

Communication, homeostasis and energy

5.1 Communication and homeostasis

5.1.1 The need for communication systems (page 11)

- Blinking when an object moves close to the eye; sweating when it gets too hot; eating when hungry.
 - Blinking uses the neuronal system as it needs to be rapid; sweating uses the hormonal system as it is a longer-term response – it must be continued until you are cool; eating also uses the hormonal system as it is not a rapid response.
- Bending towards the light; opening stomata when it gets light.
- Kidney; lungs; liver; skin.
- Heart – pumps blood; blood vessels – deliver blood to organs; liver – metabolises many substances and stores sugars, etc.; kidney – excretion of metabolites; lungs – excretion of carbon dioxide; skin – temperature control; brain – coordination; adrenal gland, thyroid glands, pancreas, etc. – release hormones.
- So that actions of all cells and tissues in body can be coordinated.
 - So that only the cells that need to respond will respond to the signal.
 - To enable response to rapid changes in the environment.
 - So that the response can be suited to the environmental change – a short-term change in the environment only requires a short-term response, but other changes may require a long-term response.

5.1.2 Homeostasis (page 13)

- The maintenance of a constant internal environment despite changes in external and internal factors.
- Body temperature – to keep enzymes working at their optimum.
Blood glucose concentration – to supply sufficient glucose to tissues for respiration without decreasing the water potential of the blood too much.
Blood salt concentration – to maintain the water potential of the blood and to maintain blood pressure.
Water potential of the blood – to maintain blood pressure and to ensure cells are in the correct conditions.
Blood pressure – to ensure it is high enough to deliver blood efficiently, but without damaging blood vessels.
Carbon dioxide concentration – carbon dioxide reacts with water to form an acid; a change in pH could alter protein structure and affect enzyme activity.
- To detect changes in the environment.
 - To carry out a response.
- Input is the information sent from the sensory receptors to the coordination centre about changes in the environmental conditions. Output is the information sent by the coordination centre to the effectors.
- Negative feedback occurs where the change in conditions detected by the sensory receptors is reversed by the action of the effectors. Positive feedback occurs where the initial change in conditions is increased by the action of the effectors.
- As temperature increases the rate of chemical reactions increases. This increases the release of heat from these reactions. As a result the animal gets even warmer. This speeds up the chemical reactions even more. Causes heat stroke, enzymes may be denatured and the animal dies.

5.1.3 Temperature control in ectotherms (page 15)

- Cell activities depend upon enzyme activity. All enzymes have an optimum temperature. Too low and they work too slowly, too high and they become denatured.
- Early in the morning the fly is cold, its muscles do not work effectively and it cannot move quickly.
- Flapping wings uses the wing muscles. They generate heat as they contract, warming the dragonfly.
- If the animal is too cold it can absorb heat from the rock and from the sun.

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5. Insects are ectothermic, therefore they do not use metabolic energy to keep warm. Therefore, more of their food goes towards growth. They can grow much more quickly than endotherms.

5.1.4 Temperature control in endotherms (page 17)

1. Vasodilation is the widening of arterioles leading to the skin surface. More blood can flow to the surface, carrying heat, which can be radiated away. Therefore, the body will cool down. Vasoconstriction is the narrowing of arterioles leading to the surface of the skin. Less blood flows close to the surface and so less heat is lost by radiation. The body stays warmer.
2. Elephants have a small surface area to volume ratio. In hot weather they tend to overheat. The ears have a good blood supply and act as radiators to help lose heat from the body.
3. Australia is warm, therefore the birds do not lose much heat to their surroundings. The birds can survive even though they have a large surface area to volume ratio. Antarctica is cold: a small bird with a large surface area to volume ratio would lose too much heat. A larger bird has a smaller surface area to volume ratio and does not lose such a high proportion of its body heat.
4. A shrew is very small and very active. It has a large surface area to volume ratio and loses a lot of heat to the environment. An elephant has a small surface area to volume ratio and does not lose such a high proportion of its body heat to the environment. Also, if the shrew lives in the UK it is in cooler conditions and loses more heat to the environment than an elephant living in a warmer climate. The shrew needs to eat more in order to replace the energy lost as heat.
5. The arctic fox has enough fur to keep warm while stationary or sleeping. When it is active it tends to overheat. It must lose heat through its lower legs to the snow. Having less fur on the lower legs enables heat to be lost. Also, fur on the lower legs may get very wet and enhance heat loss when the animal wants to conserve heat.

5.1 Practice questions (page 20)

1. B
2. C
3. A
4. D
5. A
6. (a) Maintenance of the internal environment; constant; despite changes in external and internal factors.
(b) Skin: used to regulate body temperature; kidney: used to regulate water potential of blood; liver: used to regulate blood sugar levels/regulate temperature/remove toxins.
(c) Positive feedback increases a change: this will lead to greater change/fluctuations; homeostasis should decrease or reverse a change.
7. (a) Hypothalamus of the brain.
(b) Monitors temperature of blood; receives information about external temperatures from skin receptors; sends output to the effectors.
(c) Any three from: reduced metabolism in liver; increased sweating; vasodilation; hair lies flat; sit in shade.
(d) Two marks for two correct decisions and two marks for linked justifications.
Find shelter; to avoid exposure.
Huddle together; to reduce total surface area of group.
Put on more layers of clothing; to increase insulation.
Eat more (warm) food; to supply energy for metabolism.
8. (a) Skin temperature will fluctuate more due to sun; core body temperature is maintained by homeostasis.
(b) Any three from: constant from 0 to 6 hours at 37 °C; drops briefly to 36 °C; rises to 39 °C at 14 hours; then falls steadily to 35 °C at 20 hours.
(c) 14 hours (accept 12–14 hours).
(d) Not as much water in the body; cannot use water to cool; cannot use latent heat of vaporisation to cool.

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9. (a)

Response	Explanation
A lizard will go underground or hide in a crevice when temperatures are high.	To avoid gaining too much heat from the environment.
Adders are venomous snakes found in the UK. They can often be found in sunny patches on a footpath.	To gain heat from the Sun.
The horned lizard can expand its rib cage when lying in the sun.	To increase its surface area for absorption of heat.
Early in the morning a dragonfly can be seen sitting on a plant stem flapping its wings.	To generate heat in its muscles.

(b) Detect the temperature of the surroundings; convert changes in heat to electrical impulses; send impulses to the central nervous system.

10. When it is too hot the jerboa will: burrow underground/find shade; reduce its metabolism; dilate the blood vessels in the skin; lose more water for evaporation.

When it is too cold the jerboa will: sit in the sun if during the day; go underground at night; constrict the blood vessels in the skin; reduce loss of water for evaporation; speed up metabolism in liver.

5.2 Excretion as an example of homeostatic control

5.2.1 Excretion (page 25)

1. Salts, urea, water, uric acid and ammonia.
2. Make the water potential too low (too negative). This draws water into the blood causing increased blood pressure. Potentially it could draw water out of the blood cells making them less effective.
3. Carbon dioxide reacts with water to form carbonic acid. Reducing the pH of the fluid will alter the shape of the enzyme active site, making the enzyme less active. Ammonia is highly alkaline: this will also affect enzyme active sites.
4. Excretion is the removal of metabolic products. Faeces mainly consists of fibre and other wastes that have never entered the body – they are not metabolic products.
5. Ammonia is highly toxic and highly soluble. Fish can access enough water to dilute the ammonia so it is not toxic. Mammals live on land and may not have access to enough water to dilute the ammonia sufficiently – so they convert it to a less toxic form and allow a higher concentration in their urine.

5.2.2 The structure of the liver (page 27)

1. The liver needs oxygen for respiration – so it receives oxygenated blood via the hepatic artery. The products of digestion enter the blood from the intestines. These may contain high levels of glucose, amino acids and toxins. If these uncontrolled concentrations are allowed to circulate the body they could interfere with cell activity. So the blood from the intestines goes straight to the liver in the hepatic portal vein.
2. The diet may contain toxins, for example, alcohol. Or digestion may release toxins from the food.
3. After a meal the concentrations of glucose and amino acids will rise. Once the products of digestion have been absorbed and passed to the liver the concentrations in the hepatic portal vein will fall.
4. Hepatic artery → branch of hepatic artery → sinusoid → branch of hepatic vein → hepatic vein.
5. The hepatic artery divides into many branches. These carry blood to the liver lobules. The branches divide to form many sinusoids. The sinusoids are very narrow and are lined by liver cells.
6. Ribosomes to synthesise proteins (enzymes). Mitochondria to supply ATP for active processes.

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5.2.3 Liver function (page 29)

1. In respiration, to release energy for metabolic processes. To build larger molecules, such as glycoproteins. Released into blood to raise blood glucose concentration.
2. These molecules contain energy. Parts of the molecules can be used in respiration to make ATP.
3. Ammonia is highly toxic and highly soluble. It will increase pH and affect enzyme activity. Urea is less toxic and less soluble – it can be kept in higher concentrations so that less water is used in excretion.
4. To release energy in the form of ATP. ATP is used to synthesise enzymes and for any energy-requiring reactions. The aerobic respiration also generates heat, which can be used in endotherms to maintain body temperature in cold conditions.
5. There are many different metabolic reactions taking place – each needs its own enzymes. Enzymes are proteins synthesised by the ribosomes.

5.2.4 Kidney structure (page 31)

1. The kidneys remove metabolic waste – the concentration of metabolic waste in the blood must be kept low. The wastes are concentrated in the urine so a large volume of blood is needed to make a small volume of urine. Many of the cells in the kidney are active – they need a good supply of oxygen.
2. This makes the tubules longer so there is a larger total surface area for the selective reabsorption that takes place.
3. The substances reabsorbed from the fluid in the nephron must be returned to the blood.
4. Useful substances, such as glucose and amino acids, must all be removed from the fluid in the nephron. Wastes, such as urea and excess salts, should remain in the fluid so that they can be excreted as urine.
5. A large volume of blood passes through the kidney. If the water in it is all lost in urine the body will dehydrate very quickly. A terrestrial animal cannot find and drink enough water to replace all the water that passes through the kidney.

5.2.5 The function of the kidney 1 (page 33)

1. Ultrafiltration is filtration at a molecular level. The pores in the filter are small enough to prevent larger molecules from passing through.
2. To raise the pressure in the glomerulus would require some form of pumping action. The pressure is maintained at a high level by resistance to flow in the efferent arteriole – the blood cannot escape from the glomerulus easily so there is little drop in pressure.
3. The filtering mechanism is fine enough to prevent most proteins from passing out of the blood capillaries. The proteins are too large. Only a few very small proteins can pass into the urine.
4. The filtering mechanism does not prevent the movement of glucose and amino acids – they are small enough to pass through the filter with the water in the blood plasma.
5. Proteins are not reabsorbed. Water is withdrawn from the fluid in the nephron and this concentrates the proteins.
6. Large volumes of dilute urine would be produced. Very rapid dehydration.

5.2.6 The function of the kidney 2 (page 35)

1. The wall of the collecting duct is permeable to water. As the duct passes through the region of lower water potential water is drawn out of the urine by osmosis. This conserves water, making the urine more concentrated.
2. Terrestrial animals do not always have access to water. They need to conserve water so that they do not need to drink constantly.
3. The camel is adapted to dry climates. Water is not available easily. A long loop of Henle can concentrate the salts in the medulla more and therefore concentrate the urine more effectively.
4. The beaver lives in a watery habitat. It has water easily available and can drink as much as it needs. It does not need to concentrate the urine so much.
5. (a) Water is reabsorbed from the fluid in the distal convoluted tubule, but urea is not reabsorbed. Therefore the concentration of urea rises. Also, some urea is actively pumped into the distal tubule.

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- (b) Both water and sodium are reabsorbed from the proximal tubule in equal amounts. Sodium is reabsorbed by secondary active transport and water is withdrawn by osmosis.

5.2.7 Osmoregulation (page 37)

1. Change in water potential → osmoreceptors in hypothalamus → hypothalamus/pituitary complex releases more/less ADH → collecting duct wall reabsorbs more/less water.
2. ADH will remain active as long as it is in the blood. If too much water is reabsorbed then the water potential of the blood will rise too high. Therefore ADH must be removed from the blood so that it does not cause too much reabsorption.
3. Hepatocytes in the liver.
4. The water potential of the blood must be kept constant. If it rises too high it must be brought down, but if it falls too low it must be raised to the correct level. Negative feedback brings about a reversal of the change that acted as a stimulus.
5. When ADH binds to the plasma membrane of the cells in the collecting duct it initiates a series of enzyme-controlled reactions. This causes vesicles containing aquaporins to move to and bind with the plasma membrane. The aquaporins are inserted into the plasma membrane and increase the permeability to water.
6. Neurosecretory cells have vesicles containing a hormone (e.g. ADH) rather than a neurotransmitter. They secrete the hormone (ADH) into the blood rather than into the synaptic cleft.
7. The osmoreceptor cells will absorb water by osmosis. They swell and stop stimulating the neurosecretory cells.

5.2.8 Kidney failure (page 39)

1. Dialysis does not take place continuously. Therefore a patient must limit the intake of substances that might increase excretion rates. Otherwise concentrations might build up too quickly.
2. Water, salts, proteins.
3.
 - (a) Dialysis relies on movement of excess water by osmosis, so as the water moves into the dialysis fluid the water potential changes, and osmosis will slow down and stop. Also, excess salts and urea move by diffusion – their concentration in the dialysis fluid must be kept low.
 - (b) If the dialysis fluid is too cold it will cool the patient's blood; equally, if it is too hot it will warm up the patient's blood.
 - (c) Infective pathogens could enter the blood stream causing disease.
- 4.

Advantages	Disadvantages
Cleans the blood of excretory products	Time-consuming
Maintains the water potential of the blood	Travel opportunities are limited
Keeps patient alive – until transplant available	May feel dependent on treatment, possibly causing depression
No need for major surgery	Diet must be monitored carefully
	Risk of infection

5.2 Practice questions (page 42)

1. A
2. C
3. C
4. B
5. D
6.
 - (a) Ornithine cycle.
 - (b) Excess amino acids; deamination.
 - (c) A = urea; B = carbon dioxide.

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- (d) Any eight described in correct order from: sinusoid; hepatic vein; vena cava; right side of heart; pulmonary artery; lungs; pulmonary vein; left side of heart; aorta; renal artery.
7. (a) Any three from: generate heat to keep warm; store glucose as glycogen; break down hormones and drugs; convert excess amino acids to urea.
- (b) Alcohol converted to ethanal; by ethanol dehydrogenase; ethanol converted to ethanoic acid; by ethanal dehydrogenase; ethanoic acid converted to acetyl CoA.
- (c) Break down of fatty acids requires NAD; to oxidise the fatty acids; if all NAD used to detoxify alcohol none left for fatty acid breakdown.
8. (a) Separation of a mixture; at a molecular level.
- (b) (i) Squeezed between the cells of the endothelium; through pores/fenestrations in endothelium cells.
(ii) Podocytes; gaps between major processes; minor processes hold cell away from capillary wall.
(iii) Basement membrane.
- (c) Efferent vessel narrower than afferent vessel; increases resistance to flow.
9. (a) Proteins are too large to pass through capillary wall and basement membrane into Bowman's capsule.
- (b) Amino acids pass out of blood into Bowman's capsule; selectively reabsorbed in proximal convoluted tubule.
- (c) (i) $100 \times 9.0 / 0.3 = 3000\%$
(ii) Water is reabsorbed from the collecting duct.
- (d) Water potential of blood becomes more negative; detected by osmoreceptors; in hypothalamus; signals sent to posterior pituitary; release of ADH; targets cells in collecting duct; makes wall of collecting duct more permeable to water.
10. (a) Sodium ions are removed from the cells lining the tubule; using active transport/ATP; this reduces the concentration of sodium in the cells; sodium ions diffuse into cells from fluid in tubule; through cotransport proteins; glucose taken into cell with the sodium.
- (b) The loop of Henle creates a high concentration of salts in the medulla.
- (c) Beaver (has access to a lot of water) does not need to save water/concentrate urine; short loop creates low salt concentration in medulla; little water reabsorbed from urine.
Kangaroo rat (has little water to drink) must save water/concentrate urine; longer loop can create higher concentration of salts in medulla; reabsorbs a lot of water from the urine.
Humans somewhere in the middle. Have access to plenty of water, but not excessive amounts, so they have a medium-length loop of Henle.
11. (a) $100 \times 6/70 = 8.57\%$
- (b) Sweat.
- (c) Decreases/becomes more negative.
- (d) Change in water potential detected by osmoreceptors; in hypothalamus of brain; osmoreceptors shrink; send impulse down neurosecretory cells; to posterior pituitary; release ADH into blood; ADH targets cells in collecting duct; they become more permeable to water; more water reabsorbed from fluid in collecting duct.

5.3 Neuronal communication

5.3.1 Roles of sensory receptors (page 47)

- Ions are charged particles and cannot diffuse through the phospholipid bilayer.
- Sensory receptors respond to changes in the environment. A constant sound is no longer a change. The receptor or the sensory neurone will become habituated to the sound and an impulse no longer reaches the brain.

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- Particles must be moved against their concentration gradient. This requires active transport – which requires energy in the form of ATP.
- Sodium ions will diffuse rapidly down a concentration gradient even without the immediate availability of ATP.
- Diffusion that is helped in some way by a protein. This is usually by supplying a pore through which the ions can diffuse easily.

5.3.2 Structure and function of neurones (page 49)

1.

Sensory	Motor
cell body outside CNS (in dorsal root ganglion)	cell body in CNS
short axon	long axon
long dendron	short dendrites
carry action potentials to CNS	carry action potentials away from CNS
myelinated	myelinated

- Transmitting action potentials is an active process – need to pump ions to create concentration gradients.

3.

Myelinated	Non-myelinated
individual Schwann cells wrapped around each neurone	one Schwann cell surrounds several neurones
very close junction between neurone and Schwann cell	looser junction
nodes of Ranvier present	no nodes of Ranvier
saltatory conduction	not saltatory
much faster transmission speed	slower transmission

5.3.3 Nerve impulses: action potentials (page 51)

- The neurone is using ATP to pump ions. Sodium ions are pumped out as potassium ions are pumped into the cell. This creates and maintains the resting potential across the plasma membrane.
- The concentration gradient will enable rapid movement of ions across the membrane when the ion channels open. Sodium ions can move in quickly and potassium ions can move out.
- To ensure that the inside of the cell remains negative compared with outside.
- In the generator region the sodium ion channels are opened by the presence of acetylcholine; elsewhere they are charge-gated – opened by changes in potential across the membrane.
- After an action potential the neurone membrane becomes hyperpolarised – more negative inside than at rest. The sodium ions and potassium ions need to be moved back to their original positions in order to reverse this hyperpolarisation.
- When the membrane begins to depolarise this causes more sodium ion channels to open allowing more sodium ions to flow into the neurone, increasing the depolarisation.

5.3.4 Nerve impulses: transmission (page 53)

- They are voltage-gated. A small change in the potential across the membrane caused by the local currents inside the cell opens the gates.
- The myelin sheath is closely bound to the membrane of the neurone: this prevents movement of ions across the membrane. Movement of ions across the membrane can only occur where there are gaps in the myelin sheath. These gaps occur at the nodes of Ranvier. The local currents are extended to carry the impulse between the nodes of Ranvier.
- Only a few ions need to move along the neurone to alter the charge at the next node. The ions can move along very quickly.
- Each action potential lasts 2–3 ms and is followed by a short refractory period while the membrane is hyperpolarised and ions are pumped back to their original locations.

