

Now test yourself answers

1 Cell structure

1 Stains enable structures to be seen that would otherwise be transparent. Some stains will only stain certain organelles and structures, so that they are easy to identify.

2 $\frac{25}{125} = 0.2 \text{ mm}$

3 $79 \text{ mm} = 79\,000 \mu\text{m}$
 actual size of object = $\frac{\text{size of image}}{\text{magnification}}$
 $= \frac{79\,000}{16\,000}$
 $= 4.9 \mu\text{m}$

4 $100 \text{ graticule units} = 8 \times 0.01 \text{ mm}$
 $= 0.08 \text{ mm}$

Therefore:

$1 \text{ graticule unit} = \frac{0.08}{100}$

$= 0.0008 \text{ mm}$

$= 0.0008 \times 1000 \mu\text{m}$

$= 0.8 \mu\text{m}$

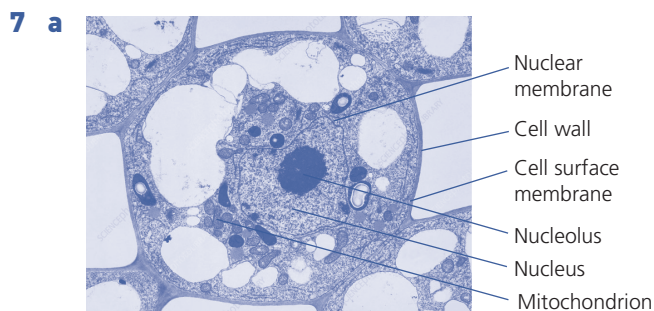
Cell measures 84 graticule units

$= \frac{84}{0.8} = 105 \mu\text{m}$

5 RER, ribosome, Golgi body, vesicles, cell surface membrane, nucleus (where mRNA is produced)

6

Structure	Animal cells	Plant cells
Nucleus	✓	✓
Nucleolus	✓	✓
Cell surface membrane	✓	✓
RER	✓	✓
SER	✓	✓
70S ribosomes	✓	✓
80S ribosomes	✓	✓
Centrioles	✓	✗
Mitochondrion	✓	✓
Small circular DNA	✓	✓
Nuclear envelope	✓	✓
Lysosomes	✓	✗
Golgi body	✓	✓
Chloroplast	✗	✓
Cell wall	✗	✓
Plasmodesma	✗	✓



8 Cell wall, nucleus, cell membrane and possibly mitochondria would be visible with a light microscope.

9 a Scale bar is 5 mm long and represents 1 nm.
 Diameter of image of virus is 29 mm.
 Therefore actual size = $29 \div 5 = 5.8 \text{ nm}$

b Scale bar is 10 mm long and represents 0.1 μm .
 Length of image of bacterium is 46 mm.
 Therefore actual size is $(46 \div 10) \times 0.1 = 0.46 \mu\text{m}$.
 $0.46 \mu\text{m} = 460 \text{ nm}$
 So $460 \div 5.8 = 79$ viruses could line up inside the bacterium.

2 Biological molecules

1 First do the reducing sugar test. Use excess Benedict's solution so that all the reducing sugar is used up in the test. Filter to remove the brick red precipitate. Collect the filtrate. It would be a good idea to do the reducing sugar test again, just to check that you really have got rid of all the reducing sugar. If you have, then do the non-reducing sugar test.

2 a Between 5.0% and 10.0%

b The student could use a colour chart to match the final colour. They could also do more standards between 5.0% and 10.0%.

c Any three of: volume of reducing sugar; volume of Benedict's reagent; temperature of the water bath; final colour of Benedict's reagent; concentration of Benedict's reagent.

3 Fructose: monosaccharide; gives a positive result with Benedict's test.

Glucose: monosaccharide; gives a positive result with Benedict's test.

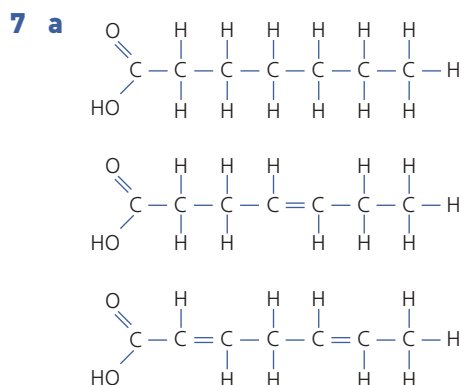
Lactose: disaccharide; formed from glucose and galactose; gives a positive result with Benedict's test.

Maltose: disaccharide; formed from glucose and glucose; gives a positive result with Benedict's test.

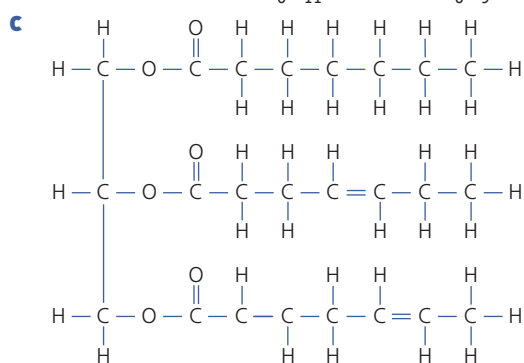
Sucrose: disaccharide; formed from glucose and fructose; does not give positive result with Benedict's test.

