1.1 Practical skills assessed in a written examination

1.1.1 Planning (page 11)

1. Any sensible suggestion, even if it would be time consuming, such as scraping off the *Pluerococcus* in each quadrat, and collecting and finding its dry mass.

2. For example, string, long enough to go around circumference of mature oak tree trunks; metre rule to measure height above ground and make sure all sampling is done at same height; quadrat of 10 cm sides; test tubes, modelling clay, gaffer tape to collect rain-water run off; light meter; pencil and notepad for recording raw data; thermometer; compass.

3. For example, sample trees of more species; compare old and young trees (different trunk circumferences/canopy cover); compare trees in different habitats/ecosystems; sample walls in various locations; use data loggers to gather more data without having to stay at each site for long; use computer software to help analyse the large data sets gathered; use statistical tests to compare distributions and see if differences are significant; gather and record more information about each tree sampled – grooves in the bark/anything shading certain sides of it.

4. Subjectivity of estimating density of *Pleurococcus.* Percentage errors in the equipment used, such as thermometer/light meter/metre rule/equipment used to measure mass or volume of water run off.

1.1.2 Implementing an investigation (page 15)

1. Temperature is the independent variable (IV) and so should be the first column; the units for temperature should be shown in the column heading and not in the table rows; the unit for time should be written as (s); there should be a column for mean values; there should also be a column showing mean rate of reaction; the numbers in each column should be to the same number of decimal places, so many figures need a trailing zero.

2. Mean rates of reaction: 2.15; 3.38; 4.76; 8.11; 9.26; 15.23

3.

Temperature (°C)	**Time taken for indicator to become yellow (s)**			**Mean time taken for indicator to become yellow (s)**	**Mean rate of reaction (1000/*t*) ($s^{-1} \times 10^3$)**
	1	**2**	**3**		
10	454.0	476.0	468.0	466.0	2.15
15	287.0	295.0	305.0	295.7	3.38
20	210.0	208.0	212.0	210.0	4.76
25	121.0	123.0	126.0	123.3	8.11
30	105.0	110.0	109.0	108.0	9.26
35	68.0	63.5	65.5	65.7	15.23

4. The range is not wide enough to investigate the question; the range will not indicate the effect of going beyond the optimum temperature; the investigation will not be valid.

5. Subjective; hard to spot the exact point when yellow is reached as colour likely to change gradually.

6. For example, use a wider range of temperatures – need to extend the upper range to 50 or 60 °C. Use shorter intervals of temperature. How was the temperature kept constant – was a thermostatically controlled water bath used and was the temperature checked with a thermometer? Could measure pH with a pH meter. Or could give each tube the same reaction time and then use colorimetry to measure colour change by reading absorbance; stir mixtures in test tubes to same degree in each tube.

Development of practical skills in biology

1.1.3 Analysis of data 1: Qualitative and quantitative data (page 17)

1. (a) 5 400 000
   (b) 1.7
   (c) 0.99
   (d) 15/15.0
   (e) 0.68

2. Volume of water taken up in 15 minutes = $2\pi rl$ (where r = radius of tube bore and l = distance moved by air bubble)

   $= 2 \times \frac{22}{7} \times 1 \times 65 \text{ mm}^3$

   $= 408.6 \text{ mm}^3$

   So, rate of uptake per second = $\frac{408.6}{(15 \times 60)}$

   $= 0.45 \text{ µl s}^{-1}$

3. For example, use solutions of protein (e.g. albumin, gelatine) of known concentrations; use same volume of each solution; add same volume of same strength biuret reagent; measure degree of colour intensity – ideally by colorimetry (green filter) – and make a calibration curve, otherwise keep or photograph this set of standards for comparison; try unknown solutions – same volume as before and add same volume and concentration of biuret reagent; use colorimetry and calibration curve to find quantity of protein in each unknown, or compare the unknown results with the set of standards.

1.1.4 Analysis of data 2: Graphs (page 19)

1. Histogram
2. Line graph
3. Bar graph
4. Line graph
5. Scattergram
6. Bar graph

1.1.5 Evaluation (page 21)

1. The accuracy of the stopwatch is $\pm$0.1 s. A reading over 5 minutes (300 seconds) has a percentage error of 0.1/300 × 100 = 0.03%. If you measure a reaction time at 0.3 s the accuracy is still $\pm$0.1 s. So the percentage error is 0.1/0.3 × 100 = 33.3%.
2. 37–39 °C.
3. Each bubble may contain a different volume of oxygen; not all bubbles are the same volume; it is easy to miscount the bubbles; using a gas syringe a larger volume of gas can be measured, so the systematic error is less; a gas syringe is a precision instrument and allows us to measure the actual volume of gas produced in 5 minutes, therefore, we can calculate a more accurate value for rate of photosynthesis.

1.1 Practice questions (page 24)

1. B
2. D
3. A
4. D
5. i, iii and iv

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6. (a) Label six test tubes with % reducing sugar; transfer 5 cm^3 of each solution to the appropriate tube; add 2 cm^3 Benedict's reagent; heat in beaker of water at near boiling for five minutes; compare colour of tube *X* to known concentrations in other tubes.

   (b) Temperature of water in beaker not controlled; difficult to compare colours.

   (c) Any valid point, such as: use a colorimeter; measure absorbance/transmission through coloured tubes; draw a calibration curve and measure *X* against the curve; ensure that excess benedict's is used, centrifuge the tubes to reveal the amount of blue remaining in the solution and measure the absorbance/transmission through this blue colour, using a red filter).

7. (a) Any three from: ensure shoot is healthy; cut shoot at an angle; cut shoot under water; assemble apparatus under water; ensure leaves are dry; ensure there are no leaks in apparatus; ensure there are no air bubbles in apparatus.

   (b) Wind speed in left-hand column; columns with appropriate headings; units in column heading; three readings taken; mean calculated; four rows or results.

Wind speed (m/s) (or fan setting)	**Rate of transpiration (mm s^{-1})**			
	Trial 1	**Trial 2**	**Trial 3**	**Mean**
0				
1				
2				
3				

   (c) As wind speed increases, rate of transpiration will increase.

   (d) (Spearman's rank) correlation coefficient.

8. (a) To avoid bias/some large or colourful plants may attract attention and cause bias, giving inaccurate results.

   (b) Map the area; use randomly generated numbers (generated by computer or from a table of random numbers) as coordinates for sample sites.

   (c) Any five from: suitable clothing for weather; suitable footwear; quadrat; point frame; table to record results; clipboard and pencil; key for identification.

   (d) Convert to stratified sampling; select sample sites in each region of vegetation; ensure number of sites covering each vegetation type reflects the total area of vegetation type.

9. (a) Include units in column heading

   (b) Measure surface area of each leaf

   (c) Column giving the second reading for the rate of transpiration for seven leaves (27); this result is very different from the rates achieved in the other two trials (53, 56).

   (d) Results for four, six and eight leaves are reliable with a small variation (less than 10%) between the readings; results for five leaves are less reliable as the first reading is (approx 33%) larger than other two; results for seven leave are not reliable as mentioned in (c).

   (e) To make results more reliable; to identify anomalous results.

10. (a) 0.05 mm

    (b) $0.05 \times 24 = 1.2$ mm

    (c) The value of each epu depends on the magnification of the stage graticule; if the objective lens is changed, the sample will measure a larger number of epu.

2.1 Cell structure

2.1.1 Microscopes (page 30)

1. ×600 (40 × 15)
2. Advantages: cheap; easy to use; portable/can be used in the field; can study whole/living specimens.

   Disadvantages: low resolution, cannot magnify much above ×1500/×2000 and still give a clear image; cannot see very small objects.
3. (a) Binocular optical microscope
   (b) Optical or laser scanning microscope
   (c) Scanning electron microscope
   (d) Transmission electron microscope
   (e) Transmission electron microscope
4. Advantages: high resolution; high magnification; can be used to study very small objects.

   Disadvantages: very expensive; large and not portable; difficult to use – high degree of skill and a lot of training needed; cannot examine living specimens; cannot see any colours; stains used may be toxic.
5. 175 000×, although this depends how fast the electrons are travelling.
6. Goes up in steps, with each step getting bigger by a factor of 10. Enables plotting of very small or very large sizes on a small sheet of graph paper, and comparisons over a large range.

2.1.2 Slides and photomicrographs (page 32)

1. $A = \frac{I}{M}$ s
2. 10 µm (10/1000 = 10^{-3} mm).
3. Most are transparent/do not have colour, so it is difficult to distinguish different structures. Certain stains adhere to specific areas in cells/tissues and can make it easier to view these structures.
4. Your diagrams should show a cut:
   (a) down the middle of the carrot lengthways
   (b) across the carrot.

2.1.3 Measuring objects seen with a light microscope (page 34)

1. 10 µm. $\left(\frac{100}{10\,000} = 0.01\,mm\right)$.
2.

Measurement	In metres (m)	In millimetres (mm)	In micrometres (µm)
5 µm	0.000 005 m or 5×10^{-6} m	0.005 mm or 5×10^{-3} mm	
0.3 m		300 mm	300 000 µm
23 mm	0.023 m		23 000 µm or 23×10^{3} µm
75 µm	0.000 075 m or 75×10^{-6} m	0.075 mm	

3. (a) 50 000 µm
   (b) 25 000 µm
   (c) 0.1 µm

4. (a) 500 000 nm
   (b) 400 nm
   (c) 1 000 000 nm

5. (a) Ideally, use a cavity slide. Place a little pond water into the depression on a cavity slide and add a drop of methyl cellulose. Lower a coverslip over the liquid. Observe under low power with dark ground illumination or adjust the iris diaphragm for low light level.
   (b) Because it has depth, and, at high magnification, the microscope lenses cannot focus on the nearest and farthest away part of the organism at the same time.

2.1.4 The ultrastructure of eukaryotic cells: membrane-bound organelles (page 38)

1. mRNA
2. Steroid hormones
3. Where ribosomes are made.
4. Stores/transmits genetic information; controls activities of cell; provides instructions for protein synthesis.
5. Erythrocyte/red blood cell.
6. To prevent them from digesting/breaking down the cell components.
7. More mitochondria would be produced, by division of the organelles. (Mitochondria may also be larger.) An increase in the number (or size) of mitochondria improves the efficiency of respiration in the muscle cells.

2.1.5 Other features of eukaryotic cells (page 40)

1. Free ribosomes are mainly concerned with assembling proteins to be used within the cell. Ribosomes on RER mainly assemble proteins that are exported out of the cell.
2. Tubulin
3. Strength and support of individual cells and contributes to strength and support of whole plant; prevents turgid cells from bursting; maintains the cell's shape; fully permeable; allows solute and solvent molecules to pass through.
4. Motor proteins drag chloroplasts along cytoskeleton threads or 'tracks'.

2.1.6 How organelles work together in cells (page 41)

1. Because they are using energy to synthesise and export many molecules of insulin/protein.
2. Via motor proteins that drag them along cytoskeleton threads.
3. Nine or (eight and nine).

2.1.7 Prokaryotic cells (page 43)

1. Similarities: both have cytoplasm, plasma membrane, ribosomes, DNA and RNA.
2. Differences: prokaryotic cells have no nucleus; no membrane-bound organelles; 'naked' DNA/no histone proteins; circular not linear chromosomes; no mitosis/divide by binary fission; smaller ribosomes; less well-developed cytoskeleton; no centrioles; flagellum not undulipodium; may have pili; may have a waxy envelope; peptidoglycan cell wall; may have plasmids; and they are much smaller.
3. Theory to explain origin of chloroplasts and mitochondria from bacteria that became engulfed by another cell. According to the theory, both cells benefitted from the association.
4. They divide by fission; have loops of DNA; have smaller ribosomes; and are about the same size as bacteria.
5. Binary fission.
6. For example, cholera, TB, whooping cough, *Campylobacter* food poisoning.

Foundations in biology

2.1 Practice questions (page 46)

1. D
2. C
3. C (an SEM cannot examine living specimens)
4. A (proteins are made at ribosomes)
5. B
6. (a) (i) U T S R (Z) (do not include V as the question asks about a newly synthesised protein)
   (ii) Ribosomes at RER; because these proteins are to be exported, so will need to be transported to Golgi
   (iii) Exocytosis
   (b) To increase surface area; for exocytosis/passage out of mucin.
   (c) Mitochondria; for aerobic respiration; to produce ATP for protein synthesis and exocytosis
   (d) For protection (of cells/epithelia) from the acid in stomach
7. (a) Nuclei are largest/heaviest organelles
   (b) Chloroplasts are less massive than nuclei, but have greater mass than other organelles/named organelles.
   (c) Palisade cells in leaves have many chloroplasts.
   (d) (i) To prevent osmosis/water gain or loss
   (ii) To prevent enzyme action that may degrade chloroplasts
   (e) Chlorophyll
   (f) To carry out photosynthesis; trap light energy (and convert it to chemical energy)
8. (a) A: mitochondrion; B: nuclear envelope; C: endoplasmic reticulum (ignore rough/smooth); D vacuole; E plasma membrane; F cellulose cell wall; G Golgi
   (b) (i) Actual measurement in mm × 1000 divided by 10 = ×7500
   (ii) Length in mm × 1000/7500 (mag); 1.73 μm
   (iii) $4/3 \times \pi r^3 = 4/3 \times 22/7 \times 125 = 524\ \mu m^3$
   (c) EM uses electron beam/does not use light.
   (d) Any two from: maintains cell stability; makes cell turgid when swollen; contributes to supporting plant.

2.2 Biological molecules

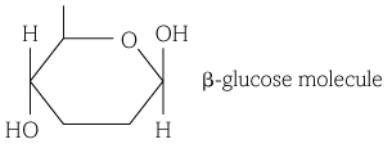
2.2.1 Molecular bonding (page 51)

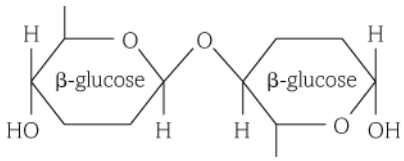
1. There is an uneven distribution of charge across the molecule. The oxygen end is slightly negative, while the hydrogen end is slightly positive.
2. A covalent bond involves the sharing of electrons between two atoms. A hydrogen bond is just an electrostatic attraction between a slightly negatively charged hydrogen atom and another atom with a slight positive charge.
3. Enzymes
4. Three pairs of electrons are shared between two nitrogen molecules.
5. (a) Oxygen has two spaces.
   (b) Nitrogen has three spaces.
   (c) Carbon has four spaces.

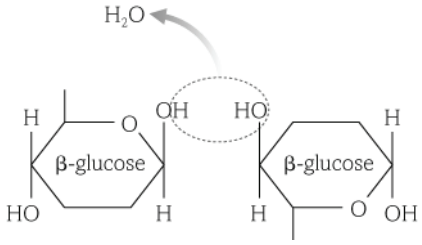
2.2.2 Properties of water (page 53)

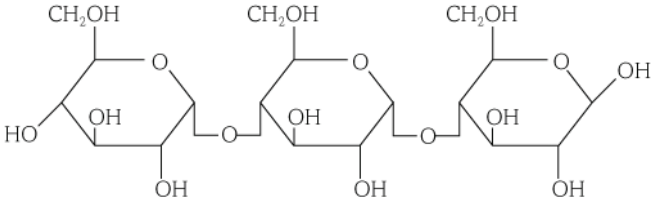
1. Temperatures on the Earth vary, as do temperatures within organisms due to living processes. Metabolic reactions require liquid water.
2. There is an uneven distribution of charge across the molecule. The oxygen end is slightly negative, while the hydrogen end is slightly positive. Other polar molecules dissolve easily in water and form attractions with the water molecules. Non-polar molecules, such as fatty acids, have an even charge distribution and so polar water molecules cannot easily cluster round them.
3. Living things need stable temperatures to survive, particularly because enzymes denature at extremes of temperature. Water requires a lot of energy to raise its temperature by 1°C. It also removes a lot of energy when it evaporates (such as in sweating or transpiration). Both factors help to regulate temperatures.
4. In liquid water, molecules are close together. In ice, molecules are spread out, so that ice becomes less dense than water.
5. The latent heat of vaporisation is the amount of energy required for water molecules in the liquid to break away from other water molecules and become a gas. The specific heat capacity of water is the amount of energy required to raise 1 g of water by 1°C.

2.2.3 Carbohydrates 1: Sugar (page 55)

1. $C_3H_6O_3$
2. $C_{12}H_{22}O_{11}$
3. 

4. (a) 

(b) 

5. Deoxyribose has one less oxygen atom than ribose.
6. 

2.2.4. Carbohydrates 2: Polysaccharides as energy stores (page 57)

1.

	Amylose	**Amylopectin**	**Glycogen**
Do you find it in humans or plants?	plants	plants	animals
Where in the organism is it stored?	starch grains in cells	starch granules in cells	glycogen granules in cells
Is it a form of starch?	yes	yes	no
What is the monomer?	glucose	glucose	glucose
Is it branched?	no	yes	yes
Is it soluble?	no	no	no
Which glycosidic bonds does it have: 1–4 or 1–6?	1–4	1–4 and 1–6	1–4 and 1–6
Is it spiralled?	yes	yes	yes
Are hydrogen bonds important in holding the structure in place?	yes	yes	yes

2. It allows animals to access glucose for respiration more quickly.

3. Makes the molecule less soluble, and allows internal hydrogen bonds to form.

4. Hydrogen bonding

5. More compact. Offer more ends for glucose molecules to be hydrolysed, ready for respiration.

2.2.5 Carbohydrates 3: Polysaccharides as structural units (page 60)

1. The cell walls support the weight of the plant. The cell wall prevents a turgid cell from bursting.

2. The H and OH on carbon 1 are reversed in β-glucose, compared to α-glucose. Because every other β-glucose molecule is rotated in a cellulose chain, it is possible to form hydrogen bonds between chains, which provides extra strength. If α–glucose molecules were used, there would not be hydrogen bonds between chains, and the cell wall would have much less tensile strength.