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5.3.5 Synapses 1 (page 55)

- The swelling at the end of the neurone provides more space to store vesicles of the neurotransmitter and a larger surface area for exocytosis of the neurotransmitter.
- Many mitochondria produce ATP, which is required to synthesise the neurotransmitter and move the vesicles.
 - Smooth endoplasmic reticulum is where the acetylcholinesterase is synthesised and placed into vesicles.
- Because an action potential arriving at the pre-synaptic bulb will cause changes to the potential across the membrane – these will then open the voltage-gated calcium ion channels.
- Acetylcholinesterase hydrolyses the acetylcholine. If the acetylcholine remained in the synaptic cleft it would keep stimulating the post-synaptic neurone.
- The nicotine molecule has a shape that is similar to that of acetylcholine and complementary to that of the acetylcholine receptor site so it will fit into the site.

5.3.6 Synapses 2 (page 57)

- An action potential is a signal being carried along one cell. It is an electrical impulse. A cell signal is a message passed from one cell to another. It is a chemical signal.
- A synapse or nerve junction that uses acetylcholine (the neurotransmitter) as the signal between two neurones.
- Summation is the combined effect of several small potentials. Small potentials combine together to produce a larger potential that may reach the threshold.
- Adding more acetylcholine receptor sites to the membrane makes it more sensitive to the presence of acetylcholine. Having more receptor sites means that there are more sodium ion channels and the summation effect will enable the threshold potential to be reached more quickly.
- If you have just picked up something very hot the automatic reaction is to drop it. However, if you see that it is a very valuable item (such as a hot plate of food when you are very hungry) an IPSP sent to the relevant neurone can stop you dropping the food long enough to put it down safely.

5.3 Practice questions (page 60)

- B
- C
- C
- A
- C
- Smaller diameter reduces speed; 15 μm diameter allows 120 m s^{-1} , while 1.5 μm diameter allows 5 m s^{-1} .
 - $5 / 2 = 2.5$ times.
 - Myelin sheath does not allow ionic exchange across membrane; ionic exchange occurs only at nodes of Ranvier; action potential jumps from node to node/saltatory conduction.
- To detect changes in the environment; convert change to electrical impulse.
 - Pacinian corpuscle.
 - A = dendron; B = myelin sheath.
 - Membrane at rest is polarised; membrane is deformed by pressure; opens sodium ion channels; sodium ions flood into cell; causing depolarisation; called generator potential; if pressure is great enough this produces an action potential.
- E, B, A, C, D
 - Acetylcholine/neurotransmitter molecules; diffuse across cleft.
 - Vesicles of neurotransmitter; fuse to pre-synaptic membrane.
 - Sodium ion channels open; sodium ions flow into post-synaptic cell.

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- (iv) Calcium channels open; calcium flows into pre-synaptic cell.
9. (a) A small depolarisation; of the post-synaptic membrane.
 (b) Two small EPSPs together; create a larger post-synaptic potential.
 (c) Spatial summation is two or more pre-synaptic neurones contributing to the post-synaptic potential; temporal summation is two or more impulses in the same neurone contributing to a post-synaptic potential.
 (d) A change that repolarises the post-synaptic membrane; preventing an action potential forming.
 (e) An action potential will only form when the EPSPs pass the threshold potential; all action potentials are identical in magnitude.
10. (a) Negative; ATP/energy; anions; sodium; depolarisation; hyperpolarised.
 (b) Sodium ions flood into the axon making the inside positive compared with the outside; sodium ions flow along the axon; formation of local current; change in potential further along axon; opens charge-gated channels; allowing sodium ions to flow in.

5.4 Hormonal communication

5.4.1 Endocrine communication (page 65)

1. Exocrine glands secrete substances (often enzymes) into a duct, which leads to the point of action. Endocrine glands secrete hormones directly into the blood.
- 2.

Gland	Hormone
pituitary gland	antidiuretic hormone
thyroid gland	thyroxine
pancreas	insulin and glucagon
testes	testosterone
ovaries	oestrogen and progesterone
adrenal glands	adrenaline and corticosteroids (glucocorticoids and mineral corticoids)

3. They have complementary shapes. The receptor is found on the plasma membrane of the target cells for that hormone.
4. So that the correct hormone can bind, and no other molecule will be able to bind and have the same effect.
5. First messengers are hormones (cell-signalling molecules) that carry a signal around the body in the blood. Second messengers are molecules inside cells that activate an enzyme cascade.
6. They are synthesised from lipid-based molecules, such as cholesterol, and are soluble in fats. This means they can dissolve in the phospholipid bilayer.

5.4.2 Adrenal glands (page 67)

1. Both tissues are endocrine tissues. They secrete hormones directly into the blood.
2. The hormones released by the cortex are steroid hormones. These can dissolve in a cell membrane and enter cells by simple diffusion. Adrenaline released from the medulla is a derivative of an amino acid and cannot pass through a cell membrane by simple diffusion.
3. They bind to a receptor protein in the cell cytoplasm and are transported into the nucleus. Once in the nucleus they act directly on the DNA to stimulate synthesis of mRNA and proteins.
4. More blood is pumped from the heart with each beat and there are more beats per minute. More blood flowing around the body per minute transports more oxygen and glucose to the muscles enabling greater activity.

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- The role of adrenaline is to prepare the body for activity. The tissues (especially the muscles) will need to use more energy. Energy is supplied via respiration of glucose and as more glucose is used the blood glucose concentration will fall. Therefore more glucose will be needed to replace that used for respiration in the muscles.

5.4.3 The pancreas and release of insulin (page 69)

- Exocrine function is to release enzymes via the pancreatic duct. These enzymes pass along duct to the intestines to digest food. The endocrine function is to release hormones. Insulin and glucagon are released directly into the blood.
- The cells of the acini synthesise and secrete enzymes. They need many ribosomes to synthesise proteins: these ribosomes will be on the rough endoplasmic reticulum. They will also have a lot of Golgi apparatus as these are involved with packaging the enzymes into secretory vesicles. Many mitochondria will be present to supply ATP for the active processes.
- Active trypsin would digest any proteins in the cell and pancreatic duct. It is activated in the intestines.
- This would reduce the blood glucose concentration too much. It will be secreted as long as the blood glucose concentration is too high, once blood glucose concentration drops to the normal level secretion will stop.
- During insulin secretion: an increase in glucose concentration in the cell leads to the opening of calcium ion channels in the cell membrane. The calcium ions cause insulin vesicles to fuse with the cell membrane and insulin is released by exocytosis.

During neurotransmitter secretion at a synapse: when an action potential arrives at the synaptic bulb, again, calcium ion channels open and calcium ions diffuse into the synaptic bulb. The calcium ions cause vesicles containing the neurotransmitter to fuse with the pre-synaptic membrane. The neurotransmitter is released by exocytosis.

5.4.4 Regulating blood glucose (page 71)

- mmol dm^{-3} is a unit of concentration. 'mmol' is a millimole – i.e. one thousandth of a mole. dm^{-3} means per decimetre cubed, or per litre. So mmol dm^{-3} means thousandths of a mole per litre.
- Hepatocytes must respond to both hormones as they have antagonistic effects on the cell. Insulin causes the cell to take in glucose and convert it to glycogen; glucagon causes the cell to break down glycogen and release glucose.
- First messengers: insulin, glucagon; second messenger: cAMP.
- The blood glucose concentration must be kept fairly constant – so if it rises too high it must be reduced again and vice versa. This mechanism that reverses a change that has acted as a stimulus is negative feedback.
- It might rise due to eating or drinking sugary foods. It will also rise a little due to the effects of adrenaline. It falls due to fasting or exercise.

5.4.5 Diabetes (page 73)

- Proteins will be digested in the stomach/intestines. Insulin would not be absorbed as a complete molecule.
- Hyperglycaemia is raised blood glucose concentration. Hypoglycaemia is a lowered blood glucose concentration.
- Regular exercise uses up the glucose in the blood helping to keep the concentration lower.
- A pump produces a slow, regular release, which maintains the concentration of insulin, rather than a sudden increase in concentration after an injection, followed by a gradually declining concentration as the insulin is metabolised in the liver. Pumps may also be able to monitor the glucose concentration and respond directly to blood glucose concentrations – they could adapt the amount released according to the blood glucose concentration. Avoids any phobia of needles or dislike of injections.
- A human gene is inserted into the bacteria. Therefore the insulin produced is from a human gene and will have precisely the correct amino acid sequence.

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5.4 Practice questions (page 76)

1. D
2. A
3. C
4. C
5. B
6. (a) A = acinus/enzyme-secreting cells; C = duct.
(b) α cells, which secrete glucagon; β cells, which secrete insulin.
(c) (i) Ribosomes synthesise the (named) hormones.
(ii) Golgi apparatus place the hormones in secretory vesicles.
7. (a) Three from: Type 1 diabetes is juvenile-onset, whereas Type 2 tends to appear later in life. Type 1 is caused by an inability to make enough insulin; Type 2 diabetes is an inability to respond to insulin in the blood. Type 1 may be an autoimmune disease; Type 2 is the result of lifestyle. Type 1 is treated by insulin injections; Type 2 is treated by changes in lifestyle.
(b) Lose weight, exercise regularly, monitor the carbohydrates in the diet.
(c) It is a cure rather than a treatment as the patient will be able to make insulin in the pancreas. The patient does not need to inject insulin regularly so there is less inconvenience and less chance of infection caused by the needle. It may work out cheaper as there is no need produce as much insulin over the lifetime of the patient.
8. (a) Starch contains α -glucose; starch can be digested easily to glucose; cellulose contains β -glucose; cellulose cannot be digested.
(b) Rise in blood glucose concentration detected by β cells (in islets of Langerhans); causes production of ATP; closes K^+ channels; K^+ accumulates in cell; change in potential opens Ca^{2+} channels; Ca^{2+} enters cells; causes vesicles containing insulin to fuse to plasma membrane.
(c) Pasta; contains a lot of glucose in the form of starch.
(d) Bacon and fibre-rich cereal; have no effect on blood glucose concentration.
9. (a) Insulin causes a decrease in blood glucose concentration; glucagon causes an increase.
(b) Activation of enzymes; puts more glucose channels into the plasma membrane; converts glucose to glycogen; increases use of glucose in respiration; converts more glucose to fat.
(c) Any three from: obesity; lack of regular exercise; a diet high in sugars, particularly refined sugars; Asian or Afro-Caribbean origin; family history.

5.5 Plant and animal responses

5.5.1 Plant responses to the environment (page 81)

1. They could discourage insects from feeding on the plant.
2. A tropic response is directional; a nastic response is non-directional.
3. Because, like animal hormones, they are chemical messengers that can be transported away from their site of manufacture to act on other parts of the plant.
4. Only the target tissues will have the necessary complementary-shaped receptors on their cell surface membranes to which the particular hormone molecule can bind.
5. Because the ethene produced by the bananas will cause premature ageing of the flowers so they will not last as long.

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5.5.2 Controlling plant growth (page 83)

- With plant tip intact:
High auxin levels → high abscisic acid levels → low cytokinins in lateral buds → inhibit lateral bud growth
Remove plant tip:
Low auxin levels → low abscisic acid levels → higher cytokinin levels in lateral buds → lateral buds grow
- Under water, low oxygen levels stimulate ethene production. This reduces abscisic acid levels, which leads to increased activity of gibberellin. Gibberellin leads to stem elongation so the stems of the rice plants elongate and the foliage is above the water.
- The researchers used two dwarf plants. The main plant (homozygous for *le*) was able to make GA₂₀, but did not have the enzyme to convert GA₂₀ to GA₁. The second plant had a mutation in the first step of the pathway and was unable to make the precursor GA₂₀, but it was able to make the enzyme needed to convert GA₂₀ to GA₁. When part of the second plant was grafted to the main plant, the graft supplied the enzyme, which could act on the GA₂₀ made by the main plant. As a result the shoot grew tall. This showed that once both the GA₂₀ and the enzyme were available the plant could make GA₁ and normal growth was restored.
- Gibberellins act on stems (elongation) and seeds (germination); gibberellins act to stimulate growth; auxins are plant growth regulators with a wider range of actions. Auxins often interact with other plant hormones.
- Experimental conditions may not mirror conditions in nature. An experiment should work with concentrations of hormones naturally found in plants and in the parts of the plant that the hormone molecules normally reach.
- There could be one or more other factors that also play a part in the change. For example, there may be another factor that causes a change in both the variables being measured. Only when all other variables are known and controlled can we suggest that there is a causative effect. Even then we cannot be certain until we fully understand the mechanism.

5.5.3 Plant responses: investigating tropisms (page 87)

- They cause cells to elongate.
- Auxins promote the active transport of H⁺ into the cell wall, by an ATPase enzyme on the cell surface membrane. This increases the 'stretchiness' of the cell wall because the low pH provides optimum conditions for expansins (wall-loosening enzymes) to work. The enzymes break bonds within the cellulose so the walls become less rigid and can expand as the cell takes in water.
- Because root and shoot cells in the elongation zone exhibit different responses to the same concentrations of auxin.
- Growth is defined as a permanent increase in size. Tropic responses involve cell elongation and do cause a permanent increase in size – therefore this is growth. These tropic responses do not take place at meristems where cells divide so they do not involve an increase in the number of cells – just an increase in cell size.
- It is important to show that the presence of IAA is causing the effect. There must be one control to show that having no IAA has no effect. However, it is possible that the lanolin is causing the effect – therefore applying lanolin on its own is used as another control to show that lanolin with no IAA has no effect.
- Take 15 cereal seedlings.
 - Five are controls and are left complete, cut the tip off five and cover the tips of another five with an opaque cap.
 - Shine a light from one direction onto all the seedlings for several days. Ensure all seedlings receive the same amount of light.
 - Note the direction of growth, if any, of all the seedlings.
 - Take 30 cereal seedlings. Cut the tips off all of the seedlings.
 - Place the cut tips on agar blocks to allow the diffusion of auxin into the agar blocks.
 - Divide seedlings into the following groups:
Five are controls
Five are topped with an agar block containing auxin

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Five are topped with an agar block offset to the right containing auxin

Five are topped with an agar block offset to the left containing auxin

Five are topped with a block containing no auxin

Five are topped with an offset block containing no auxin.

4. Note the direction of growth in all the seedlings after a few days.

5.5.4 Commercial uses of plant hormones (page 89)

- Leaf senescence: cytokinins; citrus fruit senescence: gibberellins.
 - Ethene.
 - Auxins.
- Cytokinins.
- Restricting ethene levels prevents fruit ripening. This allows unripe bananas to be shipped to Europe from the Caribbean, which can then be ripened on arrival and sold.
 - Restricting gibberellins can keep flowers short and stocky because it causes cell elongation.
- Advantage of using hormones: the plants are still able to breed naturally (sexual reproduction) when hormones are not used. This enables plant breeding and artificial selection to continue so that new varieties can be produced or new characteristics can be introduced to maintain production as environmental changes occur.

Disadvantage of using hormones: expensive to use on a large scale.

Advantage of parthenocarpy: enables large scale production, such as banana farming, and the reproduction by asexual methods means that the genotype and therefore the phenotype remain constant. Good characteristics, such as large fruit, are not lost through genetic variation.

Disadvantage of parthenocarpy: reduces genetic diversity and biodiversity. The species cannot evolve and artificial selection cannot be carried out – therefore breeders cannot introduce new characteristics to maintain production as the environment changes.
- Silver inhibits ethene synthesis. Without ethene the flowers should stay fresh for longer.
- Gibberellins can help to increase grape yield by elongating grape stalks, which allows the grapes to grow to a bigger size.

Gibberellins can increase the yield of sugar cane because gibberellins stimulate growth between the nodes, making the stems elongate. As the sugar is stored in the cells of the internodes, this increases the yield of sugar from each plant.

5.5.5 The mammalian nervous system (page 92)

- They carry impulses for relatively long distances (up to one metre in humans). Signal may need to be responded to quickly as the sensory receptor may have detected immediate danger to the animal. So rapid transmission is important – and myelinated neurones transmit more quickly than unmyelinated ones.
- We are unaware of the dilation. It is coordinated by the autonomic nervous system without any need for conscious thought.
- The sympathetic system prepares the body for activity – oxygen and nutrients must be supplied to the muscles. Therefore blood is diverted towards the muscles and away from the digestive system.
- Increase in: heart rate, stroke volume, breathing rate, depth of breathing, blood pressure. Diversion of blood towards muscles.
- This enables a large number of alternative nervous pathways to be created. One neurone will receive signals from many sources and can contribute to many pathways by sending the impulse to many other regions of the brain or effectors.

5.5.6 The brain (page 95)

- The cerebellum organises coordinated movement and balance – therefore the person may lose their sense of balance and ability to coordinate many movements, such as walking or cycling.

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2. The cerebrum is divided into two hemispheres connected by the corpus callosum. Signals from the left side of the cerebrum coordinate movement of the right side of the body.
3. To connect both sides of the cerebrum.
4. The visual area and visual association area, the auditory area and auditory association area, and the motor area in the cerebrum. Also the cerebellum.
5. Auditory area, auditory association area, speech areas and motor area in cerebrum.
6. The areas of the brain dealing with sight are at the back of the brain.

5.5.7 Reflex actions (page 97)

1. (a) The earthworm will escape a potential predator (e.g. bird).
(b) This avoids damage to the sole of the foot.
2. It does not involve the brain; the nervous pathway is very short; few synapses involved; most of the length of the neurones involved is myelinated.
3. The eyes and nose detect that the object is of value; the association areas of the brain send impulses, which inhibit the action of the synapse; this prevents the response to let go.
4. So that they are carried very rapidly and arrive in time to stop the reflex action.
5. The blinking reflex is a cranial reflex; it involves three neurones; the knee jerk reflex is a spinal reflex; it involves only two neurones.

5.5.8 Coordinating responses (page 100)

1. Examples such as: being threatened by a bully; hearing a big dog barking and growling nearby; crossing a road and hearing a car coming very quickly towards you.
2. One action of adrenaline is to reduce blood flow to the digestive system. Therefore the digestive system may not receive sufficient blood flow to operate effectively.
3. The higher centres of the brain send impulses down the sympathetic part of the autonomic nervous system to the adrenal glands. This stimulates the release of adrenaline.
4. The parasympathetic system is active while the body is at rest or asleep. Its activity tends to conserve energy.

5.5.9 Controlling heart rate (page 102)

1. Myogenic means that the heart muscle is able to initiate its own contraction.
2. Physical activity involves muscular contraction, which requires energy. The energy is supplied by respiration, which breaks down glucose or other substrates. The most energy is released through aerobic respiration. Therefore the heart rate must increase to supply more oxygen for increased aerobic respiration.
3. Increased carbon dioxide may have the effect of increasing heart rate – this is positive feedback.
4. As the heart rate (and stroke volume) increase the blood pressure rises. This is detected by stretch receptors in the carotid sinus. These receptors send signals to the cardiovascular centre to reduce blood pressure.
5. The stretch receptor maintains a potential across its membrane – the membrane is polarised. When the muscle is stretched the membrane of the stretch receptor is deformed. This opens sodium ion channels and sodium ions flow into the receptor cell causing depolarisation. This depolarisation is a generator potential. If sufficient ions enter the cell the generator potential reaches the threshold and causes more sodium ion channels to open. This produces the action potential.