- 4 $C_{12}H_{22}O_{11}$ (this is two glucose molecules added together with one water molecule taken away)
- 5 Cellulose is made up long chains of glucose linked by β 1–4 glycosidic bonds. This results in the glucose molecules being alternately one way up, then the other. This means that chains lying side by side can form hydrogen bonds with each other, making microfibrils. Starch, on the other hand, is made up of long chains of glucose linked by α 1–4 glycosidic bonds. It twists into a spiral, and one starch molecule does not form bonds with others, so no fibrils are formed. Moreover, it is difficult to break down β 1–4 glycosidic bonds, so not many organisms can digest cell walls.
- 6 Similarities: Both are made of hexose sugars/glucose. Both have 1–4 glycosidic bonds. Both are polysaccharides. Both are polymers.

Differences: Amylose is a helical molecule/cellulose is a linear molecule. Amylose has α -glucose/cellulose has β -glucose. Amylose has all glucoses in the same orientation/cellulose has every other glucose molecule inverted.



- b Saturated: $COOHC_6H_{13}$
Unsaturated: $COOHC_6H_{11}$ and $COOHC_6H_9$



(The $C=C$ double bonds can be in any locations and the order of the fatty acids on the glycerol can be different.)

- 8 Primary structure: peptide bonds
Secondary structure: hydrogen bonds
Tertiary structure: hydrogen bonds, ionic bonds, disulfide bonds, hydrophobic and hydrophilic interactions
- 9 a It is composed of more than one polypeptide.
b Hydrophilic amino acids on the surface of haemoglobin are able to interact with water molecules.
c One oxygen molecule combines with the iron in the haem group of each subunit.
- 10 a Secondary structure is the first-level coiling or folding of the polypeptide chain. This is often an alpha helix or a beta pleated sheet. Tertiary structure is the three-dimensional folding of the polypeptide chain, for example to form a globular shape.
b A collagen molecule is a chain of amino acids linked by peptide bonds. A collagen fibre is made up of many collagen molecules linked together by covalent bonds between lysine molecules.
- 11 a A hydrogen bond is a weak attraction between a small negative charge (e.g. on the oxygen of an $-OH$ group) and a small positive charge (e.g. on the hydrogen of an $-OH$ group).
b Hydrogen bonds cause forces of attraction between water molecules. This means that extra energy has to be applied to separate the molecules from one another. Therefore the melting point and boiling point are higher than for similar compounds that do not have hydrogen bonding between their molecules.
c Carbohydrates, proteins

3 Enzymes

- 1 a Substrate: hydrogen peroxide; products: oxygen and water
b The active site shape of amylase is not complementary to hydrogen peroxide; it is complementary to starch.
c
 - Hydrogen peroxide binds into the active site of catalase enzyme.
 - The bonds of the hydrogen peroxide are strained due to contact with the R groups of amino acids, leading to it to break down into oxygen and water.
 - The catalase enzyme lowers the activation energy needed for the reaction to occur.
- 2 a Either:
 - Mix a solution of casein with protease enzyme and use a colorimeter to measure the light transmitted by the solution. The casein solution is cloudy, so less light will be transmitted. As the casein is digested, the solution will clear, so more light will be transmitted.

or:

- Mix the solutions in a test tube and draw a cross on one side of the tube. The time taken for the cross to become visible through the solution could be recorded.
 - b** – The change in pH of the solution could be measured with indicator solutions or a pH meter.
 - As the lipase is broken down into fatty acids and glycerol, the pH of the solution will fall.
- 3** The rate of reaction decreases as the substrate concentration falls. The fastest rate will occur at the start of the reaction when the substrate concentration is not limiting.
- 4** Variable to change (independent variable): catalase from different fruits
Variable to measure (dependent variable): initial rate of reaction (e.g. volume of oxygen given off per second)
Variables to standardise: volume and concentration of catalase extract; volume and concentration of substrate (hydrogen peroxide solution); temperature; pH
- Use a liquidiser to mash up the same mass of two fruits. Run the liquidiser at the same speed for the same period of time.
 - Filter the extracts and collect equal volumes of each.
 - Measure equal volumes of the extract into several test tubes.
 - Use serial dilution to make up a range of concentrations of hydrogen peroxide (see p. 104 for how to do this).
 - Add a small amount of pH 7 buffer to each tube.
 - Place all tubes (fruit extract and substrate) in a water bath at 37°C and leave for 20 minutes to come to temperature.
 - Add fruit extract to one of the hydrogen peroxide tubes, and measure the rate of oxygen production (e.g. by collecting over water, or by placing on a balance and measuring loss of mass).
 - Repeat for each hydrogen peroxide concentration.
 - Plot graphs of oxygen production against substrate concentration for each tube.
 - Use your graphs to calculate the initial rate of reaction for each tube (see p. 38 for how to do this).
 - Plot graphs of initial rate of reaction against substrate concentration for each of the two fruit juice extracts.
 - Use your graphs to find $V_{\max}$ for each fruit juice extract.
 - Read off the substrate concentration that corresponds to $\frac{1}{2}V_{\max}$. This gives you the value of K_m .

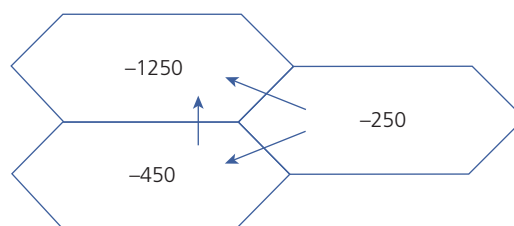
- The fruit juice extract with the larger value of K_m is the one with greater affinity for its substrate.