3. Answers will be dependent on examples chosen.

4. To form a glycosidic bond, between two molecules of β-glucose one monomer must be inverted. This allows a chain of β-glucose monomers to form hydrogen bonds between the hydroxyl group on carbon 2, and the hydroxyl group on carbon six. Chains of β-glucose can, therefore, hydrogen bond together, which gives the final structure strength and stability.

5. (a) Plant cells need water as a reaction medium. Mineral ions are required for biochemical processes within the cell. The selectively permeable cell membrane inside the cell wall controls which substances enter and leave the cytoplasm.

   (b) Xylem vessels transport a column of water from the roots to all parts of the plant. It is important that the column is maintained without the water diffusing away.

6. One advantage from e.g.: high tensile strength; high stability; enable formation of microfibrils.

2.2.6 Lipids 1: Triglycerides (page 62)

1. Because they are not made up of many repeating units. Instead, they are made of smaller units of glycerol bonded to three fatty acid chains.

2. Breakdown and eventual respiration of fats produce water.

3. Oils have an even distribution of charge on the surface of their molecules, which makes them insoluble in water.

4. Saturated fats: made from fatty acids which have no double bonds.

   Monounsaturated fats: There is a double bond between two carbon atoms.

   Polyunsaturated fats: There is a double bond between more than one pair of carbon atoms.

   Having one or more C=C bonds changes the shape of the hydrocarbon chain, giving it a kink where the double bond is. Because these kinks push the molecules apart slightly, it makes them more fluid. Lipids containing lots of saturated fatty acids are often solid at 20°C. If there are more unsaturated fatty acids, the melting point is lower.

5.

	Carbohydrates	**Triglycerides**
Elements	C, H, O	C, H, O
Bonds	glycosidic	ester
Hydrogen bonds involved in maintaining structure?	yes	no
Single bonds present	yes	yes
Double bonds present	no	yes
Chains or rings?	rings and chains	long chains
Polymers formed?	yes	no
Components	sugars	glycerol, fatty acids

6.

	Glycosidic	**Ester**	**Peptide**
Formed by	condensation	condensation	condensation
Digested by	hydrolysis	hydrolysis	hydrolysis
Formed between	two monosaccharides	glycerol and fatty acid	two amino acids
Formed between	a hydrogen and a hydroxyl group	a carboxyl group and a hydroxyl group	an amino group and a hydroxyl group

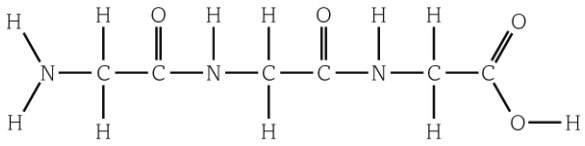
2.2.7. Lipids 2: Phospholipids and cholesterol (page 64)

1. Triglycerides contain one glycerol and three fatty acids. Phospholipids contain one glycerol, one phosphate and two fatty acids.
2. It makes one end of the glyceride polar, which makes it attract water. The fatty acid end of the glyceride remains non-polar.
3. Condensation
4. The polar parts of the phospholipid point outwards into the water. The non-polar parts are concealed inside the micelle away from the water.
5.

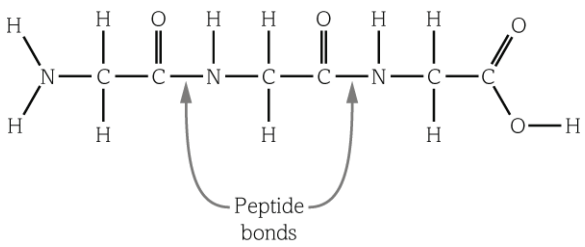
Lipid	**Structure**	**Role(s) in living organisms**	**How does the structure help it perform its roles in living organisms?**
Triglyceride	glycerol molecule bonded to three fatty acids	energy source energy store buoyancy insulation protection	high proportion of hydrogen atoms low density
Phospholipid	glycerol molecule bonded to two fatty acids and a phosphate group	membranes	polar head attracted to water on outside of membrane non-polar tail on inside of membrane provides stability controls entry of molecules to cell
Cholesterol	four carbon-based rings	membrane fluidity regulation	small size enables molecule to sit in hydrophobic part of membrane and regulate fluidity

2.2.8 Proteins 1: Amino acids (page 66)

1. (a)



(b)



(c) Two

(d) Because it is formed from three amino acids.

2. Because they can take on H^+ ions (onto their NH_2 group) and they can lose H^+ ions (from their –COOH group), depending on pH.

3. Similarities: both formed by condensation; both broken by hydrolysis; both formed between two monomers.

   Differences: peptide bond is between C and N, whereas glycosidic bond formed as C–O–C; peptide bond formed between two amino acids, whereas glycosidic bond formed between two sugars.

4. (a) NH_3^+, COOH
   (b) NH_2, COO^-

2.2.9. Proteins 2: Protein structure and bonding (page 69)

1. The primary structure is the sequence and order of amino acids in a polypeptide chain. The secondary structure describes the way in which the primary structure folds and coils.

2. The tertiary structure describes the way in which the secondary structure folds and coils. The quaternary structure describes how more than one polypeptide chain interact.

3. Ionic, disulfide, hydrogen

2.2.10 Proteins 3: Fibrous and globular proteins (page 71)

1.

	Collagen	**Cellulose**	**Haemoglobin**
Monomer	amino acid	β-glucose	amino acid
Bonds	peptide	glycosidic	peptide
Shape	helix	straight	globular – neither helical nor straight
What holds chains together?	hydrogen bonds	hydrogen bonds	hydrogen bonds
Tensile strength	high	high	low

2. Lack of strength, because disulfide bridges would not exist.

3. (a) Fibrous proteins

	Elastin	**Keratin**	**Collagen**
Elastic	yes	no	yes
Strength	high	high	high
Disulfide bridges	no	yes	no
Hydrogen bonds	yes	yes	yes
Shape	helix	helix	helix
Cross-links between chains and molecules	yes with hydrogen bonds	yes with disulfide bridges	yes with hydrogen and covalent bonds
Occurrence	lungs, blood vessel walls, bones	nails, hair, claws, hoofs, horns, scales, fur and feathers	blood vessel walls, tendons, bones, connective tissue

(b) Globular proteins

	Haemoglobin	**Insulin**	**Pepsin**
Quaternary structure	4 polypeptide chains	2 polypeptide chains	1 polypeptide chain
Prosthetic group	haem	none	none
Function	carry oxygen	control blood sugar levels	digest protein
Hydrogen bonds	yes	yes	yes
Disulfide bridges	no	yes	yes
Cross-links between chains	yes	yes	no
Occurrence	red blood cells	released by the pancreas into the blood	stomach

4. They act as enzymes, with active sites to digest food and catalyse other reactions. They act as signalling molecules like hormones, enabling control of body systems by binding at receptors. They bind to and carry molecules around the body. These three functions depend on molecule shape.

5. *Ab initio* protein modelling involves building a protein shape 'from scratch' using information about bonds and the standard geometry of how atoms bond together. Comparative protein modelling looks for similar sequences of amino acids in other proteins, and uses those as predictors of protein shape.

2.2.11 Inorganic ions (page 73)

1. Sodium, potassium, hydrogen, ammonium, hydrogencarbonate, chloride, phosphate, hydroxide

2. Calcium, phosphate (also *magnesium)

3. Ammonium, nitrate, sulphate

4.

Ion		Effect of deficiency
Calcium	Ca^{2+}	• weak bones and teeth • blood does not clot effectively • weak muscles • fat digestion inhibited • neurological problems • permeability of cell membranes disrupted • cell walls do not develop properly
Sodium	Na^{+}	• problems with control of water levels • kidney problems • neurological problems • weak muscles • wilting in plants
Potassium	K^{+}	• problems with control of water levels • kidney problems • neurological problems • weak muscles • fatigue • unhealthy leaves and flowers • wilting
Hydrogen	H^{+}	• stunted plant growth • fatigue • poor regulation of blood and tissue fluid ph
Ammonium	NH_4^{+}	• stunted growth • poor regulation of blood and tissue fluid ph • nitrogen cycle stops functioning correctly
*Molybdenum	Mo^{4+} and Mo^{5+}	• stunted growth in plants
*Iron	Fe^{2+} and F^{3+}	• anaemia and fatigue • shortness of breath
*Magnesium	Mg^{2+}	• weakened bones and teeth • pale colour in plants and stunted growth
Nitrate	NO^{3-}	• stunted growth and yellow leaves in plants • inability to control blood sugar • nitrogen cycle stops functioning correctly
Hydrogencarbonate	HCO_3^{-}	• poor regulation of blood and tissue fluid ph • transport of carbon dioxide stops working properly
Chloride	Cl^{-}	• reduced control of water levels in the body • transport of carbon dioxide stops working properly • oxygen transport in the body stops working properly, causing shortness of breath and anaemia • regulation of blood and tissue fluid ph stops working properly • rate of digestion of protein in the stomach reduces.
Phosphate	PO_4^{3-}	• weakness in bones, teeth and insect exoskeletons • particular enzymes stop working properly • respiration no longer stores energy as atp, causing serious effects on health • poor regulation of blood and tissue fluid ph • root growth stunted in plants
Hydroxide	OH^{-}	• poor regulation of blood and tissue fluid ph
*Sulfate	SO_4^{2-}	• some enzyme controlled reactions stop working properly. • root growth stunted in plants
*Iodide	I^{-}	• regulation of metabolic rate stops working properly

5. Two possible answers include:

   Nitrate and ammonium – they both contain nitrogen which is essential for formation of proteins.

   Sodium and potassium – they are both group 1 metals with similar physical properties.

   *Information on these ions is given for interest/extension, but it is not possible to deduce these answers from pages 72–73.

2.2.12 Practical biochemistry 1: Qualitative tests for biological molecules (page 75)

1. The groups which can act as reducing agents on the component monosaccharides are unavailable as they are involved in the glycosidic bond of sucrose. So, sucrose cannot act as a reducing agent and is referred to as a non-reducing sugar.
2. You check first that the sugar cannot act as a reducing agent. You then split the monomers apart, and check to see if the groups which can act as reducing agents are now exposed to undertake chemical reactions.
3. A precipitate is a solid which is commonly suspended in a liquid. An emulsion is made up of thousands of tiny droplets (usually of oil), suspended in water or a water-based solution.
4. The biuret test is positive only in the presence of peptide bonds. A solution of amino acids contains no peptide bonds.
5. Because they are non-polar and, hence, hydrophobic – which means they cluster together into droplets, rather than mixing with polar water molecules.

2.2.13 Practical biochemistry 2: Quantitative tests for biological molecules (page 77)

1. (a) Carry out the Benedict's test using fixed volumes and concentrations of the two juices with fixed amounts of Benedict's solution. Filter the precipitates out of each solution. Place the filtrates into separate cuvettes and measure transmission of light through them. Compare the samples with the calibration graph to read off the concentration of reducing sugar present. Repeat the experiment a number of times to find the mean for each result.

   (b) Plot separate calibration curves for apple juice and orange juice, with known concentrations of sugar, so the colour of the juice is controlled for when reading off the calibration curve.
2. They both take a variable which cannot be easily measured and turn it into an electrical signal. A biosensor uses a biologically derived intermediate, which then determines the strength of the electrical signal. A colorimeter uses absorption of light to determine the strength of the electrical signal.
3. Unless you know the strength of the electrical signal with known concentrations or values, you cannot interpret the signal you get from either apparatus.
4. By comparing each reading with the same zero reading (in both experiment and calibration), we can be sure that readings are measuring correctly and are comparable.

2.2.14 Practical biochemistry 3: Chromatography (page 79)

1. Different solutes have different solubility in the solvent and have different polarity, which influences how they bind (adsorb) to the TLC plate.

2. Saturated fatty acid. Unlike the others, the fatty acid is non-polar and will not form many hydrogen bonds with the TLC plate. Only the COOH group can form hydrogen bonds, which is less opportunity than in any of the other molecules given

3. (i) First, take the solutions of pure amino acids in turn, and follow the procedure below.
   - On a piece of TLC paper, draw a line *in pencil* and put a tiny pencil dot on the line to show you where to place your solution. If you draw the line or dot in ink, the pigments in the ink will also separate.
   - Spot the solution onto the pencil dot several times using capillary tubing. Wait for the spot to dry before putting on the next spot, and try to make the spot as small and concentrated as possible. When it is completely dry, lower it into the solvent beaker. Ensure the level of the solvent at the start is *below* the pencil line.
   - Cover the beaker with a watch glass, or glass plate. Also wrap filter paper around the inside of the beaker, itself soaked in solvent. This helps to stop the solvent drying out on the TLC paper as it passes upwards.
   - Let the apparatus 'run' until the solvent has reached a point just underneath the top of the TLC paper. Then, remove it from the solvent, and lay it on a white tile to dry.
   - Spray with ninhydrin, and make a note of the location of a brown or purple spot.
   - Calculate the R_f value by measuring the distance from the pencil line to the centre of the spot, and the distance from the pencil line to the solvent front.

   (ii) Next, take the polypeptide solution and add the protease.

   (iii) Check the polypeptide has been completely digested by undertaking a biuret test.

   (iv) Using the digested polypeptide solution, follow the instructions in (i) above.

   (v) Compare the R_f values of the spots on the polypeptide TLC with those from the known solutions of amino acids. When there is a match, that amino acid was part of the original polypeptide chain.

2.2 Practice questions (page 82)

1. D
2. B
3. C
4. D

5. (a) A balanced diet contains the proper proportions of carbohydrates, fats, proteins, vitamins, minerals, and water necessary to maintain good health.

(b) (i) Three from: heat and electrical insulation, buoyancy, waxy coatings (plants and insects), protection of internal organs, outer coating of bacteria.

(ii) A diet that is high in lipids could lead to a high level of blood cholesterol and associated health problems, such as heart disease and stroke.

(c)

	Triglyceride	**Phospholipid**
Difference	3 fatty acids	2 fatty acids
Difference	3 ester bonds	2 ester bonds
Difference	absence of phosphate	presence of phosphate
Similarity	both contain glycerol	
Similarity	both contain fatty acids	
similarity	both contain ester bonds	
similarity	both contain elements C,H and O	

(d) (i) Emulsion test

(ii) Add ethanol/alcohol to sample**,** shake/stir/agitate/mix thoroughly, add (to) water.

(iii) Mixture turns, cloudy/milky/white.

6. (a) (i) Primary structure

(ii) Diagram showing NH_2 at one end; COOH at opposite end; C in centre (of a single amino acid) bonded (separately) to one R and one H.

(b) (i) Strength/toughness/insolubility

(ii) Peptide bonds between amino acids/in polypeptide; every third amino acids is the same/glycine; coil/twist/spiral/helix; left-handed (helix); glycine/small R group allows closeness/twisting (of polypeptide chains); three polypeptide chains; hydrogen/H bonds between (polypeptide) chains; no/few hydrophilic (R) groups on outside (of molecule); (adjacent molecules joined by) crosslinks; crosslinks/ends of molecules being staggered; fibril formed.

(c) (i) Haemoglobin carries oxygen in red blood cells in the blood.

(ii) Three differences from:

Haemoglobin	**Collagen**
4 polypeptide chains	3 polypeptide chains
wide variety of amino acids	high proportion of glycine
mainly alpha helix	mainly left-handed helix
soluble	insoluble
globular	fibrous
no crosslinks between molecules	cross links present

7. (a) (i) Triglycseride: D
Monosccharide: A
Protein: F

(ii) Phosphate: B
Glycosidic bonds: E
Peptide bonds: F
Disulfide bonds: F

(b) Insoluble; does not affect water potential/Ψ of cell; can be broken down/hydrolysed/built up quickly and easily; lots of branches for enzymes to attach; compact, therefore high energy content for mass/energy dense.

(c) (i) α/alpha glucose

(ii) Respiratory substrate/used for respiration; source of/releases/provides energy; formation of ATP; conversion into a named compound.

(iii) D

(d)

Glycogen	**Cellulose**
no hydrogen bonding	hydrogen bonding
α/alpha glucose	β/beta glucose
1,4 and 1,6-glycosidic bonds or 1,6-glycosidic bonds present	1,4-glycosidic bonds only or 1,6-glycosidic bonds not present
branched	not branched/linear/straight
no fibres/fibrils	fibres/fibrils
granules	no granules
all glucose units in same orientation	adjacent glucose units in opposite orientation

8. (a) (i) N

(ii) Protein/polypeptide

(iii) Peptide bond: occurs between amine group (of one amino acid) and carboxyl group (of the other); H (from amine) combines with OH (from carboxyl); condensation reaction/water is lost/eliminated.

(b) (i) Water has a high latent heat of vaporisation/a large amount of energy is required to change from liquid to gas. So, evaporation is an effective cooling mechanism; example of cooling in living organisms.
Water has a high specific heat capacity/a large amount of energy is needed to raise/change temperature. This means that it provides a thermally stable environment for aquatic organisms; organisms use less energy on temperature control; the temperature of organisms changes very slowly; reactions/enzymes/metabolism functions correctly.
Ice is less dense than water/floats and so provides a habitat for organisms; water (beneath ice) is insulated/remains liquid/doesn't freeze; (aquatic) organisms do not freeze/can still swim.
Water is an (effective) solvent; provides a medium for reactions/(internal) transport medium/able to dilute toxic substances; allows underwater photosynthesis; organisms can still obtain, oxygen/(named) minerals/food/carbon dioxide, from water.
Water exhibits cohesion/adhesion; example of cohesion/adhesion, in living organism; e.g. transpiration stream/apoplast movement; surface tension; habitat for (named) invertebrates.
Water has a high density; allows flotation/support.

(ii) Three from: amylose, amylopectin, cellulose, DNA, proteins.