5.5.10 Muscle (page 105)

1. Cardiac muscle is in the walls of the heart chambers, smooth muscle is in the walls of the airways and blood vessels, striated muscle is in the intercostal muscles.
2. (a) The elastic recoil of the heart walls and the flow of blood into the chambers.
(b) The recoil of the elastic fibres in the walls of the blood vessels and the pressure of the blood in the vessels.

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- (c) The recoil of the elastic fibres in the walls of the airways and the elasticity of the cartilage.

3.

Smooth	Striated	Cardiac
no striations	striations	striations
contains actin and myosin	contains actin and myosin	contains actin and myosin
individual, tapered cells joined in a tissue	multinucleate fibres	cells joined by intercalated discs
no fibres	parallel fibres	fibres with cross bridges
slow continuous contraction	rapid contraction	continuous rhythmic contractions
involuntary	voluntary	involuntary

4. Any three from: both transmit signals across a short gap (cleft); both contain vesicles of transmitter in pre-synaptic swelling; both use acetylcholine as transmitter; both stimulated by action potentials; both release transmitter from vesicles as a result of calcium ions entering the pre-synaptic swelling.

5.5.11 Muscle contraction (page 107)

- Cross bridges form and cause the filaments to slide past one another.
- (a) ATP supplied by aerobic respiration.
(b) ATP supplied by anaerobic respiration and from creatine phosphate.
- ATP joins the myosin head as it detaches from the actin. The ATP is hydrolysed to ADP and P_i releasing energy, which causes the myosin head to swing back to its starting position. When the myosin binding site is exposed the myosin can bind to the actin and move causing the actin filament to slide. As the filament slides the ADP and P_i are released.
- ATP is hydrolysed to release energy for active transport – this transports calcium ions to the sarcoplasmic reticulum and pumps them back into the sarcoplasmic reticulum, allowing the muscle to relax.
- When the ATP runs out the calcium ions start to leak out of the sarcoplasmic reticulum. The calcium binds to the troponin and exposes the myosin binding sites on the actin. The myosin binds and causes the filaments to slide – contraction of the muscle. However, there is no ATP left to release the myosin from the actin so the muscle remains contracted.

5.5 Practice questions (page 110)

- D
- D
- C
- A
- B
- GA caused a small increase in growth; less than 0.5 mm; IAA caused a greater increase in growth; just over 2 mm.
 - $4.2 - 1.3 = 2.9$. $(2.9 / 1.3) \times 100 = 223\%$
 - No IAA or GA applied; other conditions all the same.
 - Repeat each application with several plants; to make results more reliable; calculate a mean increase in length; measure a longer portion of the stem; to make results more accurate.
- The tip of a plant usually produces auxin; this inhibits growth of lateral shoots; cutting tips off the shoots removes this inhibition; lateral shoots can grow.
 - Allow two marks for each of three different growth substances. Examples:

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Auxins: prevent leaf and fruit drop, promote flowering, encourage root growth, parthenocarp, herbicides.

Cytokinins: delay leaf senescence, promote bud and shoot growth.

Gibberellins: delay senescence in citrus fruits, stalk/stem elongation, speed up malting process in brewing.

Ethene: speed up fruit ripening, promote fruit drop in cotton/cherry/walnut, promote female sex expression in cucumbers, promote lateral growth.

8.
 - (a) A cerebrum; B pituitary; C hypothalamus; D medulla oblongata; E cerebellum.
 - (b) Pituitary is visible/the medulla oblongata is on top.
 - (c) Eyes.
 - (d) Organised into the sympathetic and parasympathetic nervous systems:
Parasympathetic has: long pre-ganglionic fibres; ganglion in effector tissue; uses acetylcholine as neurotransmitter.
Sympathetic has: short pre-ganglionic fibres; ganglion just outside CNS; uses noradrenaline as neurotransmitter.
9.
 - (a) stress; rest
increase; decrease
dilates; constricts
decreases; increases
 - (b) Increased respiration produces carbon dioxide; reduces pH of blood; chemoreceptors in carotid body/aorta/brain; send impulses to cardiovascular centre in medulla oblongata; sends impulses down sympathetic nerve; to sinoatrial node.
10.
 - (a) A = myosin; B = actin.
 - (b) Sarcomere.
 - (c) Z lines further apart; H zone wider.
 - (d) Anaerobic respiration; creatine phosphate stores; CP used to transfer phosphate to ADP making ATP.
 - (e) Calcium ions are released from sarcoplasmic reticulum; bind to troponin; exposing binding site for myosin.

5.6 Photosynthesis

5.6.1 The interrelationship between photosynthesis and respiration (page 115)

1. Photosynthesis is the process used by autotrophs that utilises sunlight energy, converting it to chemical energy that makes it available to heterotrophs.
2. Photosynthesis depends on light therefore the rate is zero in the dark and increases as light intensity increases. It is highest at around midday when the intensity of light is highest. Respiration does not depend on light. It may be a little higher around midday/afternoon when the environment is warmer and this could increase the rate of enzyme-catalysed reactions. This may also be true for photosynthesis – a higher temperature may speed up the enzyme-catalysed reactions of the light-independent stage.
3. The point at which the rate of oxygen production by photosynthesis equals the rate of oxygen uptake for respiration in a plant/autotroph. OR The point at which the rate of carbon dioxide uptake for photosynthesis equals the rate of carbon dioxide production by respiration in a plant/autotroph.
4.
 - (a) About 0700 hours/7am.
 - (b) About 0800 hours/8am.
5. Photosynthesis. There was no free oxygen in the atmosphere on Earth until about 2 billion years ago, after oxygenic photosynthesis had evolved – oxygenic photosynthesis used water as a raw material and broke it down, releasing free oxygen.

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5.6.2 Chloroplasts and photosynthetic pigments (page 118)

1. Granum/grana/thylakoid membranes/thylakoids.
2. Stroma.
3. In the thylakoid membranes.
4. Funnel-shaped; contain a molecule of chlorophyll a (either P₆₈₀ or P₇₀₀) at the primary pigment reaction centre at the base; also contain accessory photosynthetic pigments/named pigments.
5. Photosystem I contains the P₇₀₀ type of chlorophyll a at the primary pigment reaction centre, whereas photosystem II contains the P₆₈₀ type of chlorophyll a at the primary pigment reaction centre.
6. Many grana consisting of many thylakoid membranes gives large surface area for pigments, electron carriers and ATP synthase enzymes for light-dependent stage. Stroma has enzymes for light-independent stage. Stroma close to grana so products of first stage can pass to stroma for second stage. Oil droplets in stroma as source of lipids to make membranes. Ribosomes for protein synthesis of enzymes/electron carriers/anchoring proteins. DNA – genes coding for some chloroplast proteins.
7. There are different types of these, with slightly different molecular masses/sizes of molecules/solubilities in the solvent.
8. The molecules of pigment will have different solubilities in different solvents.

5.6.3 The light-dependent stage (page 121)

1. Electron donor; source of protons/hydrogen ions; source of by-product, oxygen; keeps cells turgid so they can function (all metabolic reactions need to be in solution).
2. Iron is needed for electron carriers in the chain (on thylakoid membranes) and for ferredoxin. A reduction of electron carriers could reduce rate of photosynthesis.
3. The enzyme-catalysed splitting of water molecules, in the presence of light. It takes place in PSII on thylakoid membranes of chloroplasts.
4. Accepts electrons from photosystems/chlorophyll in illuminated chloroplasts.
- 5.

	Cyclic photophosphorylation	Non-cyclic photophosphorylation
Photosystems involved	PSI only	PSI and PSII
Does photolysis occur?	no	yes
Fate of electrons released from chlorophyll	pass via electron carriers back to PSI. (energy from them generates a little ATP)	from PSII, pass via electron transport chain/electron carriers to PSI; PSI electrons accepted by NADP
Products	ATP	ATP, reduced NADP, oxygen

5.6.4 The light-independent stage (page 123)

1. Because it is being continually regenerated so no need for large amounts (which would be a waste of plant's resources).
2. TP/triose phosphate (also known as glyceraldehyde phosphate/GALP/PGAL).
3. RuBisCO is an enzyme and therefore a protein, for which nitrogen is needed, obtainable by plant from nitrate ions in soil.
4. NADP, ATP are derivatives of nucleic acid/DNA and so have nitrogen-containing bases (adenine); RuBP is a protein so made of amino acids, all of which have an amine group; electron carriers in the electron transport chain are proteins; chlorophyll has a porphyrin group and contains nitrogen.
5. As protons are pumped into the thylakoid space, out of the stroma, the pH of the stroma rises to 8, optimum for RuBisCO. The light-dependent stage produces ATP and this activates RuBisCO. Concentration of Mg²⁺ increases in the stroma and this acts as (metallic ion) cofactor and activates RuBisCO. Reduced ferredoxin (reduced by accepting electrons lost from illuminated PSI) activates enzymes that catalyse steps in the Calvin cycle.
6. It is necessary for photosynthesis and therefore for producers of (pretty well) all food chains.

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5.6.5 Factors affecting photosynthesis (page 125)

1. It is not temperature because increasing the temperature makes no difference. It is not light intensity as the graph has plateaued and not increased with increasing light intensity. Therefore the limiting factor is carbon dioxide.
2. Temperature. Here, increasing the temperature increases the rate of photosynthesis. The concentrations of carbon dioxide for these two curves are the same.
3. Insufficient light intensity stops the light-dependent stage. This stops the flow of NADP and ATP so the light-independent stage cannot run. Without ATP and reduced NADP, TP cannot be made from GP. GP accumulates. TP drops. RuBP cannot be regenerated from TP so RuBP drops.
4. Insufficient carbon dioxide for RuBP to accept and be changed to GP. RuBP accumulates. GP drops and therefore TP drops as it cannot be made by reduction of GP.
5. Leaves lose more water by transpiration than can be replaced by uptake at roots. Cells lose water/become plasmolysed. Tissues become flaccid. Leaves wilt. Roots are unable to take in water and secrete abscisic acid, which travels in xylem to leaves causing stomata to close to prevent further water vapour loss. Closed stomata reduce gaseous exchange so not enough carbon dioxide for photosynthesis. Plasmolysed cells cannot function as enzymes cannot work. Reduced water availability for photosynthesis – as source of electrons and protons.
6. (a) As environmental temperatures warm in many areas of the Earth, due to climate change, and we have to produce even more food for the growing population, an altered enzyme structure so that photorespiration does not occur would increase plant growth at higher temperatures.
(b) Active site (shape).

5.6.6 Factors affecting photosynthesis: practical investigations (page 129)

1. Accumulation of oxygen in the air spaces of the spongy mesophyll reduces their density.
2. To check that the data are reliable; to check data are concordant; will give more accurate/reliable mean.
3. Float up quickest with red light as that wavelength absorbed in greater amounts by chlorophyll; then blue light as chlorophyll has another peak of absorption in blue light; slow if at all with green light – chlorophyll does not absorb green light, some accessory pigments absorb a little.
4. (a) Light-dependent – light harvesting.
(b) The Calvin cycle – many enzymes involved.
(c) The Calvin cycle – carbon dioxide accepted by RuBP.
5. Air spaces in spongy mesophyll, out via open stomata.

5.6 Practice questions (page 132)

1. A
2. B
3. B
4. C
5. D
6. (a) (i) Plant absorbs carbon dioxide for photosynthesis; rate of photosynthesis greater than rate of respiration/more CO₂ is absorbed than is released by respiration; this raises pH of the solution.
(ii) No photosynthesis so no absorption of CO₂; plant continues to respire so CO₂ is released into solution; formation of carbonic acid/lowers pH.
(iii) For comparison to see colour change in other tubes.
(iv) Indicator would remain red as snails produce carbon dioxide by respiration; this balances (or nearly balances) net absorption of carbon dioxide by plant for photosynthesis.
(b) GP, TP, glucose, starch. GP first stage of Calvin cycle/light-independent stage after accepted by RuBP; then TP made; from which hexose sugar/glucose is made; which is then polymerised to starch.

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- (c) More CO₂ to diffuse into leaves/chloroplasts; via stomata; more carbon fixation; reference to RuBP accepting CO₂; six turns of Calvin cycle to make two TP molecules; TP converted to other organic compounds/named compounds; some used for respiration to provide ATP for growth; some used for synthesis of new structures during growth.
7. (a) Correct position/where RuBP accepts CO₂.
- (b) (i) Five.
(ii) Three.
(iii) Three.
- (c) Between GP and TP.
- (d) Six.
- (e) Stroma.
- (f) It is continually regenerated from TP.
- (g) (i) Glucose and fructose.
(ii) Condensation reaction.
- (h) GP cannot be changed to TP; as no reduced NADP to reduce it; RuBP cannot be regenerated.
- (i) ATP provides energy for formation of TP from GP; ATP provides phosphate groups for regeneration of RuBP; RuBP activates RuBisCO; RuBP accepts carbon dioxide; max. 3.
8. (a) 3.3, 5.2, 5.6, 5.8, 0.0; all correct 2 marks, one error = 1 mark.
- (b) $3.2 / 1.6 = 2.0$
- (c) $5.6 / 5.2 = 1$
- (d) For respiration, the rate doubles for a 10 °C rise in temperature as expected; at this temperature range enzymes working well; for photosynthesis much smaller/not as expected; plant may be suffering water stress; reference to photorespiration – for example, less CO₂ fixed; max. 4.
- (e) Illuminated chloroplast produces oxygen; in light-dependent stage of photosynthesis; from photolysis of water; bacteria cluster where there is most oxygen; therefore greatest rates of photosynthesis: red/630–700 nm and blue light /400–500 nm; chlorophyll a/photosystems absorb light of these wavelengths.

5.7 Respiration

5.7.1 The need for cellular respiration (page 137)

- RNA, because the sugar is ribose sugar, which occurs in RNA.
- (a) Anabolic as it involves synthesising large molecules from smaller ones.
(b) Catabolic as it involves breaking down large molecules to smaller ones.
(c) Anabolic as it involves synthesising large molecules from smaller ones.
- It is found in all living organisms/all types of cells. It is concerned with transmitting energy and is readily available for hydrolysis, releasing small manageable amounts of energy to meet the cell's needs, but not in quantities that could damage the cell.
- It can remain in solution in cells, without being hydrolysed into ADP and P_i and energy until needed to drive a metabolic process.
- (a) Chemical energy in food is converted to light energy.
(b) Chemical energy in food is converted to electrical energy.

5.7.2 Glycolysis (page 139)

- It is continually being recycled – reduced and then reoxidised.
- It contains adenine, ribose sugar and phosphoryl groups, and therefore is derived from two nucleotides.
- Oxidation involves removal of hydrogen atoms from substrate molecules.

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- Both had diets deficient in tryptophan so they could not synthesise nicotinamide. The Mexican Indians soaked their corn in calcium hydroxide, which is alkaline, so this would have enabled the large amounts of nicotinamide in the corn to be absorbed into their blood from their intestine. Those in the southern USA did not soak their corn in limewater so the nicotinamide in the corn would not have been absorbed from their intestines.
- It removes hydrogen atoms from triose phosphate molecules, oxidising triose phosphate to pyruvate.
- Two molecules of ATP are used at the beginning of glycolysis and four are produced, giving a net gain of $4 - 2 = 2$.
- The NAD being used to oxidise ethanol (ethyl alcohol) and ethanal is not available for use in respiration.

5.7.3 The structure of the mitochondrion (page 141)

- They need to synthesise many molecules of neurotransmitter and export them, via exocytosis, into the synaptic cleft. The mitochondria supply the energy needed to do this.
- Skin cells are not very metabolically active, unlike muscle cells; muscle cell mitochondria are likely to be bigger, have more cristae, more electron transport proteins and more enzymes than mitochondria in skin cells; muscle cells need a lot of ATP for contraction.
- Derived from the mitochondria in the parent cell by binary fission.
- The link reaction and the Krebs cycle.
- Oxidative phosphorylation.
- For example, has envelope; folded inner membrane to give large surface area; ATP synthase enzymes and proton channels; electron transport chains; matrix; both have prokaryote-type ribosomes; both have loops of DNA.
- For example, chloroplasts have chlorophyll; coenzymes in chloroplasts are NADP, in mitochondria NAD and FAD; different enzymes; chloroplast usually a bit larger, but both in region of 2–10 μm .

5.7.4 The link reaction and the Krebs cycle (page 143)

- Because it is continually being used and regenerated.
- In the mitochondrial matrix.
- Each substrate molecule has a different shape and so each stage needs an enzyme with an active site that has a shape complementary to a specific substrate; the active site of one enzyme will not fit more than one substrate molecule.
- The products of one reaction will be the reactants for the next reaction and will be close to the enzyme needed to catalyse it.
- Because they do not undergo glycolysis; they can only join via the link reaction or directly onto the Krebs cycle – both aerobic stages of respiration.
- NAD helps the oxidation reactions during the link reaction and the Krebs cycle; in the process it becomes reduced. FAD helps the oxidation of substrate during the Krebs cycle and in the process becomes reduced. Both FAD and NAD carry hydrogen atoms to the electron transport chain and these hydrogens will be involved in making many molecules of ATP. CoA carries acetate onto the Krebs cycle.

5.7.5 Oxidative phosphorylation and the chemiosmotic theory (page 145)

- Because a gradient causes the protons to diffuse through channels and the flow releases energy to make ATP.
- It accepts electrons that are released from the last membrane-embedded electron carrier.
- Into blood plasma, out of capillary dissolved in tissue fluid, diffuses into cytoplasm of respiring cell, diffuses through cytoplasm and into mitochondria.
- The accumulation/high concentration of protons lowers the pH.
- They combine with hydrogen atoms and carry them to the electron transport chain.
- Inner mitochondrial membranes/cristae.
- The accumulation of protons on one side of a membrane and their subsequent movement down the electrochemical gradient provides energy to power the formation of ATP from ADP and P_i .

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- By removing free protons in the matrix the concentration of protons in the intermembrane space remains higher than in the matrix.

5.7.6 Anaerobic respiration in eukaryotes (page 147)

1.

	Lactate fermentation	Ethanol fermentation
Hydrogen acceptor	pyruvate	ethanol
Is carbon dioxide produced?	no	yes
Is ATP produced?	no	no
End products	lactate and NAD	ethanol, carbon dioxide and NAD
Enzymes involved	lactate dehydrogenase	pyruvate decarboxylase and ethanol dehydrogenase
Is NAD reoxidised?	yes	yes
Site of pathway	cytoplasm of cells	cytoplasm of cells

- Anaerobic = 2 molecules per molecule of glucose.
Aerobic, 2 per molecule during glycolysis (substrate-level phosphorylation), 2 per molecule during the Krebs cycle (substrate-level phosphorylation) and about 28 per molecule during oxidative phosphorylation, however, 2 possibly used to transport pyruvate and some NAD into the mitochondria, so net gain is 30.
- Before. If it is in ancient prokaryotes it was probably the first respiratory pathway and evolved before there was free oxygen in the atmosphere.
- The muscle contains slow twitch fibres for sustained contraction; they use aerobic respiration because much ATP is needed and they will have many mitochondria, all with electron transport proteins that contain iron – giving dark red colour. They also contain myoglobin, a protein with a haem (iron- containing) group that stores oxygen. Chicken breast contains fast twitch muscle fibres, with no or few mitochondria, as they rely on anaerobic respiration to produce the ATP. No myoglobin. Therefore no iron-containing proteins and no red colour.
- There is a very small quantity of ATP molecules in the muscles because it is usually continuously recycled.
- The yeast cells are killed when the alcohol content reaches 15% so no more fermentation can take place and no more ethanol can be produced.