- 5** Temperature: thermostatically controlled water bath or monitor the temperature of a water bath with a thermometer and keep adjusting with warm water.
pH: add pH buffer solutions to the mixture.
- 6** **a** Temperature, enzyme concentration, substrate concentration, competitive inhibitors
b Temperature, pH and non-competitive inhibitors
- 7** The enzymes do not contaminate the final product; they are more stable, so can work at a wider range of temperatures and pH; the enzymes are not lost, so can be reused many times.

4 Cell membranes

- 1** The drugs will fit into the receptor proteins. This means that they can either block the cell signalling molecule from binding to reduce the effect of the cell signalling molecule or stimulate the receptor in the absence of the cell signalling molecule.
- 2** Rectangular cuboid: surface area = 250 cm²; volume = 250 cm³; surface area-to-volume ratio = 1:1
Cylinder: surface area = 151 cm²; volume = 126 cm³; surface area to volume ratio = 1.2:1
- 3** **a** Diffusion takes place when molecules or ions can move freely through the membrane, through the phospholipid bilayer. Facilitated diffusion takes place when molecules or ions can only move through protein channels in the membrane, not through the phospholipid bilayer. Note that both processes are passive, and movement is down a concentration gradient.
- b** Charged polar molecules cannot pass through the hydrophobic phospholipid tails in the interior of the membrane. Channels and carriers allow polar, charged molecules to pass through them.
- 4** Sodium ions: facilitated diffusion
Carbon dioxide molecules: diffusion
Glucose molecules: facilitated diffusion
Ethanol: diffusion

5



- 6** Pure water: water moves from higher water potential (water) to lower water potential in the potato cells due to the presence of solutes in the potato cells.
Concentrated salt solution: water moves from a higher water potential in the potato cells into the

solution, where the water potential is lower due to the higher concentration of salt in the solution.

- 7 Facilitated diffusion takes place down a concentration gradient, and is passive.
Active transport takes place up a concentration gradient, and requires energy input from the cell. Note that in both of these processes, molecules or ions move through proteins in the membrane.
- 8 Air spaces in the soil fill up with water, so there is less oxygen. Root cells are therefore unable to respire aerobically, so have less ATP. If there is less ATP, they are less able to perform active transport.

5 Mitotic cell cycle

- 1 a Telomere
b Sister chromatids
c Histones
d Centromeres
- 2 a Mitosis
b S phase (in interphase)
c Cytokinesis
d G₁ phase (in interphase)
- 3 X: prophase but could be moving into early metaphase – it is often difficult to precisely identify where one stage ends and another starts.
Y: anaphase

Stage	Number of cells in stage	Percentage of cells in stage	Estimated time spent in stage/h
Interphase	65	67.0	16.1
Prophase	15	15.5	3.7
Metaphase	2	2.1	0.5
Anaphase	5	5.2	1.2
Telophase	10	10.3	2.5

6 Nucleic acids

- 1 There is only room in the DNA double helix for one nucleotide with one ring, and one with two rings, to link together. Moreover, C and G join with three hydrogen bonds, while A and T join with two.
- 2 RNA has U, DNA has T. RNA has ribose, DNA has deoxyribose.
- 3 14% are guanine. If 36% are A then 36% must be T, making a total of 72% A + T. That leaves 28% for G and C. The proportion of G must be equal to the proportion of C so there must be 14% G and 14% C.
- 4 DNA polymerase: joins adjacent nucleotides during DNA replication.
DNA ligase: joins the sections of DNA on the lagging strand.

- 5 DNA polymerase can only work in a 5' to 3' direction. It starts at the base of the leading strand and can work upwards in a continuous motion towards the replication fork. On the lagging strand it has to join at the replication fork and work downwards and can only rejoin when the replication fork has moved on. This is slower and requires DNA ligase to join gaps between sections of DNA.
- 6 Three
- 7 UUACGAUACGCA
- 8 GUA, CCU, GAC
- 9 a AUG ACU UGU AGU; Met–Thr–Cys–Ser
b AUG ACA UGU AGU; Met–Thr–Cys–Ser
c AUG CCU UGU AGU; Met–Pro–Cys–Ser
d AUG ACU UGA AGU; Met–Thr

7 Plant transport

- 1 Errors include: shading, drawing individual cells, some lines are not clear, label lines are not straight.
- 2 In the root, xylem and phloem are in the centre; in the stem they are located in bundles towards the outside.
In the root, the xylem and phloem are in the centre in one 'bundle'; in the stem, they are in separate bundles.
In both root and stem, xylem is on the inside while phloem is on the outside.
- 3 Any three from: xylem contains lignin, phloem does not; phloem has companion cells, xylem does not; xylem vessels have no cross walls, sieve tube elements have sieve plates; sieve tube elements and companion cells contain cytoplasm, xylem does not; companion cells contain organelles, while there are no organelles in any xylem vessels.
- 4 Your plan diagram should:
 - be large – preferably larger than the diagram in the book
 - be drawn with clear, clean lines
 - not show any individual cells
 - be made up of four concentric lines – a pair of lines quite close together on the outside to represent the epidermis and root hairs; a line much closer to the centre of your drawing representing the boundary between the cortex and the endodermis; another line close to the last one representing the inner edge of the endodermis; and then a cross-shaped structure representing the xylem and phloem
- 5 Apoplast pathway passes through cell walls; symplast passes through cytoplasm. Apoplast does not cross a membrane; symplast crosses membranes. Symplast moves by osmosis; apoplast does not. Symplast passes through plasmodesmata; apoplast does not.