2.3 Nucleic acids

2.3.1 DNA – deoxyribonucleic acid (page 88)

1. (a) A molecule of DNA is very large (several thousand base-pairs), hence 'macro'.
   (b) The molecule is a polymer, made of many nucleotides.
2. (a) It contains a 5-carbon sugar, a phosphate and a nucleotide/nitrogenous/organic base.
   (b) ATP is a phosphorylated nucleotide, and it is involved in all energy-requiring metabolic reactions; coenzymes, e.g. FAD, NAD, NADP and coenzyme A, all contain nucleotides. Many metabolic processes require these coenzymes. ATP, ADP and AMP help to regulate many metabolic pathways.
3. Purines have two rings; pyrimidines have one ring.
4. (a) In DNA, adenine always pairs with thymine and cytosine always pairs with guanine.
   (b) 27%. If 23% is A, then 23% is thymine, so 54% is C and G.
5. They run in the 5' to 3' direction, in opposite directions to each other, as determined by the orientation of the sugar molecules. The 3' refers to carbon 3, and the 5' refers to carbon 5.
6. Within eukaryotic cells, it is tightly coiled and wound around histone proteins to form linear chromosomes, which are located in the nucleus. There are also loops of DNA within mitochondria and chloroplasts. In prokaryotic cells, DNA is naked/not associated with histone proteins, and is found in a loop within the cytoplasm.
7. Each chromosome is a molecule of DNA.
8. GTCAAGATCCCATTA
9. Two strands make it stable; the bases are located inside the sugar–phosphate backbones, and so they are protected and the integrity of the code is maintained; molecules are long, so they can store a lot of genetic information; the hydrogen bonds between the bases can break, enabling the molecule to unzip for transcription and replication.

2.3.2 How DNA replicates (page 90)

1.

Enzyme	Function
Gyrase	catalyses the unwinding of DNA
Helicase	catalyses the breaking of hydrogen bonds between complementary base pairs of DNA
DNA polymerase	catalyses the addition of new nucleotides to both old strands

2. Because each of the two new molecules produced contains one old and one new strand.
3. (a) One-eighth hybrid and seven-eighths light
   (b) All would have been hybrid, but the band would be slightly higher in the tube, as more nucleotides of each new molecule would contain ^{14}N.
   (c) The nucleotide bases
4. From food. As all food is derived from living organisms, it will contain DNA. We have enzymes called nucleases to digest DNA to nucleotides, and nucleotidase enzymes to break down nucleotides to bases, sugars and phosphates.
5. During interphase when the DNA replicates, before the cell enters mitosis or meiosis.

2.3.3 How DNA codes for polypeptides (page 93)

1. Respiration

2. Ribosomes – act as catalysts, allowing (two) amino acids to align so that a peptide bond forms between them
Nucleus/nucleolus – where mRNA is made (tRNAs and ribosomes are also made there)
Endoplasmic reticulum – newly made proteins pass into the cisternae and go to the Golgi apparatus to be modified/finished
Mitochondria – make ATP.

3.

Feature	**DNA**	**RNA**
Type of sugar	deoxyribose	ribose
Nucleotide bases	A, G, T and C	A, G, U and C
Number of polynucleotide strands	2	1
Number of different types	1	3
Location in eukaryotic cells	nucleus, mitochondria and chloroplasts	nucleolus, cytoplasm
Shape of molecule	double helix	not a double helix

4. Uracil and cytosine

5. In the nucleus

6. They would be too large, if joined, to pass through the nuclear envelope.

7. They are unchanged at the end of the reaction. They allow (two) amino acids to come close together, so that a peptide bond can form between them. This makes protein synthesis much quicker than by random association.

8. Comparing DNA replication and transcription

	DNA replication	**Transcription**
Product	two molecules of DNA, identical to each other and to the parent molecule	one molecule of mRNA, which is complementary to the template strand of the gene and, therefore, a copy of the coding strand of the gene
Catalysed by	DNA polymerase	RNA polymerase
Where in eukaryotic cells it occurs	in nucleolus of nucleus	in nucleolus of nucleus
When during the cell cycle it occurs	(S phase of) interphase, before the cell divides (see topic 2.1.6.)	(G_1 phase of) interphase, when a gene needs to be expressed (i.e. when the protein coded for by the gene needs to be made) in the cell (see topic 2.1.6)
Template molecule	the whole DNA molecule	one strand (the template strand) of a gene, which is *part of* a DNA molecule
Nucleotide bases present in the new molecule	adenine, thymine, guanine and cytosine	adenine, uracil, cytosine and guanine
Sugar present in the new molecule	deoxyribose	ribose

2.3 Practice questions (page 96)

1. C
2. D (ADH = antidiuretic hormone, FSH = follicle stimulating hormone)
3. C
4. D
5. D (The genetic code is non-overlapping; ribosomal subunits do not join until they have passed into the cytoplasm.)
6. (a) (i) V = phosphate group
   W = deoxyribose (sugar)
   X = adenine
   Y = thymine
   Z = guanine
   (ii) Hydrogen bonds
   (iii) Nitrogen
   (iv) Nucleotide
   (b) 24% are T; so (100 – 48) = 52 are T and A; therefore 26% is C.
   (c) RNA is shorter; (usually) single stranded; U replaces T/RNA has A, U, C and G, DNA has A, T, C, G; RNA contains ribose, DNA contains deoxyribose.
7. (a) S/synthesis, during interphase
   (b) So that each new cell that is produced has the identical genetic content as the parent cell.
   (c) A diagram to show the strands unwound; new nucleotides aligning by complementary base-pairing rules; two new strands; each new molecule has one old strand and one new (clearly distinguished using e.g. different colours).
   (d) (i) Helicase – breaks H bonds between complementary base pairs.
   (ii) DNA polymerase – catalyses formation of new DNA/addition of complementary bases to exposed nucleotide bases.
   (iii) Ligase – joins fragments made on lagging strand/formation of phosphodiester bonds between sugar and phosphate.
   (e) Change in DNA base sequence transcribed to change in mRNA codons; may alter sequence of amino acids in protein (primary structure); may alter way protein folds into tertiary structure; different adjacent amino acids may change bonds (disulphide bridges); if shape is different protein cannot carry out function, e.g. an enzyme active site cannot bind to substrate; an antigen won't fit into an antibody; a chemical won't fit into membrane receptor.
8. (a) Different protein structure in adult and larva suggest proteins transcribed from different genes; larval gene must be 'off' in adult/adult gene 'off' in larva. Alternatively, the RNA product of one gene may undergo different post transcriptional modification in the larva and adult, or the protein product of one gene may undergo different post translational modification in adult and larva.
   (b) Gene must be 'on' more in one of these forms/different rates of transcription.
   (c) Protects against infection; from bacteria on food; lysozyme breaks down bacterial cell walls.
   (d) May contain antibodies/lysozyme that inhibits growth of/kills bacteria.

9. (a) Valine – glycine – leucine – threonine – threonine – arginine
   (b) (i) UAA; UAG; UCA
   (ii) Stop codon: assembly of the protein ends.
   (c) (i) Some amino acids have more than one triplet code, for example valine has four codons.
   (ii) There are 64 possible combinations of bases (4 bases in groups of 3, so 4^3) but only 20 amino acids (plus stop codons); as there are more than 21 triplets, some amino acids are coded by more than one triplet.
   (iii) Degeneracy reduces the effects of (point) mutations; so reduces changes to amino acid sequence of proteins (and therefore changes to tertiary structure).
   (d) The same base triplets code for the same amino acids in (nearly) all organisms.

10. (a) A gene unwinds and unzips (enzymes = gyrase and helicase); H bonds break; exposing nucleotide bases; (activated) RNA nucleotides align to template strand; complementary base pairing; mRNA is a copy of the coding strand; mRNA uses U instead of T.
   (b) mRNA at ribosome; tRNA brings an amino acid; anticodon–codon bonding via temporary H bonds; complementary base-pairing/U–A and C–G; 2 amino acids are located side by side and a peptide bond forms; via a condensation reaction; ribosome moves along mRNA; ATP needed.
   (c) (i) Both involve unwinding of DNA and breaking of H bonds; both occur in nucleus.
   (ii)

Transcription	**DNA replication**
only part of DNA molecule involved	involves whole molecule
RNA polymerase	DNA polymerase
Produces one molecule of mRNA	Produces two molecules of DNA
Occurs in G_1 of interphase	in S phase
only template strand is template	both DNA strands are templates
in mRNA A,U,C and G	in new DNA mol A,T,G and C present
in mRNA ribose	in new DNA deoxyribiose

   (d) Using a thin section of tissue, on slide; methyl green pyronin stain; DNA stains green and RNA red.

2.4 Enzymes

2.4.1 Enzymes – biological catalysts (page 102)

1. (a) Because each type has a specifically shaped active sit that is complementary only to the shape of the substrate molecule.
   (b) Because they speed up/make possible reactions, and are unchanged and reusable at the end of the reaction.

2. (a) Glycosidases
   (b) Esterases

3. The number of substrate molecules converted per second.

4. This leads to a change in the codon sequence in the mRNA, which leads to change in the sequence of amino acids (primary structure) of the protein. This changes the tertiary structure of the protein and so may change the shape of the active site. If the active site is no longer complementary to the shape of the substrate molecule, the enzyme cannot catalyse its reaction.

5. A non-functional enzyme may mean that a metabolic reaction cannot proceed normally.

2.4.2 Cofactors (page 104)

1. The NAD is recycled/regenerated after it has been changed during an enzyme-catalysed reaction in which it is used as a coenzyme.
2. They may bind to the active site of the enzyme, together with the substrate molecule, acting as co-substrates and making the shape of the substrate complementary to the shape of the enzyme's active site; or they may change the charge distribution on the surface of the enzyme's active site or on the surface of the substrate molecule, enabling ES complexes to form more easily.
3. Similar: Both form temporary bonds with enzyme; both are non-protein
   Different: metallic cofactors are inorganic; coenzymes are organic.
4. Metallic cofactors bond temporarily, whereas prosthetic groups are permanently bound to the enzyme's active site/are part of the enzyme structure.
5. (a) Covalent
   (b) Ionic
   (c) Ionic or hydrogen

2.4.3 The mechanism of enzyme action (page 107)

1. Because they bring the substrate molecules close together, as the substrate molecules fit into the enzyme's active site, and form S–E complexes, and stay there long enough to react.
2. Because each one is catalysed by a specific enzyme and there are many types of enzymes within a cell. Also, many reactions take place within organelles, so are separated from other reactions.
3. In the lock-and-key hypothesis, the enzyme active site and the substrate have complementary shapes. In the induced fit-hypothesis, the active site moulds itself around the substrate to give a better complementary fit, producing a stable ES complex.
4. These proteins may have many disulfide bridges as these bonds are heat stable.
5. The ES complex consists of an enzyme with substrate molecule(s) in its active site before the reaction takes place. The E–P complex is enzyme with product molecules in its active site after the reaction, but before the product is released.
6. Intracellular, as some stages of respiration take place in cytoplasm and some in mitochondria; respiration is a metabolic process that makes ATP and this happens inside cells.
7. Because, at the end of each reaction, the enzyme molecule is free of product and is able to accept another substrate molecule and form another product.

2.4.4 The effect of temperature on enzyme activity (page 110)

1. The molecules have less kinetic energy, so move more slowly, there are fewer collisions and fewer ES complexes are made.
2. Cooling the enzyme slows the rate of reaction but does not permanently alter the molecular structure. So, on warming to 40°C, enzyme molecules gain KE and can move again – they catalyse the reaction. Enzymes that have been boiled are denatured and this involves irreversible change to the shape of the active site.
3. Because high temperatures cause hydrogen and ionic bonds to break within the protein molecule, altering the shape of the active site, so that it is no longer complementary to the shape of the substrate molecule.
4. There may be differences in enzyme concentrations in different types of living tissues/in tissues of different ages/in different extracts of enzymes.
5. (a) IV – this is the variable that the investigator changes to find out how the DV is affected.
   DV – varies as a result of changing the IV.
   (b) So that all the reactant molecules are at the specified temperature/have the same level of KE at that temperature.
   (c) So that the reaction does not start before you start timing it.

2.4.5 The effect of pH on enzyme activity (page 112)

1. Because changes in pH change the balance of hydrogen ions/protons, and these interfere with the hydrogen bonds that hold the shape of the enzyme's active site. If the shape of the active site changes slightly, the substrate molecules do not fit in so well.
2. Because if it changes to below 7.35 or above 7.45, the proteins in it may not function properly.
3. A solution that resists changes in pH by donating or accepting protons.
4. Because they both cause a change of pH. Either too many or too few protons interfere with the hydrogen bonds holding the shape of the active site.
5. The optimum pH would be much lower/in region of 1. (NB each number is an order of magnitude to the power of 10).
6. To prevent them from digesting any proteins in the cells/tissues where they are made.

2.4.6 The effect of substrate concentration on the rate of enzyme-catalysed reactions (page 114)

1. Between A and B, the concentration of substrate is the limiting factor. As substrate concentration increases, rate of reaction increases. At point B the maximum rate of reaction is reached, because there are no more active sites available for substrate molecules to form ES complexes. Between B and C, the substrate concentration is no longer the limiting factor. Something else is limiting the reaction – the availability of enzyme active sites, in other words the enzyme concentration. Adding more substrate molecules does not increase the rate of reaction as the number of enzyme active sites is limited.
2. To breakdown urea that is in soil (derived from nitrogenous waste/urine) to ammonia that can be absorbed and used to make new amino acids, for protein synthesis.
3. No repeats, so cannot check concordance/reliability/spot any anomalies/cannot calculate a (accurate) mean. Difficult to carry out so that each tube has exactly the same amount of time. Fairly limited range of substrate concentrations.
4. Timing; accurate volumes; precision of apparatus
5. Use repeats and calculate mean. Each tube could be investigated separately so that timing would be more accurate. Use larger volumes so error is relatively reduced.
6. Use same source and solution of phosphatase enzyme. Change concentration of PPP. Keep temperature the same – around 45°C. Use pH 5.

   After 15 minutes, add sodium carbonate solution to give colour change and arrest reaction. Use green filter and colorimeter to measure absorption/depth of pink colour and compare rates of reaction.
7. More active sites will be available, so substrate molecules can collide with them and form ES complexes/product.
8. (a) If temperature changes, the enzyme and substrate molecules will have more or less KE and this will alter rate of collision/rate of formation of ES complexes/formation of product molecules.
   (b) If time alters, there will be more/less time for ES complexes to form, so more/less product will form.
   (c) If reactant molecules are well mixed, this increases the chance of collisions/formation of ES complexes, so will increase rate of reaction.
   (d) Wavelength affects absorption and this is what is being used to measure rate of reaction.

2.4.7 The effect of enzyme concentration on the rate of reaction (page 116)

1. To meet their needs/catalyse their metabolic reactions at appropriate rate/to provide the correct amounts of specific product molecules, without wasting energy producing enzymes that are not needed.
2. From digestion of proteins in food.
3. Because enzymes are catalysts, so they can form many ES complexes through reuse/change many substrate molecules/a small amount of enzyme converts a large amount of substrate. They have a high turnover number.

4. At the beginning of the reaction, the rate is fastest as there are many enzyme and substrate molecules for collisions, to form ES complexes. Later in the reaction, substrate concentration may become limiting. If initial rates of reaction are used in each case the comparisons are standardised.

2.4.8 Enzyme inhibitors (page 119)

1. Competitive inhibitors have a similar shape to those of the enzyme's substrate, so they may attach to the active site when enzyme and inhibitor molecules collide; they form enzyme–inhibitor complexes; they compete with the substrate for the enzyme's active site; because the active site is occupied, the substrate molecules cannot fit into it, so there are fewer ES complexes, fewer catalysed reactions, and fewer product molecules are made.
2. They attach to a part of the enzyme molecule, other than the active site, and cause the enzyme to change shape. This distorts the shape of the active site, so it is no longer complementary to the substrate; substrate cannot fit into active site and fewer ES complexes form.
3. Competitive. Increasing substrate concentration increases the chances of an enzyme molecule colliding with a substrate molecule rather than with an inhibitor molecule; the active site is not permanently occupied by the inhibitor.
4. The product molecules may remain bound to the enzyme/regulatory subunits of enzyme, keeping the enzyme in its inactive form (the active site may not be exposed). Many metabolic pathways are regulated by different enzymes that form a large multi-enzyme complex. The end product may bind to an enzyme early in the pathway.
5. Many enzyme molecules that each catalyse a stage in a metabolic pathway are enclosed together within organelles. As the product from one reaction is the substrate for the next, the diffusion distance is greatly reduced and this decreases time for product/substrate to reach the active site of the next enzyme.

2.4.9 Enzyme inhibition: poisons and medicinal drugs (page 121)

1. To try to deliver more oxygen to the tissues.
2. Because the inhibitor prevents breakdown of the neurotransmitter acetylcholine, thereby keeping muscles in a state of contraction and leading to paralysis. If the muscles involved in breathing cannot function, the victim suffocates.
3. Digitalin inhibits the ATPase enzymes associated with the sodium–potassium pump, preventing sodium ions being transported out of cells and leading to an accumulation of sodium ions inside the cell; this stimulates another ion channel to transport sodium ions out and calcium ions in at the same time (as it is an antiport). The rise in calcium ion concentration in the cells increases muscle contraction. This strengthens the heartbeat.
4. It breaks down the prey/victim's connective tissue and this allows the venom/toxin to rapidly spread throughout the body.
5. Competitive inhibition. Irreversible.

2.4 Practice questions (page 124)

1. C A shows the effect of increasing temperature, B shows effect of changing substrate concentration; D shows substrate concentration over time.
2. D Maltose is a reducing sugar and amylase is an enzyme (protein). (Maltase and lipase are also protein enzymes; amylase is carbohydrate, a constituent of starch.)
3. D Cofactors are non-protein molecules; organic coenzymes are cofactors but they bind temporarily to enzymes.
4. D
5. C Enzymes can also work outside cells.

6. (a) (i) Crushing breaks open cellulose cell walls of root tissue; boiling causes hydrolysis of starch to sugar/maltose; high temperature breaks bonds and brings about addition of water (from medium).
   (ii) Chewing adds enzymes/amylase from saliva; this also catalyses hydrolysis of starch to sugar/maltose.
   (b) Glycosidic bonds
   (c) Maltose
   (d) Cofactors
   (e) Two of: mouth is at higher temperature so enzymes have more kinetic energy; so more collisions and ES complexes formed per unit time. In mouth, enzyme and substrate molecules are in closer proximity to each other.

