FOR THE
IB DIPLOMA

Biology

Study and Revision Guide

ANSWERS

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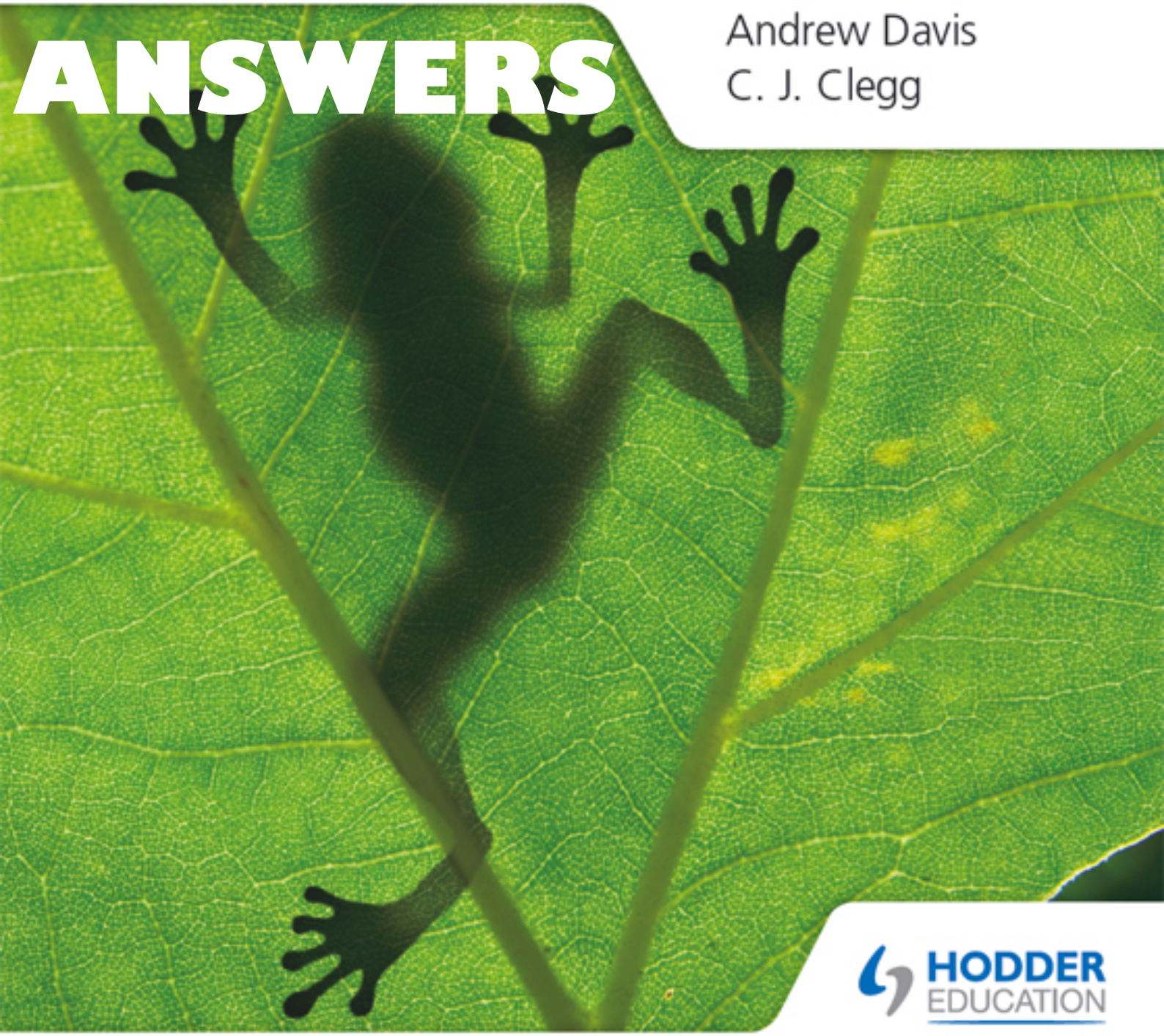


HODDER EDUCATION

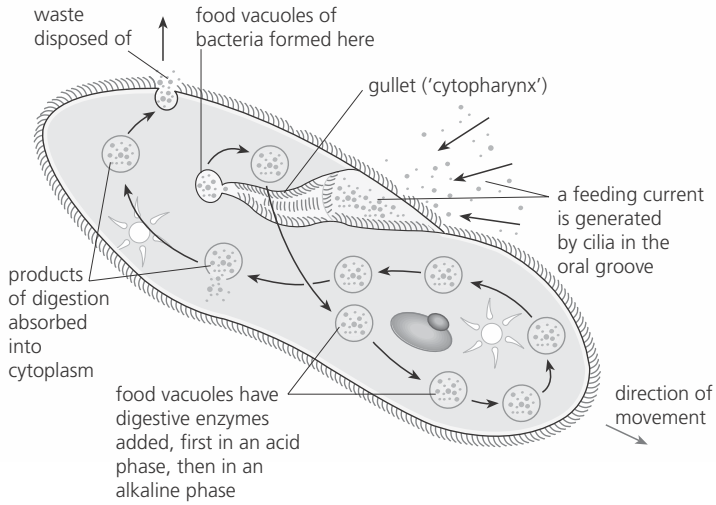
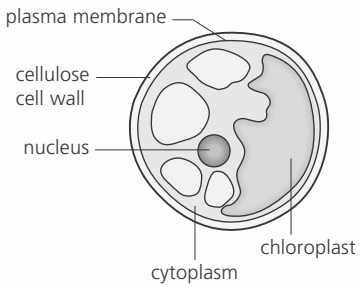
Answers

Topic 1 Cell biology

Quick check questions (p.10)

1 **nutrition** (obtaining food, to provide matter and energy needed for growth and survival), **metabolism** (all the chemical reactions inside cells, including respiration), **growth** (an irreversible increase in size), **response** (responding to stimuli), **excretion** (removing waste products of cell metabolism), **homeostasis** (keeping the conditions inside the organism within acceptable limits), and **reproduction** (producing offspring, either asexually or sexually)

2

***Paramecium* – a large protozoan (about 600 µm), common in freshwater ponds.**		***Chlorella* – a small alga (about 20 µm), abundant in freshwater ponds where its presence colours the water green.**
		
A 'particle feeder', it takes in small floating unicellular organisms into food vacuoles in the cytoplasm where the contents are digested and the products absorbed.	**nutrition**	Manufactures sugars by photosynthesis in the light, using carbon dioxide and water (in a way that is almost identical to photosynthesis in flowering plants).
Obtains the biochemicals it requires for metabolism by digestion of food particles. Energy transferred by respiration makes this possible. Respires aerobically, transferring energy to maintain cell functions.	**metabolism (including respiration)**	Manufactures all biochemicals it requires for metabolism using sugars (from photosynthesis) and ions (such as nitrates) from the surrounding water. Energy transferred by respiration makes this possible. Respires aerobically, transferring energy to maintain cell functions.
Loss of waste products (mainly CO_2 and NH_3) over the entire cell surface.	**excretion**	Loss of waste products (mainly CO_2) over the entire cell surface.
Commonly, reproduction occurs by nuclear division followed by a transverse constriction of the cytoplasm.	**reproduction**	Periodically the cell contents divide into four autospores that each forms a cell wall around themselves. Eventually these are released by breakdown of the mother-cell wall.
Typically detects favourable food particles in the water and moves towards them.	**sensitivity**	Typically responds to the absence of light by nuclear followed by cell division.
Small cells grow to full size prior to cell division (dividing into two cells).	**growth/development**	Small cells grow to full size prior to cell division into autospores.
Contractile vacuoles are used to expel water from the cell that has entered by osmosis. This maintains water levels within closely controlled limits.	**homeostasis**	Water enters the cell by osmosis and is collected in contractile vacuoles. These vacuoles expel the water through the plasma membrane so that internal water levels are kept within acceptable limits.

3

	Embryo	Umbilical cord blood	Adult
ease of extraction	can be obtained from excess embryos generated by fertility (IVF) programs	easily obtained and stored, although there are limited numbers available	exist in brain, bone marrow, blood vessels, skeletal muscle, skin, teeth, heart, gut, liver, and other organs and tissues; difficult to obtain as they are buried deep in tissues and there. In general, limited numbers available
ethics of the extraction technique	can only be obtained by destruction of an embryo	umbilical cord is removed at birth and then discarded – using cord as source of stem cells does not have ethical issues associated with it	an adult patient can give permission for cells to be extracted and used
differentiation	can differentiate into any cell type	limited capacity to differentiate	limited capacity to differentiate, and dependent on the tissue they are extracted from
risk of cancerous tumour	higher risk of development	lower risk of development	
genetic damage	less chance of genetic damage than adult cells		damage can occur due to accumulated mutations throughout life
compatibility to patient	stem cells are not genetically identical to the patient and may be rejected	fully compatible with the patient as the stem cells are genetically identical	

Comparing three different sources of stem cells: embryonic, umbilical cord and adult

Arguments **for** therapeutic cloning:

- Stem cell research may lead to future beneficial technologies and scientific breakthroughs that would not have occurred if their use had been banned.
- Can be used in cell therapy, where incorrectly functioning cells are replaced with working ones, and so used to cure serious diseases or disabilities.
- By using cord cells or adult stem cells:
  - cells are genetically identical to the patient and so are less likely to be rejected
  - transplants do not require the death of another human.
- If embryonic stem cells are used:
  - cells can be taken from embryos that have stopped developing and would have died anyway (e.g. abortions)
  - cells are taken at a stage when the embryo has no nervous system and so can arguably feel no pain
  - stem cells can be created without the need for fertilization and destruction of **'natural'** human embryos.

Arguments **against** therapeutic cloning

- Arguments against therapeutic cloning relate to embryonic stem cells:
  - involves the creation and destruction of human embryos ('right to life' issues)
  - embryonic stem cells are capable of continued division and may develop into cancerous cells and cause tumours
  - more embryos are generally produced than are needed and so excess embryos are killed

- ☐ alternative technologies may fulfil similar roles, with additional cost and effort (e.g. nuclear reprogramming of differentiated cell lines)
- ☐ there are religious / moral objections ('playing God' argument).
- ☐ the embryo which is created could potentially be used in IVF and develop into a human fetus
- ☐ although cloning humans reproductively is illegal, this has not been ratified by all nations. There is the potential for a race to clone the first human.

Quick check questions (p.15)

1 The following organelles are common to both types of cell, and can be seen in electron micrographs of both types of cell:

Common organelles	Principal role
nucleus with nuclear envelope	cell management
mitochondria	aerobic stages of respiration
ribosomes	site of protein synthesis
plasma membrane	control of movement in and out from cell

Exocrine cell, e.g. secretory cell of pancreas: these cells must produce enzymes (proteins) in large quantities, and so must have plentiful RER, Golgi apparatus, and vesicles for transport of enzymes from cell via the plasma membrane.

Palisade mesophyll cells carry out most of the photosynthesis in leaves and so have many chloroplasts. Other organelles present, not seen in animal cells: large permanent vacuole, cell wall.

2 Figure 1.7 = *mesophyll cell of leaf*; many chloroplasts present indicating photosynthetic role.

Figure 1.8 = *proximal convoluted tubule cell from a kidney nephron*; many mitochondria indicating high energy needs for e.g. active transport; microvilli (brush border) increase surface area for absorption of substances into blood (in this case, glucose).

Figure 1.9 = *plasma cell* which secrete antibodies (glycoprotein) into the blood to destroy pathogens (see Topic 11, page 284); extensive RER indicates high levels of protein production (in this case, antibodies).

Quick check questions (p.18)

1 Phosphate heads of phospholipids together with membrane proteins form a mosaic structure; parts of the membrane can move around freely: phospholipids move and swap places, and proteins also move within the phospholipid bilayer, making the structure fluid.

2 A lipid bilayer is made of two layers of phospholipids, whereas a double membrane of some organelles (like the one present in a mitochondrion) is composed of two bilayers of phospholipids; other organelles such as RER, SER, and Golgi apparatus are made from a single lipid bilayer.

3 Freeze-etching studies of plasma membranes show that when a membrane is split open along its mid-line, some proteins are seen to occur buried within or across the lipid bilayers showing the existence of integral proteins; when cells tagged with red marker are fused with cells tagged with a green marker, the red and green markers become mixed within the membrane of the fused cell: this shows that plasma membrane is strong but 'fluid', and that the proteins are not fixed in a peripheral layer but are free to move within the membrane.

Quick check questions (p.24)

1

	Simple diffusion	Facilitated diffusion
Specificity?	not specific	specific
Passage directly through phospholipid membrane?	yes	no
Passage through intrinsic proteins (channel proteins or carrier proteins)?	no	yes

2 The concentrated solution of glucose (in which the osmolarity is high / water potential low) will show a net gain of water molecules at the expense of the dilute glucose solution.

3 The jam has a higher osmolarity than the tissues of the fungal spore, and so is hypertonic compared to the cells of the fungus; water is drawn from the fungus, from higher water potential / lower solute potential in the fungus to lower water potential / higher solute potential in the jam; this dehydrates and eventually kills the fungus.

4 a Proteins act as channels for facilitated diffusion, as pumps, enzymes, and hormone-receptor sites, and they have both hydrophilic and hydrophobic regions based on the charges of their amino acids. Lipids are hydrophobic molecules with long mono- or polyunsaturated chains of carbohydrates.

b Active transport is a type of selective transport that moves solutes against their concentration gradient with the expenditure of energy, using protein carriers, whereas bulk transport involves the movement of vesicles in a process known as cytosis (also requiring energy).

c Endocytosis is the uptake of fluid or particles across the plasma membrane. Exocytosis is exporting (of e.g. enzymes) across the plasma membrane.

Quick check questions (p.27)

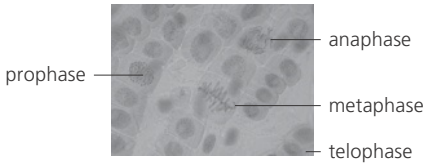
1 Fossils located in lower strata in a sedimentary rock were deposited longest ago: this is why it would be expected to see greater deviation from modern structures.

2 When sterilized broth was exposed to air, the flask became contaminated with bacteria (the nutrient liquid become cloudy), whereas broth contained in a swan-necked flask did not become contaminated with bacteria – the neck of the flask protected the broth from air-borne spores.

3 A eukaryotic cell may have formed from large prokaryote cells that came to contain their chromosome (whether of RNA or DNA) in a sac of infolded plasma membrane, leading to the formation of a distinct nucleus; prokaryotic cells that were taken into primitive eukaryotic cells may have survived as organelles inside the host cell (such as mitochondria and chloroplasts), rather than being digested as food; integrated organelles would have become integrated into the biochemistry of their 'host' cell over time.