5.7.7 Practical investigations into respiration rates in yeast (page 149)

- Facilitated diffusion as glucose is water-soluble and will not diffuse through the lipid bilayer of the yeast plasma membrane.
- For example, more dead cells may be present in the flask where conditions were anaerobic. We cannot tell when the cells died. However, we should still see more cells in the aerobic conditions as the ethanol will have been oxidised and the yeast cells will have made more ATP.
- The vessels have to be cooled. The larger the vessel the smaller the surface area to volume ratio and the harder it is for the heat to be dissipated. If the vessels are not cooled, yeast cells will die as their enzymes and other proteins will be denatured.
- $50 \times 50 \times 1000 \times 10 = 2.5 \times 10^7$
- Large flask and small volume of medium to give aerobic conditions; same volumes of media and same volume yeast inoculum in each flask; covered with muslin; kept in thermostatically controlled water baths at different temperatures; shaking water baths; same sample intervals, for example, 12 hours, 24 hours; use haemocytometer and obtain cell counts per cm^3 ; use dilution of sample if necessary.

5.7.8 Energy values of different respiratory substrates (page 152)

- Because fats contain more energy than an equal mass of carbohydrate, because their molecules contain more hydrogen atoms, meaning more protons for oxidative phosphorylation and more ATP produced.
- It is a fat/lipid and so dissolves in and diffuses through the lipid bilayer of both the outer and inner mitochondrial membrane.

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3. There is insufficient carbohydrate and fat to be used for respiration/as respiratory substrates, so their own muscle proteins will be hydrolysed to provide amino acids for respiration, to make ATP for their metabolic reactions/growth/cell division.
4. Because fat molecules contain many more hydrogen atoms: these will eventually combine with oxygen to give water. More hydrogen atoms means more water.
5. Fatty acids derived from hydrolysis of the lipid undergo beta oxidation and then two-carbon molecules enter the Krebs cycle so they are respired aerobically. Glycerol can be converted to triose phosphate and then to pyruvate, which could be respired aerobically or anaerobically.
6. Protein/amino acids, or a mixture of fat and carbohydrate.
7. The germinating seeds were respiring aerobically (fat, carbohydrate or protein) with some anaerobic respiration (starch/glucose/carbohydrate).

5.7.9 Practical investigations into factors affecting the rate of respiration (page 155)

1. With fewer molecules in that tube the pressure is reduced, so pressure in the other tube is greater and this pushes the fluid in the manometer tube downwards on that side and up towards the tube that contains the respiring organisms.
2. It indicates if there is any change to air pressure or temperature, both of which would cause the manometer fluid to move.
3. To absorb carbon dioxide released by the respiration of the organisms.
4. Volume of oxygen absorbed is $(2 \times 3.142 \times \text{radius of capillary bore} \times \text{distance moved by manometer fluid})$. If this is divided by the time period it will give results in $\text{cm}^3 \text{ minute}^{-1}$ and if divided by the mass of organisms, gives respiration rate in $\text{cm}^3 \text{ minute}^{-1} \text{ g}^{-1}$.
5. Higher temperatures could harm or cause stress to animals so this would be unethical.
6. Explanation should match their data and refer to enzymes needed, for example, for hydrolysis, isomerisation. These processes make the process take longer/go slower; some enzymes may not be able to be made as the strain of yeast may not have the gene coding for that enzyme; gene for specific enzymes may have to be switched on/induced, which takes time; synthesis of the enzymes takes time.

5.7 Practice questions (page 158)

1. B
2. C
3. B
4. B
5. D
6. (a) Pyruvate = 3C; acetyl CoA = 2C; boxes on the Krebs cycle in clockwise direction – 6C; 5C; 4C.
(b) X = reduced FAD; Y = 2 carbon dioxide/2 CO_2 .
(c) Cytoplasm/cytosol.
(d) (i) Matrix of mitochondria.
(ii) (By combination with) coenzyme A/CoA; then released; combines with oxaloacetic acid.
(e) Go to electron transport chain; on cristae/folded inner membranes of mitochondria; or involved in changing pyruvate to ethanol and carbon dioxide, or to lactate, under anaerobic conditions; gives up hydrogen atoms/protons and electrons; becomes reoxidised/able to be reused.
7. (a) (i) A = glycolysis; B = anaerobic respiration; C = aerobic respiration/the link reaction **and** the Krebs cycle **and** oxidative phosphorylation.
(ii) A.
(iii) Yeast/fungi/plants/animals/bacteria/protocists.

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- (b) (i) Glucose cannot enter mitochondria, but pyruvate does; plus up to two other suggestions such as: carbon dioxide is produced during the link reaction; and the Krebs cycle; (both of which occur) in the matrix of mitochondria.
 - (ii) Lactate is the product of anaerobic respiration; which takes place in the cytoplasm (not in mitochondria).
 - (iii) Cyanide inhibits oxidative phosphorylation; so all aerobic respiration stops; reduced NAD from glycolysis is reoxidised with anaerobic respiration; as these are liver cells, this involves lactate pathway; so glycolysis can continue; but no decarboxylation during glycolysis.
8. (a) $RQ = \text{volume of carbon dioxide produced} \div \text{volume of oxygen consumed/used during respiration during a specific period of time/per unit time}$.
- (b) (i) Fat/lipids/fatty acids; because RQ is between 0.6 and 0.8; respiration of fatty acids needs more oxygen than an equivalent mass of carbohydrate; as more hydrogen atoms to be converted to water/fatty acids are more reduced than carbohydrate molecules.
 - (ii) Seed X has a RQ of 1, suggesting it is respiring mostly carbohydrate. This is confirmed by the data on stored organic compounds which show that seed X has a greater quantity of stored carbohydrate (70%).
Seed Y has a RQ of between 0.8 and 0.9, suggesting it is respiring mostly protein/amino acids, or maybe a mixture of fats and protein/amino acids. This is confirmed by the data which show that seed Y has a greater quantity of stored protein.
- (c) Use of respirometer; suitable living organisms; equilibration/acclimatisation; correct use of taps and syringe; suitable temperature; with sodium/potassium hydroxide to measure oxygen used; without sodium hydroxide to find carbon dioxide evolved; same time period.
 - (d) If anaerobic respiration/mixture aerobic and anaerobic respiration is being used.

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6.1 Cellular control

6.1.1 Gene mutations (page 164)

- In some cases a change to the triplet code does not change the amino acid coded for at that point in the polypeptide chain.
- Substitution/point mutation at position 6, TAC becomes TAA so A substitutes for C. Instead of coding for tyrosine, this triplet codes for stop/is a termination triplet, so the protein is truncated.
 - Substitution/point mutation at position 4. GTT becomes ATT, so A substituted for G. Isoleucine inserted in polypeptide chain at this point, instead of valine.
 - G substituted for T in first triplet, so instead of methionine, isoleucine (protein will not be made as most have to start with methionine). Missense mutation.
 - Deletion of T at triplet 2, so causes frameshift. So instead of Met-Phe-Pro-Val-Lys-Tyr-His-Gln-Gln-Arg-STOP (-His), the amino acid sequence will be Met-Phe-Leu-Leu-Asn-Thr-Ile-Ser-ser-Ala-Ser-
 - Expanded triple nucleotide repeat, two extra CAG triplets. Amino acid sequence becomes Met-Phe-Pro-Val-Lys-Tyr-His-Gln-Gln-Gln-Gln-Arg-STOP (-His)
 - G substituted for A in triplet 11, so stop triplet now codes for tryptophan, protein will be longer, new amino acid sequence is Met-Phe-Pro-Val-Lys-Tyr-His-Gln-Gln-Gln-Gln-Arg-Tyr-His-
- TAC AAA GGA CAA TTT ATG GTC GTC GCG ATC GTG
 - AUG UUU CCU GUU AAA UAC CAG CAG CGC UAG CAC
- An incorrect amino acid would be inserted into the polypeptide chain, even though there is no point mutation in the DNA/gene.

6.1.2 Regulation of gene expression (page 168)

- A = 3; B = 1; C = 4; D = 2
- It will not waste energy/ATP and amino acids synthesising enzymes for metabolising lactose unless lactose is present to be metabolised.
- Lactose.
- Regulation of gene expression by activating or inhibiting binding of RNA polymerase to promoter region; makes sure that only certain genes in specific cell types are expressed; they therefore play a role in cell differentiation; help regulate cell cycle and cell division.
- cAMP activates PKA which then activates other proteins by phosphorylating them. The other proteins are usually enzymes, so a metabolic reaction or pathway is activated. This could involve the making of molecules other than proteins. Phosphate groups could also activate CREB protein that then enters the cell nucleus and acts as a transcription factor, regulating transcription of a particular gene.
- The whole gene introns and exons are first transcribed to give a length of primary RNA that also has both introns and exons. The introns are then removed and the exons are joined up, so the final mRNA is shorter as it does not contain introns.
- In the last test where the *E. coli* are given ONPG, but not lactose, no yellow colour is produced so there is no β -galactosidase enzyme.

6.1.3 Genetic control of body plan development (page 171)

- Homeobox sequence: part of a homeobox/homeotic gene, 180 bp long (- introns) that codes for a 60 amino acid sequence in a protein that is a transcription factor; homeodomain – the 20 amino acid sequence, encoded by the homeobox sequence.
- It is part of the transcription factor protein that plays a part in gene regulation during development of embryo to adult form; this sequence can fold into a particular shape – alpha helix-turn-alpha helix that can bind to a specific part/promoter region of a gene and regulate/initiate transcription.

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3. It shows they arose early in evolutionary history, in an ancestral life form that has given rise to all present day fungi, plants and animals. The gene sequences are still present in the genomes of all these organisms so are critical in regulating their development.
4. *Hox* genes are a subset/type of homeobox genes; found only in animals whereas homeobox sequences/genes are in plants, animals and fungi. They are expressed early in embryonic development and the genes in the clusters are expressed in sequence – corresponding to development of the various organs along anterior-posterior axis of animals. *Hox* genes encode transcription factors that activate other genes that promote mitotic cell division, apoptosis, cell migration and help to regulate the cell cycle.
5. The genes controlling organs along the anterior-posterior axis are activated in the same order that the organs are developed.
6. There are no hydrolytic enzymes involved.
7. Adults are not growing. If the two processes do not balance, then either a tumour or cell loss and degeneration will occur.
8. It contains high amounts of retinol that the body can change to retinoic acid. If there is too much retinoic acid in the blood going to the fetus, it could interfere with the *Hox* genes controlling body plan development and cause abnormalities.

6.1 Practice questions (page 174)

1. A
2. B
3. C
4. C
5. C
6. (a) It will contain many more (amino acids); arginine; will be longer; may not fold correctly; due to misalignment of certain amino acids that can form bonds/named types of bonds.
- (b) Ribosomes.
- (c) Prevents protein from folding; cannot assume its normal shape/tertiary structure; may not have complementary shape to a molecule it should react with/or any suitable alternative wording – can be in context of specific protein, for example, enzyme/receptor on plasma membrane/antibody/could block active site.
- (d) Because the code is read in triplets; non-overlapping; and extra triplets would not affect the non-CGG triplets/how they are read.
- (e) Huntington disease.
7. (a) Round; biconcave discs; small; large SA/V ratio; flexible, can squeeze through narrow capillaries; no nucleus/RER/mitochondria, so more room for haemoglobin to carry oxygen.
- (b) (i) Point mutation; substitution T for A; on 6th triplet.
- (ii) Changes amino acid sequence/primary structure; at position 6 in amino acid chain; valine instead of glutamic acid.
- (c) Protein containing more than one polypeptide chain.
- (d)

TAC	CAC	GTG	GAC	TGA	GGA	CAC	CTC
-----	-----	-----	-----	-----	-----	-----	-----

8. (a) The bacteria had been in a medium containing lactose; so the enzymes(s) had already been induced; no time lag needed for lactose to bind to repressor protein; and detach it from operator region; of *lac* operon; so RNA polymerase can bind to promoter region.

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- (b) (i) No lactose in the medium; so no β -galactosidase induced; no lactose to bind to repressor protein; and detach it from operator; so RNA polymerase cannot bind to promoter/structural gene not transcribed.
- (ii) Lactose is present, so not because lactose cannot bind to repressor; mutation/change to DNA; in *lac* operon; no functional enzyme.
- (c) No yellow develops in tube 3; no lactose present to induce enzyme to convert ONPG; presence of ONPG does not induce enzyme (otherwise would get yellow colour).
- (d) ONPG must fit into active site of β -galactosidase; reference to complementary shapes; but no part of ONPG fits to/is complementary to, repressor molecule.
- (e) Structural enzyme/promoter region.

6.2 Patterns of inheritance

6.2.1 Genetic variation (page 179)

1. (a) A mutagen is an agent that causes/increases the chances of a mutation.
- (b) Chemical – for example, benzopyrene, mustard gas, nitrous acid, aniline dyes/ aromatic amines, free radicals, colchicine.
Physical – for example, X-rays, gamma rays, UV light.
Biological – some viruses, transposons, food toxins.
2. During interphase/when DNA is replicating/during S phase.
3. During S phase a section could be duplicated; or during mitosis/meiosis when chromosomes/chromatids are separating from each other; after crossing over, a translocation, inversion or deletion could happen and non-disjunction could happen during anaphase of meiosis.
4. $(2^{92})^2$
5. Three of:
Deletion – a portion of a chromosome is lost; a series of genes and regulatory nucleotide sequences are therefore lost.
Inversion – a section of a chromosome may invert (turn through 180 degrees); although all the genes are still present, some may now be too far away from their regulatory nucleotide sequences to be properly expressed.
Translocation – a piece of one chromosome becomes detached and attaches to another chromosome. This may also interfere with the regulation of the genes on the translocated chromosome.
Duplication – a piece of a chromosome may be duplicated. Overexpression of genes can be harmful.
Aneuploidy – sometimes cell division fails and as a result half the gametes produced have the whole number of chromosomes.
Polyploidy – If a diploid gamete is fertilised by a haploid gamete the resulting zygote will be triploid (having three sets of chromosomes). The fusion of two diploid gametes can make a tetraploid zygote. Once the chromosome number had doubled, meiosis could occur as chromosomes could pair up.
Non-disjunction – this is where one pair of chromosomes (or chromatids) fails to separate, leaving one gamete with an extra chromosome. When fertilised by a normal haploid gamete, the resulting zygote has one extra chromosome. Down syndrome or Trisomy 21 is caused by non-disjunction.
6. When organisms only reproduced asexually – by binary fission or mitosis, mutation was the only source of genetic variation. With the advent of meiosis, as well as mutation, crossing over during prophase 1 of meiosis, giving shuffled alleles, and independent assortment of chromosomes at anaphase/metaphase 1, independent assortment of chromatids at metaphase/anaphase 2 and random fusion of gametes produces more genetic variation. Therefore within a population there is a more diverse gene pool for natural selection to act on.

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6.2.2 Monogenic inheritance (page 182)

1. A/a, E/e, F/f, G/g, H/h and I/i heterozygous; B/B and C/C homozygous dominant; d/d homozygous recessive.

2. (a) Parent phenotypes: mother brown × father black
 Parent genotypes: Bb × bb
 Gamete genotypes: B and b × all b
 Offspring genotypes: Bb and bb
 Phenotype ratios: 1 brown : 1 black
 Phenotype probabilities: 0.5/50% brown and 0.5/50% black

- (b) BB × bb
 All offspring will be Bb, brown.
 Phenotype probability: 1/100% brown; 0/0% black

- (c) Bb × Bb
 Gametes: B b and B b
 Offspring phenotypes: BB 2 × Bb bb
 Phenotype ratios: 3 brown : 1 black
 Phenotype probabilities: 0.75 brown; 0.25 black

- (d) BB × Bb
 Gametes: all B and B b
 Offspring: 100% brown.

3. (a) ¼ or 0.25 or 25%
 (b) ¼ or 0.25 or 25%
 (c) ½ or 0.5 or 50%.

4. (a) Ff × Ff
 Gametes: F f and F f
 Offspring: FF 2 × Ff ff
 Offspring FF do not develop, therefore 1/3 (33%) chance of being ff and 2/3 (67%) chance of being Ff.

- (b) Ff × ff
 Gametes: F f and all f
 Probabilities: 50%/0.5 Ff and 50%/0.5 ff.

5. Grey mouse is heterozygous, Aa. Albino mouse is homozygous, aa.
 Gametes: A a and all a
 Probabilities: 50% Aa, grey and 50% aa, albino. 15:18 close to this ratio, sample is small.

6.2.3 Dihybrid inheritance (page 184)

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1.

- (a) Parent phenotypes: P_1 tall purple P_2 short white
 Parent genotypes: $TTPP$ $tppp$
 Gamete genotypes: TP tp
 F_1 genotypes: $TtPp$ all heterozygous at both gene loci

- (b) Possible genotypes from F_1 parents: $TtPp$

TP Tp tP tp

Punnett square:

♂ gamete	TP	Tp	tP	tp
♀ gamete	$TTPP$ tall purple	$TTPp$ tall purple	$TtPP$ tall purple	$TtPp$ tall purple
Tp	$TTPp$ tall purple	$TTpp$ tall white	$TtPp$ tall purple	$Ttpp$ tall white
tP	$TtPP$ tall purple	$TtPp$ tall purple	$ttPP$ short purple	$ttPp$ short purple
tp	$TtPp$ tall purple	$Ttpp$ tall white	$ttPp$ short purple	$ttpp$ short white

9 tall purple - flowered

3 tall white - flowered

3 short purple - flowered

1 short white - flowered

Ratio of tall purple : tall white : short purple : short white

9 : 3 : 3 : 1

2. (a) Genotype of the ebony-bodied, short-winged females is $ggvgvg$.
 Genotype of grey-bodied, long-winged males is $GG++$.
 Genotype of eggs, produced by meiosis is $gvvg$; genotype of sperm, also produced by meiosis is $G+$.
 Genotype of all F_1 is $Gg+vg$;
 They will all have the phenotype grey body and long wings.

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(b)

F₁ genotypes: Gg+vg

F₁ gamete genotypes: (G+) (Gvg) (g+) (gvg)

Punnett square:

♂ gamete	(G+)	(Gvg)	(g+)	(gvg)
♀ gamete				
(G+)	GG++ grey long	GG+vg grey long	Gg++ grey long	Gg+vg grey long
(Gvg)	GG+vg grey long	GGvgvg grey vestigial	Gg+vg grey long	Ggvgvg grey vestigial
(g+)	Gg++ grey long	Gg+vg grey long	gg++ ebony long	gg+vg ebony long
(gvg)	Gg+vg grey long	Ggvgvg grey vestigial	gg+vg ebony long	ggvgvg ebony vestigial

9/16 grey-bodied and long-winged

3/16 grey-bodied and vestigial-winged

3/16 ebony-bodied and long-winged

1/16 ebony-bodied and vestigial-winged

3. (a) (i) BBLl (they must be heterozygous at the L/l gene as some offspring have short hair, but homozygous at the B/b gene locus as no offspring have white fur).
 (ii) bbll (these females are exhibiting the recessive phenotype for both gene loci).
 (iii) Black male genotype is BBLl
 White, short-haired female genotype is bbll
 All eggs have genotype bl
 Male gametes genotypes are 50% BL and 50% Bl.

