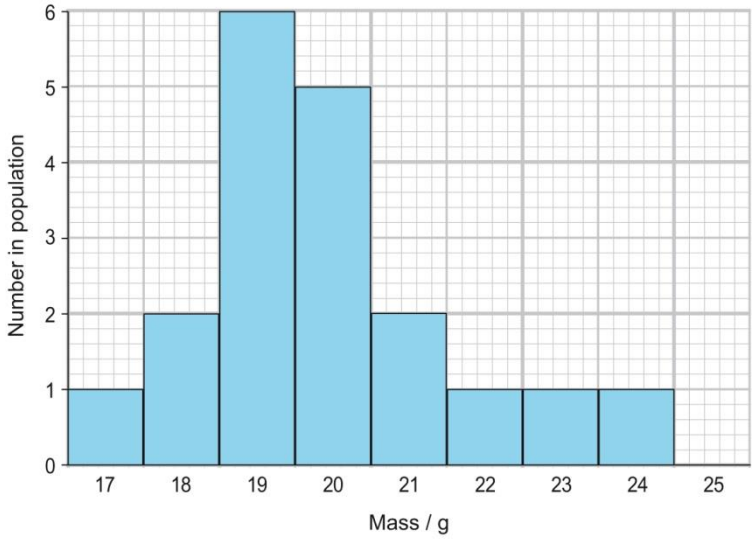
b. Measuring variation in the base sequence of DNA gives a much more reliable measure of genetic diversity. However, it requires specialist laboratory facilities and equipment, and is still quite expensive to do (although, as technologies continue to be developed, costs are coming down all the time).

A2. a.

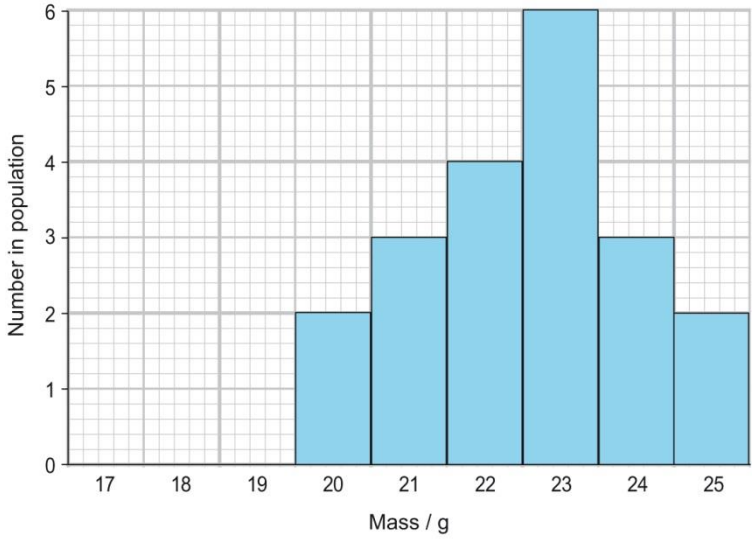
Mass / g	17	18	19	20	21	22	23	24	25
Number in population A	1	2	6	5	2	1	1	1	0
Number in population B	0	0	0	2	3	4	6	3	2

b.

Population A



Population B



c. Population A: mean = 20.4 g, standard deviation = 1.69; Population B: mean = 22.5 g, standard deviation = 1.47.

d. Population A has a lower mean mass by 2.1 g. The range of mass is greater than that for population B, with a range of 17 g to 23 g (7 g) compared with 20 g to 25 g (5 g). This is reflected in the standard deviations, which show that the spread of masses around the mean mass is greater for population A than for population B.

e. We would need much more evidence before we could decide whether or not these two populations belong to the same species or to different species. First, the sample is small, and further samples should be made before we try to draw any firm conclusions. Second, these differences in fruit mass could be explained entirely by environmental differences between the habitats of the two populations, and need not reflect any

genetic differences between them. To determine whether or not they belong to different species, we could try to interbreed plants from the two populations; if they are able to produce fertile offspring, then they belong to the same species. If this is not possible, we could collect more data about other measurable features (e.g. number of flower petals, length of leaves) or compare the sequences of bases in DNA or of amino acids in a particular protein.

PRACTICE QUESTIONS

1. The Indian short-nosed fruit bat shares between 68.5 and 69.9% of its amino acid sequence in β haemoglobin with birds, but 85.6% with the lowland gorilla, strongly suggesting that it is more closely related to the gorillas than to birds. Similarly, the California big-eared bat has only between 66.4% and 67.1% similarity in its amino acid sequences in β haemoglobin with birds, but 84.2% with gorillas.

2. a. Any two of: *Orcytolagus, Helix, or Trichonympha*.

   b. Animals, Plants, Protoctista.

   c. Whether or not they can produce fertile offspring.

3. a.

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Carnivora
Family	Felidae
Genus	*Acinonyx*
Species	*jubatus*

   b. Smaller groups are placed within larger groups, with no overlap between groups.

   c. i. Organisms of one species cannot breed with another to produce fertile offspring.

   ii. Any two of: The sequences of bases in their DNA; The sequence of bases in their mRNA; The frequency of measurable or observable characteristics; The amino acid sequences in particular proteins.

4. a. i. Order: birds

   ii. Family

   b. i. It tells you how much the individual measurements are spread on either side of the mean. In this case, it shows that there is considerable overlap between the individual measurements of mass between the two species, both for males and females, indicating that the difference between the two means may not be significant.

   ii. It is likely that the females respond to a particular throat colour. So female crimson topaz hummingbirds may respond only to green throated males, and female fiery topaz hummingbirds may respond only to yellowish-green throated males. Similarly, the males of crimson topaz hummingbirds may only mate with females with throats with grey edges, while male fiery topaz hummingbirds may only mate with females with no grey edges.

   c. The degree of similarity between amino acid sequences of a particular protein – e.g. the beta chain of the haemoglobin molecules – indicates the degree of relationship between two species. If these are significantly different, this could indicate that these birds belong to two different species.

5. a. It is important that each individual organism has an equal chance of being included in sample.

   b. i. $n(n-1) = (563 \times 562) + (20 \times 19) + (12 \times 11) + (36 \times 35) + (9 \times 8)$

   $= 316\,406 + 380 + 132 + 1260 + 72$

   $= 318\,250$

   so $d = (640 \times 639) \div 318\,250$

   $= 1.29$

   ii. There are only three species in the wheat field, rather than five in the wood, and almost of all of them belong to one species, so the index of diversity will be lower.

c. The evidence from this survey does support the idea that farming reduces species diversity. However, it is far from conclusive. The survey is very small, and only includes counts for six species, whereas in reality there will be far more species present. The survey would need to be repeated in the same area, counting more species, and also carried out in different areas and at different times of year.

d. Hedges, particularly those that contain a number of different species of trees, provide habitats for many different species of animals than an open field. They also allow other plants to colonise the soil beneath the hedge, because this is not now disturbed by regular cultivation if the fields are arable, and may be inaccessible to grazing animals if the fields are pasture.

6. a. i. A classification system in which smaller groups are placed within larger groups, with no overlap between groups.

ii. A group of organisms that are placed together because of their close evolutionary relationship.

b. i. There is only one difference between the cytochrome c amino acid sequence of humans and animal A. This suggests a very close evolutionary relationship between them – they had a common ancestor that lived a relatively short time ago.

ii. Both B and C have 12 differences in their amino acid sequences compared with humans, but these differences may not be the same ones in each organism.

iii. Many animals do not have haemoglobin. Cytochrome c is a protein that is found in all animals.