Quick check questions (p.32)

1 prophase (centre left), anaphase (upper right), metaphase (below centre photo), and telophase (lower right) – as indicated below



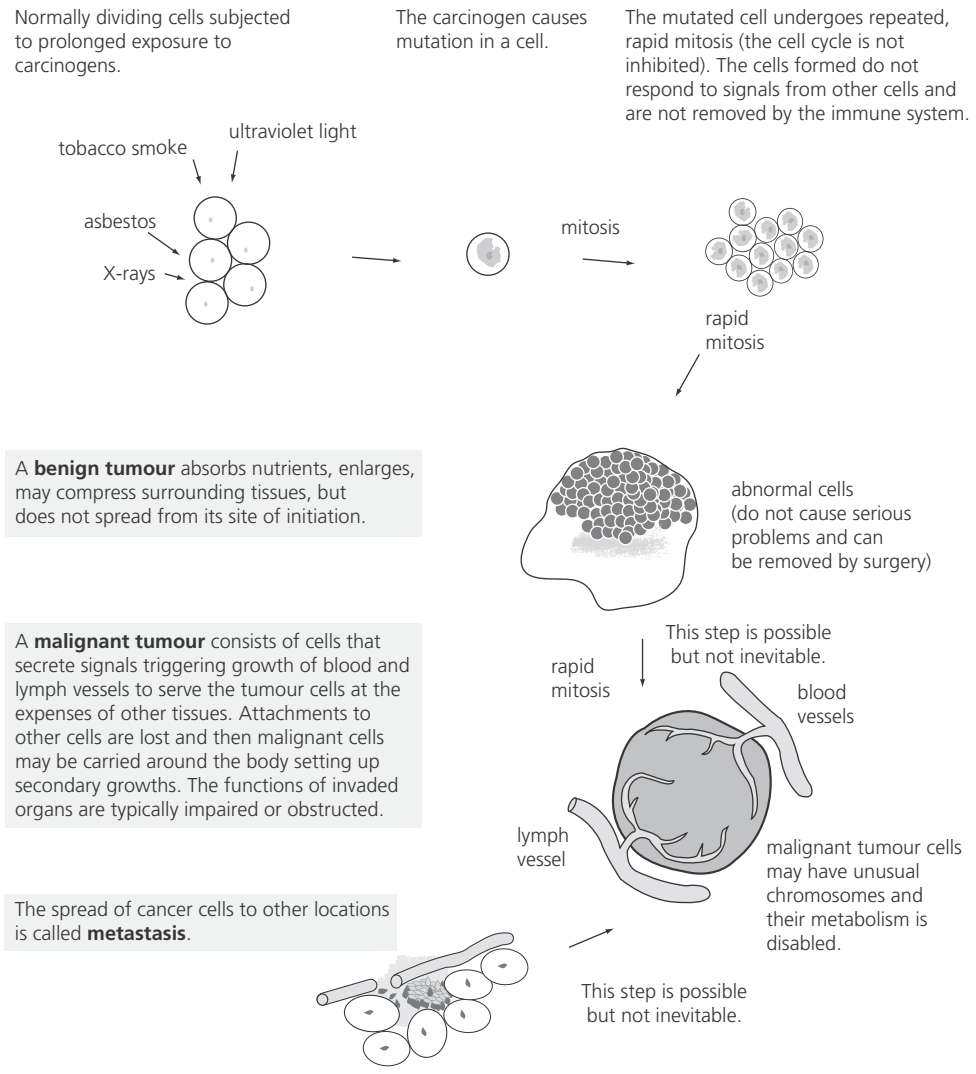
2 Tumours are abnormal growth of tissue that develop in any part of the body, at any stage of life; a cancer is a malignant tumour.

Mutagens are agents that cause gene mutations; anything that causes a mutation has the potential to cause a cancer; mutagens include: chemicals that cause mutations (carcinogens), high-energy radiation such as e.g. X-rays, short-wave ultraviolet light, some viruses.

In normal cells **oncogenes** control of the cell cycle and cell division; if a mutation occurs in an oncogene it can become cancerous; this leads to malfunction in the control of the cell cycle, uncontrolled cell division, and ultimately tumour formation.

A **primary tumour** is a cancer growing at the site where the abnormal growth first occurred; cancerous cells can detach from the primary tumour, penetrate the walls of lymph or blood vessels and circulate around the body; circulating cancerous cells invade tissues at different locations and develop, by uncontrolled cell division, into a **secondary tumours**.

Metastasis is the movement of cells from a primary tumour to set up secondary tumours in other parts of the body (see figure below).



Steps in the development of a malignant tumour

3 The mitotic index is used to differentiate benign from malignant tumours; tissue with a high mitotic index indicates a rapidly dividing cell mass – a possible indicator of tumour formation; the mitotic index can be used to investigate the response to chemotherapy in most types of cancer (i.e. a reduction in the mitotic index indicates that treatment has been successful in reducing the cancer).

Exam practice (p.32)

1 a yield (much) higher for all numbers of cycles than without catalyst;

maximum reached at 4 cycles;

yield at 7 cycles lower than at 4 cycles [2 max]

b both (histidine and glycine) show catalytic activity;

histidine more effective / greater % yield than glycine (after 4 / 7 cycles);

glycine more effective (than histidine) after 1 cycle;

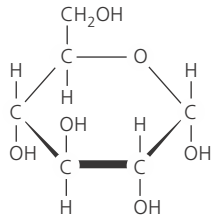
effectiveness of glycine decreases after 4 cycles whereas of histidine remains high [3 max]

Topic 2 Molecular biology

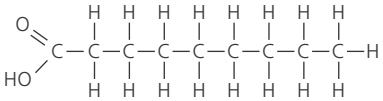
Quick check questions (p.36)

1 **anabolic reactions**: synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions; **catabolic reactions**: breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers

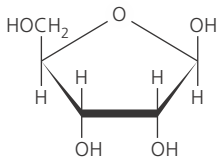
2 **Glucose ($C_6H_{12}O_6$)**



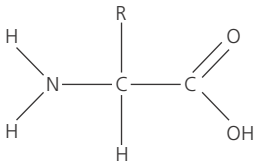
Saturated fatty acid



Ribose ($C_5H_{10}O_5$)



Generalized amino acid



3 **condensation reactions**: a chemical reaction which joins molecules together to form a larger molecule (producing water as a by-product); **hydrolysis reactions** split molecules into smaller subunits (through the addition of water)

Quick check questions (p.40)

1

Property	Benefit to life
1 a liquid at room temperature, water dissolves more substances than any other common liquid	liquid medium for living things and for the chemistry of life
2 much heat energy needed to raise the temperature of water	aquatic environment slow to change temperature; bulky organisms have stable temperatures
3 evaporation requires a great deal of heat	evaporation causes marked cooling (much heat is lost by evaporation of a small quantity of water)
4 much heat has to be removed before freezing occurs	cell contents and water in aquatic environments are slow to freeze in cold weather
5 surface water molecules orientate with hydrogen bonds pointing inwards	water forms droplets and rolls off surfaces; certain animals exploit surface tension to move over water surface
6 water molecules slide past each other easily (low viscosity)	water flows easily through narrow capillaries, and through tiny spaces (e.g. in soils, spaces in cell walls)
7 water molecules adhere to surfaces	water adheres to walls of xylem vessels as it is drawn up the stem to the leaves, from the roots
8 water column does not break or pull apart under tension	water can be lifted by forces applied at the top, and so can be drawn up xylem vessels of tree trunks by forces generated in the leaves

A summary of the properties of water molecules and the associated benefits to life

2 Water molecules are polar and so can form hydrogen bonds, whereas methane molecules are non-polar and so do not form hydrogen bonds; water is a liquid at room temperature whereas is a gas at room temperature; hydrogen bonds pull the molecules very close to each other, which is why water is a liquid at the temperatures and pressure that exist over much of the Earth's surface, with distinctive thermal properties.

Property	Water	Methane
boiling point (°C)	100	–160
melting point (°C)	–182	0
specific heat capacity (J per g per °C)	4.2	2.2
latent heat of vaporization ($J g^{-1}$)	2257	760

3 Because the latent heat of vaporization for water it is very high, the evaporation of water in sweat on the skin causes marked cooling; energy is transferred from the blood / body into water, converting water from a liquid to a gas; since a great deal of heat is lost with the evaporation of a small amount of water, cooling by evaporation of water is very efficient.

Quick check questions (p.47)

1

Animals		Plants	
Monosaccharides		**Monosaccharides**	
glucose	• transported to cells in the blood plasma • used as a respiratory substrate for cellular respiration or converted to glycogen (a storage carbohydrate, see below)	glucose	• a first product of photosynthesis
galactose	• used in the production of lactose (milk sugar)	fructose	• produced in cellular respiration as an intermediate of glucose breakdown • used in the production of sucrose
Disaccharides		**Disaccharides**	
lactose	• produced in mammary glands and secreted into the milk as an important component in the diet of very young mammals	sucrose maltose	• produced in green leaves from glucose and fructose • transported in plants in solution, in the vascular bundles • breakdown product in the hydrolysis of starch
Polysaccharides		**Polysaccharides**	
glycogen	• storage carbohydrate formed from glucose in the liver and other cells (but not in brain cells) when glucose is not immediately required for cellular respiration	cellulose starch	• manufactured in cells and laid down externally, in bundles of fibres, as the main component of the cell walls • storage carbohydrates

Key carbohydrates and their roles in animals and plants

2 Lipids are normally used for long-term energy storage whereas carbohydrates are used for short-term energy storage; the amount of energy released in cell respiration per gram of lipids is double that for carbohydrates; lipids add 1/6 th as much to body mass as carbohydrates; fats are stored as pure droplets whereas when 1 g glycogen is stored it is associated with 2 g of water (a critical factor for active animals as energy stores have to be carried).

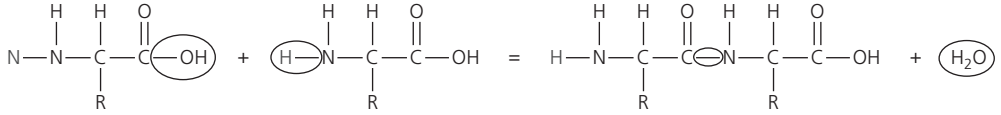
3 Evaluation = make an appraisal by weighing up the strengths and limitations; evidence for health claims comes from research: some of this research is more scientifically valid than others; research can be evaluated according to whether it has specific strengths or limitations.

Strengths: whether there is a statistically significant correlation between intake of the lipid being investigated and rate of the disease or the health benefit; there is comparison of mean values and analysis of how different they are; statistical assessment of any difference is carried out; analysis of variation within the data is done (i.e. how widely spread the data are, which can be assessed by the spread of data points or the relative size of error bars, where the more widely spread the data the smaller the significance that can be placed on the correlation and conclusion).

Limitations: whether the measure of the health was a valid one, e.g. cholesterol levels in blood are more informative than body mass index; a smaller sample is less reliable than a larger one; the sample does not reflect the population as a whole, but rather a particular sex, age, state of health, lifestyle, or ethnic background; data are gathered from animal trials rather than humans trials, and so may be less applicable to humans; certain variables are not controlled, e.g. other aspects of the diet; levels and frequency of the lipid intake being investigated are not realistic; methods used to gather data were are rigorous, e.g. if only a survey was used, how truthful were the respondents?

Quick check questions (p.50)

1



Formation of the peptide bond

The peptide bond is circled in the figure. Water removed by condensation reaction to form the peptide bond is also circled.

2

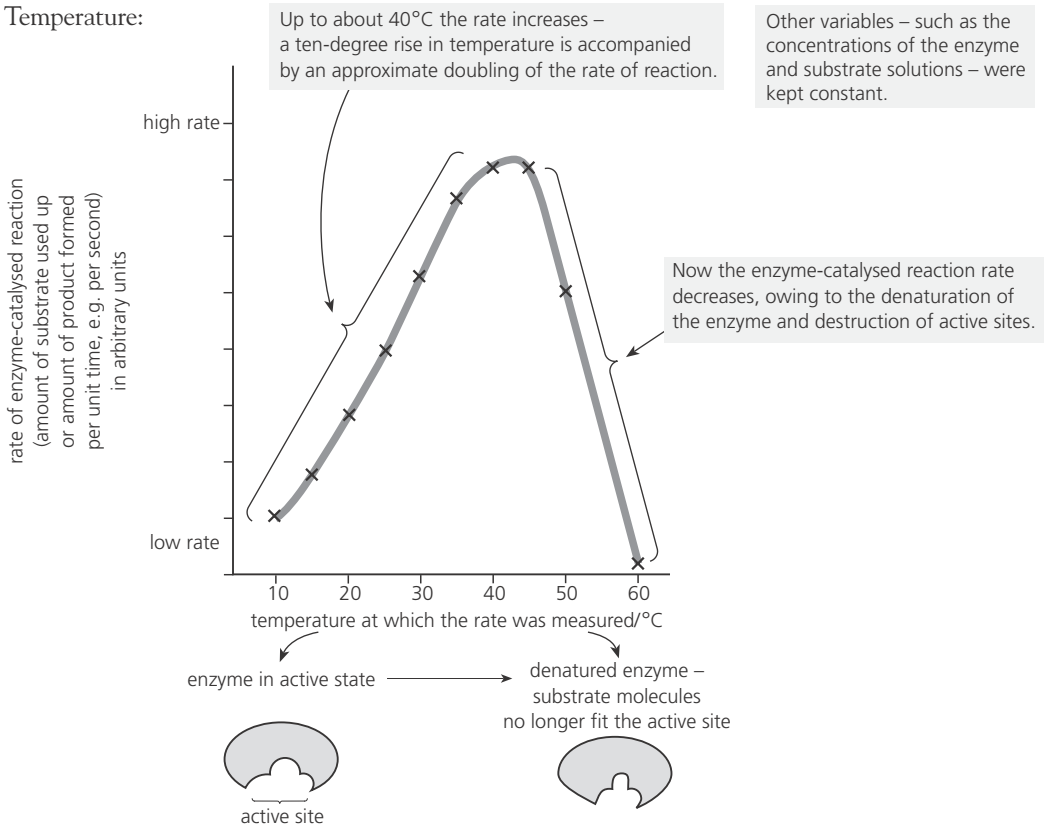
Protein	Type	Functions
RuBisCo	globular protein – enzyme	Ribulose bisphosphate carboxylase (RuBisCo) combines CO_2 is with an acceptor molecule in photosynthesis. It is abundant in the stroma of chloroplasts and makes up the majority of all the protein in a green plant. It is the most abundant enzyme present in the living world.
insulin	globular protein – hormone	Produced by the β cells of the islets of Langerhans in the pancreas. It consists of two polypeptide chains linked by disulfide bridges. Insulin in promotes glucose uptake by cells and indices the liver to synthesize glycogen.
spider silk	fibrous protein – structural	A strong protein fibre produced by spiders and the silk worm. It is composed of a fibrous protein including fibroin. It is extruded as fluid from specialized glands and is used to produce spider's webs and egg and cocoons. The mixture hardens in contact with air.
rhodopsin	conjugate protein – pigment	A light-sensitive protein found in the rod cells of the retina in mammals. It is a compound of a protein (opsin), a phospholipid and retinal (vitamin A). The effect of light energy on this pigment is to split it into opsin and retinal.
collagen	fibrous protein – structural	Occurs in skin, tendons, cartilage, bone, teeth, the walls of blood vessels, and the cornea of the eye. Consists of three helical polypeptide chains, wound together as a triple helix forming a stiff cable, strengthened by many hydrogen bonds. Many of these triple helixes lie side by side, forming collagen fibres, held together by covalent cross-linkages. The whole structure has very high tensile strength.
immunoglobulins	globular protein – antibody	Antibodies are found in the bloodstream. An antibody is a glycoprotein secreted by a plasma cell. Antibodies have regions that are complementary to the shape of the antigen. Antibodies bind to specific antigens that trigger an immune response. Some antibodies are antitoxins and prevent the activity of toxins.

3 The proteome is the entire set of proteins expressed by the genome of the individual organism; since the genome, the whole of the genetic information of an organism, is unique to each individual, the proteome it causes to be expressed is also unique; every individual has a unique proteome.

4 Denaturation is a structural change in a protein that alters its three-dimensional shape; the change in shape of the active site means that the substrate can no longer bind to form an enzyme–substrate complex; denaturation occurs when the bonds within the globular protein, formed between different amino acid residues, break, changing the shape of the active site; temperature rises and changes in pH of the medium may cause denaturation of the protein of enzymes; exposure to heat causes atoms to vibrate violently and this disrupts bonds within globular proteins; heat causes irreversible denaturation of globular protein; small changes in pH of the medium similarly alter the shape of globular proteins; the structure of an enzyme may spontaneously reform when the optimum pH is restored, but exposure to strong acids or alkalis is usually found to irreversibly denature enzymes.