(b)

Gametes	BL	Bl
bl	BbLl black long-haired	Bbll black short-haired

If the black male had the genotype BBLL, then all the offspring would have been black and long-haired.

4. (a) (i) 4.
 (ii) YYRR; YYRr; YyRR; YyRr.
 (b) (i) YYrr; Yyrr.
 (ii) yyRR; yyRr.
 (iii) yyrr.

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- (c) Yellow wrinkle-seeded crossed with green round-seeded plants:

Parent genotypes: YYrr × yyRR

Gametes: Yr × yR

F₁ genotype: YyRr

F₁ phenotype: All yellow round-seeded

Yellow round-seeded crossed with green wrinkle-seeded plants:

Parent genotypes: YYRR × yyrr

Gametes: YR × yr

F₁ genotype: YyRr

F₁ phenotype: All yellow round-seeded

6.2.4 Multiple alleles (page 186)

1. (a) Agouti.
(b) Agouti.
(c) Chinchilla.
(d) White/albino.
(e) Himalayan.
(f) Chinchilla.

2.

Phenotype	Possible genotypes
agouti	CC, Cc, CC ^{ch} , CC ^h
chinchilla	C ^{ch} C ^{ch} , C ^{ch} C ^h , C ^{ch} c
himalayan	C ^h C ^h , C ^h c
albino	cc

3. Breed the chinchilla rabbit, possible genotypes C^{ch}c, C^{ch}C^h or C^{ch}C^{ch}, with a white rabbit, or more than one white rabbit. Observe the phenotypes of the offspring: if there are some white rabbits then the male is C^{ch}c. If there are some himalayan rabbits then he is C^hC^h. If there are only chinchilla rabbits then he is C^{ch}C^{ch}.
4. As there are albino offspring, both rabbits must be heterozygous, so the himalayan is C^hc and the chinchilla is C^{ch}c.
5. Both must be heterozygous, CC^{ch}. Genotypes of offspring will be CC, 2 × CC^{ch} and C^{ch}C^{ch}. Three agouti and one chinchilla.
6. Only the Ys can produce a baby of blood group O (baby 1), assuming Mrs Y is genotype I^AI^o. Her partner is I^oI^o. Both can donate an I^o allele to the baby.
Baby 2 (blood group B) could be produced by the X partners if it receives an I^o allele from Mrs X and an I^B allele from her partner.
7. No. If both are heterozygous they can produce children of groups A, B, AB and O.
8. Both parents must carry an allele, c, for white coat. The brown cat is C^Bc and the black cat is C^bc. Combinations of their gametes can produce C^BC^b, brown, C^Bc, brown, C^bc black and cc white.

6.2.5 Sex linkage (page 188)

1. (a) This enables them to pair up for meiosis.
(b) The gene for the sex-linked disease is nearly always on the X chromosome and males pass the copy of their X chromosome to their daughters. They pass a Y chromosome to their sons.

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- (c) Yes. The X with the mutated allele that they pass to their daughters could then pass to the daughter's sons – their grandsons.
2. (a) $X^{CO}X^{CB} \times X^{CB}Y$; gametes (X^{CO}) and $(X^{CB}) \times (X^{CB})$ and (Y)
 Offspring: $X^{CO}X^{CB}$ $X^{CO}Y$ $X^{CB}X^{CB}$ $X^{CB}Y$
 tortoiseshell female black male black female black male
- (b) $X^{CO}X^{CO} \times X^{CB}Y$; gametes $(X^{CO}) \times (X^{CB})$ and (Y)
 Offspring: $X^{CO}X^{CB}$ and $X^{CO}Y$
 tortoiseshell female ginger male
- (c) $X^{CB}X^{CB} \times X^{CO}Y$; gametes $(X^{CB}) \times (X^{CO})$ and (Y)
 Offspring: $X^{CB}X^{CO}$ and $X^{CB}Y$
 tortoiseshell female black male
- (d) $X^{CO}X^{CB} \times X^{CO}Y$; gametes (X^{CO}) and $(X^{CB}) \times (X^{CO})$ and (Y)
 Offspring: $X^{CO}X^{CO}$ $X^{CO}X^{CB}$ $X^{CO}Y$ $X^{CB}Y$
 ginger female tortoiseshell female ginger male black male
3. X^hX^h . Most likely genotypes of parents: X^HX^h and X^hY .
4. (a) The same as it was before, which is 1 in 4 (or 1 in 2 of all male fetuses).
 (b) A whole length of nucleotide bases/base triplets that should be expressed/translated will be removed. The protein will be shorter and because certain amino acids are not present may not fold into the correct tertiary structure.
5. In birds females are heterogametic.
 Genotype of the female birds is X^BY ; their phenotype is black feathers with white bars.
 Genotype of the male birds is X^bX^b ; their phenotype is black feathers.
 Female gametes: X^B and Y . Male gametes are all X^b .
 Offspring genotypes: X^BX^b and X^bY
 Offspring phenotypes: male with white spot on head female with black head

6.2.6 Codominance (page 190)

- 1 (a) Parent phenotypes: black \times white
 Parent genotypes: $C^BC^B \times C^WC^W$
 Gamete genotypes: C^B C^W
 F₁ genotypes: all C^BC^W
 F₁ phenotypes: all blue
 F₁ gametes: C^B and $C^W \times C^B$ and C^W
 F₂ genotypes: C^BC^B $2 \times C^BC^W$ C^WC^W
 F₂ phenotypes: $\frac{1}{4}$ black : $\frac{1}{2}$ blue : $\frac{1}{4}$ white
 1 : 2 : 1
- (b) (i) Blue drakes with white ducks: $C^BC^W \times C^WC^W$
 Offspring: 50% blue and 50% white
 (ii) Blue drakes with black ducks: $C^BC^W \times C^BC^B$
 Offspring: 50% blue and 50% black
2. (a) The red and white spotted flowered camellia plants are heterozygous. Alleles for red and white are codominant.
 Gametes: $C^RC^W \times C^RC^W$
 C^R C^W C^R C^W

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Offspring: $C^R C^R$ $2 \times C^R C^W$ $C^W C^W$
 Phenotype ratios: 1 : 2 : 1

- (b) Take cuttings as the offspring produced this way would be genetically identical to the parent and would all be heterozygous.
3. Roan bull $C^R C^W$ \times white cows $C^W C^W$
 Expect 50% calves to be white and 50% to be roan.
 Probability of being roan is $\frac{1}{2}$ or 0.5. Same probability of being white. Probability of red calves is 0.
4. Mother group MN, genotype MN, gametes M and N
 Father group N, genotype NN, gametes all N.
 Probable offspring: 50% MN and 50% NN.
 Probability: group MN 0.5; group N 0.5.
5. (a) Heterozygotes have one normal allele that is expressing the protein – enzyme. They also have one mutated allele so that is making an abnormal enzyme that does not function. Hence they have only half the amount of enzyme as in people who are homozygous for the normal allele.
- (b) (i) At the molecular level both alleles are expressed – one makes the normal functioning enzyme and the other coding for an abnormal enzyme/enzyme with abnormally shaped active site, which does not function. Hence at this level they can be considered as codominant. (At the phenotype level the faulty allele is considered recessive – this genetic disease has a recessive inheritance pattern.)
- (ii) For example, no one is responsible for the alleles they inherit; we cannot control the genetic lottery of making our gametes and what happens at fertilisation.

6.2.7 Autosomal linkage (page 192)

1. females males
- (a) Parental phenotypes: red-eyed, thin wing-veined \times brown-eyed, thick wing-veined
 Parental genotypes: $(RE+TV+)$ $(RE+TV+)$ \times $(retv)$ $(retv)$
 Gamete genotypes: $(RE+TV+)$ $(retv)$
 F_1 genotypes: all $(RE+TV+)$ $(retv)$
 F_1 phenotypes: all red-eyed with thin wing veins

F_1 interbreeding: $(RE+TV+)$ $(retv)$ \times $(RE+TV+)$ $(retv)$
 Gamete genotypes: $(RE+TV+)$ and $(retv)$ \times $(RE+TV+)$ and $(retv)$
 Punnett square:

Gametes	$(RE+TV+)$	$(retv)$
$(RE+TV+)$	$(RE+TV+)$ $(RE+TV+)$ Red eyes and thin wing veins	$(RE+TV+)$ $(retv)$ Red eyes and thin wing veins
$(retv)$	$(RE+TV+)$ $(retv)$ Red eyes and thin wing veins	$(retv)$ $(retv)$ Brown eyes and thick wing veins

Expected F_2 phenotype ratio: 3 red-eyed and thin wing-veined: 1 brown-eyed and thick wing-veined.

The observed results show roughly a 3: 1 ratio, but there is also a small number of recombinants; those with red eyes and thick wing veins, and those with brown eyes and thin wing veins. These are the result of recombinations of alleles at prophase I of meiosis due to crossing over and allele swapping between non-sister chromatids.

Possible recombinant gametes produced by the male and female flies are $(RE+tv)$ and $(reTV+)$

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Therefore the 11 flies with red eyes and thick wing veins are genotype (RE+ tv)(retv)

And the 12 flies with brown eyes and thin wing veins are genotype (reTV+)(retv)

- (b) The red-eyed, thick-winged flies must be homozygous for thick wing veins as that is a recessive characteristic. They could be homozygous or heterozygous at the eye colour locus, as red eyes is a dominant characteristic. Therefore their possible genotypes could be (RE+tv) (RE+tv) or (RE+tv) (retv)

Flies with genotype (RE+tv) (RE+tv) produce gametes of genotype (RE+tv)

Flies with genotype (RE+tv) (retv) can produce gametes of genotype (RE+tv) or gametes of genotype (retv)

The brown-eyed, thin-winged flies must be homozygous for eye colour as brown eyes is a recessive characteristic, but could be homozygous or heterozygous for wing veins, as thin wings is a dominant characteristic. Therefore their possible genotypes are (reTV+) (reTV+) or (reTV+) (retv)

Flies with genotype (reTV+) (reTV+) produce gametes of genotype (reTV+)

Flies with genotype (reTV+) (retv) can produce gametes of genotype (reTV+) or gametes of genotype (retv)

Possible matings could be:

- 1 (RE+tv) (RE+tv) × (reTV+) (reTV+)
- 2 (RE+tv)(RE+tv) × (reTV+) (retv)
- 3 (RE+tv) (retv) × (reTV+) (reTV+)
- 4 (RE+tv) (retv) × (reTV+) (retv)

Mating 1

Gametes are (RE+tv) and (reTV+) so if we assume there is no crossing over then all offspring will be genotype (RE+ tv)(re TV+)

All will have the phenotype red eyes and thin wing-veined.

Mating 2 assuming no crossing over

Gametes for first parent are all of genotype (RE+tv)

Gametes for other parent may be (reTV+) OR (retv)

Possible gamete combinations are:

either (RE+tv)(reTV+) giving offspring with phenotype red eyes and thin wing veins

or (RE+tv) (retv) giving offspring with phenotype red eyes and thick wing veins.

Mating 3 assuming no crossing over

Gametes of first parent are either (RE+tv) or (retv)

Gametes of second parent are all (reTV+)

Possible gamete combinations are:

either (RE+tv)(reTV+) giving offspring with phenotype red eyes and thin wing veins

or (retv) (reTV+) giving offspring with phenotype brown eyes and thin wing veins.

Mating 4 assuming no crossing over

Gametes of first parent are (RE+tv) or (retv)

Gametes of second parent are (reTV+) or (retv)

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Possible gamete combinations are:

(RE+ tv) (reTV+) giving offspring with phenotype red eyes and thin wing veins

(RE+tv) (retv) giving offspring with phenotype red eyes and thick wing veins

(retv) (reTV+) giving offspring with brown eyes and thin wing veins

(retv) (retv) giving offspring with brown eyes and thick wing veins.

Even if crossing over occurred when gamete formation occurred in these parent flies, because each one is homozygous at one locus, recombinant gametes would not differ from non-recombinant gametes.

- (c) Red-eyed with thick wing-veined wings × brown-eyed and thick wing-veined.

(RE+) (tv) (RE+) (tv) × (re) (tv) (re) (tv)

Gametes: (RE+) (tv) × (re) (tv)

Offspring genotypes: (RE+) (tv) (re) (tv)

Offspring phenotypes: red-eyed thick wing-veined wings

Crossing over would not have any effect on the outcome.

Brown-eyed flies with thin wing-veined wings × brown-eyed flies with thick wing-veined wings

Gametes: (re) (TV+) × (re) (tv)

Offspring genotypes: (re) (TV+) (re) (tv)

Offspring phenotypes: brown-eyed with thin wing-veined wings.

Crossing over would not have any effect on the outcome.

2. Rabbit parents genotypes: (BC) (bc) × (bc) (bc)

Gametes: (BC) and (bc) × (bc)

Offspring genotypes: (BC) (bc) (BC) (bc) (bc) (bc) (bc) (bc)

Offspring phenotypes: 50% black full colour, 50% brown chinchilla

The brown full colour and black chinchilla rabbits are the result of recombinant gametes formed during crossing over in meiosis 1 in the black full colour rabbits.

This can produce gametes (bC) and (Bc)

If these gametes combine with the bc gametes, the following offspring genotypes can appear: (bC)(bc), which have the phenotype brown full colour and (Bc)(bc), which have the phenotype black chinchilla.

6.2.8 Epistasis (page 196)

1. (a) DDEE, DdEE, DdEe, DDee, Ddee, are all white; ddEE, ddEe – yellow; ddee – green.

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(b)

Genotypes of F_1 /parents: DdEe

Gametes: (DE) (De) (dE) (de)

Punnett square:

♂ gamete	(DE)	(De)	(dE)	(de)
♀ gamete	(DE)	DDEE white	DDEe white	DdEE white
(De)	DDEe white	DDee white	DdEe white	Ddee white
(dE)	DdEE white	DdEe white	ddEE yellow	ddEe yellow
(de)	DdEe white	Ddee white	ddEe yellow	ddee green

Phenotype ratio of 12 white : 3 yellow : 1 green

This is a modified (9 : 3) : 3 : 1 ratio

2.

 F_1 genotypes: AaBb

Gametes: (AB) (Ab) (aB) (ab)

Punnett square:

♂ gamete	(AB)	(Ab)	(aB)	(ab)
♀ gamete	(AB)	AABB purple	AABb purple	AaBB purple
(Ab)	AABb purple	AAbb white	AaBb purple	Aabb white
(aB)	AaBB purple	AaBb purple	aaBB white	aaBb white
(ab)	AaBb purple	Aabb white	aaBb white	aabb white

9 purple : 7 white

3. PpRr × pprr (walnut comb x single comb).

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4. The litters produced by the true-breeding black and brown cats, producing all brown cats, tell us that brown is dominant and black is recessive. The gene B/b codes for fur colour, B = brown and b = black. Another epistatic gene locus, C/c, codes for pigment production. Cats with genotype cc are white.

Parent phenotypes: black cat white cat
 Parent genotypes: bbCc Bbcc must be heterozygous at B/b locus as litter contains black kittens
 Gametes: (bC) and (bc) (Bc) and (bc)
 Offspring genotypes: BbCc bbCc Bbcc bbcc
 Offspring phenotypes: brown black white white
 Phenotype ratio: 1 : 1 : 2

5. (a) (i) Genotypes for purple: AABB, AaBB, AaBb, AABb.
 (ii) Genotypes for pink: AAbb; Aabb.
 (iii) Genotypes for white: aaBB, aaBb, aabb.
 (b) (i) AaBb × AAbb
 Offspring genotypes: AABb; AAbb; AaBb; Aabb
 Purple; pink; purple; pink; 50% purple and 50% pink.
 (ii) AaBb × Aabb

Gametes	(AB)	(Ab)	(aB)	(ab)
(Ab)	AABb purple	AAbb pink	AaBb purple	Aabb pink
(ab)	AaBb purple	Aabb pink	aaBb white	aabb white

Phenotype ratio: 3 purple: 3 pink: 2 white.

- (iii) AaBb × aabb

Gametes	(AB)	(Ab)	(aB)	(ab)
(ab)	AaBb purple	Aabb pink	aaBb white	aabb white

Phenotype ratio: 2 white : 1 purple : 1 pink.

- (iv) AaBb × aaBb

Gametes	(AB)	(Ab)	(aB)	(ab)
(aB)	AaBB purple	AaBb purple	aaBB white	aaBb white
(ab)	AaBb purple	Aabb pink	aaBb white	aabb white

Phenotype ratio: 4 white : 3 purple : 1 pink.

6. (a) White cockerel must have genotype IiCc.
 (b) Brown hen has genotype iiCc or iiCC.

If she is iiCc:

Male gametes → Female gametes ↓	(IC)	(Ic)	(iC)	(ic)
(iC)	IiCC	IiCc	iiCC	iiCc

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	white	white	brown	brown
(ic)	IiCc white	Iicc white	iiCc brown	iicc white

Phenotype ratios are 5 white : 3 brown.

7. Purple-flowered sweet pea genotypes: AaBb.

White-flowered sweet peas not true-breeding, genotype: aaBb (they must be homozygous at a otherwise they would be purple).

Gametes	(AB)	(Ab)	(aB)	(ab)
(aB)	AaBB purple	AaBb purple	aaBB white	aaBb white
(ab)	AaBb purple	Aabb white	aaBb white	aabb white

Phenotype ratio: 5 white : 3 purple.

8. DdEe × DdEe

Gametes: DE; De; dE; de.

Gametes	(DE)	(De)	(dE)	(de)
(DE)	DDEE dark brown/black	DDEe medium brown	DdEE medium brown	DdEe light brown
(De)	DDEe medium brown	DDee light brown	DdEe light brown	Ddee dark blue
(dE)	DdEE medium brown	DdEe light brown	ddEE light brown	ddEe dark blue
(de)	DdEe light brown	Ddee dark blue	ddEe dark blue	ddee pale blue

Phenotypes: 1 dark brown/black : 4 medium brown : 6 light brown : 4 dark blue : 1 pale blue.

6.2.9 Using the chi-squared test (page 198)

- yy/homozygous recessive.
- 3 yellow : 1 grey.
- Expected would be 156 yellow and 52 grey. Observed is 140 yellow and 68 grey. χ^2 calculates as 6.56. Two degrees of freedom. Chi-squared critical value at $p = 0.05 = 3.84$. Calculated value is larger, therefore this is a significant difference at $p = 0.05$ level and we reject the null hypothesis.
- YY is a lethal combination. The $\frac{1}{4}$ YY embryos do not survive, so the ratio of yellow to grey will be 2 : 1. $140 : 68 = 2.06:1$. Chi-squared test shows difference between observed and expected (139 and 69) is not significant.
- Yy × yy; would expect 50% Yy, yellow, and 50% yy, grey: a 1:1 phenotype ratio.