- 6 By crossing a membrane, mineral ions have to pass through channels and carriers because they cannot pass the phospholipid bilayer. This means that the cells can control which mineral ions pass through.
- 7 When the transpiration rate is high, there is high tension within the xylem. This creates a suction that narrows the xylem vessels, causing the tree trunks to narrow.
- 8 Any two from: rolled up leaf to trap water vapour; stomata in pits to trap water vapour; thick upper epidermis to reduce water loss; hairs to trap water vapour.
- 9 a Energy is provided.
b Energy is not provided.
- 10 Movement of water up the xylem is down a water potential gradient, from roots to leaves. This gradient is maintained by transpiration in the leaves, which lowers the water potential there. The gradient is always in the same direction.
Movement of sap in phloem is down a pressure gradient, from source to sink. High pressure is produced by active loading of sucrose into the phloem at a source, which causes water to follow by osmosis. Different parts of the plant can act as sources at different times – for example, leaves when they photosynthesise or roots when the starch stored in them is broken down. Different parts can also act as sinks at different times – for example, roots in autumn when they are building up starch stores or flowers when they are using sugars to produce nectar.
- 11 a Leaves are sources; flowers and roots are sinks.
b Leaves are sources; fruits and roots are sinks.
c Roots are sources; leaves are sinks.
d Roots are sources; leaves are sinks.

8 Transport in mammals

- 1 Any three from: arteries have more muscle to control blood flow; arteries have more elastic fibres to allow wall to expand and recoil as high pressure, pulsing blood passes through; arteries have more elastic fibres to smooth the blood flow; veins have valves to prevent backflow of blood, which is at low pressure.
- 2 No. The pulmonary artery carries deoxygenated blood.
- 3 Skeletal muscle contraction presses on veins, moving the blood. The valves prevent blood from flowing backwards.
- 4 Plasma contains large plasma proteins that will not pass through the gaps in the capillary wall.
- 5 Rapidly respiring muscle tissues have a high oxygen demand and have a high rate of carbon dioxide release. The high carbon dioxide concentration will produce a Bohr shift, so that more oxygen is released to the muscle tissue.

- 6 The haemoglobin will have a higher affinity for oxygen and so bind it more tightly. It can bind to oxygen in an atmosphere with a lower partial pressure.
- 7 Time taken for one complete heartbeat is about 0.75 seconds. So in 1 minute there will be $60/0.75 = 80$ beats.
- 8 Some blood will flow backwards, so that there is a slower movement of oxygen around the body. This means that tissues are less able to respire.
- 9 To allow time for the ventricles to fill.
- 10 To push the blood upwards into the arteries.

9 Gas exchange

- 1 Goblet cells produce mucus to trap bacteria and dust. The cilia then beat to move the mucus out of the lungs into the oesophagus and stomach, where the bacteria are digested.
- 2 Loss of elastic fibres means that the alveoli will not stretch to take in a full volume of oxygen and will also not recoil, so it is difficult to expel air. The diffusion gradient between blood and alveolus is not maintained.
- 3 Trachea or bronchus. Ciliated epithelia and cartilage are present in both. It is not bronchiole because cartilage is not present in the bronchioles.

10 Infectious disease

- 1 *Vibrio cholerae*
- 2 Any two from: poor sanitation; lack of sewerage; lack of water purification; poverty; overcrowded areas.
- 3 The cause of an infectious disease is the pathogen that enters the body and makes you ill. A vector for a disease is an organism that transmits the pathogen into the body.
- 4 Any two from: *Plasmodium falciparum*, *Plasmodium malariae*, *Plasmodium ovale*, *Plasmodium vivax*.
- 5 There are many possible methods. The broad strategies would focus on: preventing being bitten (nets, long-sleeved clothing etc.), reducing mosquitoes (insecticides, draining water etc.), taking antimalarial drugs, vaccination.
- 6 Social methods include better housing, pasteurising milk, reducing malnutrition.
Medical methods include HIV medication, antibiotics, vaccination.
- 7 HIV-positive means that the person has been infected with the virus. AIDS means that the virus is causing the symptoms of disease.
- 8 Penicillin affects bacterial cell walls. Eukaryotic cells and viruses do not have cell walls made of peptidoglycan.

- 9 Any two from: only use antibiotics when necessary; do not use antibiotics against viral infections; ensure people finish a course of antibiotics; use more than one antibiotic at the same time.