Quick check questions (p.56)

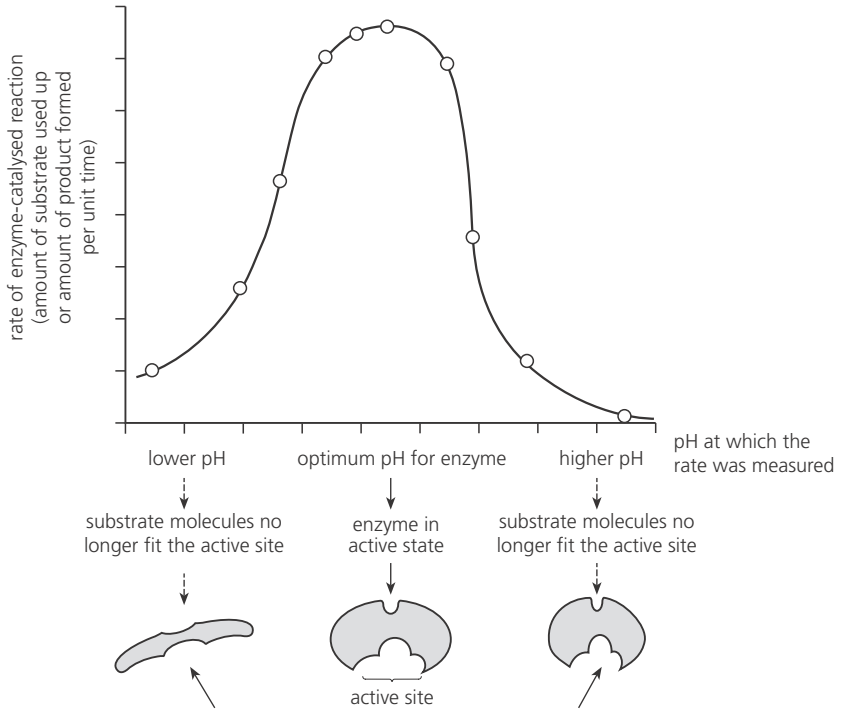
1 Temperature:



Temperature and the rate of an enzyme-catalysed reaction

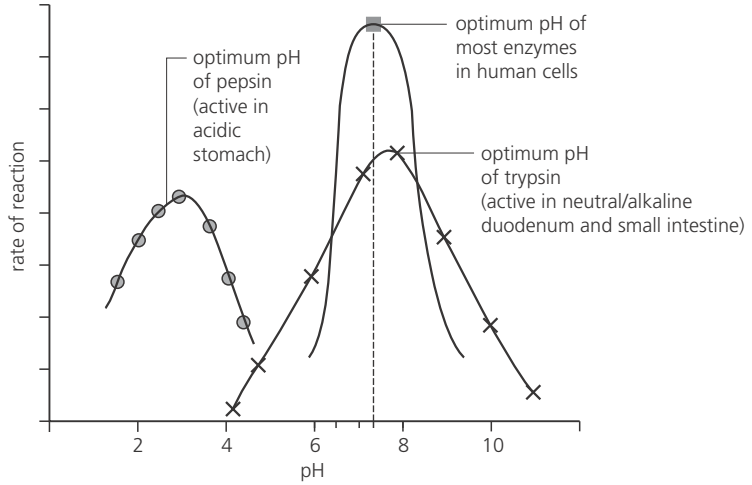
From 10 to 40°C, increasing temperature increases the kinetic energy of enzyme and substrate; there are increased collisions between enzyme and substrate; more enzyme–substrate complexes form; rate if reaction increases; optimum temperature at 40°C where the rate of enzyme activity is at its peak; above 40°C, rate of reaction decreases as enzyme denatures; thermal energy disrupts the hydrogen bonds holding the enzyme together; active site changes shape; substrate can no longer fit in active site

pH:



structure of protein changes when a change of pH alters the ionic charge on $—COO^-$ (acidic) and $—NH_3^+$ (basic) groups in the peptide chain, so the shape of the active site is lost

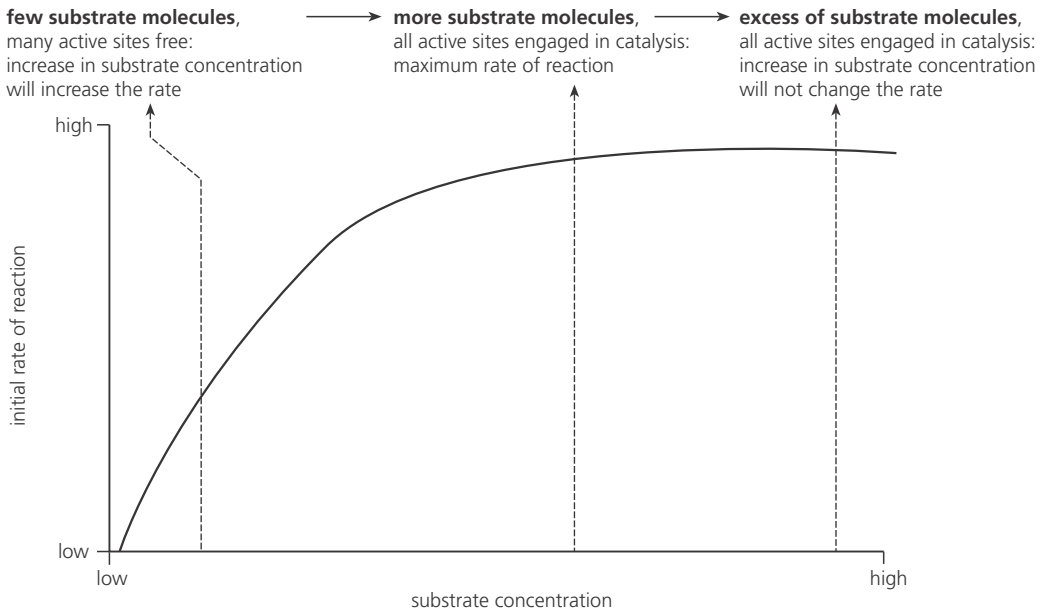
the optimum pH of different human enzymes



pH effect on enzyme shape and activity

Changing the pH will alter the charge of the enzyme which may change the shape of the molecule; changing the shape or charge of the active site will diminish its ability to bind to the substrate, halting enzyme function; enzymes have an optimum pH and moving outside of this range will result in a diminished rate of reaction; different enzymes may have a different optimum pH range

Substrate concentration:



The effect of substrate concentration

2 Lactase is obtained from yeast or bacteria; lactase is bound to the surface of alginate beads; milk is passed over the beads repeatedly; the lactose is broken down into glucose and galactose; the immobilized enzyme remains to be used again and does not affect the quality of the lactose-free milk.

Advantages of lactose-free milk: many people are allergic to lactose, and so this milk is suitable for consumption; the process increases the sweetness of milk because glucose and galactose are sweeter than lactose, thus negating the need for artificial sweeteners; lactose-free milk reduces the crystallization of ice-creams (glucose and galactose are more soluble than lactose); it shortens the production time for yogurts or cheese (bacteria ferment glucose and galactose more readily than lactose).

3 The experiments described on pages 52–55 of the Study and Revision Guide are designed so they collect **accurate**, quantitative measurements. They are carried out at an appropriate level of **precision**, and controlled so that outcomes from the experiment are **valid**.

- **Accuracy** – how close to the true value a result is reliable; results are repeated so that any results that do not fit the overall pattern of data can be identified and mean results calculated.
- **Precision** – the number of significant digits to which a value can be reliably measured. For example, if a digital thermometer can measure to two decimal places, this is the precision of data that can be recorded.
- **Validity** – when an experiment is controlled and repeated.
- **Independent variable** – the variable that is being changed.
- **Dependent variable** – the dependent variable 'depends' on the independent variable.
- **Controlled variable** – a variable that is kept the same in an experiment, to ensure that the experimental method involves manipulating only one variable to determine if changes in this one variable cause changes in another variable.

  Replicates ensure the **reliability** of an experiment – consistency within the results suggests that conclusions drawn are valid, and allow anomalies to be identified.

When designing an experiment, the following need to be taken into account:

- What is the independent variable?
- What is the dependent variable?
- What are the controlled variables?
- What are potential sources of error when the experiment is carried out (i.e. what are the limitations of the experiment likely to be)?
- How will you measure the dependent variable?
- How will you improve precision in the experiment?
- How will you improve the reliability of the experiment? Experiments require replicates to ensure reliability.
- How will you ensure the accuracy of the experiment?

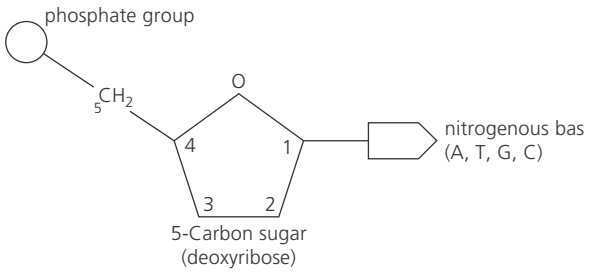
Quick check questions (p.59)

1

DNA	Feature	RNA
very long strands, several million nucleotides	**length**	relatively short strands, 10 to several thousand nucleotides
contains deoxyribose	**sugar**	contains ribose
contains bases C, G, A, and T (not U)	**bases**	contains C, G A, and U (not T)
consists of two polynucleotide strands of complementary base pairs (C with G and A with T) held by H-bonds in the form of a double helix	**forms**	consists of single strands, and in three functional forms: messenger RNA (mRNA) transfer RNA (tRNA) ribosomal RNA

The differences between DNA and RNA

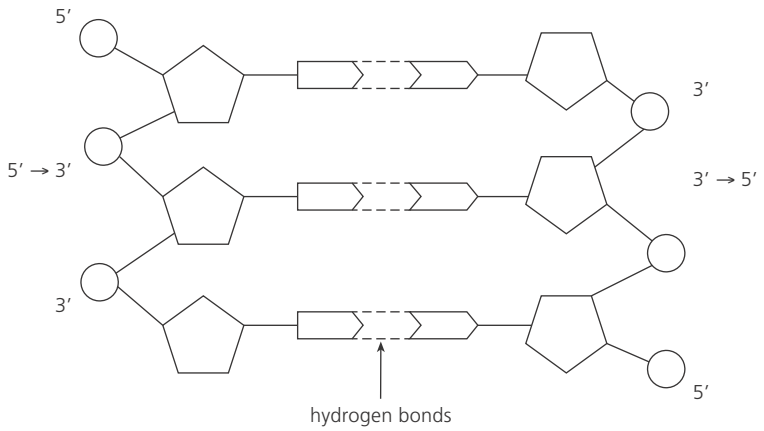
2



A nucleotide of DNA

If the figure above were to represent a nucleotide of RNA, the 5-C sugar would be ribose, and the nitrogenous bases would be A, U, G, or C.

3

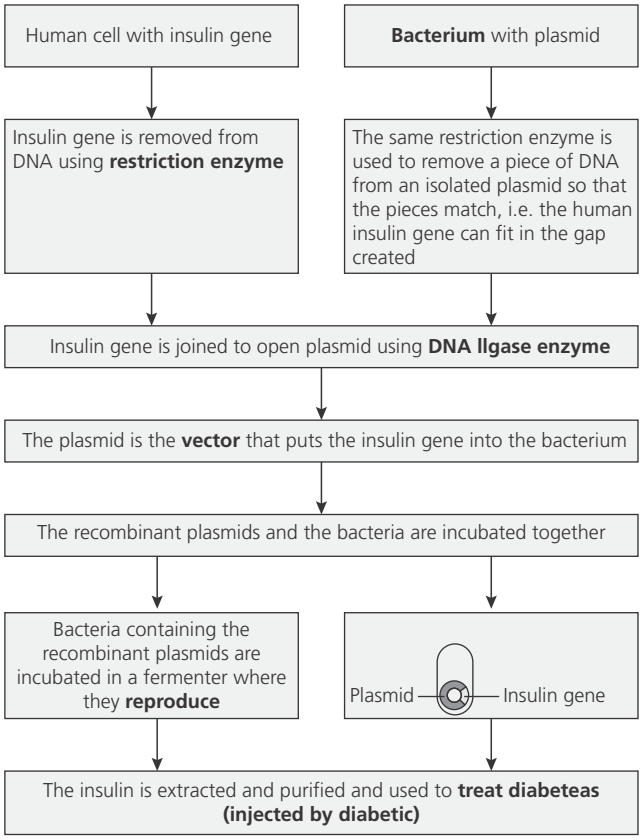


A short section of DNA

Quick check questions (p.64)

1 All living things use the same bases and the same genetic code; each codon produces the same amino acid in transcription and translation, regardless of the species; the sequence of amino acids in a polypeptide remains unchanged; it is possible to take genes from one species and insert them into the genome of another species.

Technique of gene transfer from humans to bacteria:



Genetic modification in bacteria

2 serine – aspartic acid – lysine – stop (Ser-Asp–Lys–STOP).

This sequence might be located at the end of the gene.

3 **a** Gly – Asn – Pro – Phe – Val – Thr – His – Cys

b CCA–TTA–GGA–AAA–CAA–TGA–GTA–ACA

c Triplet codes are in DNA. Codons are in mRNA which could be found in both nucleus and cytoplasm. Anticodons are part of the tRNA molecule – which could be found inside the nucleus and in the cytoplasm, but which are functionally active in the cytoplasm.

Quick check questions (p.69)

1 **Baking**: Bread is made by adding water to flour, kneading the mixture to make dough and then baking it; an ingredient (e.g. yeast) is added to the dough to create bubbles of gas, so that the baked bread has a lighter texture; after kneading (mixing), the dough is kept warm to increase yeast respiration; yeast can respire aerobically or anaerobically; oxygen in the dough is soon used up so the yeast must respire anaerobically; carbon dioxide produced by anaerobic cell respiration is trapped and so forms bubbles in the dough, causing the dough to swell and rise; ethanol is also produced by anaerobic cell respiration, but evaporates during baking.

Ethanol production: bioethanol is produced from sugar cane and maize, using yeast; bioethanol is ethanol produced by organisms and is used as a renewable energy source; starch and cellulose in the plant material are broken down by enzymes into sugars; large industrial fermenters are used to keep the yeast in optimum conditions; when yeast carry out anaerobic respiration, the sugars in the plant material are converted to ethanol and carbon dioxide; ethanol produced by the yeasts is purified by distillation and water is removed to improve combustion.

2 Certain human activities, such as weightlifting and sprinting, require anaerobic respiration; aerobic respiration generates a much greater yield of ATP, but anaerobic respiration can supply ATP very rapidly, because oxygen is not required; rapid generation of ATP enables us to maximize the power of muscle contractions; anaerobic cell respiration produces lactate; there is a limit to the concentration of lactate that the body can tolerate and this limits how much or how long anaerobic respiration can be carried out for; after the activity, lactate must be broken down: this involves the use of oxygen; it can take several minutes for enough oxygen to be absorbed for all lactate to be broken down; the demand for oxygen that builds up during a period of anaerobic respiration is called the oxygen debt.

3 In the respirometer, the far side of the U-tube manometer is the control tube (A). Here, conditions are identical to those in the respirometer tube, but in the former, no living material is present. However, any change in external temperature or pressure is equally experienced by both tubes, and their effects on the level of manometric fluid are equal and opposite so they cancel out.

4 Soda lime removes the carbon dioxide produced by the respiring maggots and the change in volume is due to the oxygen used inside the system. When water is used instead of the soda lime, the CO_2 released by the animals replaces the used volume of O_2. Use of soda lime allows determination of the oxygen uptake by the respiring animals.

5 Is it acceptable to remove animals from their natural habitat for use in an experiment? Can the animals be safely returned to their habitat? Will the animals suffer pain or any other harm during the experiment? Can the risk of accidents that cause pain or suffering to the animals be minimized during the experiment? Can contact with the alkali be prevented? Is the use of animals in the experiment essential or is there an alternative method that avoids using animals (such as plant material)?

Quick check questions (p.74)

1 Primordial Earth had a reducing atmosphere that contained very low levels of oxygen gas (ca. 2%); cyanobacteria (prokaryotes) containing chlorophyll first performed photosynthesis about 2.5 billion years ago; photosynthesis creates oxygen gas as a by-product (by the photolysis of water); oxygen levels remained at 2% until about 750 million years ago (mya); from 750 mya until the present day there has been a significant rise to 20%; oxygen generation also allowed the formation of an ozone layer (O_3); ozone shielded the Earth from damaging levels of UV radiation; which led in turn to the evolution of a wider range of organisms; iron compounds in the oceans were oxidized; insoluble iron oxides precipitated onto the seabed; time and further sedimentation produced rocks with layers rich in iron ore (banded iron formations); oxygen in the atmosphere led to the production of oxidised compounds (e.g. CO_2) in the oceans.