6.2.10 Discontinuous and continuous variation (page 200)

1. Monohybrid inheritance pattern:

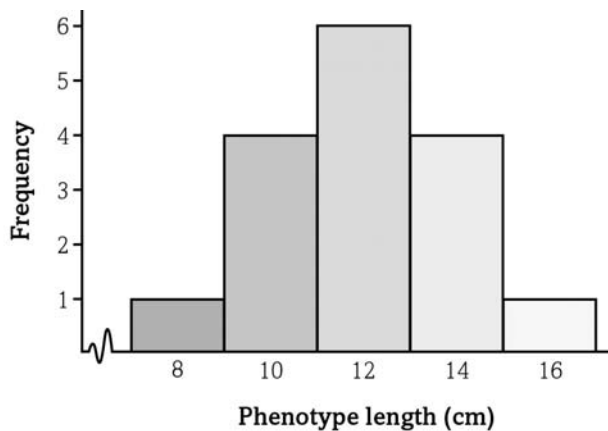
Parent phenotypes: resistant resistant
 Parent genotypes: $R^{WR}R^{WS}$ $R^{WR}R^{WS}$
 Gamete genotypes: R^{WR} R^{WS} R^{WR} R^{WS}

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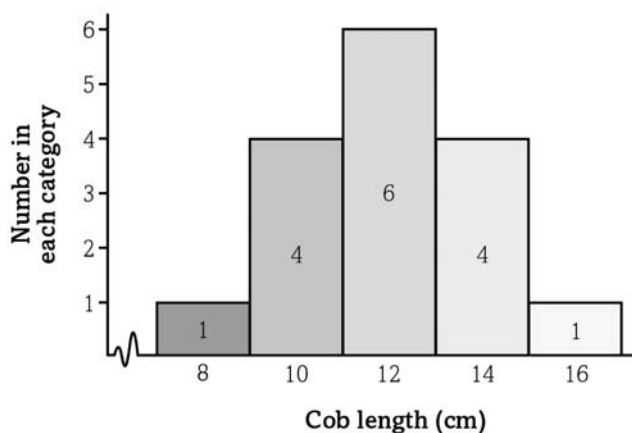
Offspring genotypes: $R^{WR}R^{WR}$ $2 \times R^{WR}R^{WS}$ $R^{WS}R^{WS}$

Offspring phenotypes: 3 resistant : 1 susceptible.

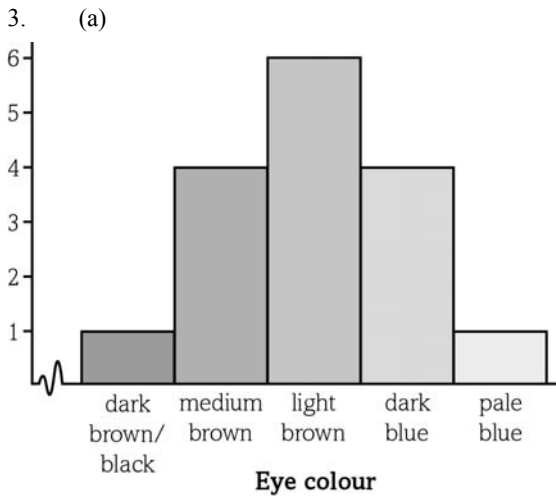
2.



♂ gamete \ ♀ gamete	AB	Ab	aB	ab
AB	AABB 16 cm	AABb 14 cm	AaBB 14 cm	AaBb 12 cm
Ab	AABb 14 cm	AAbb 12 cm	AaBb 12 cm	Aabb 10 cm
aB	AaBB 14 cm	AaBb 12 cm	aaBB 12 cm	aaBb 10 cm
ab	AaBb 12 cm	Aabb 10 cm	aaBb 10 cm	aabb 8 cm



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eye colour may also read
pale blue → dark brown/black

(b) Continuous variation.

6.2.11 Factors affecting the evolution of a species (page 203)

- More large and small, and fewer intermediate sized animals.
 - Disruptive selection.
- May be too few females/imbalance of the sexes so not all animals can mate – reduced number of offspring born. May be hard for individual animals to find mates. If very few males, then many offspring will be genetically related and if they interbred this could increase the frequency of harmful alleles.
- Cheetahs have been through a genetic bottleneck. Today's population has descended from a small number of individuals (founder effect) and there will have been inbreeding; this increases the chances of homozygous offspring with harmful recessive alleles.
 - Two of the three: poor sperm quality and susceptibility to the same infectious diseases.
- This is due to the founder effect. The population was founded by a small number of individuals. We all carry some harmful recessive mutation, but in a large population with random mating, it is rare that carrier parents mate and produce a homozygous recessive child with the disorder. Within a small population where individuals are genetically related, more will carry that recessive allele and the probability of producing offspring with the disorder increases.
- Small gene pool due to founder effect. More alleles for the inherited form of breast cancer within the population and more chance of individuals homozygous for that trait being born.

6.2.12 The Hardy–Weinberg principle (page 205)

- Mutation, migration, natural selection/directional selection/disruptive selection/stabilising selection, (changes in population size) – genetic drift, isolation of a population with subsequent selection/genetic drift, non-random mating/in-breeding.
- 36% of people cannot roll their tongue. They are homozygous recessive. Therefore p^2 is 0.36.
 $p = 0.6$. Therefore $q = 1 - 0.6 = 0.4$. $2pq = 0.48$. Therefore 48% of the population are heterozygous for tongue rolling.
- The symptomless carriers are heterozygotes, $2pq$. Those affected with the disease have genotype q^2 .
 $q^2 = 1/500 = 0.002$. $q = \sqrt{0.002} = 0.045$. $p = 1 - 0.045 = 0.96$. $p^2 = 0.91$. $2pq = 0.09$. Therefore 9% of the population carry the recessive allele. This is about 1 in 11 people.

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- (b) Because being heterozygous gives some protection against malaria, in areas where malaria is endemic and acting as a selection pressure, heterozygotes will have a selective advantage.
4. (a) If alleles are codominant we know that those of group M are genotype MM, group N are genotype NN and those of group MN are heterozygous. If 26% are group M and 25% group N, then 49% are group MN. The frequency of heterozygotes is = 0.49.
- (b) Within the gene pool of this population (assuming the population is 100%), there are 200 alleles altogether for this characteristic. If 49% of the population is genotype MN, then for these heterozygotes there are 49 M alleles and 49 N alleles in the gene pool. The 26% who are MM give 52 M alleles to the gene pool and the 25% who are NN give 50 N alleles to the gene pool. The frequency of the M allele is = $(49 + 52)/2 = 50.5\%$ or 0.505. Therefore frequency of N allele is $(1 - 0.505) = 0.495$.

6.2.13 Isolating mechanisms (page 207)

- Mules will have 63 chromosomes (32 from mother and 31 from father) so there is an odd number of chromosomes; they cannot pair up; meiosis cannot take place; gametes cannot be made.
- Sympatric speciation/reproductive isolation; urban and rural birds are not geographically isolated; the changes in song could prevent mating between rural and urban-dwelling birds as song is part of courtship ritual.
- For example, habitat destruction, such as clearing forests for wood/space; climate change; pollution; agriculture; use of pesticides; antibiotics; changes may cause wildlife to migrate; may introduce a novel selection pressure.
- (a) Marine and land Galapagos iguanas can interbreed. Not yet sufficiently genetically different to be classed as different species.
- (b) Allopatric (resulting from geographic isolation).

6.2.14 Artificial selection (page 209)

- Grow plants in cold temperatures; select those that grow best; cross-pollinate and collect seeds grown from these, also in cold temperatures; select those that grow best and use as parents; keep repeating over many generations.
- Lack of vigour, loss of fertility and reduction in population size, due to organisms being inbred and becoming homozygous at many gene loci.
- Gene banks are sources of alleles to introduce back into the artificially bred strains and increase hybrid vigour.
- Animal welfare issues; named examples of problems faced by dogs; general ideas – animals no longer able to survive in the wild because traits desired by humans may put them at a selective disadvantage.
- For example, dogs have no choice; dogs try to please and will not realise the danger they are in; the army regards the dogs as equipment; however, many soldiers' lives saved as a result; animals have been exploited in human service over many thousands of years; dogs are well looked after and bond with their handler; sometimes the handler is allowed to keep the dog after it has retired/left the service/been invalidated out.

6.2 Practice questions (page 212)

- C
- D
- C
- B
- B
- (a) (i) Allele – a version of a gene.
(ii) Homozygous – having two identical alleles, at a particular gene locus/for a particular genotype.

(b)

	mother	father
Parent phenotypes	Manx	Manx

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Parent genotypes	Mm	×	Mm		
Gamete genotypes	M	m	×	M	m

Punnett square:

gametes	M	m
M	MM lethal – fails to develop	Mm Manx cat
m	Mm Manx cat	mm cat with tail

Phenotype ratio is 2 Manx cat : 1 tailed cat.

- (c) Mm × mm gives gametes M, m, m and m.

Predicted phenotype ratio is 1 Manx cat : 1 tailed cat.

- (d) In the wild, M allele leads to spine deformity and would put the cat at a disadvantage; natural selection, rather than artificial selection operating; more mm cats survive and reproduce; therefore frequency of m allele increases and frequency of M allele decreases.
7. (a) The enzyme responsible for catalysing the reaction leading to melanin formation has a low optimum temperature/an optimum temperature below cat core body temperature; this enzyme coded for by a gene; (accept idea that gene works better in cooler temperatures – max 1).
- (b) They have been in the uterus where the environmental temperature is uniformly very warm.
- (c) (i) Hybrid vigour – greater vigour for growth/survival/fertility of hybrids; increased heterozygosity/heterozygous at more gene loci.
(ii) Inbreeding depression – reduced vigour/growth/survival/fertility; increased homozygosity.
- (d) Use symbols, for example, B = black, b = Siamese.
- (i)

Parent phenotypes	Siamese	×	black
Parent genotypes	bb	×	BB
Gamete genotypes	b	×	B
F ₁ genotypes	all Bb		
F ₁ phenotypes	all black		

(ii) Interbreed F₁:

Parent genotypes	Bb	×	Bb		
Gamete genotypes	B	b	×	B	b

Punnett square:

gametes	B	b
B	BB black	Bb black
b	Bb black	bb Siamese

- (e) Siamese rats may have been bred from a small number of rats; therefore inbreeding/small gene pool; inbreeding depression; outbreeding increases hybrid vigour/heterozygosity.
8. (a) (i) Sex linkage – gene locus/loci on one of the sex chromosomes.
(ii) Autosomal linkage – gene locus/loci on one of the autosomes/chromosome other than X and Y.

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(b)

	females		males
Parent phenotypes	red-eyed	×	white-eyed
Parent genotypes	$X^R X^R$	×	$X^r Y$
Gamete genotypes	all X^R	×	X^r Y
F ₁ genotypes	$X^R X^r$	and	$X^R Y$
F ₁ phenotypes	red-eyed female	and	red-eyed males

F ₂ generation interbreeding	$X^R X^r$		×	$X^R y$	
F ₂ gametes	X^R	X^r	×	X^R	Y
F ₂ genotypes	$X^R X^R$	$X^R Y$		$X^r X^R$	$X^r Y$
F ₂ phenotypes	red-eyed females	red-eyed males		red-eyed females	white-eyed males

F₂ phenotype ratio is: 2 red-eyed females : 1 red-eyed male : 1 white-eyed male.

- (c) (i) The mother is a symptomless carrier; she has an abnormal allele for blood clotting factor/factor 8 on one of her X chromosomes; and has passed the abnormal allele to her son on the X chromosome.

(ii)

Parent genotypes	$X^H X^h$		×	$X^H y$	
Gametes	X^H	X^h	×	X^H	Y
Offspring genotypes	$X^H Y$	$X^h Y$		$X^H X^H$	$X^h X^H$
Offspring phenotypes	unaffected male	male with haemophilia		unaffected female	carrier female

Probability is 1 in 4 (or 1 in 2 of all males conceived).

- (d) (i) Polygenic; many genes infers many chromosomes involved; gene loci are on autosomes; alleles passed from both parents to affected offspring.
- (ii) Need environmental trigger/dihydrotestosterone; derived from testosterone and females have very little testosterone/males have much more testosterone.
9. (a) Crossing over; allele swapping/shuffling; between non-sister chromatids; at prophase 1; of meiosis; independent assortment of chromosomes at metaphase/anaphase 1/independent assortment of chromatids at metaphase/anaphase 2; haploid gametes; genetically unique gametes; random fertilisation/gamete combination.
- (b) (i) To break down/convert homogenistic acid.
- (ii) Recessive.

Parent genotypes	Aa	×	Aa
Gametes	A a	×	A a

gametes	A	a
A	AA	Aa

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a	Aa	aa
---	----	----

Offspring phenotypes: 3 unaffected : 1 with alkaptonuria

- (iii) Increases probability of both parents having this rare recessive allele; as cousins have the same grandparents.
- (c) For example, genes code for other proteins besides enzymes; some genes code for more than one protein; some genes code for RNA that regulates other genes, so do not code for a protein at all.
- 10. (a) (i) Dairy produce in diet exerts selection pressure/is agent of selection.
PLUS EITHER:
Intolerant individuals by not being able to tolerate dairy may suffer malnutrition/undernutrition, or may produce fewer offspring
OR
Those with (useful/advantageous) mutation, making them tolerant, will not suffer malnutrition/are more likely to survive and reproduce/produce more offspring.
PLUS
Those with the mutation making them lactose intolerant may pass on allele for lactase enzyme/allele for regulatory gene that does not switch off lactase gene.
[Answers should include main point 1 and 4 plus up to 2 from either/or section]
- (ii) Yoghurt has been made using bacteria; these will have digested/converted the lactose to monosaccharides/glucose and galactose.
- (b) (i) They are lactose intolerant/cannot digest lactose; so will suffer intestinal problems/vomiting/flatulence/discomfort.
- (ii) Heated; to hydrolyse lactose to glucose and galactose.
OR
Treated with (immobilised) lactase enzyme; to digest lactose to glucose and galactose.

6.3 Manipulating genomes

6.3.1 DNA sequencing (page 218)

- CTTAAGCTACCCGATT
- AGTTCCCGACCTAA

6.3.2 Applications of gene sequencing (page 220)

- As they have conferred a selective advantage on their 'owners' those genes are likely to survive/remain in the genome a long time, or the genes will be in the genome of the species that have evolved from the original species.
- To find out about evolutionary relationships – how closely related particular species are to each other; creation of phylogenetic or evolutionary trees/classification.
- To find out to which diseases they are susceptible and to find out which medicines will/will not give them side effects; personalised medicine; variable sequences allow DNA profiling.

6.3.3 DNA profiling (page 222)

- White blood cells, as they have a nucleus, whereas red blood cells do not.
- The cells from the attacker's skin, or hair roots that might have been pulled out by the victim, will both be sources of the attacker's DNA.

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- For example, some people fear that their personal DNA on a database could be mined for information and abused by insurance companies; some people see it as an invasion of privacy; a national database may not have DNA from visiting people/illegal immigrants; it could make crime-solving easier; other valid points.

6.3.4 The polymerase chain reaction (page 224)

- Cofactors for the enzyme DNA polymerase.
- It is heat stable/has a high optimum temperature so this stage of the PCR requires less cooling; this speeds things up.
- For example, PCR – short lengths of DNA replicated, in natural replication – whole molecules of DNA are replicated; PCR – process repeated over and over again immediately, in natural replication – DNA replicates once per cell cycle; PCR – heat breaks H bonds between complementary base pairs, in natural replication – helicase/gyrase enzymes involved in unwinding/unzipping; both use DNA polymerase, but PCR uses Taq DNA polymerase so it can be run at higher temperature.
- DNA polymerase cannot bind to single-stranded DNA.
- 20.
 - 22.

6.3.5 Electrophoresis (page 227)

- Hydrogen bonds.
- As they migrate through the gel – attracted to the anode because the fragments all carry an overall negative electric charge – smaller fragments travel faster, so in a fixed time they travel further in the gel.
- In TLC the molecules pass through a medium and smaller molecules travel faster, therefore further in a fixed time period, than the larger molecules.
- That is the optimum temperature for the restriction enzymes.
- Within the probe is a sequence of DNA nucleotide bases, complementary to a DNA sequence (within a fragment). This binds to the piece of DNA. If the probe is also labelled with radioactive isotopes or fluorescence, it can show the position of the DNA fragment in the gel.

6.3.6 Genetic engineering (page 230)

- The mRNA obtained has had the introns removed, so when reverse transcribed there are no intron codons to act as templates and produce DNA base triplet introns.
- Hydrogen bonds.
- Using mRNA as a template, this produces complementary single-stranded DNA.
 - Catalyses the joining of sugar and phosphate groups within the DNA backbone/strands.
 - Cleaves DNA at specific recognition sites
 - Enable annealing between gene and plasmid to make recombinant DNA.
- Inside a modified virus; in a recombinant plasmid (that may be in *A. tumefaciens*); using a gene gun – DNA coating on tiny fragments of gold or tungsten. (Accept liposomes.)

6.3.7 Issues relating to genetic manipulation (page 233)

- In context of suitable examples – for example, Golden Rice™ could alleviate much suffering – blindness also prevents children in India from learning and working so increases poverty; GM food has been eaten in USA and some other parts of the world for over 20 years without apparent adverse effects – in contrast to much non-GM, but processed food – for example, high fat and high sugar food that has led to obesity problems; benefits of Golden Rice™ are likely to far outweigh any potential hazards; children in those areas of the world do not have access to carrots, green vegetables, mangoes, etc. that are good sources of beta carotene; pest-resistant – reduces need for pesticide; better for environment as pesticides can kill useful insects/accumulate in food chains and also kill those applying it if they do not have full protective clothing (which is the case in many less developed countries). May also use examples other than those in the topic – for example, drought resistance, flood

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resistance – to increase yield and help provide enough food for people in areas where food security is at risk.
Risks: modified genes could have unknown adverse effects on humans/animals that consume them; GM crops may escape into the wild and become invasive species.

2. For example, earthquakes, floods, volcanic eruptions, drought, disease, extreme weather events.

For example, vaccines, surgery, cars, Internet/computers/mobile phones, clothes.

6.3.8 Gene therapy (page 235)

1. At present, scientists/doctors can only insert a functioning copy of an allele. In recessive disorders the non-functioning allele fails to produce the functioning protein, so if a functioning allele is inserted the patient will produce that protein in the cells that have received the allele. In a dominant condition, the faulty allele produces an altered protein that harms the cells/patient. As these patients already have one functioning allele, adding another will not remove the product of the faulty allele. At present, the dominant alleles cannot be taken out of cells.
2. May give a precise tool for identifying where the faulty alleles is and cutting the DNA to 'snip' it out. However, this would have to be done at zygote/embryo stage and would be germ line therapy.
3. It depends where the inserted allele inserts itself in the patient's genome. It could disrupt a gene that regulates cell division, leading to cancer; or it could interfere with the regulation of other genes.
4. Location of insertion of the allele within the altered virus – could also disrupt cell division or regulation of other genes; virus may provoke an immune response or inflammatory response in patient – this may be particularly harmful in someone already ill, for example, cystic fibrosis patient; if virus was used as delivery for a therapy that has to be repeated at intervals, patient's immune response may prevent the virus entering cells on subsequent administrations.
5. It will alter all the patient cells' genomes and may/will be passed to their offspring – thereby altering the genetic make-up of many people (who did not have a chance to consent); it may also be unpredictable due to where it locates.