7. (a) Amino acids
   (b) Enzyme A; because aspirin can inhibit synthesis of both thromboxanes and prostaglandins; but enzymes have specificity (the active site is only complementary in shape to one substrate molecule).
   (c) By adding a chemical group permanently to the enzyme's active site; aspirin prevents the substrate molecule fitting into active site; the shape of the active site will be altered so that it is no longer complementary to that of substrate.
   (d) Two of: they have no DNA; therefore no genes to code for the enzyme; they are unable to transcribe/make mRNA.
   (e) Two of: the body makes new platelets; from stem cells (in bone marrow); and these will contain uninhibited enzymes.

8. (a) Hydrolysis/digestion; of starch/amylose to maltose/sugar.
   (b) Using Benedict's reagent and heat, giving a red colour; use standards of known concentration and colour comparison/colorimetry.
   (c) 32–34; mmol dm^{-3}; (use tangent or 16/0.5).
   (d) Smoking inhibits amylase; can't tell which type of inhibition as there is no data on substrate concentration.
   (e) For example, it can be argued that this is an invalid conclusion; only the effect on digestion of starch has been studied; small sample/needs replicates or larger sample; don't know of other variables/named variables (e.g. ethnicity, age) within the groups; SE bars overlap, so difference is not significant; cannot say that digestion permanently affected as there is no evidence/we do not know if that was investigated; unlikely to be permanent as we can make more enzyme/amylase.

2.5 Biological membranes

2.5.1 The structure of cell membranes (page 130)

1. Hydrophilic heads have a phosphate group that gives a charge/polarity and are miscible with/easily surrounded by polar water molecules. So, heads face outwards on both sides and interface with watery cytoplasm and watery environment/tissue fluid. Hydrophobic tails are tucked inside the bilayer, away from the watery interfaces.

2. Molecules in the bilayer can move to some extent, and so give fluidity. Embedded proteins form a mosaic pattern.

3. Hydrophilic: water-loving/able to interface/mix with water
   Hydrophobic: water-hating/not able to mix with water
   Glycoprotein: substance whose molecules contain both protein and carbohydrate
   Glycolipid: substance whose molecules contain both carbohydrate and lipid
   Glycocalyx: the carbohydrate groups on the exterior of a plasma membrane

4. So that the hydrophilic amino acids are in contact with the polar water that is in the channels, allowing soluble materials to pass through.

5. There is more protein in the neurone axon membrane than in the myeline sheath. Axons require carrier proteins in order that passage of ions into and out of cells can transmit electrical impulses, whereas the myelin sheath is insulating.

6. Composition depends on cell function – if cells need to transport specific types of molecules across their membranes, they will have more proteins for channels and carriers; if cells have enzymes embedded in their membranes, they will have a greater proportion of protein; if cells have recognition or signalling molecules (for example, in the case of immune system cells), they will have more glycoproteins.

2.5.2 Diffusion across membranes (page 132)

1. Small, so a high surface area to volume ratio.
2. (a) More CO_2 in than out, as the rate of photosynthesis is greater than the rate of respiration. In fact, probably none out, as the cell would use that produced in respiration for photosynthesis.
   (b) More CO_2 out than in, as there is no photosynthesis, but the cells is still respiring.
3. (a) The cell will use O_2 made in photosynthesis for respiration; more oxygen out than in, as the rate of photosynthesis is higher than the rate of respiration.
   (b) No photosynthesis so no O_2 passing out, but some passing in for respiration.
4. Molecules are too large to pass through lipid bilayer, and they are not lipid soluble/are water soluble, so surrounded by water molecules.
5. It is not using cellular/metabolic/ATP energy/energy from respiration.
6. Concentration gradient – the steeper it is the faster the diffusion
   Diffusion distance/thickness of membrane – the greater the distance/thicker the membrane, the slower the rate of diffusion
   Surface area – the greater it is, the faster the rate of diffusion
   Size of molecule – smaller molecules diffuse faster
   Temperature – increased temperature increases the rate of diffusion, as molecules have more kinetic energy.

2.5.3 Osmosis (page 135)

1. Sucrose solution (the cellulose cell wall is fully permeable).
2. Temperature: increases the kinetic energy of water molecules, so increased temperature will increase the rate of osmosis
   Size of molecule – osmosis applies only to water, and the size of water molecules is constant
   Surface area of membrane – the greater the surface area, the more water molecules can pass across
   Thickness of membrane – the thicker the membrane (such as in the case of a double membrane/envelope of some organelles), the slower the rate of osmosis.
3. If the blood-plasma water potential is too high, then the blood cells will take in water and undergo haemolysis, leaving fewer cells to function/causing anaemia. If the blood-plasma water potential is too low, then the blood cells will lose water by osmosis, undergo crenation, and be unable to carry out metabolic processes/function properly.
4. The water potential decreases.
5. Water would enter the cell by osmosis, down the water potential gradient, across the partially permeable membrane.
6. The cell wall is rigid and strong. When the cell is turgid, the wall exerts a force and prevents further osmosis.
7. Plasmolysis – shrinkage of plant-cell contents due to water loss by osmosis
   Crenation – shrinkage of an animal cell due to water loss by osmosis
   Haemolysis – bursting of animal cells due to too much water entering by osmosis
   Turgid – bloated cell
   Flaccid – plant tissue in which cells are plasmolysed
8. Water potential increases.

2.5.4 How substances cross membranes using active processes (page 137)

1. Ion influx lowers the water potential, and so causes water to enter by osmosis.
2. The motor proteins 'walk' along the cytoskeleton threads, dragging the vesicles – towards the plasma membrane for exocytosis, or from the plasma membrane into the cell for endocytosis. ATP is needed for this movement.
3. (a) Exocytosis.
   (b) Yes, for movement of the vesicle and fusion of vesicle and plasma membrane.
4. (a) Exo(pino)cytosis must be active, requiring ATP; a reduction in respiration reduces the number of ATP molecules available for hydrolysis to provide the energy for emptying the vesicle.
   (b) The cell would swell and, eventually, burst/undergo haemolysis, as it does not have a wall.
5. Active transport moves substances against their concentration gradient; facilitated diffusion moves them down their concentration gradient. Both involve membrane-embedded protein carriers; in facilitated diffusion these proteins are in the form of channels. (Bulk transport is also a type of active transport, involving ATP and fusion of vesicles to the plasma membrane.)

2.5.5 Factors affecting membrane structure and permeability (page 139)

1. When the temperature drops, the cholesterol molecules in the lipid bilayer prevent the phospholipid molecules from packing too close together, and so maintain membrane fluidity; when the temperature increases, the cholesterol in membranes reduces the potential increase in fluidity.
2. They have kinks in their tails that push other fatty acid molecules away, resisting the compression caused by the drop in temperature; this maintains fluidity.
3. (a) A smaller proportion of unsaturated fatty acids, so the saturated/unsaturated ratio increases.
   (b) A greater proportion of unsaturated fatty acids, so the saturated/unsaturated ratio decreases.
4. Reduces the rate of reaction. The enzymes may drift within membrane, such that the active site is no longer so easily accessed by substrate molecules.
5. Less able/more difficult, as the membrane becomes less fluid and cannot fold so well to form phagocytic vesicles.

2.5 Practice questions (page 142)

1. B (Plasma membrane have antigens embedded in them but they do not make the antigens.)
2. C (Flaccid is incorrect as it applies to tissues.)
3. D
4. B
5. A
6. (a) (i) Active transport
   (ii) Two of: transport is against concentration gradient; K^+ intake increases as oxygen and glucose uptake increase, therefore aerobic respiration increases; this indicates ATP is involved.
   (b) Potassium ions by diffusion down the concentration gradient; probably facilitated diffusion through channel protein in tonoplast membrane (membrane enclosing vacuole).
   Chloride ions by active transport; against concentration gradient; use of protein carriers in tonoplast/vacuole membrane.
   (c) Sugar solution has lower/more negative water potential than *Nitella* cell/cytoplasm/vacuole; therefore water leaves cell by osmosis; down water potential gradient; through partially permeable membrane; cell becomes plasmolysed.
   (d) Such algae actively transport in salts/ions; to reduce their water potential; so there is no gradient across their membranes and no loss of water from cytoplasm/vacuole.

7. (a) Fluid-mosaic model: lipid bilayer gives fluidity/allows movement of structures within it; proteins are embedded in the lipid bilayer giving a mosaic appearance.
   (b) A: lipid bilayer
   B: extrinsic glycoprotein
   C: intrinsic glycoprotein
   D: cytoskeleton (protein/thread)
   (c) Facilitated diffusion (of solutes/ions/molecules)
   (d) Size; lipid solubility; polarity/charge distribution
   (e) To remove toxic waste from metabolism; to obtain oxygen for aerobic respiration; to obtain amino acids for making proteins; to obtain glucose for respiration; to obtain lipids for making membranes; to obtain vitamins/minerals.
   (f) To maintain integrity of membrane; aid membrane flexibility; support
   (g) These are (part of) antigens/antigenic markers/receptors/cell recognition sites/for immune response.
   (h) Thickness (hence diffusion distance); surface area.
8. (a) Amoeba cytoplasm has lower water potential than surroundings/freshwater; water enters amoeba down water potential gradient; across partially permeable membrane.
   (b) Motor proteins walk along cytoskeleton threads; dragging contractile vacuole.
   (c) Exocytosis/exopinocytosis
   (d) (i) Water would still enter cell by osmosis; as this is a passive process/does not use ATP; rate of osmosis may not fall as water being enclosed in contractile vacuole would maintain water potential gradient; alternatively, water may remain in cytoplasm and not form into a contractile vacuole, so the rate of osmosis would slow as water potential gradient would be less.
   (ii) Cell would swell and burst/haemolysis (as there is no cell wall).

2.6 Cell division, cell diversity and cell differentiation

2.6.1 The cell cycle and its regulation (page 147)

1. $4/12 \times 24 = 8$ hours
2. G_1/G_0
3. To prevent uncontrolled cell division (and tumour formation); to detect and repair damage to DNA; to make sure the cell's DNA is only replicated once; to make sure the cycle progresses in one direction only (and does not go backwards).
4. So that each new cell has a full genome/set of genetic instructions.
5. (a) G_1; (b) M; (c) S; (d) G_0; (e) G_0; (f) G_2

2.6.2 Mitosis (page 149)

1. (a) 144 (b) 72 (c) 144 (d) 144 (e) 72
2. They are differentiated and have a large vacuole and rigid cell wall.
3. Centriole: the bundles of microtubules that form the spindle for nuclear division
   Centrosome: area of the cell cytoplasm where the centriole is
   Chromosome: a molecule of DNA wound around histone proteins and coiled/contains many genes/found in the nucleus;
   Centromere: region of a pair of sister chromatids that attaches to the spindle threads during nuclear division
4. Growth, repair of tissues, replacement of cells, asexual reproduction
5. Mitosis.

2.6.3 Meiosis (page 152)

1. In sexual reproduction, two gamete nuclei are going to fuse. So, in order to maintain the normal chromosome number, the chromosome number in the gametes must be halved. The fusion of two haploid (n) cell nuclei produces a diploid (2n) nucleus.
2. By shuffling alleles during crossing over in prophase 1. By independent assortment of chromosomes in metaphase/anaphase 1; by independent assortment of chromatids in metaphase/anaphase 2.
3. The resulting zygote will contain genetic material from two unrelated individuals.
4. If there is genetic variation within the population, there are more likely to be some individuals that are adapted to a change in the environment, so the population can survive. This also helps to drive evolution.
5. Telophase 1/end of meiosis 1.
6. Four haploid nuclei (cells) that are genetically different from each other and from the parent cell.

2.6.4 Diversity in animal cells (page 154)

1. Able to express all genes; able to undergo mitosis; not specialised/able to differentiate into other types of cells.
2. Some genes become switched off and others are expressed more; as a result, the proportions of different organelles differ from that of other cells; the shape of the cell changes; some of the cell contents change.
3. To carry oxygen from lungs/gaseous exchange surface to respiring cells; they are small and flexible to squeeze through narrow capillaries; they are flattened and have a large SA/V ratio, so oxygen can diffuse through the cell surface membrane and reach all the haemoglobin molecules; there are few organelles and little cytoplasm, so more haemoglobin molecules can be present, each one able to combine with oxygen.
4. Neutrophils ingest and kill invading bacteria and some fungi. They are attracted to and can move towards a site of infection. They can engulf a pathogen by phagocytosis (their cytoskeleton threads enable them to move and carry out phagocytosis). They have a nucleus, ER and ribosomes – they can synthesise toxic chemicals to kill pathogens and also make proteins that can pierce and rupture the pathogen cell membrane.
5. Many mitochondria to make ATP to power their undulipodium; small, long and thin for easy movement; have an acrosome that stores digestive/hydrolytic enzymes which, when released, digest the outer layer of the ovum, allowing the sperm head to penetrate; head has little cytoplasm and contains just the haploid male nucleus, which can be introduced into the ovum so that fertilisation can take place – fusion of male and female genetic material.
6. They cannot carry out aerobic respiration so will not use any of the oxygen they are carrying.
7. No protein synthesis/translation as no ribosomes or RER; no transcription as no nucleus; no aerobic respiration as no mitochondria; no nuclear division as no nucleus, due to being specialised/differentiated.

2.6.5 Cell diversity in plants (page 156)

1. In waterlogged soil, the air spaces are filled with water. Therefore, roots cannot take in oxygen for aerobic respiration, and so cannot produce enough ATP to transport in mineral ions, or for any other metabolic activities.
2. Guard cells are vital in regulating plant gaseous exchange. They have chloroplasts that can produce ATP and so they can actively transport potassium ions into the cell, lowering water potential and causing water to enter by osmosis. As the guard cells swell, the stoma between them opens, allowing gaseous exchange.
3. Would expect it to be high as these cells carry out active transport so need a lot of ATP.
4. For example, determine the area (A) of the field of view on low or medium power of a microscope by focusing on a piece of graph paper and counting the squares (mm^2). Strip a piece of epidermis from the lower side of the leaf, mount in distilled water on a microscope slide and observe on low power. Count all stomata (N). Now you know how many stomata per area of field of view, so find number of stomata per mm^2 by dividing N/A. Draw around the leaf on a piece of graph paper and find the area of the leaf (L). Number of stomata on the underside of the leaf = $\frac{N}{A} \times L$.

2.6.6 Animal tissues (page 158)

1. (a) One of: outer ear/pinna, epiglottis
   (b) Intervertebral discs, discs in knee joint
   (c) Embryonic skeleton, ends of long bones, between ribs and sternum, nose, trachea and larynx
2. Epithelial, connective, muscle, nervous
3. The walls are thin, giving a short diffusion distance for gaseous exchange.
4. Chondroblasts are immature and can divide by mitosis; they secrete the extracellular matrix of cartilage. Once the matrix has been secreted, the chondroblasts become less active, mature cells called chondrocytes.
5. By diffusion, from tissue fluid forced out of blood vessels into the underlying connective tissue.
6. (a) Movement – by contraction. Skeletal muscles are attached to bones by tendons, and contract to move the bones.
   (b) Skeletal, cardiac and smooth

2.6.7 Plant tissue and organs (page 160)

1. Leaves, palisade mesophyll cells – chloroplasts for photosynthesis
   Guard cells (around stomata) and spongy mesophyll – gaseous exchange, carbon dioxide in and removes oxygen
   Root hair cells – take in water
   Xylem vessels – transport water
   Phloem sieve tubes – transport sugar (sucrose)
2. Connective tissue
3. In plants the vascular tissue does not transport oxygen or carbon dioxide, whereas in animals it does.
4. (a) Anchorage, storage and absorption of water and mineral ions.
   (b) Sexual reproduction.
5. Lignin is found in xylem vessels and sclerenchyma cells.

2.6.8 Organs and organ systems in animals (page 161)

1. Organelle; cell; tissue; organ; organ system
2. Musculo-skeletal system to move for cooking and eating the meal; nervous system to coordinate movements and taste the cooking/meal; integumentary system to protect your underlying tissues from any mechanical damage or damage due to heat; digestive system to digest the meal and absorb the products of digestion; immune system (and stomach acid) to kill any pathogens ingested with the food; circulatory system to take nutrients to respiring cells; endocrine system to deal with the excess sugar entering the blood after the meal; respiratory system (gaseous exchange) to keep you alive by supplying oxygen for respiration and removing carbon dioxide.
3. Nervous system to coordinate activities and work as a team e.g. anticipate the moves of others; musculo-skeletal system for movement; circulatory system to bring glucose and oxygen to the muscle cells for respiration to produce ATP, and to remove carbon dioxide, lactic acid and heat; respiratory system for gaseous exchange to supply oxygen and remove carbon dioxide; integumentary system and nervous system to lose excess heat (by vasodilation and sweating) and to cause hairs to lie flat; endocrine system for production of adrenaline and glucagon to break down stored glycogen to glucose.

2.6.9 Stem cells and their potential uses (page 163)

1. Three of the following: undifferentiated; all genes able to be expressed; pluripotent/able to differentiate into any cell type; can divide by mitosis – not bound by finite number of divisions and do not enter senescence.
2. Ethical issues as some people objected to using embryos (regarded as potential humans) in this way.
3. Animal tissue may differ in some aspects of metabolism from human tissue. IPS cells, therefore, give a better idea of how the drug will affect human tissue – will it work, will there be side effects?
4. The patient-derived iPS cells would have the faulty mitochondria in them and the differentiated cells derived from them would also have the faulty mitochondria. (Could discuss idea of removing mitochondria from such an iPS cell and implanting other mitochondria, before letting the iPS cell divide to give cell line.)

5. The organ would be 'made' from the patient's own cells so the patient's immune system would not recognise it as foreign and would not attack/reject it.