2

Carbon dioxide concentration		**Light intensity**
O_2 output (bubbles or volume) in unit time	**dependent variable**	O_2 output (bubbles or volume) or pH change in unit time
external CO_2 (i) absence of CO_2 by boiling and cooling water (ii) subsequent stepwise addition of $NaHCH_3$ solution to raise CO_2 by 0.01 mol^{-3} – until no further change in O_2 output	**independent variable**	light intensity – systematically positioning the light source (photoflood lamp or 150W bulb) at 10, 15, 20, and 32 cm from the experimental chamber
temperature, light intensity	**controlled variables**	concentration of $NaHCO_3$, temperature
possibly error in $NaHCO_3$ solution additions	**sources of error**	possibly the heating effect of the light source

Issues in the design of experiments to investigate the effect of external factors on the rate of photosynthesis

3 The R_f value would be = 3.54 / 7.9 = 0.45; the pigment is chlorophyll *b*.

Exam practice (p.74)

1 a oxygen production / release; (*not count bubbles*)

production / increase / change / measurement of biomass [1 max]

b high / higher than optimum temperatures denature enzymes (of Calvin cycle);

ribulose bisphosphate carboxylase / RuBisCo stops working / does not bind substrate;

wilting / withering / loss of water / decrease in turgor / increased transpiration;

closure / reduced aperture of stomata;

lower CO_2 level inside leaf / reduced CO_2 diffusion / uptake into leaf [2 max]

c rate decreases / drops (to zero) with drought and increases when re-watered / recovering [1]

d slight decrease / constant initially then falls / falls increasingly rapidly / decreases exponentially (in drought / up to Day 35);

increases almost to original level / but doesn't reach original level / rapidly at first then less rapidly / increases then reaches plateau (during recovery / after Day 35) [2 max]

e higher / greater (emission) at 35°C than 25°C during both drought and recovery;

both at (approximately) same level at end of drought period / at 35 days;

both increase during recovery but not to original level;

less / little difference in emission between temperatures during recovery / after watering / converse [2 max]

f decreases (rate of photosynthesis) [1]

g no effect before (the first) heat treatment;

lower rate / greater reduction in rate during heat treatments with fosmidomycin;

lower photosynthesis / fosmidomycin reduces recovery after heat treatments [2 max]

Ignore statements that fosmidomycin reduces the rate of photosynthesis if this is not related to heat treatments.

h high temperature / heat stress / treatment reduces rate of photosynthesis;

repeated heat treatments cause greater reduction in photosynthesis;

isoprene causes less change / less reduction in photosynthesis due to heat / 46°C / higher rate of photosynthesis during heat treatment with isoprene (than without);

isoprene helps photosynthesis to rise again after heat (treatments) [2 max]

i 26 (%) (*Allow a range of 25 % to 27 %*) [1]

j faster recovery with isoprene than without / than with water treatment;

recovery faster / better / improved with higher isoprene concentration (than lower);

after both time periods / after 24 hours and 1 hour [2 max]

k different plants live in / evolved in / are adapted to different temperature regimes;

(selective) advantage for plants that produce isoprene in high temperature regions;

isoprene synthesis uses energy / materials / only beneficial at high temperatures;

some plants do not have the enzymes / genes for making isoprene [2]

Topic 3 Genetics

Quick check questions (p.80)

1 a The **genome** is the whole of the genetic information of an organism, consisting of DNA (or RNA in RNA viruses) and including both genes and non-coding sequences; the **phenotype** is the expression of the alleles of an organism (the genotype), i.e. observable characteristics or traits.

b A **gene** is a section of DNA that codes for a particular characteristic; **alleles** are different forms of the same gene (e.g. the gene for eye colour has different alleles, such as blue or brown pigmentation).

c **Haploid** refers to one set of chromosomes, whereas **diploid** refers to two of every chromosome (i.e. chromosomes are in homologous pairs – one chromosome per pair from each parent).

2 Caused by gene mutation; mutation due to a base substitution; changes the code on the DNA; which leads to a change in transcription / change in mRNA; which, in turn, leads to a change in translation / change in polypeptide chain; the tRNA adds the wrong amino acid to the polypeptide chain; glutamic acid replaced by valine; produces abnormal hemoglobin; causing abnormal red blood cell shape (sickle shape); which lowers the ability to transport oxygen; sickle-cell allele is codominant; homozygote (HbS HbS) have sickle cell anemia / is lethal / heterozygote (HbS HbA) has the sickle trait / is carrier, and is more resistant to malaria.

3 The Human Genome Project (HGP) was an international 13-year effort, from 1990 to 2003; main goals were to discover the complete set of human genes and make them accessible for further biological study, and determine the complete sequence of DNA bases in the human genome; when the HGP began in 1990, only a few laboratories were able to sequence 100 000 bases, and the cost of sequencing remained very high; since 1990, technological improvements and automation have increased speed and lowered cost so that individual genes can be sequenced routinely, and some labs can sequence well over 100 million bases per year; key advances in technology include: biotechnology techniques such as PCR (used to prepare samples), computers that can automate the sequencing process, fluorescent labelling techniques that enable all four nucleotides to be analysed together, lasers that are used to fluoresce the dye markers, digital camera technology that reads the dye markers, and computers to assemble base sequence; the sequencing of the human genome has shown that all humans share the vast majority of their base sequences, but also that there are many single nucleotide polymorphisms which contribute to human diversity.

4 The number of genes in a species should not be referred to as genome size as this term is used for the total amount of DNA.

Quick check questions (p.85)

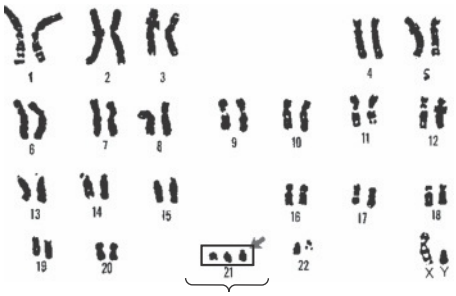
1

Prokaryotic	Eukaryotic
single chromosome	multiple chromosomes: different chromosomes carry different genes
circular DNA molecule	linear DNA molecules
plasmids	no plasmids
DNA is not associated with protein	DNA is associated with histone proteins

2 The number and type of chromosomes in the nucleus are known as the **karyotype**. A photograph showing chromosomes arranged in numbered homologous pairs in descending order of size is called a **karyogram**; karyotype is a property of a cell (the number and type of chromosomes present in the nucleus), not a photograph or diagram of them.

3 Two methods are used for obtaining fetal cells for karyotyping: amniocentesis and chorionic villus sampling; karyograms from a person with Down's syndrome show three copies of chromosome 21, rather than two, giving them a total of 47 chromosomes; the extra chromosome comes from a meiosis error: the two chromatids of chromosome 21 fail to separate, and both go into the daughter cell that forms the secondary oocyte.

karyotype of a person with Down's syndrome



an extra chromosome 21

4 John Cairns produced images of DNA molecules from *Escherichia coli* (*E. coli*); *E. coli* was grown with thymidine containing a radioactive isotope of hydrogen (i.e. the DNA was labelled); *E. coli* cells were broken open by enzymes to release the cell contents; the cell contents were applied to a photographic emulsion and placed in the dark for two months; the radioactive isotopes reacted with the emulsion; dark areas on the photographic emulsion indicated the presence of DNA; the images showed that *E. coli* possesses a single circular chromosome which is 1100 µm long (*E. coli* cells have a length of only 2 µm); the insights and improvements in theory would not have been possible without the development and use of autoradiography (exposure of photographic emulsion by radioactive isotopes).

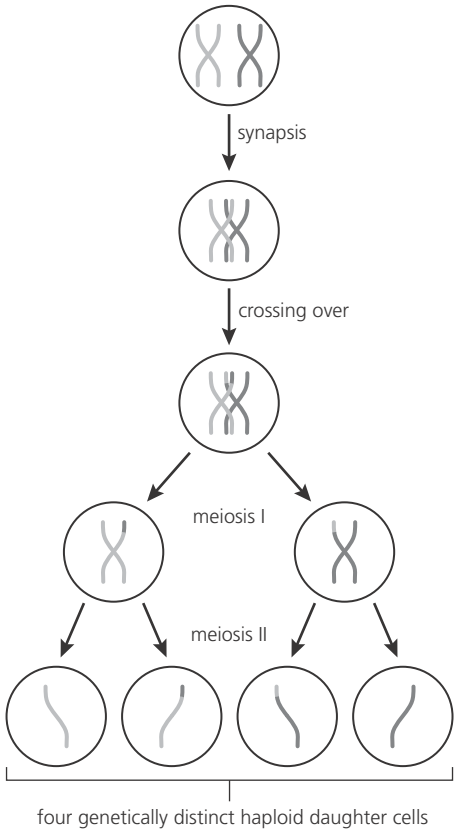
5

Total number of base pairs (bp) in haploid chromosomes		
T2 phage (a virus specific to a bacterium)	3569	(3.5 kb)
Escherichia coli (gut bacterium)	4600000	(4.6 kb)
Drosophila melanogaster (fruit fly)	123000000	(123 Mb)
Homo sapiens (human)	3200000000	(3.2 Gb)
Paris japonica (canopy plant)	150000000000	(150 Gb)

A comparison of genome size

Quick check questions (p.89)

1



2 Maternal age is one key risk factor for Down's syndrome: a 25-year-old woman has a 1 in 1200 chance of having a baby with Down's syndrome; by 35, the risk has increased to 1 in 350; by age 40, to 1 in 100; and by 49, it is 1 in 10; the risk of a child with Down's syndrome increases greatly in older mothers; chance increases from 0.05% at age 20 to 10% chance at age 49; women over the age of 40 who become pregnant are advised to have the chromosomes of the fetus assessed by screening.

3 This shows the karyotype of a male with non-disjunction of chromosome pair 21 (resulting from non-disjunction).

Quick check questions (p.101)

1 a The predicted ratio was 3:1.

b Actual ratios were:

- position of flowers: 3.145:1
- colour of seed coat: 3.147:1
- colour of cotyledons: 3.009:1

c A prediction of the likely outcome of a breeding experiment represents the probable results, provided that:

- fertilization is random
- there are equal opportunities for survival among the offspring
- large numbers of offspring are produced.

What is actually observed in a breeding experiment may not necessarily agree with the prediction. For example, there is a chance in this particular cross that:

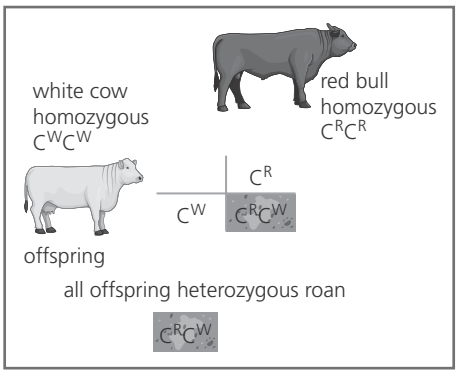
- more pollen grains of one genetic constitution may fuse with egg cells than another
- more developing seeds of one type are predated and destroyed by insect larvae of species attacking the plant (so fewer zygotes of one type complete development)
- the cross produces too few progeny in total.

2 The layout of your monohybrid cross can be drawn in the same way as Figure 3.13 or as indicated below, but the parental generation (P) will have genotypes (if you have chosen C as the allele for coat colour) of $C^RC^R \times C^WC^W$ where C^R represents the allele for red coat, and C^W represents the allele for white coat. The gametes the parental generation produce will be: C^R and C^W.

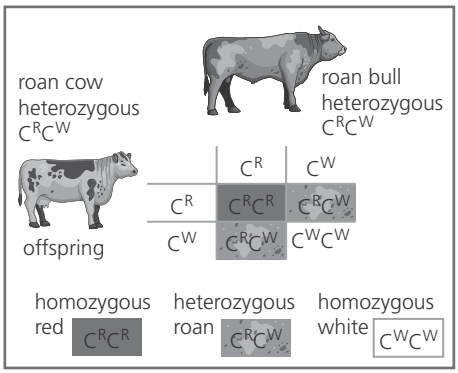
The offspring (F_1) will have genotype $C^R\ C^W$ and the phenotype will be 'roan' (see figure a).

In a sibling cross of the F_2 generation the gametes of both siblings will be $\frac{1}{2}C^R + \frac{1}{2}C^W$.

a



b



Co-dominance in cattle

From an appropriate Punnett grid (Figure b) the offspring (F_2) to be expected and the proportions are:

genotypes	C^RC^R	C^RC^W	C^WC^W
ratio	1	2	1
phenotype	red	roan	white

3 The genotype of a female with colour blindness can be represented as X^bX^b. Males cannot be carriers as only one X chromosome is present – the recessive allele is always expressed; the heterozygous condition (carrier) does not apply for sex-linked inheritance in males.

4 Males have only one copy of the X chromosome which is inherited from the mother. When the recessive allele for hemophilia is present on this X chromosome, males express the disease. Since the heterozygous condition does not exist in males, there are no male carriers. Females may be carriers but are rarely affected by the disease as they must receive two recessive alleles – one from each parent.

5 The Jones were groups A and B, giving the following possible outcomes:

Parental genotype	**Parental genotype**	**Possible blood group of offspring**
AA	BB	AB
AO	BO	A, B, AB or O
AA	BO	A or AB
AO	BB	B or AB

So the **Jones** could be the parents of any of the four children, but are the only parents who could have a child with AB blood group.

The **Lees** were B and O, giving the following possible outcomes:

Parental genotype	Parental genotype	Possible blood group of offspring
BB	OO	B
BO	OO	B or O

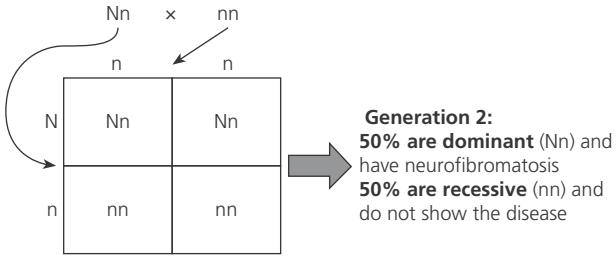
So the **Lees** might be the parents of either the B group or the O group child.

The **Gerbers** were both blood group O, so their offspring must also be blood group O. (Therefore the Lees were the parents of the B group child.)

The **Santiagos** were AB and O, giving the following possible outcomes:

Parental genotype	Parental genotype	Possible blood group of offspring
AB	OO	A or B

6 The Punnett grid for the cross between a normal-handed individual (nn) and someone with brachydactylous hands (Nn) is shown here:



The probability of having an offspring with brachydactylous hands is equal to 50%.

Quick check questions (p.112)

1 Gel electrophoresis uses a gel of agar within a chamber where a current is applied. A DNA sample is digested or cleaved using restriction enzymes; a dyeing solution is added and then the samples are inserted into the gel. The fragments separate based on their negative charge and size, creating visible bands – the smaller fragments are able to go faster and further than larger fragments. Fragments have to move through the porous structure of the gel towards the positive pole.

2 The genes of prokaryotes are more easily modified than those of eukaryotes because:

- plasmids, the most useful vehicle for moving genes, do not occur in eukaryotes (except in yeasts) and, if introduced, may not survive and be replicated there
- eukaryotes are diploid organisms, so two forms (alleles) for every gene must be engineered into the nucleus; prokaryotes have a single, circular 'chromosome', so only one of a gene has to be engineered into their chromosome
- transcription of eukaryotic DNA to mRNA is more complex than in prokaryotes, where it involves removal of short lengths of 'non-informative' DNA sequences – the introns
- machinery for triggering gene expression in eukaryotes is more complex.

3 Genetically modified crops will lead to increased nitrates in soil; cereals will require less nitrogen-containing fertilizer, and they form the bulk of human food intake.

4 **a** Cleaving DNA by a restriction enzyme at the recognition sequence (palindrome section) creates protruding 5′ and 3′ endings (sticky ends).

b The recognition sequence has complementary bases that allow other sticky ends with corresponding bases to join on to it.

5 General potential **benefits**: introduction of a new trait (e.g. *Bt* gene increases resistance to pests such as the European corn borer) results in increased productivity (therefore less land used, greater yield, and less crop damage); biodiversity is preserved, since only certain areas are cultivated with the GM crops; variability of the species is not reduced, but improved, since new features are added to the species; cross-pollination could occur, but there is not much evidence of this happening with pollen coming from regular crops; less use of chemical pesticides (therefore reduced cost and ecological damage to wild); increased disease resistance; less use of chemical herbicides; less use of chemical fertilizer; increased hardiness (better drought / cold salinity tolerance and therefore can be grown in more locations / have a longer growing season); increased nutritional content.