6.3 Practice questions (page 238)

1. C
2. A
3. B
4. A
5. C
6.
 - (a) (Composite) DNA molecule; created *in vitro*; by joining foreign DNA with a vector molecule of DNA.
 - (b)
 - (i) Enzymes that cleave/cut DNA; at a specific recognition site; may leave sticky ends or blunt ends.
 - (ii) Catalyses formation of double-stranded DNA from a single-stranded DNA template.
 - (iii) Catalyses formation of complementary DNA using mRNA as template.
 - (iv) Catalyses formation of phosphodiester bond; between sugar and phosphate groups of DNA backbone strands.
 - (c) Mix bacteria with recombinant plasmids; calcium chloride to provide calcium ions to make walls/membrane more porous/permeable; heat shock (0 °C/ice followed by 40 °C).
 - (d) The gene will be inserted in the middle of a gene for ampicillin resistance, making this gene unable to be expressed; plasmids also have tetracycline resistance gene; bacteria plated out onto nutrient agar that contains tetracycline, so only bacteria that have taken up a plasmid will grow; press sterile velvet onto bacterial colonies; keep orientation same and press velvet down onto agar containing ampicillin; only those colonies that grow in tetracycline-containing agar, but not in ampicillin-containing agar contain recombinant plasmids.
7.
 - (a) For example, if herbicide-tolerant– can spray herbicide to kill weeds and not kill crop plant; potatoes produce the toxin to kill caterpillars so no need for insecticide to be used: insecticide can kill beneficial insects; if weeds/pests reduced, greater yield of crops; due to reduced interspecific competition/predation/parasitism; accept other valid points.

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- (b) For example, the study/trial shows that these are not likely to survive if they escape into the wild; most extinct within four years; all population sizes shrunk within first year; some people fear that genes for herbicide resistance could transfer to weeds; probably unlikely as genes do not normally transfer from crop plants to wild weed plants; they are different species so cross pollination not likely/pollen not compatible; even if hybrids were produced, they are likely to be infertile (contrast this with garden escapes, such as rhododendron or Japanese knotweed that are invasive and destructive).
- (c) For example, need to produce more food to meet demands of growing population; cannot just keep using more fertiliser and pesticides; need to make crops resistant to drought/flood/higher temperatures; as well as to diseases/pests; also need nutritionally enhanced crops; suitable examples, such as Golden Rice™, bananas with more zinc; pesticide resistance could eliminate need for pesticides and exposure of sprayers to the pesticides; concerns about effects of GM crops on biodiversity; but they have been grown in US for 20 years and no apparent loss of biodiversity; no obvious ill health consequences to humans from eating them have been seen so far; suggestions GM causes reduction in honey bee populations; but this unlikely to be the case as bee populations are dwindling in UK and no commercially grown GM here; more likely to be (nicotinoid) pesticides; accept all valid points in balanced argument.
8. (a) (i) Virus genes/genome knocked out or altered; so not virulent/cannot cause infection; insert gene to be delivered within the protein coat of virus; can be injected or breathed in *in vivo*; can be injected into extracted cells *in vitro* and then altered cells placed back into patient; viruses dock with receptors on host cell plasma membranes and enter the cell, so can carry in the gene; many viruses insert their genes into host genome.
- (ii) Gene enclosed in spherical liposomes; lipid/phospholipid molecules similar to those of plasma membranes; small spheres can be put into aerosol inhaler for delivery into body/nose/respiratory tract.
- (b) Viruses, even if made non-virulent, still have antigens on their surface; and can provoke immune response; or inflammatory response; this inflammatory response could be harmful in people who are already ill; or after immune response, patient's body may not accept subsequent virus particles with the gene.
- (c) Because epithelial cells lining the airways are replaced every 10–14 days; therefore new cells will need the gene to be inserted; as the new cells are not derived from existing epithelial cells – these are differentiated and cannot divide.
9. (a) (i) The gene for the enzyme/protein is on the X chromosome.
- (ii) Type of lymphocyte involved in immune response; reference to helper/killer/suppressor/memory; do not make antibodies.
- (iii) Unregulated mitotic cell division/mitosis that leads to exponential (rate of increase increases) increase of these bone marrow cells/T cells.
- (iv) Type/family of viruses that have RNA and reverse transcriptase enzyme; they insert their genomes into host cells.
- (v) Gene involved in regulation of cell cycle/division; if mutated can become oncogene and promote cancer/unregulated mitosis and tumour formation.
- (vi) Region of DNA to which an RNA polymerase enzyme can bind to initiate transcription.
- (vii) Abnormal/unusual transcription/alterd rate of transcription and therefore abnormal amounts of protein made.
- (b) For example, quality of life of those with SCID is very low – cannot be in contact with people/any source of bacteria/infecting agent; may be able to receive injections of missing protein so some therapy available without gene therapy; usually involves treating children – issues of informed consent; some patients respond well, but some may develop cancer/leukaemia; however, with advent of human genome information could eventually be able to tell which will respond well/adversely and so not deny treatment to those who could benefit; (no right/wrong answers – accept well-reasoned, balanced arguments with some underlying biological principles).
10. (a) Somatic: body cells only/no gametes involved; genetic change cannot be passed to offspring; somatic usually needs repeated applications; somatic given at any stage of life – germ line has to be at genetic

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formation/zygote/ early embryo stage; (converse for germ line cell therapy). Germ line can affect many people – descendants of original patient.

- (b) Digest DNA with specific restriction enzymes; at 35–40 °C; for 30–60 minutes; restriction enzymes cut DNA at specific recognition sites; into shorter and different lengths of DNA; loading dye and DNA added to wells in electrophoresis gel; buffer solution; electrodes and power source; DNA fragments migrate towards anode; shorter fragments travel faster so in a set time these will travel further; stain with dye or use probes.
- (c) Polymerase chain reaction; heat to about 95 °C to break/denature double-stranded DNA into single strands; cool to 68 °C; add primers and allow them to anneal; Taq polymerase and 72 °C, so extra DNA nucleotides are added to the primers; one piece DNA now two identical pieces; cycle starts again and keeps repeating.

6.4 Cloning and biotechnology

6.4.1 Natural clones (page 243)

1. No need for: finding a mate, going through courtship, meiosis, fertilisation.
2. The cells do not differentiate as completely. There are areas of meristem (mitotically dividing stem cells) in different parts of the plant.
3. If an individual finds itself in ideal conditions it can start to reproduce without waiting to find a mate. Takes advantage of favourable environment quickly. Can reproduce quickly. If conditions ideal for adult they will also be ideal for offspring.
4. The offspring may not be dispersed well. Often the offspring fall off parent or grow from roots. Offspring grow close to parent.
5. The main stem releases plant hormones or growth substances. If production is changed (by cutting the stem) the roots are stimulated to grow suckers. Changing conditions, such as less shade after stem has been cut, may also stimulate roots to grow suckers.

6.4.2 Clones in plants (page 245)

1. The meristem is the region of stem cells. These are cells that divide by mitosis and are capable of differentiating into all types of cell.
2. The node contains a meristem (this may be a dormant bud). This is a group of cells that can divide and differentiate into different cell types. The side branch would normally grow from this meristem, but if the cutting is planted in moist soil, roots will grow.
3. Sexual reproduction introduces genetic variation. Meiosis recombines the alleles and fertilisation is random. Therefore using sexual reproduction could mean that the unusual combination of characteristics is lost. Cloning the plant will maintain the genetic combinations and so maintain the characteristics.
4. The culture medium is an ideal environment for the growth of microorganisms. If any are present they will grow and cause decay of the explants.
5. A group of stem cells that forms an undifferentiated mass.

6.4.3 Artificial clones in animals (page 247)

1. A heart transplant is major surgery with potential complications, such as trauma – injecting cells is much less major. You do not need to wait for a donor. Less chance of infection. No chance of rejection (as long as the patient's own cells are used).
2. Genetic diversity is created. Meiosis recombines the alleles and fertilisation is random. This means that no two individuals are identical. Selection can occur.
3. The mother. The mitochondria come from the cytoplasm in the egg.

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6.4.4 Introduction to biotechnology (page 250)

1. They reproduce quickly. They convert the waste to harmless substances.
2. An antibiotic reduces the growth of competitors. If food sources are becoming limited the fungus can release an antibiotic, which reduces the growth of the bacteria nearby so that more food is available to the fungus.
3. Microorganisms grow quickly and the population increases rapidly. Product is usually secreted from the cell into the surrounding medium – so it is easy to extract. Microorganisms can grow on almost any organic substrate – so it is easy to find material to act as food.
4. Sufficient food (substrate); suitable temperature; water available; suitable pH.
5. If the human gene for a human antibody is inserted into the cow genome it will express that gene and synthesise that precise protein.

6.4.5 Using biotechnology to make food (page 252)

1. Rennet is from the stomach of a calf. Mammal stomachs are acidic. Therefore the enzymes are adapted to work in low pH (acidic) conditions. The enzyme rennin has an optimum pH in the acid range.
2. The calcium is used to bind the casein proteins together. More calcium can bind more proteins together or make more bonds between the protein molecules – this may affect the texture or hardness of the cheese.
3. Aerobic respiration does not produce alcohol: it produces water and carbon dioxide. Anaerobic respiration in yeast produces alcohol and carbon dioxide.
4. In cheese the addition of rennin helps to precipitate more solid protein, which is then bound together by the calcium ions. The process also takes longer, allowing the cheese to mature and harden.
5. Cheaper than extracting from calf stomachs. More easily extracted from the fermenter than from calves. Supply can be virtually unlimited. Less impurities. Suitable for vegetarians.

6.4.6 Other processes involving biotechnology (page 255)

1. Mutations occur at random – but the rate of mutation can be increased by suitable treatment. By increasing the rate of mutation changes occur to the *Penicillium*. By chance some of these mutations may have increased the rate of penicillin production. These strains of *Penicillium* can be selected.
2. All unwanted microorganisms must be killed to prevent them from growing in the fermenter. If they do grow they reduce the productivity of the desired microorganisms and may release harmful products that spoil the harvest.
3. Insulin is synthesised by the β cells in the islets of Langerhans in the pancreas. Other cells possess the gene, but it is not activated.
4. Transcription. mRNA is synthesised in the nucleus to make a copy of the coding strand of DNA. It carries this code out to the ribosomes in the cytoplasm. It is then used as a template to align the amino acids in the correct sequence.
5. The bacteria/fungi might not break down the waste successfully. The bacteria/fungi might produce harmful by-products. The bacteria/fungi might remain in the soil and cause infections. The bacteria/fungi might escape and start to digest useful stores of the compounds (for example, bacteria used to digest oil spills might start to digest oil in storage tanks or even crude oil before it is taken out of the ground).

6.4.7 Microorganism cultures (page 258)

1. It must be sterilised before use as it may have unwanted bacteria/fungal spores on it – these should not be allowed to infect the agar plate. It must be sterilised after use to ensure it does not spread the cultured bacteria/fungal spores to other places causing infection.
2. To make the density estimates comparable. To make the results valid. A larger drop would contain more bacteria and so give an over-estimate of population density. A smaller drop would contain fewer bacteria so producing an under-estimate of population density.
3. (a) To prevent accidental opening of the dish exposing people to the cultured microorganisms.

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- (b) So that oxygen can enter the dish and allow aerobic respiration – otherwise the culture will encourage anaerobic bacteria which may be pathogenic.
 - (c) The water in the agar gel evaporates – this dehydrates the agar gel limiting growth. Also if the dish is the right way up condensation forms on the lid. This drips onto the agar and may affect the distribution of microorganisms or even have osmotic effects on the cells.
4. Peptones are short polypeptides. These contain amino acids. Amino acids are needed as a source of nitrogen and to make protein and DNA.

6.4.8 Population growth in a closed culture (page 261)

- 1. (a) No difference to growth as food not limiting growth.
- (b) May allow increased growth and an increase in population if nutrients were the limiting factor. However, if a build-up of waste was the factor limiting further growth then no additional growth would be seen.
- 2. Antibiotics kill or reduce the growth of other microorganisms. When food and nutrients are limited the fungus releases antibiotics to reduce competition.
- 3. In an open system the stationary phase may be higher or lower depending on the input of nutrients to the system. There would be no decline phase.

6.4.9 Immobilised enzymes (page 263)

- 1. In covalent bonding and adsorption the immobilisation process may affect the shape of the active site slightly. This would not fully denature the enzyme, but might slow its action.
Enzymes entrapped in a gel or a cellulose mesh may be unable to move: this could affect the rate of collisions between the enzyme active site and the substrate molecules. Also the substrate molecules would need to move through the gel to reach the enzyme.
Enzymes separated from the reaction by a membrane would be unaffected, but the substrate molecules may take longer to reach the enzymes as they must pass through the membrane.
- 2. The bonding between the enzyme and surface may affect the bonding inside the enzyme, or the charge distribution within the enzyme may change. In either case this may alter the shape of the active site.
- 3. The shape of an enzyme active site may be affected by high temperatures. However, the shape of the active site may be supported by being encased in gel or by modified bonding patterns caused by bonding to a surface (covalent or adsorption).
- 4. The enzymes do not need to be supplied with nutrients or oxygen. The population will not grow and need to be reduced to keep the fermentation working. The enzymes do not produce toxic waste products that would stop the growth of a microorganism population. Even secondary metabolites can be produced on a continuous basis.

6.4 Practice questions (page 266)

- 1. C
- 2. A
- 3. D
- 4. B
- 5. B
- 6. (a) (i) Two from: rapid; uniform growth; all potatoes have same flavour/texture.
- (ii) All the potato plants were genetically identical; all susceptible to the fungus; huge monoculture grown making it easy for the fungus to spread.
- (b) (i) Apical bud/meristem used as this is free from pathogens; tested to ensure resistance to pathogens.
- (ii) Cut explants (from apical buds/meristems); sterilise in dilute bleach; grow a callus on nutrient medium with correct proportion of plant growth hormones; divide callus to make more plants; transfer to medium containing correct ratio of plant growth hormones; to encourage root and shoot growth; transfer to soil/compost.

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7.
 - (a) Three from: all animals similar; respond to environmental conditions in the same way; all high-yielding; all grow at same rate.
 - (b) Isolate sperm from male with good characteristics; isolate egg from female with good characteristics; fertilise egg by *in vitro* fertilisation; incubate; allow eggs to divide to a group of cells; separate cells; allow to grow to a small group of cells; implant each group into surrogate mother.
 - (c) Producing sperm and egg involves meiosis; this generates genetic diversity; random choice of sperm used for fertilisation; exact combination of genes in offspring unknown.
8.
 - (a) A = lag phase; B = log/exponential phase; C = stationary phase; D = decline/death phase.
 - (b) No addition of nutrients; no removal of waste products or cells.
 - (c) Primary metabolites: line rises steeply during phase B.
 - (d) Secondary metabolites: line rises during phase C and D.
 - (e) At A: only a small number of cells dividing; the microorganisms must adapt to new environment/named adaptation (for example, by making new enzymes).
At B: no limit to nutrients and space available; cell numbers double at each generation.
 - (f) The curve would be similar at points A, B and C; D does not occur; open system supplies fresh nutrients/removes waste products; death rate (caused by lack of nutrients or build-up of waste products) does not increase.
9.
 - (a) Enzymes.
 - (b) Enzyme does not mix with product; enzyme is available for use again/use in continuous fermentation; enzyme structure is protected so higher temperature can be used.
 - (c) Two from:
Adsorption: enzyme molecules bound to a supporting surface by hydrophobic interactions and ionic links.
Covalent bonding: enzyme molecules are bonded to a supporting surface by a cross-linking agent.
Entrapment: enzyme molecules are trapped in a matrix (such as cellulose mesh or alginate gel).
Membrane separation: enzyme molecules are separated from the reaction mixture by a partially permeable membrane.
 - (d) Rate rises between 10 and 30 °C due to greater kinetic energy of substrate molecules; then falls in free enzyme as enzyme molecules are denatured at 70 °C; immobilised enzymes slower than free enzymes at 10 °C and 30 °C due to absence of enzyme movement; and due to need for substrate molecules to diffuse into the alginate gel; immobilised enzyme still active at 70 °C and at a higher rate than for free enzymes at any temperature as its structure is protected by the alginate gel.

6.5 Ecosystems

6.5.1 Ecosystems (page 271)

1.
 - (a) Parasitism; competition.
 - (b) Water; pH; light intensity.
2.
 - (a) Producers gain their energy from the environment (usually the Sun). They use this energy to produce biomass by converting small inorganic molecules (CO₂ and H₂O) to large organic molecules that contain more energy. Consumers gain their energy and biomass by eating other organisms.
 - (b) A habitat is a place where an organism lives; a niche is the role of a species in an ecosystem.
3. As each species interacts with biotic and abiotic factors, eats particular things, reproduces and excretes in particular ways, it would be impossible for two species to occupy exactly the same niche, as they would be in direct competition. Eventually one species or the other would evolve to become a better competitor and would out-compete the other species.
4. The producers are thermophilic bacteria and they use chemical energy.

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6.5.2 Transfer of biomass (page 273)

1. Energy is lost as heat via respiration and in biomass that is not eaten; materials are lost in excretion (carbon dioxide, water and nitrogenous waste), and in dead organisms and waste material that are not consumed.
2. (a) A food web is more realistic than a food chain – each trophic level usually consists of more than one species of organisms and most consumers will eat more than one type of organism.
(b) A pyramid of numbers does not reflect the varying sizes of organisms at each trophic level. A pyramid of biomass provides a more accurate picture of how much biomass exists at each trophic level.
3. (a) Energy and materials are lost as they flow through the trophic levels; there is less available for those organisms at higher trophic levels.
(b) There is not enough energy or material in the fifth level to sustain a viable population of organisms in the sixth level.
4. Biomass contains chemical energy. Energy is lost between trophic levels and so the biomass decreases between trophic levels. The pyramid shape is a visual representation of this energy loss.
5. Dry mass is the mass of organisms in a sample after all water has been removed. Wet mass is the total mass of the organisms in a sample. Ecologists are interested in dry mass, rather than wet mass, because wet mass can vary with different conditions and different organisms have different water content in their bodies.