11 Immunity

- 1 Macrophage, neutrophil, (monocyte)
 - 2 Phagocytic cells bind to a pathogen. They then engulf the pathogen and ingest it by endocytosis. The endocytosed vesicle fuses with a lysosome, which releases enzymes to digest the pathogen.
 - 3 The mitochondria provide ATP for protein synthesis and secretion. The rough endoplasmic reticulum provides sites for the synthesis of antibodies (which are proteins). The Golgi bodies prepare the antibodies for secretion.
 - 4 Macrophages ingest antigens, which they display on their cell-surface membrane. B-lymphocytes respond to the antigens, dividing by mitosis to produce plasma and memory cells. The plasma cells release antibodies. T-lymphocytes bind to the antigens on the macrophages and divide by mitosis. They produce T killer cells, which attack and kill infected cells, and T helper cells, which release cytokines to induce T-cell and B-cell mitosis. T memory cells are also produced.
 - 5 The antigens on smallpox will have a different shape from the antigens on cholera. The antibodies that bind to the smallpox antigen will be different from those that bind to the cholera antigen.
 - 6
 - a Passive, natural immunity
 - b Active, artificial immunity
 - c Active, natural immunity
 - d Passive, artificial immunity
 - 7 False positive: infection with other viruses with similar antigens; presence of viral antigens after an infection has finished.
False negative: viral antigens have mutated, so do not bind the antibody; insufficient antigen present; ELISA kit has been heated or damaged, so the antibody shapes have changed.
- 5 The electron transport proteins cannot be oxidised, so electron transport stops. If no electrons are transported, no more hydrogen ions are moved into the intermembrane space and so there is no gradient and no ATP synthesis.
 - 6 If no oxygen is present, there is no electron acceptor, the movement of electrons along the electron transport chain stops and so NADH is not oxidised. If there is no NAD regenerated, the Krebs cycle and the link reaction will stop.
 - 7
 - a 0.7 – lipid
 - b The RQ would rise because anaerobic respiration has an infinite RQ.
 - 8 If there is no soda lime then no carbon dioxide will be absorbed. If the organisms are respiring aerobically, using glucose as a substrate, then the volume of oxygen taken in will equal the volume of carbon dioxide given out, and there will be no change in the level of fluid in the manometers.
 - 9 Possible factors to keep constant include: pH, volume and density of yeast, species of yeast, concentration of DCPIP, and concentration of respiratory substrate.

13 Photosynthesis

- 1 The light-dependent stage takes place on the thylakoid membranes. The light-independent stage takes place in the stroma.
- 2 The absorption spectrum shows the wavelengths of light that can be absorbed. The action spectrum shows which wavelengths of light can be used. We would therefore expect the two to be very similar to one another.
- 3 Deep-sea algae will only be exposed to blue and green light. Accessory pigments may be able to absorb some green light.
- 4 The energy ends up in ATP molecules.
- 5 Reduced NADP, ATP and oxygen
- 6 Substrate: carbon dioxide
Product: intermediate compound or GP
- 7 ATP provides energy for the conversion of GP into TP and is used to add a phosphate to RuP to make RuBP. Reduced NADP is used to reduce the GP.
- 8 Light and carbon dioxide must be limiting photosynthesis as increasing both increased the rate.
- 9 Light intensity: use a light meter.
Carbon dioxide concentration: use the same concentration of sodium hydrogencarbonate solution.
Temperature: use a water bath and heat shield.
Same species/age/mass/surface area of pond weed – use the same specimen.

12 Respiration

- 1 Active transport, protein synthesis, muscle contraction
 - 2 Phosphorylation raises the energy level of the molecule, making it able to take part in the reaction.
 - 3 One proton and one electron
 - 4 Glycolysis – cytoplasm
Link reaction – matrix of mitochondria
Krebs cycle – matrix of mitochondria
Oxidative phosphorylation – inner membrane of mitochondria
- 1 The light-dependent stage takes place on the thylakoid membranes. The light-independent stage takes place in the stroma.
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Temperature: use a water bath and heat shield.
Same species/age/mass/surface area of pond weed – use the same specimen.

14 Homeostasis

- 1** Blood glucose concentration is high.
Insulin is released.
Blood glucose concentration falls.
Insulin release stops due to negative feedback.
- 2** Meat has a higher protein content. Excess amino acids are deaminated and the ammonium is converted into urea.
- 3 a** If blood volume decreases, the pressure decreases. A lower blood pressure results in a reduction in ultrafiltration rate.
b Excess blood pressure will force plasma protein through the slits in the basement membrane of the Bowman's capsule.
- 4** The microvilli provide a large surface area, so that there are many ion channels and pumps to absorb substances. The abundant mitochondria produce large quantities of ATP for active transport.
- 5** The loss of water from the filtrate increases the concentration of all the solutes in it.
- 6** Desert animals need to conserve water. A long loop of Henle means that there is a long medulla with a sodium chloride gradient so that large quantities of water are absorbed in the loop of Henle and the collecting duct.
- 7** If ATP is not produced in the ascending limb, there is no active pumping of sodium ions out of the ascending loop. If there is no salt gradient, there is little or no removal of water by osmosis from the descending limb.
- 8** There would be a water potential gradient from the cytoplasm of the red blood cell into the plasma. Water would move out of the cell by osmosis, through its partially permeable cell surface membrane. This would decrease the volume of the cell, so it would shrink.
- 9** If there is no ADH released, there is no ADH to bind with receptors on the membranes of the collecting duct cells. No cAMP is released, so the vesicles containing aquaporins do not fuse with the membrane. This means that the collecting duct is impermeable to water and less water is absorbed.
- 10** Insulin: produced by β cells, released when blood glucose concentration is high, causes liver cells to produce glycogen.
Glucagon: produced by α cells, released when blood glucose concentration is low, causes liver cells to break down glycogen.
- 11** One signalling molecule (e.g. a hormone molecule) activates large numbers of glycogen phosphorylase enzymes.
- 12** The biosensor gives a digital readout, which is easy to interpret and has a continuous range. Dipsticks give a colour that you have to match against a colour scale, and have a discontinuous range.