General potential **risks**: could be toxic to or cause allergic reactions in humans; transferred genes could mutate after testing; non-target organisms may be affected by toxins; increases resistance to toxin evolves in pests; accidental release may result in competition with native plant species; reducing variability in the species of crops cultivated, leading to new pests that require more attention or new modifications; cross-pollination of species, leading to super-weeds containing an insecticide gene; biodiversity reduced (through direct competition with plant populations and direct and indirect competition with animal populations); patent laws may prevent farmers producing locally suitable varieties, which would lead to unregulated field tests.

6 Many common plants root easily from stem cuttings producing full-grown (clone) plants quickly.

Factors to consider for a rigorous method:

- How will root growth be measured (multiple roots of variable length can be expected)?
- Which variables need to be controlled?
- What plant species / variety (or selection of) will be examined?
- How many cuttings are needed to ensure a reliable investigation?

Examples of factors that can be investigated:

- substrate – water, type of soil
- number of leaves on the stem
- length of stem cut
- effectiveness of commercial rooting powders
- effect of reduced transpiration (by covering plants with a plastic bag)
- proximity of a node (point of branching) to the base of the stem.

What will you investigate?
Formulate your hypothesis, for example:
- plants need oxygen for root growth.
- hormone rooting powder promotes root growth.

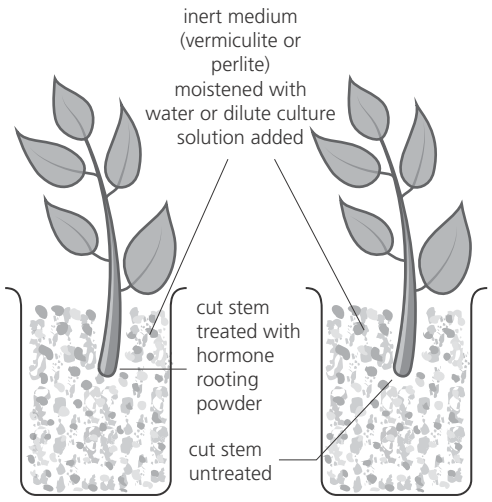
Select a plant
Most readily available plants are suitable, such as:
- willow (*Salix* sp)
- honeysuckle (*Lonicera* sp.)
- blackberry (*Rubis* sp).

Selecting and preparing the shoots
How many will you need for treatment and control?

Possible experimental apparatus

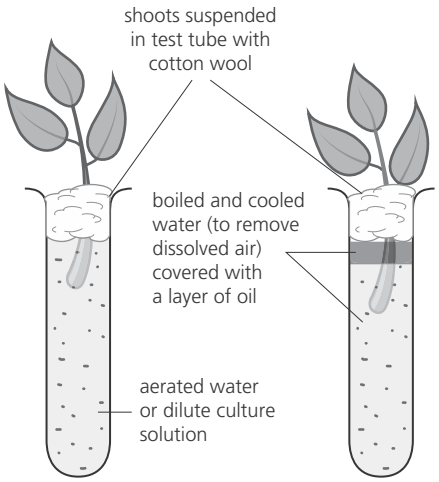
Rooting in a solid medium

The effect of rooting powder:



Rooting in water

The requirement for oxygen:



Conduct and management issues:
What environment and control will the experimental apparatus be held in?
What external conditions can and must be controlled?
Time frame – how long will the experimental run for?
When and how will observations and measurements be taken and recorded?

Finally – comclusion and points for discussion:
What changes in method would you recommend if the experimental were to be repeated?
What and where in the stem are the tissue(s) that have generated roots?
What are the roles of roots in the growth of the plants?
In what sense can the products of your experiment be described as 'clones'?

Investigating the rooting of stem cuttings

7 A fertilized egg cell is a diploid cell that will divide by mitosis during the development of new tissue cells. If a gene is inserted into this cell, all of the cells of the organism that develop from the embryo will have the gene – including the germinal cells, allowing the individual to pass on this property to its progeny.

8 a The **genotype** is the alleles of an organism and the **genome** is the whole of the genetic information of an organism.

b **Restriction endonucleases** cut, cleave, or digest the DNA at specific recognition sites; **ligase** catalyses the joining of DNA strands.

c A **bacterial chromosome** is a circular chromosome with the genes for construction and functioning of the cell, and a **plasmid** is circular extra-chromosomal DNA material.

Exam practice (p.113)

1 a i maize not modified / transformed with Bt (genes) / maize that did not have Bt gene added / not genetically modified / untreated maize [1]

ii 50 − 12 = 38 (mm^2) ; *accept 12 − 50 = –38*

(38 ÷ 50) × 100 = (–)76%; *(ECF)* [2]

b
- there was a decrease in damage by all three types of stem borers compared to control;
- there was almost no change in damage by *Eldana* compared to control;
- there was almost no damage / little effect (to Bt maize type A) by *Sesamia* (and *Eldana*);
- *Busseola* caused the most damage (to Bt maize type A) [2 max]

c
- very efficient at controlling *Sesamia*;
- type B is the most effective against the three stem borers collectively;
- no type of Bt maize controlled *Busseola* well / vice versa, i.e. *Busseola* not well controlled by any types of Bt maize;
- all types of Bt maize decreased *Sesamia* damage (significantly) / Bt maize type E not damaged by *Sesamia* / vice versa;
- Bt maize types C / H / I had more damage caused by *Busseola* (than was caused in the control) / vice versa;
- all types of Bt maize decreased *Eldana* damage (to some extent) / type B was not damaged by *Eldana* / vice versa;
- *Eldana* damage low in control / less effect;
- cannot determine efficiency since data is about leaf damage and stem borers may feed (preferentially) on other structures / stems / roots [2 max]

d (268 − 215 =) 53 g [1]

(Accept answers in range 51–57 g. Units required. No workings required.)

e
- mass increases in all three groups;
- increase is more rapid in beginning and tapers off later in the study;
- mass seems to be levelling off in rats fed Bt and non-Bt maize / rate of increase in mass is slowing down;
- rats fed rat food always have higher mass / greater mass increase than those fed either type of maize [2 max]

f
- all three foods result in the same pattern of growth / mass gain / highest rate of growth at start of study / tapering off later in the study;
- Bt maize causes same amount of growth as non-Bt maize / appears to be as good a food source as non-Bt maize / there is no significant difference between Bt and non-Bt maize (in terms of mass gain);
- corn (both types) appears to cause less growth / mass gain than rat food / vice versa;
- genetic modification does not affect growth / mass gain;
- no evidence to support risk of Bt maize to growth / mass gain;
- study does not investigate other possible risks of Bt maize to rats;
- sample size is small / only 12 rats (in each group) so this may not be enough to give trends;
- only female rats tested, no males. [3 max]

Topic 4 Ecology

Quick check questions (p.121)

1

1 a autotrophic organism producing organic compounds by means of photosynthesis **producer / autotroph**

b heterotrophic organism – go to 2

2 a organism consuming grass or vegetation only **herbivore / primary consumer**

b organism that ingests other animals – go to 3

3 a organism consuming organic matter that is living or recently killed – go to 4

b organism that feeds on decaying matter – go to 5

4 a organisms feeding on primary consumers **secondary consumer**

b organisms feeding on secondary consumer **tertiary consumer**

5 a organisms living on dead organic matter, secreting digestive enzymes **saprotroph / decomposer**

b organisms that ingest dead organic matter **detritivore**

2 a ecosystem

b population

c abiotic factor

d community

e biomass

f habitat

g abiotic factor

3 Observed results table:

	Bell heather present	**Bell heather absent**	**Sum**
Bilberry present	12	55	67
Bilberry absent	88	45	133
Sum	100	100	200

Expected frequency table or contingency table:

	Bell heather present	**Bell heather absent**	**Sum**
Bilberry present	$\frac{(67 \times 100)}{200} = 33.5$	$\frac{(67 \times 100)}{200} = 33.5$	67
Bilberry absent	$\frac{(133 \times 100)}{200} = 66.5$	$\frac{(133 \times 100)}{200} = 66.5$	133
Sum	100	100	200

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

$$= \frac{(12 - 33.5)^2}{33.5} + \frac{(55 - 33.5)^2}{33.5} + \frac{(88 - 66.5)^2}{66.5} + \frac{(45 - 66.5)^2}{66.5}$$

$$= 13.79 + 13.79 + 6.96 + 6.95$$

$$= 41.48$$

Degrees of freedom = $(2 - 1) \times (2 - 1) = 1$

Critical value for a p-value of 0.05 is 3.34.

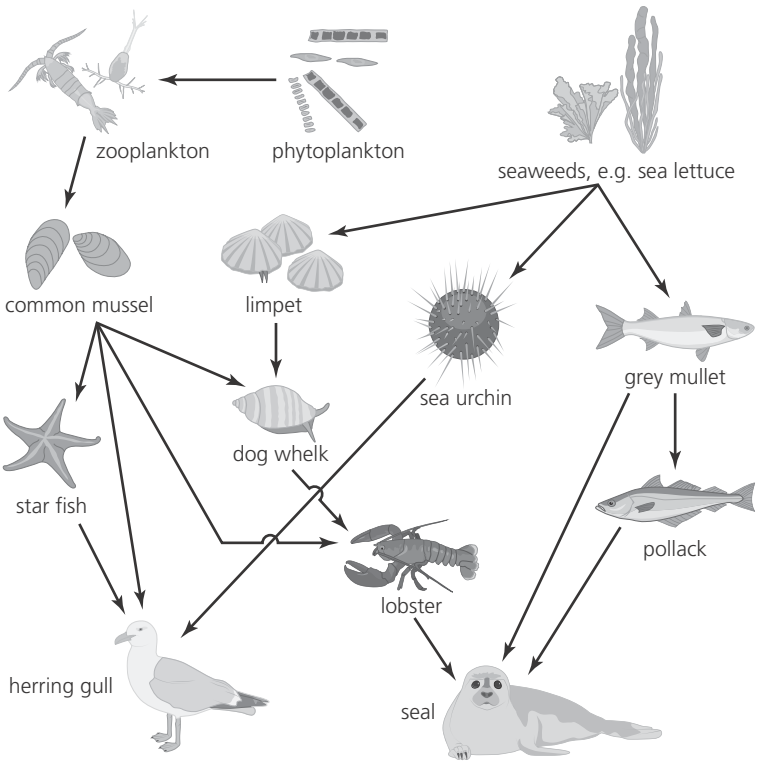
The value of chi-squared calculated is clearly larger than the critical value of 3.34 for one degree of freedom.

The results show that the distributions of the two species are not in independent of each other; the distributions of the two species are associated.

4 Saprotrophs break down dead matter / detritus; they recycle nutrients into the food chain, ultimately making them available to animals again.

Quick check questions (p.127)

1



A marine food web

Aquatic food chain A: phytoplankton → zooplankton → common mussel → dog whelk

Aquatic food chain B: seaweeds → grey mullet → pollack → seal

Trophic level of each organism:

- seaweeds and phytoplankton: producers
- zooplankton and grey mullet: primary consumers.
- secondary consumers: common mussel, pollack
- tertiary consumers: dog whelk and seal.

2 Energy is lost at each trophic level. Only 10–20% of the energy made available by producers passes to primary consumers. In a plant, not all of the solar energy available actually makes it into the leaf. There is loss of energy by reflection from the leaf, transmission through the leaf, and because some of the energy is the incorrect wavelength. The energy that is taken up by the producer is then fixed by photosynthesis, although again a proportion of this energy is lost as it is used up during inefficient photosynthetic reactions. Of the energy that is fixed in photosynthesis, some will be lost during respiration. Consumers use energy in movement; the energy dissipates and is lost as heat into the surrounding environment. Also, not all the organic matter is consumed.

The total amount of energy available to top consumers is small; a large number of producers are required to provide tertiary and quaternary consumers with enough energy.

3 a from primary to secondary consumers = (1600 / 14000) × 100 = 11.43%

b i energy taken in: 3050 kJ m^{-2} yr^{-1}

total energy lost to system: 2925 kJ m^{-2} yr^{-1}

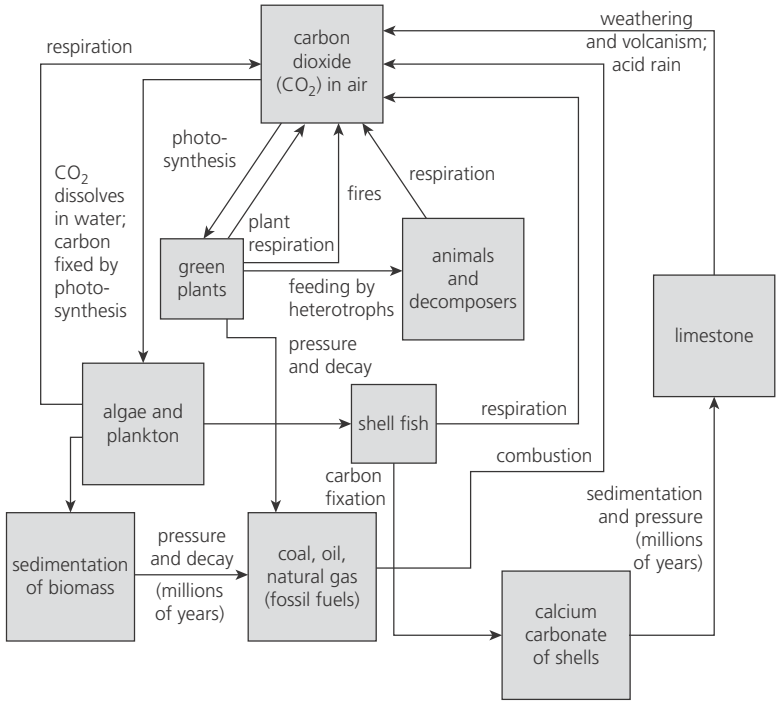
energy stored in new biomass (secondary production): 125 kJ m^{-1}

percentage of energy in biomass of the cow: 4.10%

ii energy transfer between primary and secondary consumer: 4.10% (same as the cow biomass)

Quick check questions (p.130)

1



2 Differences in the rates of flux between atmosphere and land biota: carbon is fixed by photosynthesis, giving the greatest pool of carbon in land biota. Flux rate due to respiration takes back carbon stored in land biota into the atmosphere pool, and this flux is enhanced by the burning of materials, thus making the atmosphere pool greater than the land biota. Also, the atmosphere receives a flux of carbon from other pools, such as soil, surface ocean, the mantle, and with the burning of fossil fuels from the pool of 'sedimentary rocks'.

Differences in rates of flux between deep ocean and sedimentary rocks: deep oceans store a total of 38000 GT and sedimentary rocks 1000000 GT, meaning that the sedimentary rock pool is much greater in storage of carbon than deep oceans. Carbon moves from deep ocean to sedimentary rocks as material in the ocean, e.g. calcium carbonate from coral and sea shells, settles in the bottom of the ocean and eventually forms sedimentary rock. Carbon is not moving in the opposite direction from rock to the ocean and so carbon builds up in rock formations.

3 a as CO_2

b H_2CO_3 (carbonic acid). Most of this acid dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-).

It can also exist as carbonate ions (CO_3^{2-}).

c calcium carbonate (Ca_2CO_3)

4 There is an increase in carbon dioxide concentrations, year-on-year; this is due to increased release of carbon dioxide either from natural processes (such as decomposition and release from oceans) or from human activities leading to increased combustion of fossil fuels; there is an annual rhythm in the atmospheric carbon dioxide concentration (lower in the summer months and higher in the winter months); this is due to photosynthesis on land in the Northern Hemisphere during summer months, which impacts on the composition of the global atmosphere by lowering carbon dioxide levels; the peaks are winter levels.

Quick check questions (p.134)

1 Plants absorb CO_2 into their tissues, thus reducing atmospheric concentrations of this gas. Destruction of rainforest will reduce the number of photosynthetic organisms available to fix CO_2 into organic molecule, leading to an increase of this gas in the atmosphere; rainforest has high productivity and high plant biomass, and so reduction in photosynthetic capacity will have a large impact on atmospheric carbon dioxide levels.

2 There have been considerable changes in the levels of carbon dioxide in the geological past; generally, higher levels of carbon dioxide correlate with higher temperatures, and lower levels of carbon dioxide correlate with lower temperatures; carbon dioxide is a greenhouse gas, and so increases in atmospheric concentration of CO_2 results in increased trapping of IR radiation in the Earth's atmosphere, leading to increased surface temperatures.