6.5.3 Manipulating transfer of biomass (page 275)

1. (a) Selective breeding can be used to produce disease resistance, favourable traits, faster growth rates, increased production (of eggs and milk, for example).
(b) Genetic modification can be used to gain the same types of advantages as selective breeding, but is done at the genetic level, rather than done by selective breeding. For example, Bt cotton in the USA has been genetically modified to be resistant to bollworm.
(c) Greenhouses provide a modified environment that increases the rate of photosynthesis and, therefore, the rate of production of biomass. The environment can be modified to be warmer, contain more carbon dioxide, have more intense light, have longer light periods or even continuous light, and it can be easier to control pests.
(d) Addition of fertilisers can increase the availability of minerals in the soil, which then increases the rate of production of biomass. Important minerals include nitrates, which are essential for proteins, including enzymes, phosphates, which are required for DNA and for many metabolic reactions, potassium, which is used to maintain the correct water potential in cells and magnesium, which is a part of chlorophyll. Organic fertiliser also improves the water-holding capacity of the soil and improves soil structure.
(e) Addition of pesticides reduces the amount of biomass lost through the actions of pests like insects and nematodes, and therefore increases yield.
2. A young animal invests a larger proportion of its energy into growth than an adult. Once adult size is reached there is no further growth, and further investment in feed and upkeep does not increase the yield. Therefore, harvesting them just before adulthood minimises energy loss from the food chain.
3. Selective breeding and genetic modification can increase primary and secondary productivity by producing consumers or primary producers that are more efficient at increasing their biomass.
4. Ectotherms. More of their energy would be used for growth compared with endotherms, where a higher proportion of their energy would be used to maintain their body temperature.
5. The crops being grown are the producers in the food chain. If those crops are eaten directly by people, rather than being fed to animals that are then eaten by people, there is less energy loss as there is one less trophic level in the food chain, i.e. the vegetarians are the primary consumers rather than the secondary consumers.

6.5.4 Recycling within ecosystems (page 278)

1. They feed saprophytically, which means they decompose dead organic matter and waste material, and absorb the resulting molecules directly into their bodies.

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2. Three from: *Rhizobium*: found in the root nodules of leguminous plants; fixes nitrogen from the air. *Azotobacter*: free-living soil bacterium; fixes nitrogen from the air. *Nitrosomonas*: oxidises ammonium ions to nitrites. *Nitrobacter*: oxidises nitrites to nitrates.
3. Nitrogen fixation is the process whereby atmospheric nitrogen gas is made available to plants in the form of ions (such as ammonium or nitrate ions). Nitrification is the process of oxidation of ammonium ions to nitrites, or nitrite ions to nitrate ions by nitrifying bacteria.
4. Anaerobic respiration.
5. If materials were not recycled within ecosystems, valuable minerals would remain trapped within dead organisms and would not be returned to the soil; they would soon cease to be available to the organisms within the ecosystem.
6. Plants are producers – they convert inorganic carbon dioxide to organic molecules that form the biomass and contain energy.
Animals are consumers – they consume the organic matter produced by plants.
Detritivores are animals that consume dead organic matter and start the recycling process.
Bacteria and fungi are decomposers that convert the organic matter back to inorganic molecules.
All living organisms respire, which converts organic molecules into carbon dioxide and water.
7. Burning of fossil fuels leads to an increase in the carbon dioxide available for photosynthesis and an increase in atmospheric carbon dioxide.
Deforestation removes the trees that take carbon dioxide from the air. Burning of those trees also adds to the atmospheric carbon dioxide.
Increased human populations eat and digest larger quantities of plant matter, resulting in larger amounts of detritus and waste, the decomposition of which can also increase the amount of carbon dioxide released.
Use of calcium carbonate (lime) rocks in making cement and other industrial processes returns more carbon dioxide to the atmosphere.
Increased carbon dioxide levels can result in increased levels of carbonic acid in rainwater and water sources, which has an effect on the availability of minerals in the soil.
Increased atmospheric carbon dioxide also has long-term effects on global warming and climate.
8. Similarities: both cycle chemical elements; both use atmospheric gases as a major source of the element (nitrogen gas and carbon dioxide); both are driven by living organisms; both involve decomposition by microorganisms.
Differences: nitrogen fixed by bacteria; carbon fixed mostly by plants; nitrogen is not a reactive gas and therefore is not available to plants in its elemental form whereas carbon is more reactive and so is available to plants (in photosynthesis);

6.5.5 Succession (page 281)

1. (a) The development of a community of plants from bare ground.
(b) The first group of interacting species to live on the bare ground.
(c) The final, stable set of interacting species, usually made up of larger plants and animals.
2. (a) and (d)
3. The stages of succession are the same in both habitats, i.e. pioneer species, followed by a build-up of organic material or nutrients to allow colonisation by larger species and eventually a climax community results. On bare rock, with no soil, algae and lichens are the pioneer species, as they do not need to be anchored in the soil. However, in a sand dune community, the species have sand in which to anchor, but that sand is devoid of nutrients so at this stage it cannot easily sustain species. The likely pioneer species are able to withstand these conditions. Over time, soil develops in the bare rock habitat and nutrients begin to accumulate in the sand dune habitat. Ultimately, climax communities in both habitats will usually be woodland.
4. The sea deposits sand on the beach: the sand nearest to the sea is deposited more recently than the sand further away. This means that the sand closest to the beach is at the start of succession, whereas the sand further away might already have reached its climax community.

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5. Sub-climax communities have a higher diversity than climax communities as they still contain some sub-climax species as well as the climax species. Maintaining a range of communities that have not reached their climax means that we are conserving a much wider diversity of plants and animals that do not live in the climax community.
6. The field was an example of deflected succession when it was used for grazing cattle. Grass has short roots that would not affect the remains underneath. Now that the grazing has stopped, the normal process of succession will continue and larger plants will grow – these will have longer, deeper roots that will interfere with the remains of the walls. Any remnants above ground will become overgrown and ultimately surrounded by woodland; this makes their conservation more difficult.

6.5.6 Studying ecosystems (page 283)

1. It would take too long and require too much manpower to study a whole habitat.
2. (a) Not biased. Best method if the habitat to be sampled is uniform.
(b) When sampling a habitat where there is a range of environmental conditions, such as increasing water content, regular samples can detect how the change affects the plant community.
3. (a) Use a belt transect to record distribution and abundance of species across the salt marsh.
(b) Carry out a pilot study in both habitats to decide how many quadrats to take. Carry out systematic sampling of both habitats, recording species distribution and abundance. Compare the results.
4. (a) Advantages of continuous belt transect over line transect: more data are collected; very accurate as all species present should be recorded and percentage cover can be measured; the line transect could fail to record the presence of a large number of species if they are not touching the line. Disadvantages of continuous belt transect over line transect: very time consuming and labour intensive.
(b) Advantages of continuous belt transect over interrupted belt transect: more data are collected so the data are more reliable and accurate; better if to be used over a shorter distance. Disadvantages of continuous belt transect over interrupted belt transect: very time consuming and labour intensive. The interrupted belt transect will also be fairly accurate, much more accurate than the line transect, but would be less time consuming and labour intensive than the continuous belt transect. Therefore the interrupted belt transect would be more suitable over a longer distance.
5. The transect should start at one end of the environmental range and end at the far end. The starting point should be selected at random.
6. If, for example, the quadrat covers 1/100th of the whole area being sampled, the population for the entire area would be the number of individuals recorded in the quadrat multiplied by 100. Multiplying by 100/1 is the same as dividing by 1/100.

6.5 Practice questions (page 286)

1. C
2. B
3. C
4. (a) (i) 1 (Sheep/animals) ingest/consume/eat/feed on (grass/plants); 2 digest/hydrolyse (protein) to amino acids; 3 amino acids move into blood/cells; 4 synthesis of proteins/translation.
(ii) 1 Death/leaf loss; 2 decomposition/decay; 3 excretion/urination described; 4 egestion/defaecation described.
(iii) 1 C is *Nitrosomonas*; 2 D is *Nitrobacter*; 3 C and D are nitrifying bacteria; for main points 1, 2 and 3 internal max 2; 4 plants need nitrates to make, amino acids/protein(s)/enzymes/DNA/RNA/nucleic acids/chlorophyll/cytoplasm/new cells.
(iv) 1 E continues/plants use nitrate; 2 less/no B/decay; 3 less/no C/D/recycling of nitrogen/nitrification; 4 (cabbages) harvested/removed.
(v) 1 Legume/any named leguminous plant; 2 *Rhizobium*/nitrogen-fixing bacteria (in root nodules); 3 idea of converting nitrogen gas/N₂ into compounds/ammonium/ammonia/amino acids/protein (in plants); 4 plants ploughed in/plants left to decay/ref B/ref C/ref D.

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5. (a) (i) Ecology.
(ii) Abiotic.
(iii) Ecosystem.
6. (a) Starts with previously uncolonised area/bare ground/bare rock/or appropriate alternative wording. Refer to pioneer species/named pioneer.
Series of recognisable series/stages. Progresses to climax/final equilibrium stage.
(b) Stabilise environment. Soil development/increase humus/organic material. Change soil pH. Hold more water. Release more minerals or nutrients/increase N content or fix N/hold ions from microhabitat/reduce exposure/provide shelter/reduce erosion.
(c) Any two from following: grazing; burning; mowing/application of fertiliser/application of selective herbicide. Exposure to wind. Grass able to continue to grow (linked to a statement above).
(d) Increases. Plants at later stages are large/plants in early stages are small. Trees/shrubs are woody, appear later in succession.
7. (Interspecific) competition: species 1 and species 2 named; description of interaction.
Trophic/predator-prey/predation/parasitism/grazing/herbivory: species 1 and species 2 named; description of interaction.
Mutualistic/mutualism: species 1 and species 2 named; description of interaction.
8. 1 tape measure/rope, laid; 2 line/belt, transect; 3 continuous/interrupted/or appropriate alternative wording; 4 (use quadrat to) record percentage cover of plants; 5 (use quadrat with) ACFOR scale; 6 point quadrat use described; 7 use of key to identify species; 8 data recording sheets prepared in advance; 9 correct sequencing of steps in procedure.
9. (a) (i) Succession.
(ii) Mineral content; pH; water depth.
(b) Similarity: chlorophyll breaks down/leaves change colour. Differences: bog minerals stay in plant/forest minerals stay in soil; decomposers/fungi/bacteria not present in a bog.

6.6 Populations and sustainability

6.6.1 What determines population size? (page 291)

1. Biotic: three from: predation; disease; competition; parasitism; or any other sensible suggestion.
Abiotic: two from: temperature; light intensity; water availability; oxygen concentration; carbon dioxide concentration; or any other sensible suggestion.
2. (a) Reproduction rate.
(b) Reproduction rate.
(c) They are equal.
3. A population that has reached its carrying capacity cannot increase further because limiting factors prevent its further growth.
4. *r*-Strategists tend to have a rapid rate of reproduction such that they rapidly increase population size and reach carrying capacity before limiting factors start to have an effect. As a result the population size overshoots and once limiting factors take effect the population decreases in size rapidly. For *k*-strategists, population growth is much slower, and limiting factors tend to exert more and more influence as the population size nears the carrying capacity.
5. (a) Secondary succession.
(b) *r*-Strategist species tend to have a rapid reproduction rate and a quick population growth; therefore they can colonise disturbed ground before *k*-strategists.
(c) *k*-Strategists are more likely to be members of a climax community because the *r*-strategists are likely to have reached carrying capacity and dispersed to other habitats.

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6.6.2 Interactions between populations (page 293)

- Only one type of limiting factor was varied in Figure 1, meaning that all other variables were controlled. In Figure 2, several limiting factors could have an effect on the populations studied.
- Intraspecific competition happens between individuals of the same species. Interspecific competition happens between individuals of different species.
- Intraspecific competition slows down population growth and the population will enter a stationary phase. There will be slight fluctuations up and down, but the population size will remain relatively stable.
 - Interspecific competition can affect the population size of a species as well as the distribution of species within an ecosystem. Interspecific competition may result in one population being wiped out entirely, or it may have a much smaller population. In this latter case, both population sizes could be relatively stable.
- The competitive exclusion principle does not always apply in natural habitats because of the effects of other variables acting as limiting factors. Also variation between individuals in each species can lead to selection so that the two species evolve to be slightly different. In effect the two species are not competing in exactly the same niche.

6.6.3 Conservation and preservation (page 295)

- The variety within and between all living species on Earth, including the ecosystems in which they live.
 - There is inherent value in every species; protection of current and future food sources; sources of useful organisms/substances, for example, medicines discovered in plant species; sources of natural predators, i.e. biological control, to reduce reliance on chemical pesticides; protection of pollinating insects; climate stability; aesthetic value – ecotourism; any other sensible suggestion.
 - Over-exploitation of wild populations for food; habitat disruption and fragmentation; introduction of new species to an ecosystem; pollution; artificial selection and concentration on selected traits to the detriment of wild types.
- The direct financial value of a species is linked directly to that species, for example, the value of a harvested crop or the value of drugs derived from a plant species. Indirect financial value is a benefit that comes about as a result of the presence of a species, but is not the species itself, for example, the value to the agricultural industry of pollinating insects.
- It would be impossible to preserve an entire ecosystem by putting a fence around it because the ecosystem would still be subject to the actions of many dynamic parts of that ecosystem. Environmental conditions may change and the ecosystem would change as a result. Succession may continue and alter the balance of species living within the fence. Movement of individual members of a species could be restricted by the addition of fencing.
 - Reclamation of a habitat is difficult because it is necessary to know all of the species and the stages of succession relevant to that habitat. Sometimes it is easier to replace the disrupted community with a similar one rather than try to recreate the original one.
- Because direct values can be categorised for species or habitats and could be easier to ‘sell’ to interested parties. Indirect values are difficult to quantify and may be relevant to multiple species/ecosystems and habitats.

6.6.4 Sustainable management (page 297)

- ‘Sustainable management of wood production’ means maintaining the biodiversity of trees grown while ensuring supplies and maintaining their economic benefits. Sustainable management allows extraction of timber at a rate that can be maintained indefinitely.
- Similarities: pests and pathogens are controlled; only species that will grow well are planted; trees are positioned an optimal distance apart.

Differences: wood is divided into sections for coppicing in small-scale, whereas much larger sections are felled in large-scale; more biodiversity in small-scale, less in large-scale.
- Diversity in Bradfield Wood would decrease as succession would proceed unhindered, meaning that larger tree species would dominate, cutting out the light for smaller, under-storey trees and other species.
- It reduces fish stocks to levels where reproduction is not possible and the population reduces to zero.

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5. If fish stocks are maintained at their maximum reproductive capacity, the excess fish can be harvested and the population can be maintained at its carrying capacity. This will then provide the maximum sustainable yield of fish for harvest.
6. Benefits: restricts the impact of fishing on oceanic fish stocks; is a cheap and plentiful protein source for an increasing human population.
Disadvantages: populations susceptible to pests and pathogens; possible cause of pollution.

6.6.5 Balancing the conflict between conservation and human needs (page 299)

1. (a) Created forest corridors, counteracted poachers and illegal felling; introduced biogas plants and wood-efficient stoves; constructed waterholes; monitored endangered species; eradicated invasive species.
(b) Created conservancies that allow limited grazing and tourism opportunities to co-exist.
2. Both strategies acknowledge the importance of local people and work with them; both have conservation with development aspects.
3. Both areas provide homes to many local people and those people depend on the habitat for their existence. It makes sense to improve conditions for local people while at the same time conserving the habitats. It is important to involve local people so that they do not act against the conservation aims.
4. (a) Terai: forests provide local people with a sustainable source of fuel, animal feed, food, building materials, agricultural and household tools, as well as medicines. Tiger population appears to be increasing.
Maasai: Positive partnerships between conservancies and tourism organisations. Sustainable farming and tourism opportunities for locals.
(b) Terai: Increasing tiger populations might tempt back poachers.
Maasai: Landowners are forced to move their livestock out of the conservancies during the tourist season and can be forced to re-settle elsewhere.
5. (a) They built biogas plants for groups to use; transport corridors for tigers; worked on large projects to build waterholes, eradicate invasive species and monitor endangered species.
(b) Allowing limited livestock grazing has possibly led to increased biodiversity in the area. Controlled conservancies will allow numbers of species such as wildebeest to increase once again.
6. If conservation schemes take account of the needs of local people and acknowledge their right to live in and use the habitat, the local people are more likely to see the benefits to them as well as the habitat and will support the scheme.

6.6.6 Controlling the effects of human activities (page 303)

1. Habitat disturbance; over-exploitation of resources; effects of introduced species.
2. Goats feed on Galapagos rock-purslane, a species unique to the islands, trample and feed upon giant tortoises' food supply and disrupt their nesting sites. On northern Isabela Island, the goat has also transformed forest into grassland, leading to soil erosion.
3. It provides a model for how local stakeholders can work together to sustainably manage a resource.
4. Krill are a key component of a large number of food chains and a number of their predators are unable to adapt to find krill elsewhere if their numbers are low.
5. (a) Human population growth; climate change; pollution; growth in ecotourism; continued exploitation of natural resources.
(b) Limit size of local population; control local industry, pollution levels and exploitation of natural resources; control numbers of tourists and, particularly, where they can go within ecosystem.

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6.

Human strategies	Galapagos	Antarctic	Lake District	Snowdonia
Protected areas	✓	✓	✓	✓
Legal protection of endangered species	✓	✓	✓	✓
Eradication of invasive species	✓	✓		
Encourage hedge planting			✓	✓
Discourage animal grazing			✓	✓

6.6 Practice questions (page 306)

- C
- A
- C
- Fishing quotas; mesh size; species restriction; trawler size/days at sea; penalties/sanctions; monitoring/surveillance; publicity/public education.
 - Area too large; expense of monitoring; monitoring hampered by weather/seasons; false reporting of catches/trawler size/mesh size/days; deaths of fish caught, but not kept (because of restrictions).
 - Argument for: comparison of the energy in large fish and krill shows; humans would get $100 \times$ more kJ/energy from krill than large fish.
Argument against: would require large change to fishing industry/consumer habits; or could impact ecosystem at first trophic level.
- (Pond community is) final/stable/not subject to further succession.
 - Light microscope; graticule.
 - Urea/uric acid (allow ammonium).
 - Step 1: *Nitrosomonas*; nitrite. Step 2: *Nitrobacter*; nitrate.
- (Interspecific) competition: species 1 and species 2 named; description of interaction.

Trophic/predator-prey/predation/parasitism/grazing/herbivory: species 1 and species 2 named; description of interaction.

Mutualistic/mutualism: species 1 and species 2 named; description of interaction.
- Aesthetic/amenity/recreational, value. (Eco)tourism to preserve biodiversity/preserve genetic diversity/stop extinction. Refer to interactions between species/need to preserve whole habitat. (Rainforest species/preserve gene pool as) could be useful, in future/as potential for medicine/genetic engineering/or appropriate alternative wording. To support indigenous peoples/or appropriate alternative wording. To stop effect of deforestation on atmosphere/climate/soil.
 - Management practices coppicing/pollarding/description; selective felling/description; rotational felling/description; strip felling; replant after felling; (max 2) explanation of benefits re. sustainability preserves/prevents disruption to, habitat/ecosystems/nesting sites; maintains/increases, species diversity/biodiversity; prevents, soil erosion/leaching; less disturbance by machinery; AVP; (max 2).
- 681%.
 - Habitat/ecosystem disturbance/destruction; (land used for) (named) building/roads; (land used for) agriculture/farming; deforestation; effect of (tourist) boats/divers, described; more/increased pollution; sewage/eutrophication in sea/water; oil/fuel spill in sea; (humans)

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hunting/collecting/(over-)fishing; competition from introduced species; predation/overgrazing by introduced species; (new/named), diseases/pathogens introduced.

- (b) Economic: fewer jobs/smaller profits/business closure/reduced tourism/less income/less revenue.

Ethical: question of humane killing/animal suffering, or people suffer through losing their homes/friends/jobs.