2.6 Practice questions (page 166)

1. A
2. C
3. D
4. A
5. A (They have thin cellulose cell walls.)
6. (a) Yes, as the concentration of S-cyclin increases, more DNA is present; showing that, in many cells, the DNA has replicated, therefore, these cells are preparing for division; there is more cell division when (extra) S-cyclin is present compared to at 0 mol dm^{-3} concentration.
   (b) ATP/activated nucleotide
   (c) Two of: gyrase, helicase, DNA polymerase, ligase.
   (d) (i) Meristems are in these areas; so cells here are undifferentiated and can become any type of plant cell/tissue/named type of cell/tissue.
   (ii) To prevent contamination by bacteria/fungi; that would infect/spoil the growing tissues/explants/plantlets.
   (e) G_1
   (f) Binary fission
7. (a) DNA whole molecules unwind and unzip, catalysed by enzymes; exposing nucleotide bases; (activated) DNA nucleotides align and form temporary H bonds with exposed bases; complementary base pairing occurs; leading and lagging strand are produced according to the direction of synthesis; role of ligase enzyme in joining lagging strands; semi-conservative replication; two new molecules/DNA doubled.
   (b) (i) 3
   (ii) Mitosis; DNA content of cells after division is same as it was before.
   (iii) As chromatids separate; during anaphase; so each new cell/nucleus contains the same number of chromosomes as parent cell (and as each other).
   (c) G_1 (could accept G_0 or interphase).
   (d) One from: protein synthesis/transcription/translation/growth.
8. (a)

Statement	Mitosis	Meiosis 1	Meiosis 2
Chromosomes pair up	×	✓	×
Chromosomes, consisting of two chromatids, attach to the equator of the spindle	✓	✓	✓
Independent assortment of chromosomes occurs	×	√	×
Independent assortment of chromatids occurs	×	×	×

   (b) (i) G_2
   (ii) Tubulin
   (c) (i) Two genetically identical (daughter) cells; genetically identical to the parent cell and to each other/each cell contains full genome.
   (ii) Four; haploid cells; not genetically identical
   (d) Allele shuffling; during crossing over in prophase of meiosis 1; independent assortment of chromosomes in anaphase/metaphase 1; independent assortment of chromatids in anaphase/metaphase 2; halving of chromosome number followed by joining of two gametes from different individuals.
   (e) (i) Mitosis; drones are already haploid; so sperms cannot contain a reduced chromosome number/each sperm also has to be haploid.

(ii) Ensures genetic variation among her offspring.

9. (a) (i) 46; (ii) 46; (iii) 0; (iv) 23

(b) For growth; repair of damaged tissues; asexual reproduction (named example); cell replacement using cells derived from adult stem cells.

(c) Prophase – DNA supercoils/chromatin condenses//chromosomes shorten and thicken; nuclear envelope breaks down; centriole divides and spindle forms;
Metaphase – pairs of/sister chromatids join to equator of spindle; by centromeres;
Anaphase – centromere splits; motor proteins walk along tubulin threads pulling chromatids with them; chromatids pulled to opposite poles;
Telophase – separated chromosomes reach poles; new nuclear envelopes reform.

10. (a) Xylem – elongated tubes and vessels; lignification of walls; waterproofs and strengthens the dead cells; prevents collapse inwards of tubes/vessels as water moves upwards; lignin gives support to plant.

(b) Phloem – sieve tubes, living but have little cytoplasm and few organelles; sieve plates between one sieve tube and next; transports dissolved products of photosynthesis/named product from leaves/storage organ/source, to other parts/sinks/named part; companion cells carry out metabolic functions/provide ATP to sieve tubes.

(c) Cartilage – connective tissue; much non-living extracellular matrix; collagen/elastin/hyaluronic acid (polysaccharide that traps water); matrix separates living cells and enables tissue to withstand weight/forces; chondroblasts divide by mitosis and secrete matrix; named example of location: embryonic skeleton/ends of adult long bones/nose/pinna/trachea/larynx/disc between vertebrae/epiglottis.

Exchange and transport

3.1 Exchange surfaces and breathing

3.1.1 Exchange surfaces (page 171)

1. 0.3 : 1
2. 25.7 : 1
3. 1000 : 1
4. Skin surface area to volume ratio is not large enough, could not supply all oxygen required; lung surface area to volume ratio is much larger, large enough to supply sufficient oxygen.
5. Roots absorb water from soil by osmosis; also need to absorb mineral ions, by active transport.
6. Steep concentration gradient means that absorption can be by diffusion, no metabolic energy needed.
7. Active organisms need energy, which is supplied by respiration; respiration supplies more energy if it is aerobic – needing oxygen.
8. Elephant has a large surface area, but a much larger volume, therefore surface area divided by volume is small; a single-celled organism has a small surface area but a very small volume, therefore surface area divided by tiny volume is large.

3.1.2 Mammalian gaseous exchange system (page 173)

1. Oxygen diffuses down the concentration gradient – a steeper gradient means faster diffusion.
2. On supply side (in alveolus), the air is continually replaced by ventilation movements, keeping oxygen concentration high; on the demand side (in blood), the oxygen is carried away by the flow of blood, keeping the concentration low
3. On supply side (in blood), carbon dioxide is brought from the cells by the blood flow, keeping the concentration high; on the demand side (the alveoli), the air in the alveoli is continually replaced by ventilation movements, keeping concentration low.
4. $1000/25.7 \times 100 = 3891\%$
5. Blood transports carbon dioxide to the lungs, and carries away the oxygen from the lungs, maintaining the concentration gradients of both gases.
6. The volume of air breathed in and out of the lungs increases. This supplies more oxygen to the alveoli, replacing the oxygen more frequently, so that the concentration gradient is maintained at a higher level and more oxygen is transported by the blood. Muscles can respire more.
7. Diaphragm contracts more, internal intercostal muscles contract to raise ribs so that more air is inhaled. The external intercostal muscles contract to ensure more rapid expiration.
8. Increases the surface area for exchange.

3.1.3 Tissues in the gaseous exchange system (page 175)

1. A collection of similar cells performing the same function.
2. Squamous epithelium is flat and the cells are very thin; ciliated epithelium is usually thicker (with columnar cells) and has numerous hair-like projections called cilia.

3.

Tissue	Function
squamous epithelium	provides short diffusion distance
ciliated epithelium	cilia waft mucus along airway
glandular tissue	produces mucus
cartilage	supports the airway
smooth muscle	constricts the airway
elastic tissue	recoils to dilate airways or to help expel air from the alveoli
blood	transports gases
nervous tissue	carries messages to coordinate action
connective tissue	holds other tissues together

4. During inspiration, the pressure inside the gaseous exchange system drops below atmospheric pressure.

5. Mucus traps pathogens, cilia move muscus and trapped pathogens up to back of mouth, where they may be swallowed.

6. Smoke paralyses the cilia. Therefore, mucus is not moved along and accumulates in the airway. Pathogens have ideal conditions to reproduce.

7. Blood carries carbon dioxide in towards alveoli and oxygen away, many small blood vessels give a larger surface area for gas exchange than fewer larger vessels.

8. Muscle of diaphragm causes ventilation, which refreshes the air in the alveoli; blood vessels and alveoli have squamous epithelium, which produces a short diffusion pathway; blood transports carbon dioxide in and oxygen away; elastic tissue allows dilation of airways and alveoli and recoils to return them to original size; smooth muscle can constrict the airway, which may protect lungs; ciliated epithelium keeps lungs free from infection.

3.1.4 Measuring lung volumes (page 177)

1. 0.9 dm^3

2. To ensure that anomalous results can be detected, makes result more reliable.

3. A small person (lower than normal volume)

4. During exercise, intercostal muscles function to increase volume of inspiration and expiration.

5. Volume at A = 4 dm^3, volume at B = 3.1 dm^3. 0.9 dm^3 used over 30 seconds, therefore rate of oxygen uptake =0.9/30 = 0.03 dm^3 s^{-1}.

6. Alveoli are held open by elastic fibres and airways are held open by cartilage – the space inside is filled by air.

7. Data collected will depend on the individuals in the class.

3.1.5 Gas exchange in other organisms (page 179)

1. Gill collapses out of water, so surface area exposed to air is small – insufficient to allow enough gaseous exchange. Eventually the gills will dry out.

2. To increase the surface area for gaseous exchange.

3. Buccal pump and operculum flap pump water over the gills. If the fish is unable to pump water, then the flow will stop if fish stops moving. All the oxygen in the water in the gills will be used up.

4. With an open circulation, an insect cannot easily direct the flow of blood to the tissues that need it most; the flow is also affected by body movements. Using separate air-filled tubes allows development of a system that can bring more air to the tissues that need it. If the insect relies on diffusion to some extent, the oxygen can diffuse more quickly through air than through blood fluid.

5. Oxygen can diffuse through the walls at the end of the tracheoles into the tissue fluid, withdrawing fluid from the end of the tube increases the surface area over which exchange can occur.

3.1 Practice questions (page 182)

1. D
2. D
3. A
4. i and ii only
5. iv, ii, iii, i, v
6.

A	6
B	5
C	1
D	2
E	4
F	3

7. (a) Scanning electron microscope; the surface is visible and there is a three-dimensional view.
   (b) A = gill plate/secondary lamella
   B = gill filament/primary lamella
   (c) Squamous epithelium
   (d) The floor of the mouth/buccal cavity lowers; water enters mouth; floor of mouth/buccal cavity is raised; water is pushed over gills; operculum flap opens; pulls water over gills.
8. (a) 1.33 dm^3 (accept anything from 1.20–1.40 dm^3); (one mark for correct figure and one mark for unit); working must show that at least three readings were used to calculate the mean; e.g. (1.5 + 1.3. + 1.2)/3 = 1.33 dm^3
   (b) 0.00625 $dm^3\ s^{-1}$; (one mark for correct response and one mark for correct units)
   (c) *Tidal volume:* volume of air inhaled/exhaled; in one breath; while at rest.
   Vital capacity: maximum volume of air; inhaled/exhaled in one breath.
9. (a) R = spiracle
   S = trachea
   T = tracheole
   (b) Air enters through spiracle; passes along the trachea/tracheole; diffuses into tracheole fluid and to muscle cells.
   (c) Increased ventilation movements help to pump air along trachea/tracheoles; tracheal fluid is withdrawn from trachea; increasing the surface area for exchange.
   (d) Distance is too great; to supply enough oxygen for active tissues; by diffusion; therefore, mass flow/transport is needed; (insects have) open blood circulatory system; movement of blood not as directional/efficient (as closed system); diffusion in liquid slower than in air.
10. (a) Yes
   (b) No; no test has been carried out; there may be some other factor, such as the weather conditions, that causes the asthma.
   (c) Smooth muscle
   (d) Irritant is inhaled; irritant has a shape that is complementary to the shape of receptors; on the plasma membrane of the smooth muscle cells; (smooth muscle) cells respond by contracting.
   (e) Use stem cells to grow (lung) tissue; *in vitro*; subject tissue to atmospheres containing pollutants; look for evidence of smooth muscle cells contracting.

3.2 Transport in animals

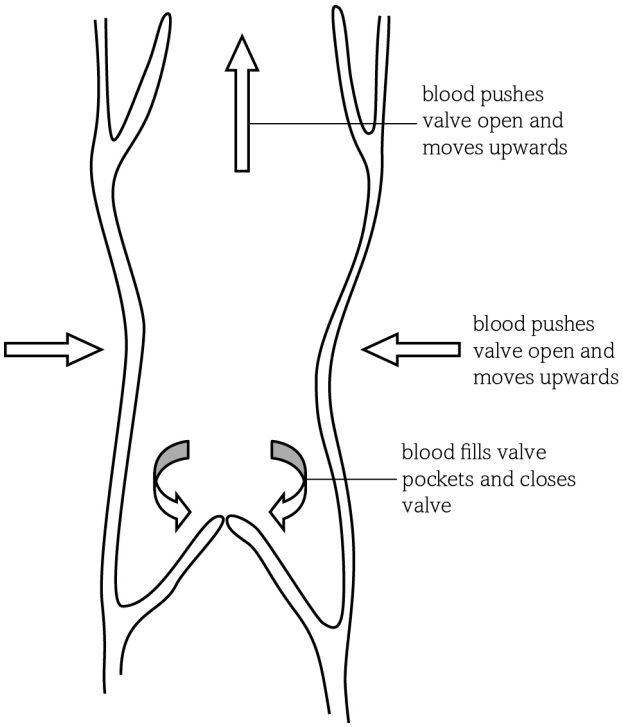
3.2.1 Transport in animals (page 187)

1. Very small animals have a large surface area to volume ratio – a surface area large enough to allow enough oxygen to enter the animal and a volume small enough that no tissue is very far from the surface. Large animals have a small surface area to volume ratio; diffusion is too slow and the distance is too great for oxygen to reach all tissues.
2. They are flat – no tissue is very far from the surface.
3. Must get transported substances into the blood and out again where needed. Need large surface area for exchange to occur quickly.
4. Pressure and rate of flow are low in a single system – blood must pass through the gaseous exchange system and then move on to the tissues.
5. Mammals are large and active – they need a lot of oxygen. Also they use metabolic energy to keep warm, so respiration and metabolism create a lot of heat. Double system allows pressure to be raised and blood to flow more quickly, delivering more oxygen to the tissues.
6. The lungs are very delicate, a high pressure would cause damage and bleeding; also flow in the capillaries of the lungs must be slow to allow full exchange of gases.
7. Closed double circulation.

3.2.2 Blood vessels (page 189)

1. A closed system keeps the blood in vessels all the time; in an open system, the blood leaves the blood vessels to surround the tissues.
2. Blood pressure can be high and the rate of flow can be fast – so lots of oxygen is supplied to the tissues. Also the blood flow can be directed to where it is needed.
3. Muscle in the heart creates the pressure in the circulatory system. Pressure is highest near heart; vessels must dilate to accommodate the pulses of high pressure blood.
4. Wall of artery stretches (dilates), so that pulse of blood is accommodated; the collagen in the wall prevents over stretching; the elastic tissue recoils to return the wall to original size, helping to maintain pressure as blood flows on.
5. Constriction reduces the diameter of the blood vessel, this increases resistance to flow and less blood can flow to the digestive system. This means there is more blood available to be directed towards the muscles where the arterioles dilate to reduce resistance to flow.

6.



7.

Artery	Arteriole	Capillary	Vein
thick wall	thin wall	very thin wall	thin wall
wall with elastic fibres	less elastic fibres	no elasticity	less elastic fibres
wall with thick muscle	spiral layer of muscle	no muscle	little muscle
small lumen	small lumen	tiny lumen	large lumen

3.2.3 Exchange at the capillaries (page 191)

1. In the ventricles of the heart.
2. Dissolved solutes such as mineral ions, sugars and proteins.
3. They are too large to pass between the squamous cells of the capillary wall.
4. Neutrophils can change shape and squeeze between cells; erythrocytes cannot change shape as much.
5. These are areas where exchange occurs and larger molecules may need to enter or leave the blood. Fenestrations allow more rapid movement of molecules and allow larger molecules through.
6. Oxygen diffuses out of the red blood cells into the plasma. The plasma moves by mass flow from the capillary into the tissue fluid that surrounds the tissues.

3.2.4 The structure of the heart (page 193)

1. They do not need to pump the blood far – so no need to generate high pressure.
2. The left ventricle needs to pump the blood all around the body (against greater resistance), so it needs to create higher pressure.
3. Left side contains oxygenated blood, right side contains deoxygenated blood; allowing mixing would make transport of oxygen less efficient.
4. Blood will flow from high pressure to low pressure. Heart needs highest pressure to maintain flow of blood around the circulatory system.

5. They stop the flaps of the atrioventricular valves turning inside out and prevent blood flow back to the atria.
6. Help to conduct the wave of excitation all over the muscle, also help to create squeezing action, rather than contraction in one direction.

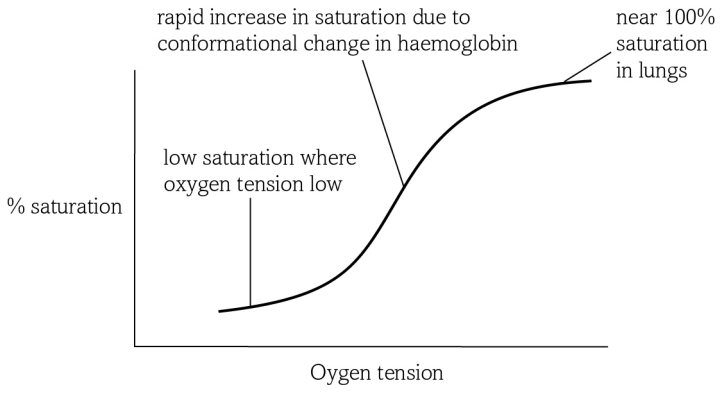
3.2.5 The cardiac cycle (page 195)

1. Atria prime the ventricles – ensuring they are full of blood.
2. Atria fill → ventricles start to fill → atria contract → ventricles fill completely → atrioventricular valves shut → ventricles contract → semi lunar valves open → blood flows into aorta → semilunar valves close → atrioventricular valves open
3. The valves are very thin tissue and could easily turn inside out; the tendinous cords prevent this (and stop backflow of blood). As ventricle walls relax and recoil, the cords may also help pull the valves open.
4. To push blood upwards towards the major arteries at the top of the heart.
5. The pressure in the ventricles drops quickly as the ventricle walls relax and recoil. Once this pressure drops below the pressure in the aorta, the blood will start to move back towards the ventricles and this pushes the valves closed.
6. Rhythmic contraction of the ventricle walls.
7. The dilation of the arteries caused by rhythmic contraction of the ventricle walls.

3.2.6 Coordination of the cardiac cycle (page 197)

1. It creates rhythmical electrical impulses which initiate the wave of electrical excitation that keeps the heart beating in a regular sequence.
2. This gives time for blood to flow from the contracting atria to the ventricles, so that the ventricles can fill properly before they contract.
3. The P wave is associated with contraction of the atria. The QRS complex is contraction of the ventricles – there is much more muscle involved, so the excitation wave is stronger.
4. In atrial fibrillation, the atria contract more frequently than the ventricles. Atria do not fill and contract properly, so ventricles do not fill accordingly.
5. Patient feels two beats for each atrial contraction - so heart rate doubles. The ventricles do not have time to fill properly so less blood is pumped and less oxygen delivered to tissues.
6. After the ectopic beat, there is a longer delay before the next beat starts – this feels as if a beat has been missed.