15 Control and coordination

- 1** Receptor, sensory neurone, synapse, relay neurone, synapse, motor neurone, effector
- 2** Sodium-potassium pump: actively pumps three sodium ions out and two potassium ions into the neurone.
Potassium ion channels: open to allow some potassium ions to diffuse out of the neurone.
Sodium ion channels: closed, preventing influx of sodium ions.
- 3** Sodium ion channels are opened by ligands or a change in membrane potential difference. This causes sodium ions to diffuse in down their concentration gradient.
- 4** The opening and closing of the potassium ion channels is caused by changes in the potential difference across the membrane. They open when this is positive inside, and close when it is negative inside. They are voltage-gated channels.
- 5** In myelinated neurones the impulse jumps from node to node, which is saltatory transmission. In unmyelinated neurones, the impulse travels down every part of the neurone membrane.
- 6** The impulse arrives, causing voltage-gated calcium ion channels to open. Calcium ions diffuse into the neurone. Vesicles move to the presynaptic membrane and fuse, causing the release of neurotransmitters. The neurotransmitters diffuse across the synaptic cleft and bind to receptors. This causes sodium ion channels to open. Sodium ions diffuse into the neurone causing depolarisation, which causes voltage-gated sodium ion channels to open and leads to an action potential.
- 7** The vesicles containing transmitter substance are present only in the presynaptic neurone, so the impulses can only be transmitted from this one, not from the postsynaptic neurone. Also, there are only receptors for the transmitter substance on the membrane of the postsynaptic neurone, not on the presynaptic neurone.
- 8** A muscle fibre is made up of many myofibrils arranged side by side. It is a specialised cell. It is surrounded by a cell surface membrane (sarcolemma) and contains several nuclei and other organelles, especially mitochondria and endoplasmic reticulum. A myofibril is one of several cylindrical structures within a muscle fibre; it contains filaments. A filament can be one of two types – either actin or myosin – and is essentially a protein molecule.
- 9** The mitochondria are the sites in which the Krebs cycle and the electron transport chain generate ATP. ATP is required for the detachment of the myosin heads from the actin filaments, allowing the filaments to slide past one another and cause the muscle to contract.

- 10** Your table could include the following:
- Both are small molecules that act as cell signalling first messengers.
 - Animal hormones are carried in the blood, but plant hormones travel in phloem or by diffusion.
 - Animal hormones are made in endocrine glands, but plant hormones are made in tissues that are not organised into glands.

16 Inheritance

- 1** **a** meiosis
b mitosis
c mitosis
- 2** The gametes in the self-pollinated plant will both be made from mother cells of the same genotype. These gametes will vary slightly in their genotypes because of independent assortment and crossing over, but this can only arise from reshuffling of the same set of alleles in each. The gametes in the cross-pollinated plant will have come from mother cells of different genotypes, in different plants. They will therefore have a different range of alleles. This will result in a wider range of possible allele combinations in the offspring from the cross-pollinated plant.
- 3** Short fur: **HH, Hh**; long fur: **hh**
- 4** **a** Parents: **Tt, tt**; child: **tt**
b 0.5 or 50%
- 5** Parents are **C^RC^W** and **C^WC^W**; offspring genotypes: **C^RC^W** and **C^WC^W** in a 1:1 ratio; offspring phenotypes: pink and white in a 1:1 ratio.
- 6** Parents' phenotypes Blood group AB × Blood group AB
Parents' genotypes **I^AI^B** **I^AI^B**
Gametes' genotypes **I^A** **I^B** **I^A** **I^B**
Offspring genotypes and phenotypes
- | | | |
|----------------------|---|---|
| | I^A | I^B |
| I^A | I^AI^A
Blood group A | I^AI^B
Blood group AB |
| I^B | I^AI^B
Blood group AB | I^BI^B
Blood group B |
- 7** The allele for colour blindness is carried on the X chromosome. A man passes only his Y chromosome to his son.
- 8** Parents' phenotypes Brown hair, long legs × Black hair, short legs
Parents' genotypes **AaLl** **aall**
Gametes' genotypes **AL** **Al** **aL** **al** **al**
Offspring genotypes and phenotypes
- | | | | | |
|-----------|----------------------------|-----------------------------|----------------------------|-----------------------------|
| | AL | Al | aL | al |
| al | AaLl
brown, long | Aall
brown, short | aaLl
black, long | aall
black, short |

- 9** Parents' phenotypes Brown eyes, dark fur × Brown eyes, dark fur
Parents' genotypes **EeFf** **EeFf**
Gametes' genotypes **EF** **Ef** **eF** **ef** **EF** **Ef** **eF** **ef**
Offspring genotypes and phenotypes

	EF	Ef	eF	ef
EF	EEFF brown, dark	EEFf brown, dark	EeFF brown, dark	EeFf brown, dark
Ef	EeFf brown, dark	EEff brown, pale	EeFf brown, dark	Eeff brown, pale
eF	EeFF brown, dark	EeFf brown, dark	eeFF blue, dark	eeFf blue, dark
ef	EeFf brown, dark	Eeff brown, pale	eeFf blue, dark	eeff blue, pale

The shaded rows and columns show the uncommon gametes and offspring phenotypes. We would therefore expect most offspring to be in the ratio 3 brown, dark : 1 blue, pale. There will be a small number of other combinations.

- 10** Parents' phenotypes Agouti × Agouti
Parents' genotypes **AaBB** **AaBb**
Gametes' genotypes **AB** **aB** **AB** **Ab** **aB** **ab**
Offspring genotypes and phenotypes

	AB	aB
AB	AABB agouti	AaBB agouti
Ab	AABb agouti	AaBb agouti
aB	AaBB agouti	aaBB black
ab	AaBb agouti	aaBb black

We would expect offspring in the ratio 3 agouti : 1 black.