3 Many people believe that scientific data prove that the climate is warming. They state that scientific data show that carbon dioxide levels and greenhouse gas levels are increasing. Moreover, data from a wide variety of sources and times indicate warming. They stress that human activities and / or fossil fuel combustion are known to increase carbon dioxide levels. The rapid rate of increase in carbon dioxide since industrialization implies a human link. They also argue that carbon dioxide and other greenhouse gases are known to impact global temperatures. Therefore it is likely that human activities are resulting in global climate change.

   Some people are sceptics of human-induced climate change. They claim that natural fluctuations occur so that the current increase in temperature could be due to short-term changes. They claim that the only technologically verifiable data we have have been collected over a short period of time. Moreover, they also state that other aspects of climate change are not fully understood. Climate has changed in the past due to natural fluctuations, such as Milankovitch cycles. Current carbon dioxide levels and global temperature fluctuations are moderate compared to geological history. Therefore it is not conclusive that humans are causing global climate change.

4 Accelerated burning of fossil fuels leads to more carbon dioxide in the atmosphere. The ocean absorbs about 25% of the CO_2 emitted into the atmosphere. Therefore as atmospheric CO_2 increases so do the levels in the ocean. As carbon dioxide dissolved in the oceans increases, the pH decreases and the water becomes more acidic. This is known as ocean acidification. Because the coral reefs are made of calcium carbonate and are, therefore, alkaline, a decrease in pH can lead to reduced calcification rates of corals and destruction of existing coral reefs. The effects of acidic stress are likely to be exacerbated under future climate scenarios. Estimates of future CO_2 levels, indicate that by 2100 seawater could be nearly 150% more acidic (a further decrease of 0.5 pH) to a level not seen for more than 20 million years.

Exam practice (p.135)

1 **a** with trout: 4 *(allow a range of 3.5 to 4.0)*

   without trout: 700 *(allow a range of 690 to 710)* [1]

   Both needed for [1].

   b more tadpoles / frogs without trout / vice versa;

   trout decrease tadpole numbers more than frog numbers / vice versa [2]

   Numbers alone, without comparative words (more, greater, less, etc.), are insufficient for the mark.

   c tadpoles / frogs are eaten by trout;

   trout could catch / eat more tadpoles than frogs (as frogs not fully aquatic);

   trout could introduce diseases / change breeding sites that affect frogs and tadpoles [1 max]

d Upper LeConte Lake: 210 (tadpoles 10 m^{-1} shoreline) (*allow a range of 200 to 220*)

Lower LeConte: 6.4 (*allow a range of 6.1 to 6.8*) [1]

Both needed for [1].

e
- disease;
- other predator;
- Upper LeConte Lake has a supply stream with tadpoles and frogs while Lower LeConte Lake does not;
- trout could have been reintroduced to either / both lakes from neighbouring streams;
- food (biotic) / temperature (abiotic) differences between the two lakes;
- other reasonable answer [1 max]

Do not accept frog density as stand alone answer.

f
- an increase in population / density in both lakes;
- in Upper LeConte Lake (rapid) increase and then decrease (in 2004) whereas in Lower LeConte Lake only increases / never decreases;
- removal of trout causes an exponential increase in frogs;
- small difference in populations 1 year after removal / lag in population increases;
- increased density of frogs only 3 years after removal;
- greater frog increase in Upper LeConte Lake than Lower LeConte Lake / vice versa [3 max]

Numbers alone without comparative words (e.g. more, greater, less etc.) are insufficient for the mark.

g
- support / non-support of prediction based on observation from data;
- reason for support / non-support;
- e.g. (yes) a permanent recovery (since) in the first (three) years after removal, both show a similar trend / number of frogs increased;
- because tadpoles / frogs had no trout predators / other valid reason;
- *OR*
- no permanent recovery since in Upper LeConte Lake numbers are decreasing after 2004;
- because tadpoles / frogs can migrate from Upper to Lower LeConte as there are no barriers / reinvasion of trout from streams / other valid reason;
- *OR*
- no prediction possible since data missing / contradictory;
- example of missing / contradictory data (*e.g. changes in pH of water / climate / depth of water / availability of food / predators / disease / frog increase in one lake but frog and tadpole decrease in other lake*) [2 max]

Topic 5 Evolution and biodiversity

Quick check questions (p.140)

1 The breeding of domesticated plants and animals has created varieties with little external resemblance to their wild ancestors. Darwin bred pigeons, and noted there were more than a dozen distinctive varieties of pigeon, all of which were descended from the rock dove. Darwin argued that if so much change can be induced in so few generations, then species must be able to evolve into other species by the gradual accumulation of minute changes over long periods of time, as environmental conditions alter and natural selection operates.

2 A species is a group of organisms that can interbreed and produce fertile offspring. All these dog types can breed and their offspring will be fertile.

3 Comparative anatomy of groups of animals or plants shows certain structural features are similar; the limbs of vertebrates conform to a common plan called the pentadactyl limb; the bones may vary in size and shape, but all vertebrates have five-fingered 'hands' at the end of each limb; these limbs are described as homologous structures, because they occupy similar positions in an organism, have an underlying basic structure in common; limbs look different in different groups because they have evolved different functions (i.e. adapted to different modes of locomotion in specific environments), for example:

- **mammals**: e.g. dolphin fin for swimming; bat wing for flying; monkey hand for grasping; horse hoof for galloping
- **birds**: forelimbs are adapted for flying by having feathers attached; unlike bats, which have elongated 2nd to 3rd digits that support the wing membrane, birds have shortened digits with feathers mounted along the arm-bones; wing bones are hollow to reduce weight; hindlimbs are adapted for support / walking on land / perching in trees; penguins have forelimbs adapted as flippers for swimming and hindlimbs for walking on land
- **amphibians**: webbed feet in many are an adaptation for swimming in water; fine bone structure as body is largely supported in water rather than being adapted for motility in land; hindlimbs are elongated for jumping
- **reptiles**: strong and sturdy bones adapted for locomotion on land; snakes have much reduced pentadactyl limbs (only visible on dissection), using skin for locomotion.

The fact that limbs of vertebrates conform but show modification suggests these organisms share a common ancestry; from this common origin, the vertebrates have diverged over a long period of time.

Quick check questions (p.144)

1 Theory of evolution by natural selection:

- populations show variation
- populations always over-reproduce to produce excess offspring
- resources, such as food and space, are limited and there are not enough for all offspring
- there is competition for resources
- the best adapted survive ('survival of the fittest')
- the individuals that survive contain alleles that give them an adaptive advantage
- these alleles are inherited by offspring and passed on to the next generation
- over time there is a change in the gene pool, which can lead to the formation of new species.

Evidence for natural selection:

- adaptive radiation of species, e.g. Galápagos finches
- homologous structures indicate adaptive radiation, e.g. the pentadactyl limb of vertebrates
- antibiotic resistance in bacteria
- industrial melanism, e.g. peppered moth

- variation in species within the fossil record, with some species surviving and others going extinct; fossils show a chronological (time) sequence in which characteristics appear and develop in complexity
- DNA and protein structure.

2 Natural selection generally occurs over a long (geological) period of time whereas artificial selection can happen over several generations (i.e. short periods of time); in artificial selection, humans select desirable species (i.e. with favourable characteristics) for breeding, whereas natural selection is driven by an organism's traits that allow them to survive and reproduce (i.e. nature selects); natural selection results in gradual change in populations due to the possession of more favourable traits by some individuals in the face of environmental change; these individuals are more likely to survive, breed, and produce offspring than others.

3 Differential reproductive success refers to the difference between individuals in a population (i.e. variation) and how many offspring they are able to leave; the 'fittest' leave more offspring while those not suited to the environment leave fewer or no offspring; differential reproductive success is dependent upon how favourable the traits are for survival; it leads to either the increase or decrease of alleles present in a population's gene pool.

4 a Exposure of pathogenic bacteria to sub-lethal doses of antibiotic may increase the chances of resistance developing in that population of pathogens; not all bacteria are killed in the population – those with a mutation for antibiotic resistance survive, multiply, and pass on the adaptive allele.

b By varying the antibiotics used, there is increased likelihood of killing all the pathogens in a population, including any now resistant to the previous antibiotics used. This approach works until multiple-resistance strains have evolved, such as in strains of *Clostridium difficile* and *Staphylococcus aureus*.

5 Members of a population of the same species show variation; some organisms are more likely to survive due to selective advantage / survival of the fittest; some organisms have a reproductive advantage; these variations may be genetically controlled / heritable; these genes are most likely to be passed on to offspring; this can change the characteristic of the population; bacteria can normally be killed with antibiotics; antibiotics impose a selection pressure; if a few bacteria have natural resistance to the antibiotic they will survive; if the resistance is heritable they will pass it on to their offspring; they will reproduce / evolve to form bacterial colonies resistant to the antibiotic; example of organism selected by use of antibiotic (e.g. MRSA bacteria / resistant TB bacteria).

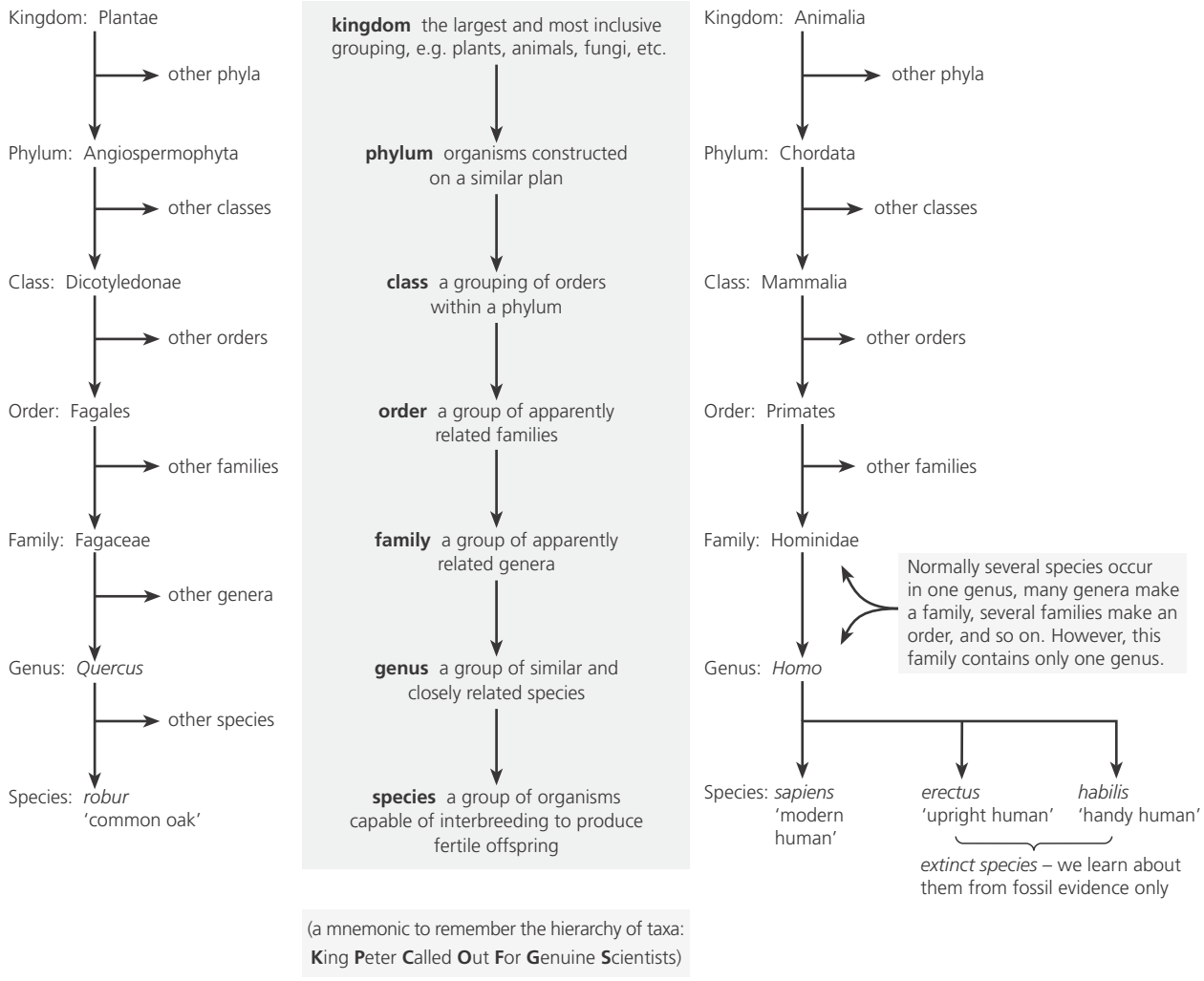
Quick check questions (p.151)

1 Archaea

2

Prokaryotic cells	Eukaryotic cells
much smaller (<5 µm)	larger than 10 µm (up to 100 µm, although egg cells can be much larger)
DNA is circular	DNA is linear
naked DNA	DNA associated with histone proteins
no membrane-bound organelles	membrane-bound organelles, such as mitochondria
DNA not in nucleus but free-floating in cytoplasm	DNA enclosed in nuclear envelope
70S ribosomes	80S ribosomes
cell wall made of peptidoglycan (murein)	cell wall present in plants (made of cellulose) and fungi (made of chitin) but not animals

3



(a mnemonic to remember the hierarchy of taxa: **K**ing **P**eter **C**alled **O**ut **F**or **G**enuine **S**cientists)

The taxa used in taxonomy, applied to genera from two different kingdoms

4 a

Phylum	**Feature**				
	Vascular tissue (xylem and phloem)	**Roots**	**Stem**	**Leaves**	**Reproduction**
Bryophyta (mosses and liverworts)	none	none; rhizoids (hair-like structures) present	mosses have a simple stem	mosses have simple leaves; liverworts have flattened thallus; no waxy cuticle	spores produced at end of stalk
Angiospermophyta (flowing plants)	present	present	some stems are woody (shrubs and trees), but not all	variable in structure; waxy cuticle with pores (stomata) in surface	female and male organs present together in one flower; seeds develop from ovules in ovaries; ovaries become fruit that disperse seeds

b

Phylum	**Feature**				
	Vascular tissue (xylem and phloem)	**Roots**	**Stem**	**Leaves**	**Reproduction**
Filicinophyta (ferns)	present	present	short; non-woody	usually divided into pair of leaflets; waxy cuticle present	spores produced on underside of leaves
Coniferophyta (conifers)	present	present	woody stem	needle-shaped leaves, with thick waxy cuticle; mostly evergreen	male cones produce pollen; female cones contain ovules that develop into seeds

c

Phylum	Feature				
	Symmetry	**Gastric tube**	**Segmentation**	**Skeleton**	**Other features**
Platyhelmintha (flatworms)	bilateral	mouth, no anus	none	none	no circulatory system, but the small, thin, flat body means that oxygen can diffuse easily to cells
Mollusca (molluscs)	bilateral	mouth and anus	none, or not visible	none, although some have shells made from calcium carbonate	rasping, tongue-like radula used for feeding

d

Phylum	Feature				
	Symmetry	**Gastric tube**	**Segmentation**	**Skeleton**	**Other features**
Porifera (sponges)	none	none (have gastric cavity)	none	internal skeleton of spicules made from calcium carbonate or silicon dioxide	the only multicellular animal to lack a nervous system
Cnidaria (jellyfish, coral and anemones)	radial	body cavity with one opening	none	coral secrete a skeleton of calcium carbonate, which protects the animal polyp	have stinging cells, found especially on the tentacles, triggered by passing prey

e

Phylum	Feature				
	Symmetry	**Gastric tube**	**Segmentation**	**Skeleton**	**Other features**
Arthropoda (jointed-limbed animals)	bilateral	mouth and anus	yes	exoskeleton	most numerically successful of all animals, and are divided into five distinct groups: crustaceans, arachnids, centipedes, millipedes and insects
Chordata (include the vertebrates)	bilateral	mouth and anus	yes (arms, legs, thorax, abdomen, head)	endoskeleton	have a dorsal strengthening structure (a notochord) in their bodies for at least some stage of their development; tubular nerve cord lies above the notochord

f

Class	Feature						
	Outer body surface	**Body temperature**	**Fin / limb**	**Gas exchange**	**Reproduction**	**Teeth**	**Other features**
Bony fish	scales (bony plates)	do not maintain constant body temperature	fins	gills	external fertilization in most species	most fishes have simple pointed teeth, although depends on diet	swim bladder for buoyance
Amphibians	moist, permeable skin	do not maintain constant body temperature	four pentadactyl limbs	simple lungs	external fertilization; tadpoles live in water	if present, only located on the upper jaw and are only in the front part of the mouth	larval stage (tadpole) lives in water, adult lives on land; the tadpole undergoes metamorphosis into the adult form

g

Class	Feature						
	Outer body surface	**Body temperature**	**Fin / limb**	**Gas exchange**	**Reproduction**	**Teeth**	**Other features**
Reptiles	scales of keratin	do not maintain constant body temperature	four pentadactyl limbs (except snakes)	lungs with extensive folding	internal fertilization; soft shell around egg	all of one type	snakes have lost their legs and use scales for movement; two-thirds of snakes are non-venomous
Birds	feathers made of keratin	maintain constant body temperature	four pentadactyl limbs (2 modified as wings)	lungs with parabronchi	internal fertilization; hard shell around egg	beak, no teeth	limb bones are hollow so skeletons are lighter, for flight

h

Class	Feature						
	Outer body surface	**Body temperature**	**Fin / limb**	**Gas exchange**	**Reproduction**	**Teeth**	**Other features**
Birds	feathers made of keratin	maintain constant body temperature	four pentadactyl limbs (2 modified as wings)	lungs with parabronchi	internal fertilization; hard shell around egg	beak, no teeth	limb bones are hollow so skeletons are lighter, for flight
Mammals	skin has follicles with hair made of keratin	maintain constant body temperature	four pentadactyl limbs	lungs with alveoli	internal fertilization; birth to live young; mammary glands for mile	several different types	body cavity is divided by muscular diaphragm between thorax and abdomen, used for ventilation