3.2.7 Transport of oxygen (page 199)

1. ‘Attraction for’
2. The iron ion in the haem group
3. Oxygen binds to haemoglobin in the capillaries surrounding the alveoli, where the oxygen tension is high. It dissociates from the haemoglobin in the capillaries of the tissues, where the oxygen tension is low.
4. 

5. A fetus has haemoglobin with higher affinity for oxygen, so that it can take up oxygen in the placenta, where oxygen tension is low. The fetal haemoglobin must have a higher affinity for oxygen than the mother's haemoglobin. In an adult, this form of haemoglobin is not needed as the oxygen tension in the lungs is higher.
6. The haemoglobin at high altitude has a higher affinity for oxygen, because the air is less dense at altitude – there is less oxygen available.

3.2.8 Transporting carbon dioxide (page 201)

1. Carbaminohaemoglobin is formed when carbon dioxide binds with haemoglobin. This means there will be less haemoglobin available to carry oxygen.
2. Carbon dioxide binds with water, forming carbonic acid (Catalysed by the enzyme carbonic anhydrase). The carbonic acid dissociates to form hydrogen ions and hydrogencarbonate ions.
3. The hydrogencarbonate ions pass out of the blood cell into the plasma, this carries –ve charges out of the blood cell; Cl^- enters the blood cell to balance the charge.
4. The conversion of carbon dioxide to hydrogencarbonate ions releases hydrogen ions. These interact with the haemoglobin to alter its shape and reduce the affinity for oxygen.
5. Carbon dioxide converted to hydrogencarbonate → releases hydrogen ions → alters pH of cell contents → hydrogen ions associate with haemoglobin → producing haemoglobinic acid → alters shape of haemoglobin → reduces affinity for oxygen → more oxygen released from oxyhaemoglobin
6. Carbon dioxide diffuses out of red blood cell → carbonic acid reconverted to carbon dioxide and water → hydrogencarbonate ions associate with hydrogen ions to make carbonic acid → hydrogen ions released from haemoglobin → oxygen associates with haemoglobin

3.2 Practice questions (page 204)

1. C
2. D
3. B
4. B
5. C
6. (a) Being large; being active; small surface area to volume ratio.
   (b) (i) Open: a blood system in which the blood is not held in blood vessels.
   (ii) Insects
   (c) A closed system holds the blood in vessels; this means the flow is directed; the pressure can be increased; allowing faster flow of blood; the flow is not affected by body movements; the flow to different tissues and organs can be modified/diverted; in a double system the pressure within each system can be different; enabling blood to flow more quickly to the tissues.
7. (a) E, F, B, G, C, H, D, A
   (b) K = SAN; L = AVN
   (c) SAN initiates excitation; excitation wave spreads over walls of atria causing contraction; slight delay at AVN; down septum in bundle of His/Purkyne fibres; start contraction of ventricles from apex of heart.
8. (a) Dissolved in the plasma; taken up by haemoglobin; to form carbaminohaemoglobin.
   (b) (i) Inside the erythrocytes
   (ii) Carbonic anhydrase
   (iii) Dissociation
   (iv) Carbonic acid
   (v) Diffuse out of the erythrocyte
   (c) Combine with haemoglobin; reduces concentration of hydrogen ions in solution; this alters the structure of the haemoglobin; so affinity of haemoglobin in reduced; more oxygen is released from the haemoglobin; called the Bohr effect.

9. (a)

Structural feature	Artery	Vein	Function
thickness of wall	thick	thin	to withstand hydrostatic pressure of blood
valves	not present	present	to ensure blood flows in correct direction
smooth muscle	thick layer	thin layer	to constrict the blood vessel
collagen	thick layer	thin layer	to withstand hydrostatic pressure of blood
elastic tissue	thick layer	thin layer	to recoil and reduce diameter of vessel after expansion

(b) Blood near the heart is under higher pressure; causes greater expansion of blood vessel; expansion and recoil help to even out the flow of blood.

(c) (i) To distribute blood to capillaries; reduce pressure in blood.

(ii) The arterioles leading to the digestive system dilate to collect nutrients; this reduces flow to muscles; muscles receive less oxygen.

10. (a) Three from: oxygen, carbon dioxide, glucose; lipoproteins; proteins; amino acids, heat.

(b) (i) Exercise releases heat; heat is transported in blood; excess heat released to atmosphere from skin.

(ii) Vasodilation; dilation of arterioles leading to skin surface; constriction of arterioles leading to vessels deeper in skin.

3.3 Transport in plants

3.3.1 Transport in plants (page 209)

1. Plants are not active, so demand for oxygen is low; a leaf is flat, so all tissues are close to the surface; living tissues of stem are also close to surface; diffusion is sufficient to satisfy oxygen demand; oxygen is produced in tissues during photosynthesis.

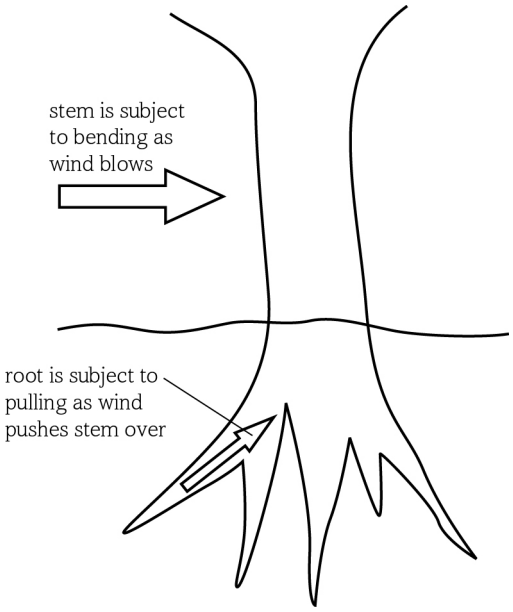
2. Diffusion is the result of the random motion of particles – particles move down their concentration gradient and different particles may move in different directions. In mass flow all particles move together, such as in the transpiration stream up a xylem.

3. Mass flow is faster and can move large amounts of fluid long distances, quickly.

4. Xylem is in centre of root, in the inner part of the vascular bundle of the stem, and on the upper part of the vascular bundle in the leaf.

5. Phloem is near the centre of the root in corners of xylem, it is in the outer part of the vascular bundle in the stem and in the lower part of the vascular bundle in the leaf.

6.

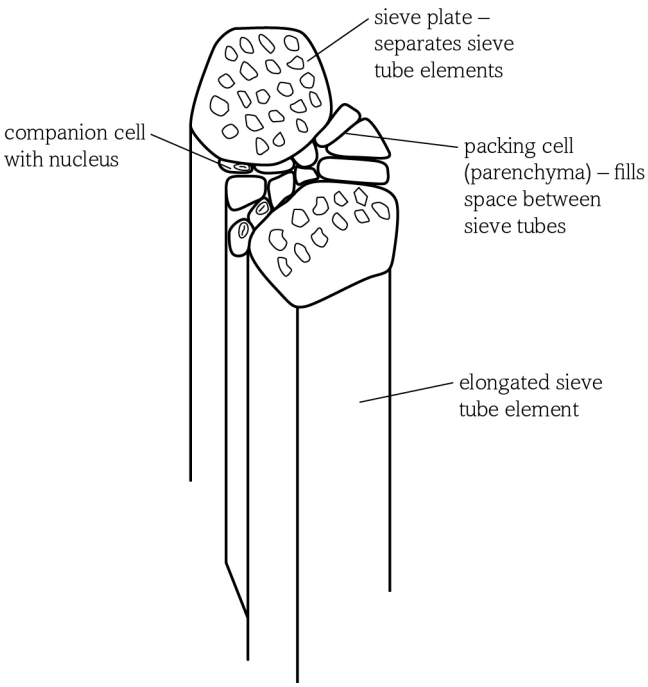


3.3.2 Transport tissues (page 211)

1.

Xylem	**Phloem**
lignified walls	walls not lignified
cells arranged end to end to form vessels	sieve tube elements arranged end to end
consists of vessels and support cells	consists of sieve tubes, companion cells and support cells
bordered pits between vessels	plasmodesmata between companion cells and sieve tube elements
no contents in vessels	sieve tube elements have a little cytoplasm, few organelles and no nuclei
no cross walls in vessels	sieve tube elements separated by sieve plates

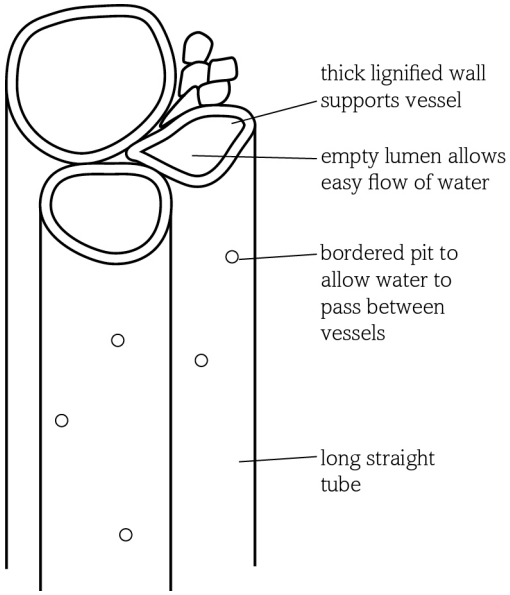
2.



3. To allow water to pass from one vessel to another, to ensure the column of water remains continuous, also allows water to leave vessel to supply other tissues in stem.

4. They have no nucleus.

5.



6. Lignification waterproofs the wall. This would kill the sieve tube element – phloem is living tissue.

3.3.3 Movement of water through plants (page 213)

1. Osmosis

2. Water potential is a measure of the tendency of water molecules to move from one place to another.
Osmosis is the movement of water molecules from a region of less negative (high) water potential to a region of more negative (lower) water potential through a partially permeable membrane.
Turgid refers to a cell or tissue that is full of water and is therefore firm.
Flaccid means that the cell or tissue is not full of water and is therefore soft.

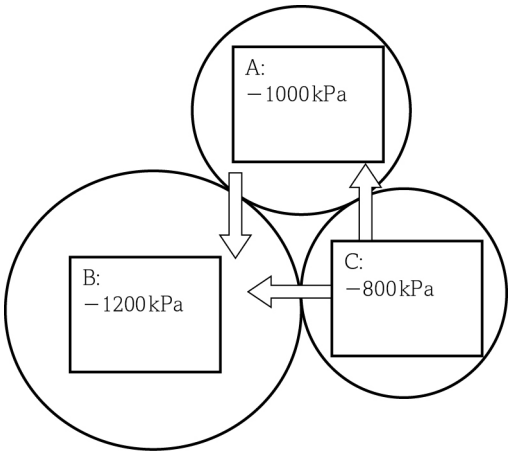
Plasmolysis is seen where the plasma membrane pulls away from the cell wall, due to loss of water from the cell by osmosis.

3. The plasma membrane

4. As water leaves the cell by osmosis, the cytoplasm and vacuole shrink. This pulls the plasma membrane away from the cell wall.

5. The same solution as surrounds the cell

6.



The water molecules move from the cell with the less negative (higher) water potential to the cell with the more negative (lower) water potential.

3.3.4 Transpiration (page 215)

1. Leaf surface area – larger surface area provides more surface for evaporation and diffusion.

Number of leaves – more leaves provide more surface for evaporation and diffusion.

Number of stomata – more stomata allow greater loss of water vapour by diffusion.

Thickness of waxy cuticle – thinner cuticle allows more evaporation.

2. Water molecules diffuse down a concentration gradient – the higher concentration of water molecules in the leaf air spaces creates higher (more negative) water (vapour) potential. There must be a more negative (higher) water potential inside the leaf than outside, or water will not diffuse out.

3. Set up potometer and measure rate of transpiration with no wind; measure three times to calculate a mean. Use a fan to create air movement and repeat the measurements of transpiration rate. Repeat at different fan speeds.

4. $\frac{(3.142 \times 0.5^{2 \times 45)}}{5} = 7.1 \text{ mm}^3 \text{ min}^{-1}$

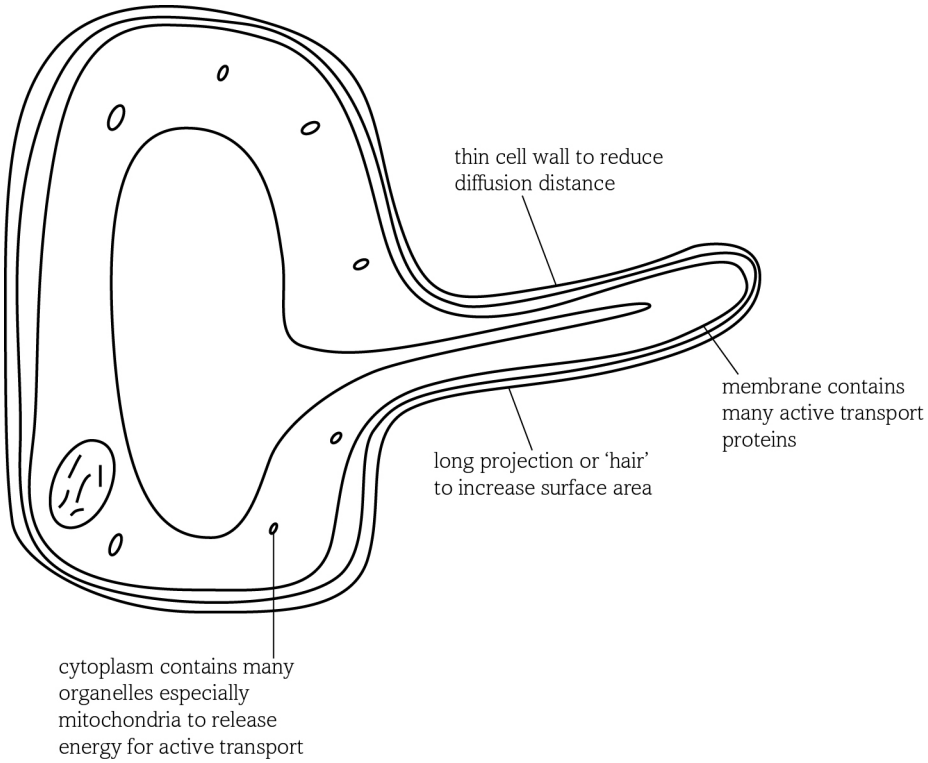
5. $\frac{(60 - 45)}{45} \times 100 = 33.3\%$

6. Brighter light causes the stomata to open wider, so more water vapour can diffuse out of the stomata.

3.3.5 The transpiration stream (page 217)

Exchange and transport

1.



2. Starch is a store of sugars – sugars can be released and respired to release energy for active processes.

3. This waterproofs four walls of the endodermis cells, blocking the apoplast pathway. Therefore, water must enter through the centre of the root, through endodermis cells, and cannot move back out via the apoplast pathway.

4. Loss of water by evaporation at the top of the plant must be replaced by water from the xylem. This puts water at the top of xylem under tension. Tension pulls the column of water up the xylem as water molecules are cohesive.

5. The polarity of the water molecule, which produces hydrogen bonds between the molecules.

6. Cells lie end to end in a column, with no cross walls and no cell contents or nuclei.

7. Tension pulls the whole column up like a chain – if molecules separate, the chain is broken and the lower part cannot be pulled up.

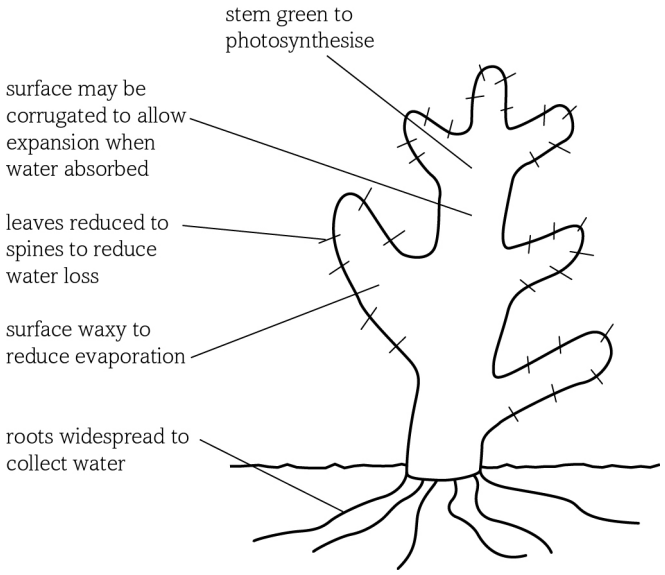
3.3.6 The adaptations of plants to the availability of water (page 219)

1. They lose water through transpiration. If water is not available from soil, the cells will become flaccid, and the plant will wilt and die.

2. Roots could be very long to reach water deep in soil; roots could be very widespread to absorb water from a large area when it does rain.

3. These adaptations trap air close to the stomata, so that water vapour collects in the trapped space. This increases the water potential in that space, so decreasing the water potential gradient between the air space inside the leaf and outside the leaf, reducing the rate of diffusion. Also, the water molecules need to diffuse a much greater distance from the leaf air space to be lost.

4.



5. Roots gain oxygen from air spaces in soil; water logged soil has no air. Roots cannot gain oxygen and respiration fails to produce enough energy.

6. Transpiration is the loss of water vapour from the leaves. If the leaves are submerged, the water vapour in the leaves cannot move out by diffusion.

3.3.7 Translocation (page 221)

1. Translocation is the transport of assimilates around the plant. Products of photosynthesis must be moved to storage areas; stored products must be moved to areas where they are needed for growth.

2. In spring, the roots act as a source and actively load sucrose into the phloem sieve tubes. This decreases the water potential in the sieve tube, so water enters by osmosis and increases the pressure; this pushes the sucrose solution away from the root. In summer, the leaves are making sugars and become the source for that sieve tube.

3. (a) In spring, the leaves need sugars to grow – so they are a sink; in summer, they make sugars which are taken away for storage – they are a source.