- 11** A white mouse could have the genotype **AAbb**, **Aabb** or **aabb**. We could cross this mouse with a pure-breeding black mouse, with the genotype **aaBB**.
- If the unknown mouse has the genotype **AAbb**, then all the offspring will be agouti (**AaBb**).
- If the unknown mouse has the genotype **Aabb**, then half the offspring will be agouti (**AaBb**) and half will be black (**aaBb**).
- If the unknown mouse has the genotype **aabb**, then all the offspring will be black (**aaBb**).

12 a If the genes are linked:

Parents' phenotypes Yellow, large × Yellow, large
 Parents' genotypes **YyPp** **YyPp**
 Gametes' genotypes **YP yp** **YP yp**
 Offspring genotypes and phenotypes

	YP	yp
YP	YYPP yellow, large	YyPp yellow, large
yp	YyPp yellow, large	yypp white, small

This would give a ratio of 3 yellow, large : 1 white, small if the genes are totally linked. If there is some crossing over, we would expect to get small numbers of other phenotypes.

b If the genes are not linked:

Parents' phenotypes Yellow, large × Yellow, large
 Parents' genotypes **YyPp** **YyPp**
 Gametes' genotypes **YP Yp yP yp** **YP Yp yP yp**
 Offspring genotypes and phenotypes

	YP	Yp	yP	yp
YP	YYPP yellow, large	YYPp yellow, large	YyPP yellow, large	YyPp yellow, large
Yp	YYPp yellow, large	YYpp yellow, small	YyPp yellow, large	Yypp yellow, small
yP	YyPP yellow, large	YyPp yellow, large	yyPP white, large	yyPp white, large
yp	YyPp yellow, large	Yypp yellow, small	yyPp white, large	yypp white, small

This would give a ratio of 9 yellow, large : 3 yellow, small : 3 white, large : 1 white, small

13 First, work out the expected numbers if there is no linkage. You should find that you would expect a 1:1:1:1 ratio of phenotypes.

	White, long	White, short	Grey, long	Grey, short
Observed numbers, <i>O</i>	12	2	2	12
Expected numbers, <i>E</i>	7	7	7	7
<i>O</i> - <i>E</i>	5	-5	-5	5
(<i>O</i> - <i>E</i>) ²	25	25	25	25
(<i>O</i> - <i>E</i>) ² / <i>E</i>	3.6	3.6	3.6	3.6
$\sum \frac{(O-E)^2}{E} = 14.4$				

We have four different categories, so the number of degrees of freedom is 3. Looking up the value of chi-squared for 3 degrees of freedom, we find that our number lies between a probability of 0.01 and 0.001 that the null hypothesis (i.e. there is no linkage) is correct. This is much less than the critical value of 0.05, so we can say that the null hypothesis is not correct, and that our results show that the two genes are linked.

14 *F8* gene: haemophilia

Haemoglobin gene: sickle-cell anaemia

TYR gene: albinism

HTT gene: Huntington's disease

15 A plant with genotype *LeLe* already makes gibberellin, so can already grow tall. Adding more gibberellin is unlikely to have any effect.

16 It is wasteful to produce the enzyme when there is no substrate for it. The bacterium saves energy and materials by not making the enzyme in these circumstances.

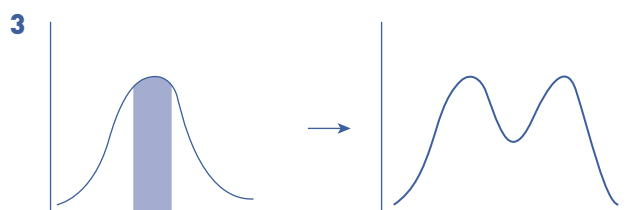
17 Selection and evolution

1 The height of maize plants: genes and environment

Cats having curly or straight fur: genes

The presence of scar tissue in skin: environment

2 A mutation occurred that caused fur to produce spines. More hedgehogs with spines survived because they were predated less. These hedgehogs with the allele for spines bred and passed on the allele for spines to the next generation. This continued over several generations, so that the allele frequency for spines increased.



4 Both reduce the number of different alleles/decrease the gene pool. The founder effect occurs when a few individuals start a new population. A genetic bottleneck occurs when many individuals die so that alleles are lost from the population.

5 Frequency of the homozygous recessive animals (*q*²) is 100 in 5000, or 0.02.

a So *q* is the square root of 0.02, which is 0.14.

b *p* is 1 - 0.14, which is 0.86.

Therefore the frequency of heterozygotes is 2*pq*, which is 2 × 0.14 × 0.86 = 0.24.

We would therefore expect about 24% of the animals to be heterozygotes.

- 6 Both reduce the gene pool and are linked to selection for a set of alleles. In natural selection, the environment selects the alleles; in selective breeding, humans select the alleles.

18 Biodiversity

- 1 It is impossible to see if extinct organisms or asexual species can breed together.
- 2 **a** Genus: *Panthera*: tiger, lion, leopard; *Acinonyx*: cheetah.
Species: *tigris* (tiger); *leo* (lion); *pardus* (leopard); *jubatus* (cheetah)
b Tigers, lions and leopards are more closely related to each other than they are to cheetahs.
- 3 estimated total population size = $\frac{38 \times 40}{6}$
= 253
- 4 Calculate $\frac{n}{N}$ for each species. Then square each value. Add them up and subtract from 1.