5 1 a Animal has hindlimbs for walking on land go to 2
b Animal does not have hindlimbs for walking go to 5
2 a Animal has claws on fingers and toes **Animal E**
b Animal does not have claws go to 3
3 a Animal has body divided into two sections go to 4
b Animal does not have body divided into two sections **Animal F**
4 a Animal has five fingers on hands **Animal G**
b Animal does not have 5 fingers **Animal H**
5 a Animal has stripes across back go to 6
b Animal does not have stripes across back go to 7
6 a Animal has thin stripes across back **Animal C**
b Animal has thick stripes **Animal D**
7 a Animal has eyes on long stalks **Animal A**
b Animal has eyes on short stalks **Animal B**

6 1 a Animal is a vertebrate go to 4
b Animal is an invertebrate go to 2
2 a Animal has fewer than 8 legs go to 3
b Animal has 8 legs **spider**
3 a Animal has two hardened wing cases **beetle**
b Animal does not have modified wings **butterfly**
4 a Animal is warm blooded (endothermic) go to 6
b Animal is cold blooded (ectothermic) go to 5
5 a Animal has legs **frog**
b Animal does not have legs **snake**
6 a Animal is adapted for life in water **dolphin**
b Animal is not adapted for life in water go to 7
7 a Animal has wings **eagle**
b Animal does not have wings go to 8
8 a Animal has a placenta go to 9
b Animal does not have a placenta **kangaroo**
9 a Animal has fur go to 10
b Animal does not have fur **rhinoceros**
10 a Animal has claws on feet **leopard**
b Animal does not have claws on feet go to 11
11 a Animal has a tail **monkey**
b Animal does not have a tail **gibbon**

Quick check questions (p.156)

1 a Bonobos and chimpanzees are most closely related, sharing the most recent common ancestor; chimpanzees and bonobos share a common ancestor with humans.

b Lemurs and lorises are in a separate clade to the other primate groups; lemurs and lorises share a recent common ancestor; the two different clades arose from different ancestral stocks and display their own distinctive character.

c The New World monkeys are only distantly related to Old World monkeys; Old World monkeys is a group that is more closely related to apes and humans than to New World monkeys; Old World monkeys and apes (catarrhines) occur in Africa and Asia, and New World monkeys (platyrrhines) live in Central and South America; geographical separation of the two groups led to independent evolution on different continents, leading to divergence of the clades.

2 **a** sharks

b four limbs

c bony skeleton

d sharks have a cartilaginous skeleton and bony fish have a skeleton made of bone (collagen and calcium phosphate

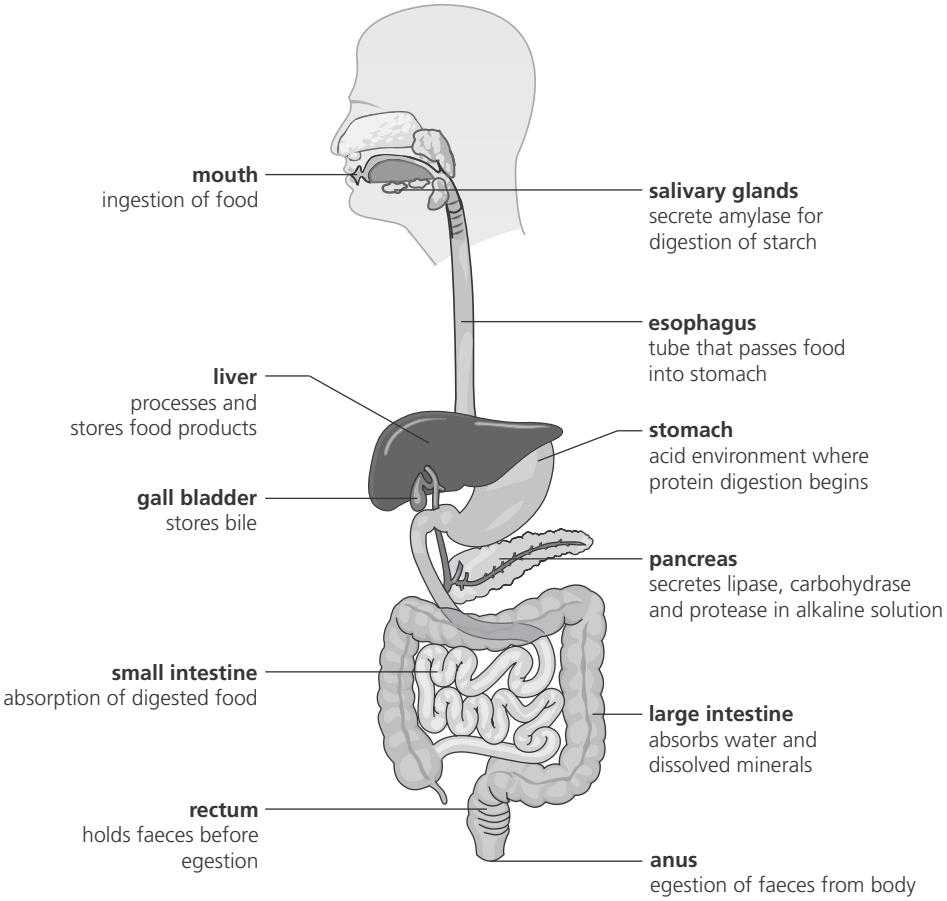
e hair, and eggs with shells

f crocodiles

Topic 6 Human physiology

Quick check questions (p.160)

1



2 A = epithelium, B = mucosa, C = circular muscle, D = longitudinal muscle

3 The usefulness of the model can be evaluated by considering: How is the function of dialysis tubing similar to the small intestine? What features of a real gut are missing from the model?

The model's **strengths**: it demonstrates that a complex carbohydrate, such as starch, cannot pass across a selective permeable membrane; it shows that molecules produced by digestion (simple sugars), which are smaller in size, can cross the selectively permeable membrane.

The model's **limitations**: it does not include intrinsic proteins, e.g. carrier and channel proteins, that can carry larger / polar molecules across the cells of the intestine; it only shows passive transport, not active transport; does not show facilitated diffusion, where molecules pass down their concentration gradient through channel or carrier proteins.

Quick check questions (p.168)

1 By dissection, and by experimentation, Harvey observed and discovered:

- the working valves in the heart and the veins, and their role in maintaining one-way flow of blood
- in systole the heart contracts as a muscular pump
- the right ventricle supplies the lungs
- the left ventricle supplies the rest of the system of arteries
- blood flow in veins was towards the heart.

William Harvey changed the understanding of blood flow around the human body by:

- discovering the circulation of blood
- showing that valves in the veins / heart ensure one-way flow of blood
- showing that blood was not consumed by the body
- predicting the existence of capillaries
- showing that the theories of Galen were false.

2
- The heartbeat originates in a tiny part of the muscle of the wall of the right atrium, called the **sinoatrial node** or **pacemaker**.
- From here, a wave of excitation (electrical impulses) spreads out across both atria.
- In response, the muscle of both atrial walls contracts simultaneously (**atrial systole**).
- This stimulus does not spread to the ventricles immediately, due to the presence of a narrow band of non-conducting fibres at the base of the atria. These block the excitation wave, preventing its conduction across to the ventricles.
- The stimulus is picked up by the AVN (**atrioventricular node**), situated at the base of the right atrium.
- After a delay of 0.1–0.2 s, the excitation is passed from the AVN to the base of both ventricles.
- The ventricle muscles start to contract from the base of the heart upwards (**ventricular systole**).
- The delay that occurs before the AVN prevents the atria and ventricles from contracting simultaneously.
- After every contraction, cardiac muscle has a period of insensitivity to stimulation, the **refractory period** (a period of enforced non-contraction – **diastole**). In this phase, the heart begins, passively, to refill with blood.
- The heart rate can be increased or decreased by impulses brought to the heart through two nerves from the medulla of the brain. The part of the medulla which controls heart rate is called the cardiovascular centre.
- Increased carbon dioxide in the blood, due to increased respiration, lowers blood pH and causes the sympathetic nerve to send signals to the heart that causes the pacemaker to increase the frequency of heart beats; increased heart rate will ensure that rate of supply of blood to tissues is increased, ensuring that more oxygen is delivered and more carbon dioxide removed; low blood pressure, low oxygen concentration and low pH indicate that heart rate needs to speed up.
- High blood pressure, high oxygen concentration and higher pH indicate that heart rate needs to slow down; signals form the vagus nerve decrease the rate.

- Epinephrine causes the pacemaker to increase the heart rate to prepare for vigorous physical activity.

3

	Artery	Capillary	Vein
overall wall thickness	have thick walls relative to the diameter of the lumen	have a thin wall containing only one layer of cells	have thin walls relative to the diameter of the lumen
outer layer (*tunica externa*) of elastic fibres and collagen	present (thick layer)	absent	present (thin layer)
middle layer (*tunica media*) of elastic fibres, collagen, and smooth muscle	present (thick layer)	absent	present (thin layer)
endothelium *(tunica intima)*	present	present	present
size	>10 μm	10 μm	>10 μm
valves	absent	absent	present

4
- Fatty tissue develops in the coronary artery wall, causing an **atheroma** to form; the fatty tissue is comprised of **LDLs** (low density lipoproteins); LDLs accumulate on the artery wall.
- **Phagocytes** (white blood cells) are attracted by signals from endothelium tissue cells and smooth muscle of the artery wall, triggered by the accumulation of fats and cholesterol.
- Phagocytes engulf fats and cholesterol by **endocytosis** and grow large.
- Smooth muscle migrates to form a tough cap over the atheroma – this narrows the lumen of the artery and impedes blood flow, leading to a **coronary occlusion**.
- The narrowing leads to less oxygen (anoxia) and nutrients reaching heart muscle; anoxia causes pain (**angina**) and impairs muscle contraction causing the heart to beat faster leading to increased blood pressure; this can lead to the atheroma rupturing leading to a blood clot forming (a **thrombus**) that further narrows the artery, resulting in acute heart problems.
- Less oxygen and glucose is delivered to the heart muscle which can lead to death of these cells (due to not enough glucose and oxygen for aerobic respiration), which can lead to a heart attack (cardiac arrest).

5 A: aorta (to body); B: pulmonary artery (to lungs); C: pulmonary veins (from lungs); D: left atrium; E: semilunar / aortic valve; F: bicuspid / mitral valve; G: left ventricle; H: right ventricle; I: tricuspid valve; J: (inferior) vena cava (from body); K: right atrium; L: pulmonary artery (to lungs); M: (superior) vena cava (from head).

Quick check questions (p.175)

1 Mucus is a sticky substance that traps dirt and bacteria entering the trachea; cilia lining the trachea move the mucus up towards the mouth; mucus is swallowed and harmful bacteria destroyed.

2 Damaged cells produce a signal that causes platelets to collect at the site of damage and release **clotting factors**. Clotting factors activate **thrombin** which then stimulates the conversion of **fibrinogen** into **fibrin**.

3 Atherosclerosis can lead to blood clots; if these blood clots occur in heart (myocardial) tissue it is known as heart disease; if the coronary artery becomes blocked, coronary tissue dies as a result of a lack of glucose and oxygen; death of heart tissue leads to irregular beating of the heart and in turn to a heart attack (myocardial infarction).

4 a The percentage of samples of *Staphylococcus aureus* that are resistant to methicillin have increased steadily between 1992 and 2000; numbers remained the same between 2000 and 2001.

b Indiscriminate use of antibiotics is leading to antibiotic resistance in bacteria; overuse of methicillin in hospitals has led to a strain of *Staphylococcus aureus* acquiring resistance to this antibiotic; this is an example of evolution by natural selection; bacteria mutate and resistance to an antibiotic naturally arises; bacteria divide rapidly therefore a resistant strain of bacteria can quickly proliferate; over time strains of bacteria can become resistant to multiple strains of bacteria.

5
- They tested their penicillin on human patients after very few tests on animals.
- They then tested humans (singly, or very small groups) already ill with acute and life-threatening bacterial infections, without any prior investigation of the effect of their penicillin on healthy people.
- They worked with small groups, and with minimal quantities of their preparation.
- Their penicillin preparation was impure so there could have been side effects from the impurities.

6 **a** Following initial infection, there is a rapid decrease in CD4 helper T cells, followed by an increase between weeks 3 and 9; there is a steady decrease in CD4 helper T cells from 1 year after infection to 10 years; HIV RNA copies increase from infection to week 3 and then decrease to week 9; there is a steady, although fluctuating, increase in HIV RNA copies between 1 and 10 years following infection.

b During initial infection, HIV infect CD4 helper T cells and replicate, causing increase in viral RNA and decrease in lymphocytes; there is then a long period when the virus remains dormant; some time after infection (in this case, one year), some event in the patient's body activates the HIV genes and the outcome is AIDS; synthesis of viral messenger RNA occurs in infected lymphocytes (CD4 helper T cells); viral messenger RNA passes out into the cytoplasm and codes for viral proteins (enzymes and protein coat) at the ribosomes; viral RNA, enzyme, and coat protein form into viral cores., which then move against the cell membrane and 'bud-off' new viruses, which are released, leading to death and breakdown of the lymphocyte; more lymphocytes are infected and the cycle is rapidly repeated; rapid decrease in lymphocytes leads to opportunistic infection, which eventually leads to death.

Quick check questions (p.182)

1 Any three of the following:

Characteristic	How it influences diffusion
large surface area	increases the rate of diffusion
thin	small distance for diffusion
a ventilation mechanism that moves air (or water) over the respiratory surface	the higher the concentration of oxygen on the 'supply side' of the respiratory membrane, the quicker gas can diffuse across the surface
blood circulation that speeds up the removal of dissolved oxygen, with a respiratory pigment that increases the gas-carrying capacity of the blood	the quicker oxygen is picked up and transported away from the gas exchange surface, the greater the rate of diffusion
moist	so gases are dissolved, making diffusion faster

2 Carbon dioxide is an acidic gas which, if it accumulates in the blood, alters the pH of the plasma solution, leading to respiratory acidosis. This imbalance causes increase in heartbeat, high blood pressure, swellings, difficulty breathing, discoloration of the skin (turning blue); coma or even death may result due to the lack of oxygen.

3 Photomicrograph B; walls of the alveoli have merged, due to breakdown of connective tissue, such as elastin, resulting in the destruction of small airways and alveolar walls, forming huge air spaces with drastically lowered surface area for gas exchange; walls of alveoli are thicker, reducing rate of diffusion of oxygen.