   (b) In summer, the roots receive sugars to convert to starch for storage – they are a sink; in spring, the starch is converted to sugar and transported to the growing points – the roots are a source.

4. At the sink, the cells must use up the sucrose, so that its concentration is reduced – sucrose can then diffuse out of the sieve tube into these cells. It can be converted to starch for storage, used to make larger molecules for growth or used in respiration.

5. Cell division – this requires energy to move cell components about (e.g. the chromosomes) during mitosis, and to make a new cell wall and other cell components during the S phase of the cell cycle.

6. Active transport is the movement of particles against their concentration gradient using metabolic energy (ATP). Active loading is a more extensive process which involves active transport at some stage. In this case, active loading uses active transport to pump hydrogen ions out of the companion cells. This results in movement of sucrose molecules by facilitated diffusion and diffusion.

7. The hydrogen ions are pumped out of the companion cells, creating a hydrogen ion concentration gradient across the cell membrane. The hydrogen ions can diffuse back into the companion cells through special transport proteins – but they only move if sucrose is carried in with them (cotransport).

8. Hydrogen ions are pumped out of the companion cells, reducing their concentration of hydrogen ions – this alters the pH, making it higher.

3.3 Practice questions (page 224)

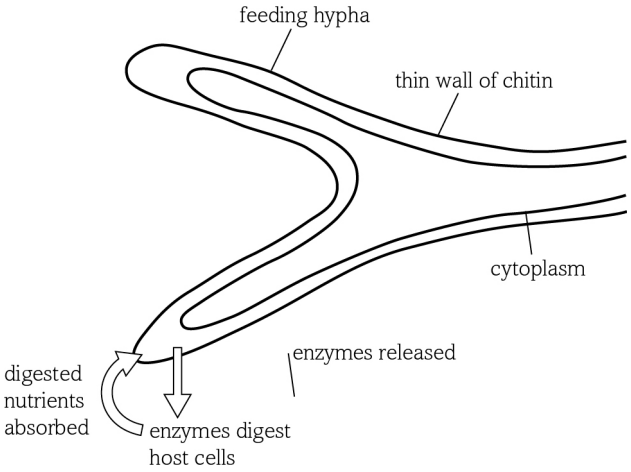
1. A
2. B
3. D
4. B
5. C
6. (a) Loss of water vapour; from the aerial parts of a plant; mostly via the stomata.
   (b) Xylem consists of dead cells; walls are lignified; making wall waterproof; no contents/nucleus/cytoplasm; elongated cells; joined end to end; to form a vessel/tube; bordered pits between xylem vessels; allow movement of water between adjacent vessels.
7. (a) Phloem
   (b) Sucrose; amino acids
   (c) Mineral ions/water/plant hormones
   (d) (i) A root is a source in spring when stored sugars are moved up to the leaves in spring; a root is a sink when sugars are stored during the summer. Alternatively, a leaf is source in summer when sugars are made in photosynthesis and is a sink in spring when it uses sugars from the roots to grow.
   (ii) Sugars are used in respiration; used to make starch for storage; used to make cellulose for growth of new cells/amino acids used to build proteins.
   (e) High pressure is created at source; active loading of sucrose into sieve tube; reduces water potential inside sieve tube; water enters by osmosis; low pressure at sink; sucrose, diffuses/actively transported out of sieve tube; increases water potential inside sieve tube; water leaves sieve tube by osmosis.
8. (a) Increases rate of transpiration
   (b) At low wind speed there is a low rate of transpiration; as wind speed increases the rate of transpiration increases; at 4 m/s the rate of transpiration decreases.
   (c) The potometer measures water taken up by the shoot; transpiration is the loss of water vapour from the shoot; the experiment assumes that water uptake = water loss.
   (d) (i) $(18 \times 3.142 \times 0.5^2)/2 = 7.1\ mm^3\ min^{-1}$
   (ii) Disagree with view; proportion of water used in photosynthesis is small/less than 5%.
9. (a) Xerophytes
   (b)

Feature	How it works
leaf rolled up	reduces surface area; traps moisture in enclosed space
stomata in pits	moisture collects in pit; reduces the water potential gradient between inside and outside leaf/increases the diffusion distance
thick way cuticle	reduces evaporation through leaf surface
lift wilts	reduces surface area exposed to sun

   (c) Three from: stomata on upper surface of leaf; air spaces in leaf/petiole; less well developed support tissue in petiole; hydathodes.
10. (a) Vacuolar/symplast
   (b) Apoplast
   (c) Xylem
   (d) Casparian strip
   (e) Casparian strip blocks apoplast pathway; water must pass through cells of endodermis; endodermis cells pump mineral ions into centre of root; water follows into centre of root by osmosis.
   (f) Water is polar; forms many hydrogen ions between molecules; this is called cohesion; loss of water from cells at top of tree causes tension; chain of water molecules pulled up xylem.

4.1 Communicable diseases

4.1.1 Organisms that cause disease (page 229)

1. Viruses: HIV, influenza
   Bacteria: tuberculosis, meningitis
   Fungi: athletes' foot, ring worm
   Protoctista: malaria, dysentery
2. Virus: tobacco mosaic
   Bacteria: ring rot
   Fungi: black sigatoka
3. Good supply of water and nutrients (especially in phloem).
4. An enzyme such as cellulase.
5. This enzyme is used to convert RNA to DNA.
6. 

4.1.2 Transmission of pathogens (page 231)

1. MRSA is transmitted by contact. Many people touch door handles; cleaning regularly means that if a contagious person has touched the handle and left bacteria there, they will be cleaned off and not transmitted.
2. They encounter different pathogens to those found at home and, initially, have no immunity to these new pathogens.
3. Immigration of people from countries where TB is more common; people living in overcrowded conditions which are not well ventilated and hygienic. Also regular TB vaccinations have been stopped.
4. These pathogens need to enter cells. To enter, they use a specific cell surface receptor or a specific enzyme; such receptors are not found on vector cells. Enzymes such as cellulase have no effect on tissues of vector; shape is not complementary to molecules of vector.
5. Cells have cellulose walls, which are not easy to digest; roots are protected by outer tissues, such as bark, which contains chemicals that have antibiotic properties. Damage exposes unprotected tissues.
6. Major storms with strong winds pull on roots and cause damage; pathogens can then enter roots.

4.1.3 Plant defences against pathogens (page 233)

1. Tyloses block xylem.
   Callose that blocks phloem.
   Necrosis – deliberate suicide of tissue containing the pathogen, to prevent it spreading.

2. Passive protection is always present – it reduces chances of pathogen entering plant. Active defences are employed in response to the presence of a pathogen; they try to kill the pathogen and prevent its spread.
3. Tyloses block old xylem vessels, preventing pathogens being transported in the old xylem vessels. Tyloses also contain chemicals, such as terpenes, which are toxic.
4. Callose can be deposited around cells in an area of infection, building a thicker barrier to the pathogen. It also blocks old phloem vessels and prevents pathogens being transported around the plant.
5. Making defensive chemicals takes energy; the plant can save energy by not producing these chemicals when they are not needed.
6. Deliberate cell death limits access of the pathogen to water and nutrients, and acts as a barrier to further movement around the plant.

4.1.4 Primary defences against disease (page 236)

1. Primary defences try to prevent entry into the organism – they prevent entry of any organisms, rather than specific ones.
2. Clots could disrupt blood flow, could cause reduced flow to vital organs, could reduce delivery of oxygen, causing heart attack or stroke.
3. A short chain of amino acids could be blocking the active site; removal of this short chain would expose the active site.
4. A sneeze or a cough, which expels air and pathogens quickly.
5. Swelling, redness, inflammation, irritation.
6. Dilation of arterioles leading to infected area, increased leakiness of capillaries, more tissue fluid produced.
7. Cilia are paralysed and mucus is not removed; pathogens collect in mucus and reproduce.

4.1.5 Secondary non-specific defences (page 238)

1. Opsonins can attach to many types of pathogen and help the process of phagocytosis, by giving the phagocyte something to bind to. They must be non-specific, so they can attach to many different pathogens.
2. A response that is not specific to the antigens on a particular pathogen.
3. The neutrophil binds to the pathogen (or to opsonin on the pathogen); the membrane folds inwards; endocytosis occurs, forming a vacuole (phagosome) that contains the pathogen; lysosomes fuse with the phagosome, releasing enzymes into phagosome; enzymes hydrolyse the pathogen.
4. Plasma membrane contains receptors for opsonins, well developed cytoskeleton for phagocytosis, many mitochondria for respiration, many ribosomes to make enzymes, many lysosomes.
5. To prevent phagocytes from treating macrophages as foreign bodies.
6. To ensure that the phagocytes do not attack our own tissues.

4.1.6 The specific immune response (page 240)

1. Infected host cells may have bits of the pathogen on their surface – these act as antigens.
2. Memory cells provide long-term immunity; they can recognise a pathogen that has attacked the body previously and can start the immune response quickly.
3. It would be wasteful to keep producing large numbers of antibodies after the infection has been removed. If the immune system kept producing more and more B and T cells, the blood would soon be filled with these cells, rather than with red blood cells.
4. They have specific target cells or tissue. These target cells possess a cell surface receptor which is complementary in shape to the shape of the cell signalling molecule.
5. B and T cells have receptors that are complementary to specific antigens. Early in development of the immune system, the cells that have receptors complementary to our own antigens are destroyed. This means that no B or T cells have receptors that are complementary to our own antigens.
6. If the antigens on our own cells and tissues change shape as a result of a mutation, they may then match those of a pathogen, so that some B and T cells recognise them as foreign.

Biodiversity, evolution and disease

4.1.7 Antibodies (page 243)

1. An antigen is a cell-surface molecule that is specific to the cell; an antibody is an immunoglobulin manufactured by the plasma cells.
2. So that they can bind to a range of different pathogens.
3. An immunoglobulin is a complex protein associated with the immune system. They are found in the blood and are able to bind to antigens.
4. Plasma cells have a lot of ribosomes, rough endoplasmic reticulum, Golgi apparatus and mitochondria.
5. This means that the shape of part of the antibody will fit the antigen like a glove or a jigsaw puzzle. This means that it will bind to this antigen and to no others.
6. The variable region is specific to the antigen – it has a shape that is complementary to the shape of the antigen; the disulfide bridges hold the four polypeptide chains together; the hinge region allows some flexibility so that the molecule can bind to more than one antigen; the constant region may have a shape that can be recognised by the neutrophils.
7. After infection, the pathogen must be detected and attacked by macrophages; antigen presentation occurs to select the correct B and T cells; these cells must reproduce in clonal expansion; then they must differentiate to form plasma cells; the plasma cells must start to produce the antibodies – each step takes time.

4.1.8 Vaccination (page 245)

1. Primary healthcare may not be well developed, people may live a long way from a health centre, people may not be educated to recognise certain diseases – but doctors need to know that the disease has occurred and its spread, in order to use vaccines effectively.
2. Live organisms reproduce and increase in numbers just like a pathogen would; this stimulates the immune system to create a full response.
3. If everyone (or the majority) is vaccinated, then the pathogen cannot reproduce inside most hosts. Even if it infects an unvaccinated person, it is unlikely to be transmitted to another host.
4. Passive immunity is provided by an external supply of antibodies – these are proteins and will not last long in the body. They may even act as antigens and be attacked by antibodies from our immune system.
5. Age, chronic heart disease, asthma, being HIV positive, diabetes.
6. Herd vaccination is where everyone, or almost everyone, is vaccinated. Ring vaccination is vaccinating people around the site of the outbreak, so that the pathogen will not be transmitted across that ring to the whole population.

4.1.9 Development and use of drugs (page 247)

1. Someone who has been hurt may have been given unripe poppy seeds to eat, and noticed an effect on the level of pain.
2. If the drug binds to the receptor that is used to bind to the host cell, then the virus cannot bind to the host cell – transmission has effectively been prevented.
3. The base sequence carries the code for the sequence of amino acids in the protein; the shape of the protein depends upon the base sequence.
4. The drug could be a similar shape to the substrate and fit into the active site of the enzyme. Alternatively, it could fit another part of the enzyme (an allosteric site) and affect the shape of the active site indirectly.
5. If antibiotics are not used properly, some bacteria may survive the treatment.
6. Bacteria that survive a treatment will be slightly resistant to the antibiotic and the antibiotic acts as a selective force which selects the resistant individuals. When they reproduce, some of their offspring may be more resistant, thus resistance evolves.

Biodiversity, evolution and disease

4.1 Practice questions (page 250)

1. C
2. D
3. A
4. C
5. D
6. (a) Artificial introduction of antigenic material; which stimulates the immune response.
   (b) Vaccinate whole population; vaccinate all people at risk (herd vaccination); vaccinate all people in the area around an outbreak (ring vaccination).
   (c) (i) Yes
   (ii) Vaccine had some effect on all measured quantities; any two examples of effect, e.g. fewer episodes, fewer days off work, fewer visits to doctor, fewer days off work.
   (iii) Any three from: sample size reasonably large; reports only collated for six months; relies on reports by volunteers; no account taken of other respiratory illnesses (may not be influenza); no account taken of habitual visits to doctor by some patients vs avoidance by some patients; no account taken of individuals willingness to take time off work.
7. (a) Cellulose/lignin in cell wall acts as a barrier; waxy cuticle prevents pathogens adhering to cell surface; bark contains chemicals harmful to pathogens; e.g. tannins; closure of stomata.
   (b) Thickening of cell walls; blocking transport tissues; callose in the phloem; tylose in old xylem; necrosis; deliberately killing cells around an infection; forms leaf spots; causes canker in stems.
   (c) Primary defences prevent entry of a pathogen into the body; secondary defences attack the pathogen once it is in the body.
8. (a) Graph A (no mark) because the number of molecules starts to rise on day 1; the rise in concentration is more rapid than in Graph B; the maximum concentration is higher.
   (b) The primary immune response takes time: pathogen must be recognised as foreign; engulfed by macrophages; antigens presented; selection of specific B cell; expansion of B cell clone; differentiation into plasma cells; protein synthesis.
9. (a) V = light polypeptide chain
   W = disulfide bridge
   X = hinge
   Y = heavy polypeptide chain
   (b) Pathogens have specific antigens; each is a different shape; each immunoglobulin is specific to an antigen; has shape complementary to the specific antigen.
   (c) Immunoglobins attach to antigens; opsonins facilitate phagocytosis; opsonins may block entry into host cell; antitoxins neutralise toxins; agglutins hold many pathogens together.
10. (a) Synovium/synovial membrane
   (b) To release synovial fluid
   (c) Wear and tear; alters the shape of the molecules that act as antigens.
   (d) Two from: smoking; excess drinking; genetic susceptibility/inherited; female hormones; excess wear due to work/exercise.
   (e) Lupus

4.2 Biodiversity

4.2.1 Biodiversity (page 255)

1. As appropriate. Examples could include: pond, woodland, field.
2. Species richness is the number of species; species evenness is how evenly they are represented.
3. It is impossible to count all the individuals or to measure every patch of the habitat for percentage cover. Sampling allows you to gain a quantitative view of which organisms are present in which proportions.
4. So that there is no bias, and so that the results are as accurate as possible.
5. Opportunistic sampling means modifying the sampling strategy according to knowledge of the habitat or during the sampling process. It is likely to lead to more 'interesting' areas being sampled more heavily. Therefore, the more uncommon organisms or larger more colourful organisms may be oversampled.
6. Random sampling; sample sites generated from random number tables.

4.2.2 Sampling plants (page 257)

1. Using randomly selected sample sites, place a quadrat at the sample site; identify all the species present; estimate the percentage cover of each species; use a point frame to measure percentage cover; look carefully to ensure all species have been found.
2. Too many plants to count individually.
3. Trampling of smaller plants, possible damage to some plants by efforts to observe closely and identify them.
4. When there is a gradient of environmental conditions which produces a gradient in the species distribution.
5. Some plants grow from seed or bulb etc. each year and may not yet be visible in spring; other plants may already have grown and died back by summer. When the different plants flower will affect how easily they are seen and identified.
6. To ensure that you have identified them correctly; to ensure you do not identify several species as one, which would reduce the value of the biodiversity calculated.

4.2.3 Sampling animals (page 259)

1. Meadow: set pitfall traps for small organisms that live on the ground, sweep net the non-woody plants, set Longworth traps for the small mammals.

   Under hedge: set pitfall traps, set Longworth traps, collect leaf litter and use a Tullgren funnel to collect small organisms in the leaf litter.
2. Select five sweet chestnut trees/bushes and five hazel trees/bushes; try to ensure all the trees are of a similar size and in the same area; collect small organisms from the trees, using a technique such as hitting the branch with a stick and collecting organisms on a white sheet, using a pooter and close observation; identify and count all the organisms collected; calculate the biodiversity (you might need to refer to topic 4.2.4 on calculating biodiversity, to help you do this).
3. Owl pellets contain the undigested parts of their prey. (bones, fur, claws etc.). It is possible to tease the pellet apart and identify the prey species from their bones.
4. Clip a small patch of fur; use a non-toxic paint.
5. If they know there is food in the trap and deliberately enter the trap to get at the food, these animals would distort the number of animals that are trapped, leading to an inaccurate estimate of population size.

4.2.4 Calculating biodiversity (page 261)

1.

Species	Field B		
	n	***n/N***	$(n/N)^2$
cocksfoot grass	38	0.38	0.1444
timothy grass	16	0.16	0.0256
meadow buttercup	14	0.14	0.0196
white clover	22	0.22	0.0484
creeping thistle	5	0.05	0.0025
dandelion	5	0.05	0.0025
sum (∑)	–	–	0.2430
$1 - \sum$	–	–	0.7570

Answer = 0.757

2. It is more diverse than field A – the species have higher evenness.
3. Because the species are more evenly represented, it is less likely that one species could be lost as a result of disturbance. If one prey species declines in number, the predators can swap to eating a different prey species. This allows the first prey species to recover.
4. So that the measure of biodiversity is accurate; species may be similar in appearance, but one may be rare or endangered.
5. Genetic diversity leads to variation between the individuals. This means that selection processes can work and evolution can occur. If the genetic diversity declines, it is more likely that offspring may receive a pair of recessive alleles that could lead to a genetic disease or abnormality.
6. A gene codes for the structure of a protein. The protein may form a characteristic of the individual which is easily identified, e.g. colour.
7. The variation may be a recessive allele, which is masked by the dominant allele. Or, the genetic variation may alter a characteristic which is not easy to spot – such as the activity of a particular enzyme.