Species	Number of individuals, n	$\frac{n}{N}$	$\left(\frac{n}{N}\right)^2$
A	2	0.010	0.000
B	35	0.174	0.030
C	1	0.005	0.000
D	81	0.403	0.162
E	63	0.313	0.098
F	2	0.010	0.000
G	5	0.025	0.001
H	11	0.055	0.003
I	1	0.005	0.000
	Total number of individuals = 201		

$$\sum \left(\frac{n}{N}\right)^2 = 0.294$$

$$\text{So } D = 1 - 0.294 = 0.706$$

- 5 Possible reasons can include: to maintain food webs; ethical reasons; social reasons, such as tourism; source of medicines; to maintain biodiversity.
- 6 Carp are an invasive species and so may have fewer predators than native species. They may out-compete native species for food and territory, consume native species, spread disease or damage habitat.
- 7 Breeding programmes aim to increase numbers while maintaining or increasing genetic diversity. Checking the pedigrees means that closely related

animals are not used to breed. This reduces the risk of inbreeding, which can lead to increased rates of genetic conditions.

19 Genetic technology

- 1 Selective breeding can only reshuffle alleles that are already present in a species. Gene technology introduces completely new alleles from a different species.
- 2 Remove mRNA from pituitary gland cells. Use reverse transcriptase to convert mRNA into cDNA. Cut cDNA with restriction endonucleases to create sticky ends. Cut a plasmid vector with the same restriction endonuclease and insert the cDNA using DNA ligase. Place the recombinant plasmid into bacteria and select the bacteria that have successfully taken it up. Grow the bacteria in a fermenter.
- 3 Add the gene for GFP along with the insulin gene. Bacteria that have taken up the GFP gene can be identified by shining UV light onto them. Bacteria that glow green in UV light are those that have taken up the GFP gene, and therefore are also likely to have taken up the insulin gene.
- 4 $2^{30} = 1\,073\,741\,824$
- 5 DNA: TAATCCGCA; RNA: UAAUCCGCA
- 6 Recombinant insulin: can be mass produced; is cheaper to produce; has the same amino acid sequence as human insulin so lower doses are required; has less risk of allergies; has no ethical or religious objections.
- 7 A genetic condition caused by a recessive allele can be treated if a dominant allele can be inserted. A genetic condition caused by a dominant allele would require the allele to be removed.
- 8 Issues include: the possible effect on someone's life of discovering a genetic condition that cannot be treated; screening embryos and unborn children raises ethical issues of selective offspring; the possibility of selecting the sex of offspring; the question of what are considered to be 'correct' genes and alleles; the potential for insurance companies to request genetic screening.
- 9 GM crops may escape and affect food chains, compete with native species, hybridise with wild species and pass their genes into other populations. They can encourage increased use of herbicides.

A Level experimental skills and investigations

1

x	$(x - \bar{X})$	$(x - \bar{X})^2$
23.0	-17.5	306.25
46.5	6.0	36.00
52.0	11.5	132.25
32.5	-8.0	64.00
43.0	2.5	6.25
50.5	10.0	100.00
26.5	-14.0	196.00
31.5	-9.0	81.00
54.0	13.5	182.25
28.0	-12.5	156.25
47.5	7.0	49.00
39.0	-1.5	2.25
58.5	18.0	324.00
47.5	7.0	49.00
33.5	-7.0	49.00
42.5	2.0	4.00
26.5	-14.0	196.00
51.0	10.5	110.25
38.0	-2.5	6.25
38.5	-2.0	4.00
Mean $\bar{X} = 40.5$		$\Sigma(x - \bar{X})^2 = 2051.75$

$$s = \sqrt{\frac{2051.75}{19}} = 10.4$$

2 $S_M = \frac{s}{\sqrt{n}}$
 $= 10.4/4.47$
 $= 2.3 \text{ mm}$

3

Quadrat	Number of species P	Rank for species P	Number of species Q	Rank for species Q
1	6	6	5	7
2	12	2=	22	2
3	1	9	3	9=
4	0	10	4	8
5	16	1	35	1
6	8	5	10	5
7	11	4	11	4
8	4	8	9	6
9	5	7	3	9=
10	12	2=	21	3

Quadrat	Rank for species P	Rank for species Q	Difference in rank, D	D^2
1	6	7	-1	1
2	2=	2	0	0
3	9	9=	0	0
4	10	8	2	4
5	1	1	0	0
6	5	5	0	0
7	4	4	0	0
8	8	6	2	4
9	7	9=	-2	4
10	2=	3	-1	1
				$\Sigma D^2 = 14$

Substitute into the equation:

$$r_s = 1 - \frac{6 \times 14}{103 - 10}$$

$$= 1 - \frac{84}{990}$$

$$= 1 - 0.08$$

$$= 0.92$$

This is well above the critical value for r_s when $n = 10$, so there is a significant correlation between the distributions of P and Q.

4

Mollusc	Shell length/mm (x)	Body mass/g (y)	xy
1	38	6.1	231.8
2	18	3.6	64.8
3	20	3.2	64.0
4	31	5.7	176.7
5	12	2.6	31.2
6	12	3.2	38.4
7	25	4.7	117.5
8	20	3.6	72.0
9	29	4.7	136.3
10	19	3.3	62.7
Mean	$\bar{x} = 22.4$	$\bar{y} = 4.07$	$\Sigma xy = 995.40$

$$n\bar{x}\bar{y} = 10 \times 22.4 \times 4.07 = 911.68$$

standard deviation for $x = 8.34$

standard deviation for $y = 1.17$

$$r = \frac{\Sigma xy - n\bar{x}\bar{y}}{(n-1)s_x s_y}$$

So:

$$r = \frac{995.40 - 911.68}{87.820}$$

$$= 0.95$$

This number is close to 1, suggesting that there is a linear correlation between these two sets of data.