4.2.5 What affects biodiversity? (page 263)

1. Improved health care, improved diet/nutrition, people living longer, lower infant mortality.
2. A monoculture is a large crop of one strain (or even one clone) of plants, so there is little or no genetic diversity; it often replaces a habitat that had many different species and good genetic diversity.
3. Selective breeding selects certain characteristics (the farmer/scientist often ignores other characteristics). These other characteristics may also be losing diversity.
4. The reduction in genetic diversity in a species.
5. As one strain is favoured and allowed to reproduce, other strains become rare or lost; the genetic variation within those strains is lost, so the species has lost genetic diversity.
6. Domesticated species are selected for certain features that humans want; they may not be suitable for survival in the wild; the genetic diversity of the species is eroded or lost; less variation between individuals means that selection and evolution cannot take place.

4.2.6 Reasons to maintain biodiversity (page 265)

1. Mountain lions kept population in check. With no predation, the deer population increased, ate all the food and the vegetation could not recover. Lack of food meant the deer starved.
2. Many plants rely on bees to pollinate their flowers. With no pollination, the plants cannot reproduce sexually and so the bee affects many other species.
3. The conditions may become hotter and drier. Plants need to be adapted to their environment to be successful. Current plants may not survive in the new conditions. Therefore, new varieties are needed that are adapted to the new conditions.
4. Ability to survive with less water and in higher temperatures, ability to limit transpiration, thicker waxy cuticle, modified enzymes that have a different optimum temperature, water storage capacity.
5. Cropping continuously without replacing the minerals and organic matter in the soil, leading to depletion of the soil. No organic matter to hold soil particles together and drought conditions, leading to dust storms.
6. Foliage protects soil from erosion by rainfall; trees absorb water from soil; transpiration returns water to atmosphere; soil with organic matter stores water like a sponge; water drains out more slowly.

4.2.7 Conservation *in situ* (page 267)

1. Conserving a species in its natural environment or habitat.
2. Conservation aims to maintain or increase the biodiversity. If a habitat is not managed, it is likely to succumb to a few dominant species and biodiversity will be lost; management is needed to keep diversity high.
3. SSSIs are sites of special scientific interest. They may contain rare or endangered species or a habitat that is very fragile. To avoid unwanted damage due to trampling during visits from people who want to see the rare species, the sites are not made obvious.
4. The threat that caused the initial loss of flora and fauna may still exist – it must be removed or controlled; local people may want to use the area for other purpose, such as agriculture; the soil may have been damaged beyond repair; competition from introduced plants or animals may be too great; the other wild animals in the area may not accept the introduced animals; the introduced animals must learn how to find food and avoid predation.
5. To allow time for the population of herbivores to establish itself (start reproducing and increase in number).

4.2.8 Conservation *ex situ* (page 269)

1. Not in normal habitat; conditions may be different (e.g. temperature, day length, light intensity, vegetation, moisture levels, food etc.). Behaviour may be modified by conditions. Size of population or density of population may also alter reproduction habits.
2. To prevent inbreeding, which may lead to unusual combinations of alleles that would not occur if genetic diversity was greater.
3. Allows research without affecting the endangered species. Species that are similar may have very similar behaviour or physiology, revealing knowledge which can be applied to the endangered species.
4. Asexual reproduction does not increase genetic diversity, sexual reproduction does. It is better to have greater genetic diversity, so that species can undergo selection of best variants and evolution can occur.
5. Both factors reduce the activity of enzymes; living tissue must respire, which slowly uses up the stored food in the seeds; reducing enzyme activity ensures the stores last longer. Also, the cooler and drier conditions reduce the chance of pathogens growing on the seeds.

4.2.9 Protection of species and habitats (page 271)

1. The government of a country may not feel the agreement is important, especially if the government has changed since signing the agreement; local people may not feel agreement is important; they want to make a living out of the environment; poachers and illegal traders are difficult to catch.
2. This is to prevent trade in these products, so that the market will collapse and people will no longer expect to be able to buy such products. As a result, their value should drop and poachers will no longer find such activity worthwhile.

3. *Ex situ* conservation can be used to help the species survive and increase the numbers of individuals, but the species is not adapted to living in the environment where *ex situ* conservation takes place. Individuals need to be reintroduced to their natural habitat, where they can become a part of the natural community and help to conserve the whole ecosystem. This is very difficult and is unlikely to work if the country of origin is not willing to invest in keeping the original habitat safe.
4. In case of disaster such as fire; to allow greater opportunities for research; allows a greater number of representatives, and therefore greater diversity, to be conserved.
5. Any scientific research must be repeated; the original research could be invalid due to the researchers overlooking some factor. It is also possible that in different conditions and with different varieties the findings may be different.
6. Income, grant aid to carry out expensive works, increased diversity on the farm, homes for natural predators of farm pests.

4.2 Practice questions (page 274)

1. C
2. A
3. B
4. D
5. i and iv
6. (a) Three from: poaching; habitat destruction; development of land; agriculture; climate change; over harvesting; over predation; competition.
   (b) *In situ* is conserving the species in its natural habitat; *ex situ* is conservation outside the natural habitat.
   (c) Three from: organisms in natural habitat; organisms behave normally; helps preserve habitat; creates jobs for local people; can generate income through ecotourism.
   (d) Species become endangered because of some threat; threat may still be present; therefore *in situ* attempts may fail; numbers can be increased *ex situ*; allowing reintroduction to wild; *in situ* conservation enables research which may help *ex situ* attempts.
7. (a) $D = 1 - [(15/170)^2 + (25/170)^2 + (40/170)^2 + (35/170)^2 + (55/170)^2]$
   $D = 1 - [0.0441 + 0.0216 + 0.0552 + 0.0424 + 0.105] = 0.732$
   $D = 1 - [0.00785 + 0.0216 + 0.0554 + 0.0424 + 0.105] = 0.768$
   (b) (i) Both have the same species richness.
   (ii) B
   (iii) Habitat A is likely to be the highly managed habitat; there are two species which dominate the habitat; giving a lower diversity.
8. (a) Any three from*:* cost; stress caused by transport; ability to adapt to the new habitat; acceptance by other wild giraffes; ability to respond to threats from predators.
   (b) Donated to another zoo
   (c) (i) $100 \times 43/51 = 84.3$ %
   (ii) Those raised in situ; they are more used to the habitat; can find food; more likely to be accepted by other wild gorillas.
   (d) Rio convention aims to conserve biodiversity; zoos can help conserve species that are rare in wild; zoos can reintroduce species to original habitat; e.g. gorillas raised in Europe can increase numbers in Africa; zoos can help to increase genetic diversity through careful breeding programmes; Marius might have been useful to increase genetic diversity in another zoo in another country; African countries provide reserves for gorillas; African countries provide wardens for reserves.

9. (a) Increasing area used for agriculture; reduces area for natural habitat; use of monoculture reduces diversity within area.

   (b) Change in climate alters conditions on the ground; species no longer adapted to conditions; must move or decline in numbers; new diseases may become common.

   (c) Any six from: economic reasons; soil depleted by over cropping; food becomes scarce/to protect our food supply; ecological reasons; loss of one species may affect ecosystem; keystone species may be lost; aesthetic reasons; important to maintain the landscape; natural habitat known to be healthy.

10. (a) Habitat diversity; genetic diversity

    (b) Species richness is a measure of how many species are found; species evenness is a measure how equally the species are represented.

    (c) (i) Avoids bias; may not cover all areas of the habitat equally.

    (ii) Using knowledge of the habitat to select sample sites.

    (iii) Data collected may be biased; may lead to an over estimate of diversity.

    (iv) Stratified, ensures that all areas of the habitat are sampled; systematic, allows the effects of environmental gradients to show.

4.3 Classification and evolution

4.3.1 Biological classification (page 279)

1. There may be very small differences between similar species.
2. Chimpanzee: animal, chordate, mammal, primate, hominidae, *Pan*, *troglodytes*

   Wolf: animal, chordate, mammal, carnivore, canidae, *Canis*, *lupus*
3. A spider does not have six legs, two pairs of wings and three body sections.
4. The use of scientific names for the genus and species.
5. To avoid confusion, when different organisms may be given the same common name, or the same organism may be given different common names in different areas. To overcome language differences.

4.3.2 Features used in classification (page 281)

1. Further research revealed organisms that did not fit within the two-kingdom approach – some single-celled organisms have features of both plant and animal; others, such as fungi, have features of neither plant nor animal.
2. They have a range of features that do not fit standard classification systems, e.g. they remain ‘rooted’ in one place, but use heterotrophic nutrition.
3. Both have wings, but birds are vertebrates – members of the phylum chordata; insects have an exoskeleton and belong to the phylum arthropoda.
4. Higher magnification and better resolution allowed more detailed observation of details inside cells.
5. Plants have chloroplasts and chlorophyll, they photosynthesise, use autotrophic nutrition, have cell walls made of cellulose.

   Fungi have no chlorophyll and do not photosynthesise, use heterotrophic nutrition, have cell walls of chitin.

6.

Prokaryotes	Protoctists
single celled	single celled and multicellular
no nucleus	nucleus
plasmids present	no plasmids
naked DNA	DNA associated with protein
circular DNA	DNA in linear chromosomes
no membrane-bound organelles	membrane bound organelles present
Many have flagellum	some have unduliopdium or cilia

4.3.3 Evidence used in classification (page 283)

1. Where two unrelated species have similar features as a result of evolving adaptations to the same environment.
2. If the features look the same, the different species may appear more closely related than they are; they may be placed in the same taxonomic group by mistake.
3. These molecules are universal – they appear almost everywhere throughout the living world. Therefore, all living things can be compared for similarities and differences.
4. These molecules are not found in all living things – therefore, they cannot be used to compare all organisms. Also, the structure of starch is dependent on the structure of glucose and is always the same.
5. The function of RNA polymerase is fundamental to living processes, such as protein synthesis. Similarities and differences will reflect relationships between groups.

4.3.4 Classification and phylogeny (page 285)

1. A common ancestor is an ancestor that is shared by two or more different groups of organisms. More than one modern day species arose from that common ancestor.
2. Classification is putting things into groups; phylogeny is the study of the evolutionary relationships between those groups.
3. Understanding the behaviour and physiology of other organisms that are closely related to us can help us understand our own behaviour and physiology.
4. (a) 4, (b) 3
5. ‘Monophyletic’ means that all members of that group arose from one common ancestor.
6. If a drug may have adverse effects, it can be tested on closely related species; the results should be applicable to the target species, saving possible harm to the target species, which may be a rare or endangered species (or it may be humans).

4.3.5 The evidence for natural selection (page 287)

1. Darwin observed that there was variation between individuals. When there is a struggle to survive, the best adapted will survive most easily; these individuals will reproduce and pass on their characteristics.
2. Fittest means ‘best adapted to the environment’, and those which are best adapted survive to pass on their characteristics – so those characteristics survive.
3. Many of the processes of life require similar structures and similar enzymes in all living things, so many cell organelles, membrane structure and protein structures are shared. For example, the enzymes and proteins associated with respiration, DNA synthesis and protein synthesis could all be the same.
4. Proteins, because they consist of a sequence of amino acids that is dictated by the DNA. The structure of a protein must remain capable of performing its function, so it is unlikely to be totally transformed through evolution.
5. Not all fossils have been found; fossils do not form easily – there may be no fossils of some/many organisms; erosion may have washed fossils away; movement of the ground caused by earthquakes may disrupt the record.

4.3.6 Variation (page 289)

1. One gene is needed to produce one polypeptide or protein; presence of a different allele can produce the difference between characteristics, or in the presence or absence of the characteristic. Where several genes are involved, there is scope for a range of characteristics.
2. Species are classified according to their similarities and differences. Closely related species will have fewer differences and those differences will be smaller than those between less closely related species.
3. Skin colour is affected by the amount of melanin that is produced – this is a genetic factor and probably involves several genes. It is also affected by sunlight –an environmental factor.
4. These areas of the body lose most heat. In the rabbit reared at 20°C, they are the coolest parts of the body and are regularly below 35°C. This activates the gene that controls production of the colour. In the rabbit reared at 30°C less heat is lost.

4.3.7 Applying statistical techniques (page 291)

1. Mean number = 106, n – 1 = 9

   $$\sum (x - \bar{x})^2 = 324$$

   $$s = \sqrt{\frac{324}{9}}$$

   $$s = 6$$

2. Null hypothesis – the means are not different.

   $$t = \frac{(84.6 - 106)}{\sqrt{\frac{6^2}{10} + \frac{8.98^2}{10}}}$$

   $$t = \frac{21.4}{\sqrt{(3.6 + 8.064)}}$$

   $$t = 6.27$$

   There are 18 degrees of freedom, so reading from the table of *t,* a value of 6.27 is greater than 2.1. Therefore, the difference between the means is significant at the 5% level.

3. Null hypothesis is that there is no correlation

Height of tree (m)	Rank 1 (R_1)	Mean length of leaf (mm)	Rank 2 (R_2)	$R_1 - R_2 = D$	D^2
27	1	88	5	–4	16
13	6	96	1	5	25
22	2	93	2	0	0
18	4	92	3	1	1
16	5	90	4	1	1
19	3	87	6	–3	9
9	7	83	7	0	0

Sum of $D^2 = 52$

$$r = 1 - \frac{6 \times 52}{7 \times (49 - 1)}$$

$$r_s = 1 - \frac{312}{336}$$

$r_s = 0.0714$

Number of pairs of measurements	Critical value
7	0.79

Our value of r_s is lower than 0.79. Therefore, there is no correlation.

4.3.8 Adaptation (page 293)

1. Anatomical: flagella, wings

   Physiological: red pigment, brightly coloured petals, ability to see colour, low stomach pH, salivary amylase

   Behavioural: squinting

2. They have both evolved to hunt and eat meat; they need similar teeth to kill their prey, cut the meat off the bone, and crush bone.

3. They live in the same habitat; they have fins rather than legs; they are a similar shape.

4. An anatomical adaptation may be used to perform a behaviour, e.g. legs are used to run away; physiological adaptations are also used perform the behaviour, e.g. the muscles must be able to contract to enable the legs to move to run away. The physiological adaptations and behavioural adaptations often cannot work unless there is a suitable anatomical arrangement.

5. Wolf:
   Anatomical – eyes at front of head, long canine teeth, strong legs
   Physiological – muscle contraction, acidity in stomach, production of proteases
   Behavioural: hunting in packs, communication by howls and growls, use of facial expressions.

4.3.9 Natural selection and evolution (page 295)

1. (a) As camouflage, so that predator remains unseen by prey.
   (b) As camouflage, so that predator does not see prey.

2. Shortage of any commodity, such as food, water, nest sites; presence of predators or disease; adverse environmental conditions, such as too dry, too wet, too hot, too cold, etc.

3. If the resource is unlimited, there will be no competition and no related struggle to survive.

4. Microorganisms have a short generation time. Selection can occur in each generation; if there are many generations in a few days or weeks, then evolution can occur much more quickly.

5. Selection occurs when the environment changes and the organisms are not well adapted – through selection they become adapted to the environment. Selection (and so evolution) slows or stops when the organisms are well adapted to the environment, until the environment changes again.

4.3 Practice questions (page 298)

1. D

2. A

3. C

4. D

5. C

6. (a) Putting organisms into groups; that reflect how closely related they are to each other.
   (b) Phylogeny reflects the evolutionary relationships between species; a natural classification will place organisms into groups that are related; it will show how closely related the different groups are.
   (c) (i) Common ancestor
   (ii) F and G
   (iii) Have common ancestor L; they show the shortest time back to the common ancestor; only a short time for evolution to make them different.
   (iv) All arise from one ancestor (O).

7. (a) Two from: hair colour; skin colour; height.
   (b) Genetic inheritance and environment.
   (c) Gender
   (d) Genetic inheritance
   (e) A mutation occurs; produces variation; new feature may confer an advantage on the individual; that individual is successful; passes allele on to next generation; a similar feature in an unrelated group living in same environment will also be successful; so similar features develop in unrelated species living in similar environment.

8. (a) Offspring look like their parents; no two individuals are identical; populations have the capacity to overproduce; in nature populations tend to be stable.
   (b) Species alive today are not found as fossils; fossil species are similar to modern species; sequences of fossils in the rock strata show how one species is replaced by another similar species.
   (c) DNA carries the code for characteristics; in sequence of bases; a change in the sequence is a mutation; a small change in the sequence often causes a change in the characteristic; the sequence of DNA of two species can be compared; unrelated species have many differences in DNA; related species have fewer differences in DNA; more mutations occur in longer time span.

9. (a) Proteins consist of a sequence of amino acids; the sequence depends upon the DNA/gene; closely related species have more similarities; therefore, the amino acid sequence is more similar than in distantly related species.
   (b) Haemoglobin is not universal/many species do not have haemoglobin; some organisms produce different versions of haemoglobin; e.g. fetal, adult, sickle-cell haemoglobin.
   (c) (i) They have the highest rate of agglutination.
   (ii) The protein had a similar amino acid sequence to the protein in species A; similar tertiary structure/3-D shape; close fit to shape of agglutinin.
   (iii) Amino acid sequence is more different; shape of protein less similar; does not fit agglutinin as well.

10. (a) Bacterium

(b) Two from: no nucleus; naked DNA; circular DNA; no membrane-bound organelles.

(c) Mutation causes variation in levels of resistance/some are individuals more resistant; antibiotic is selective pressure; resistance allows survival/confers advantage; slightly resistant individuals survive; resistance allele passed to next generation; further variation each generation increases level of resistance.

(d) (i) The number of cases drops; from 70 in 2008 to 30 in 2013.

(ii) $100 \times (70 - 30)/70$; = 57%