4 The main cause of emphysema is smoking but it can also develop in people with a long history of chest infections; emphysema can also be caused by air pollution; this causes an inflammatory response in the lungs; protease is released by white blood cells and inflamed lung tissue; protease breaks down connective tissue (e.g. elastin), resulting in the destruction of small airways and alveoli; this results in the formation of large air pockets and the breakdown of capillaries; large air pockets have a much lower surface area to volume ratio than the alveoli which causes insufficient ventilation; combined with the reduced blood supply, this in turn means inefficient gas exchange and hence low blood oxygen levels; symptoms of emphysema include: difficulty breathing, cough, loss of appetite, weight loss; there is no cure for emphysema, but there are treatments that can help manage the disease.

5 Different muscles are required for inspiration and expiration because muscles only work when they contract – this is referred to as antagonistic muscle action; when one of the pair contracts the other relaxes (i.e. is stretched) – see table below:

Inspiration		**Expiration**
relax	**internal intercostal muscles**	contract
contract	**external intercostal muscles**	relax
contract	**diaphragm**	relax
relax	**abdominal wall muscles**	contract
move upwards and outwards	**effects on rib cage**	move downwards and inwards

6 In both men and women the habit of smoking was declining. In the case of men, this followed a previous prolonged period when heavy smoking was extremely prevalent, followed by a decline in smoking since 1950. The incidence of male lung cancer was positively correlated with this decline. In the case of women, smoking had been a relatively recently adopted habit, and although now declining, the incidence of smoking had been on the increase up until 1970. The resulting lung cancer was still on the increase, for there is a significant delay in the onset of cancer after smoking is taken up.

Quick check questions (p.189)

1 **a** Stimulations of the nerve fibre are insufficient to generate an action potential; stimuli below the threshold value, and so not sufficient to reverse polarity of the membrane to +40 mV.

b **I** Sodium channels open and sodium ions rush into axon.

II Interior of the axon becomes increasingly more positive with respect to the outside.

III Interior of the axon starts to become less positive again due to potassium channels opening and letting K^+ out from axon.

IV Slight overshoot (more negative) than the resting potential (= hyperpolarization) before sodium / potassium ion pump, with facilitated diffusion, re-establishes the resting potential.

2 Acetylcholine (ACh) is a neurotransmitter used in many synapses through the nervous system; ACh is broken down in the synaptic cleft by acetylcholinesterase; the breakdown of ACh stops further transmission of the action potential; ACh is secreted in the pre-synaptic membrane and also reabsorbed by the same membrane; receptors for ACh are located on post-synaptic membrane; this ensures that action potentials pass in one direction along axons.

3 Neonicotinoids bind to acetylcholine receptors in synapses in the CNS of insects, blocking the binding of acetylcholine, inhibiting synaptic transmission; they cannot be broken down by acetylcholinesterase, and so their effects are irreversible; they only kill insect pests, and do not harm humans or other mammals; there are issues about their impact on the wider insect community – concerns have been raised about their effects on honeybees.

Quick check questions (p.197)

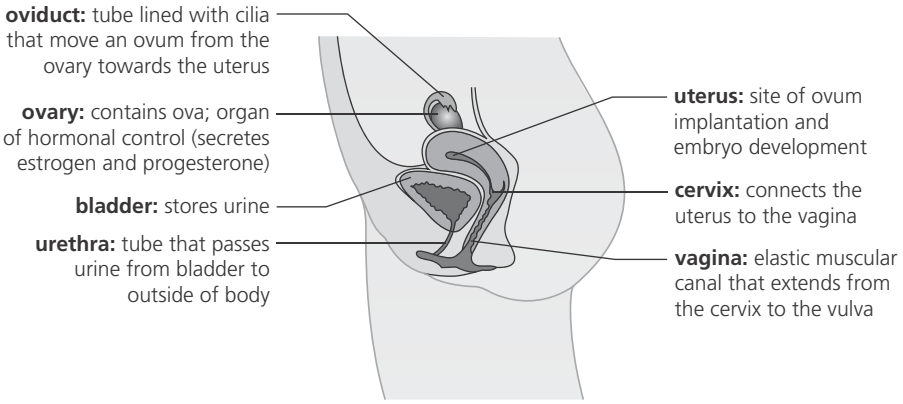
1 **Down-regulation** is the first step in IVF is the shutting down of the menstrual cycle, by stopping secretion of the pituitary and ovarian hormones; the process takes about two weeks and allows better control of superovulation; down-regulation is done with a drug, commonly in the form of a nasal spray; the next step is **superovulation**, which collects multiple eggs from the woman; high doses of FSH are injected over approximately a ten day period to stimulate the development of multiple follicles; when follicles reach 15–20 mm in diameter, an injection of HCG is given to start maturation process; after ca. 36 hours, follicles (typically 8–12) are collected from the ovaries under a general anesthetic; prepared eggs (removed from the follicles) are combined with sperm in sterile conditions; successfully fertilized eggs are then incubated before implantation; for approximately two weeks before implantation the woman takes **progesterone** (which maintains the endometrium) to aid implantation; this treatment is

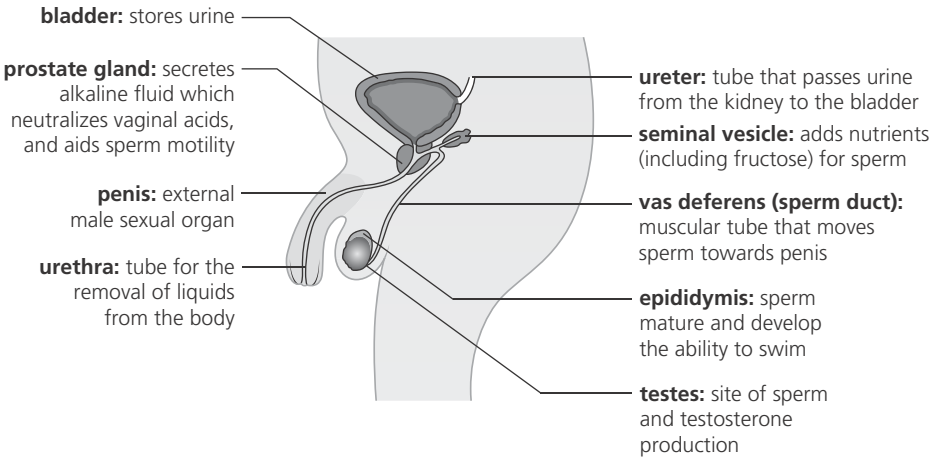
continued until pregnancy test, and if positive, until 12 weeks of gestation; because the natural success rate of implantation is around 40%, usually two or three blastocysts (growing fertilized egg) are implanted: as a consequence the chances of IVF treatment leading to multiple pregnancies are high.

2 Obese people have very high leptin concentrations; target cells in the hypothalamus may have become resistant to leptin and so they therefore do not respond to the hormone; leptin does not inhibit appetite and so food intake is excessive; adipose tissue increases as a result and so too does leptin concentrations; in contrast, some obesity may be due to mutations in genes for leptin synthesis or receptors on target cells.

3 Jet lag is a condition caused by travelling rapidly between time zones; symptoms of jet lag include: sleep disturbance, headaches, fatigue, irritability; symptoms usually disappear after a few days; jet lag is caused by the pineal gland and SCN (suprachiasmatic nuclei) continuing to set a circadian rhythm for the point of origin rather than the current time zone; taking melatonin close to the sleep time of the destination can alleviate symptoms; melatonin is secreted by the pineal gland, controlled by the SCN; melatonin naturally increases in the evening and decreases at dawn; high melatonin promotes sleep and falling melatonin causes waking at the end of the night.

4





Exam practice (p.198)

1 a 40 s / seconds (units required) [1]

b initially the heart rate decreases rapidly;

heart rate increases over the next seconds;

heart rate falls to its lowest level / reaches lowest level after 55 s / seconds / 35 s / seconds after start of dive;

in the last seconds before the dive ends, the heart rate increases [2 max]

c anaerobic respiration because the tufted duck cannot breathe / ventilate under

water / replace oxygen that has been used;

aerobic respiration because the tufted duck uses stored oxygen;

both aerobic (at the beginning) and anaerobic (at the end) because oxygen was used up during the dive [1 max]

To award [1], reason must be given.

d 200 (%) [1]

e

Heart muscles	Flight muscles
swimming at maximum speed causes increase in blood flow to heart muscles	swimming at maximum speed causes decrease in blood flow to flight muscles
swimming at normal speed, less blood flow to heart muscles (20 ml min^{-1}) / swimming at maximum speed, more blood flow to heart muscles (24 ml min^{-1})	swimming at normal speed, greater blood flow to flight muscles (39 ml min^{-1}) / swimming at maximum speed, less blood flow to flight muscles (18 ml min^{-1});
small change in blood flow to heart muscles when changing speed (4 ml min^{-1} more)	big change / almost half amount of blood flow to flight muscles when changing speed (22 ml min^{-1} less);

Award [1] for each correct row. Answers do not need to be shown in a table format, but must be comparative statements.

f legs / leg muscles need more energy / ATP for fast swimming;

legs / leg muscles need more blood to provide oxygen / glucose for energy;

(the legs need more blood) to remove carbon dioxide;

the heart needs more blood to pump faster;

intestines / kidneys / flight muscles have less blood to allow for increased flow to heart / legs [2 max]

g blood flow decreases;

as heart rate is seen to decrease in the first graph;

as lower heart rate means less requirement for oxygen / nutrients / blood / removal of waste [2 max]

h adrenaline / epinephrine / noradrenaline / norepinephrine [1]

Topic 7 Nucleic acids

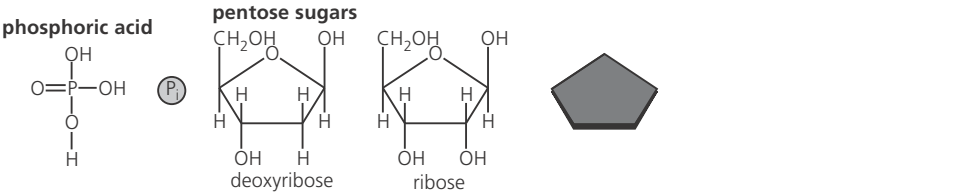
Quick check questions (p.205)

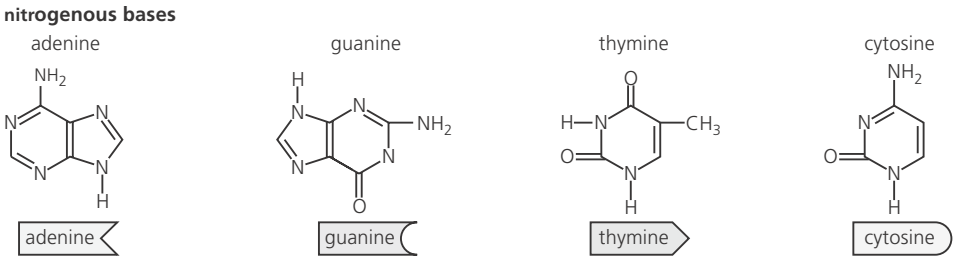
1 nitrogenous base + pentose sugar → **nucleoside**

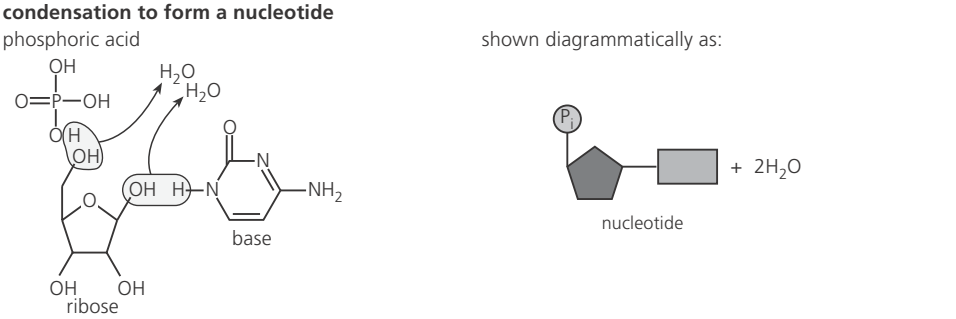
nucleoside + phosphoric acid → **nucleotide**

many nucleotides condensed together → **nucleic acid**

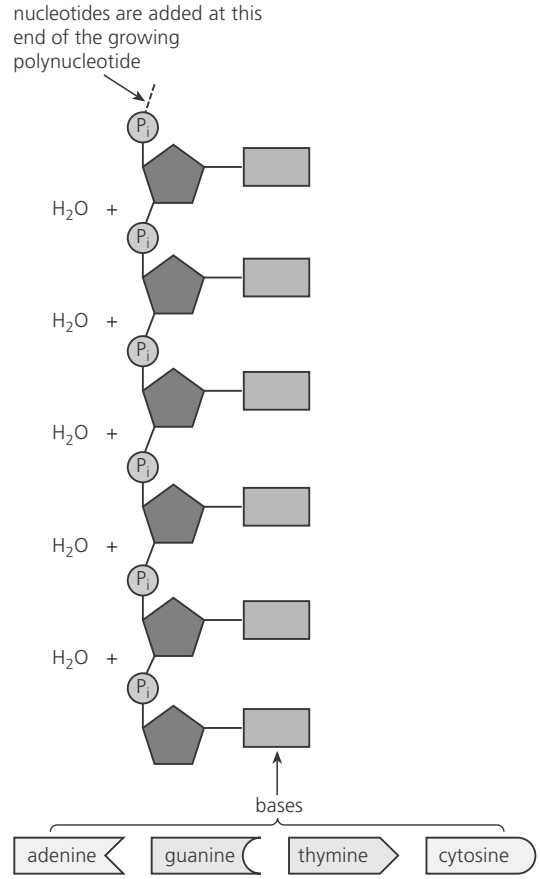
See figures below:







The components of nucleotides



How nucleotides make up a nucleic acid

2 To organize DNA to allow cell division to occur (most DNA supercoiling occurs at this time); during mitosis the two chromatids of each chromosome must be separated: the DNA molecule in a chromosome is very long – typically 50 000 µm in length; the length of all DNA in a human (eukaryotic) cell is approx. 2 m; the nucleus in a eukaryotic cell has a diameter of approximately 10 µm; by supercoiling, the DNA of each chromatid is reduced to a manageable length for separation; supercoiling of chromatin during metaphase helps to ensure correct segregation of chromosomes at cell division; essential to pack genetic material into the nucleus; to control DNA expression – supercoiled DNA cannot be transcribed; allow cells to specialize by permanently supercoiling DNA; transcription of active chromatin can be promoted or inhibited by the associated histones.

3 The attraction between histones and DNA facilitates supercoiling.

4 Tandem repeat (TR) sequences are short sequences of (non-coding) DNA, normally of length 2–5 base pairs, that are repeated many times in a head–tail manner; the TRs vary greatly in terms of the different number of copies of the repeat element that can occur in a population; for maternal profiling, mitochondrial DNA is usually used; for paternal profiling, the Y chromosome is commonly used; chromosomes occur in pairs (with the exception of the X and Y chromosomes) and the tandem repeat on each may vary; dyes markers are attached to the tandem repeats during PCR; restriction enzymes can be used to cut DNA between the tandem repeats; electrophoresis enables scientists to calculate the length of the tandem repeat sequence of an individual; if different tandem repeats at different loci are used then a unique profile for an individual can be identified.

5 Hershey and Chase would have expected that only the bacteria infected with the virus labelled with ^{35}S (an element in proteins but not in nucleic acids) would have produced radioactive virus. Remember, they were not aware that the protein coat of the virus remained outside of the host cell at the time of infection.

6 The strands of the molecule of DNA that run parallel to each other but with opposite 3′ to 5′ alignments.

7

1 Formation of replication fork	
helicase enzyme	separates the two strand of DNA to expose a replication fork and prevents them rejoining
DNA gyrase enzyme	
single-strand binding proteins	
2 a DNA replication in the leading strand – a continuous process	
DNA primase	forms a single short length of RNA primer
DNA polymerase III	forms the DNA strand, beginning at the RNA primer
2 b DNA replication in the lagging strand – a discontinuous process	
DNA primase	forms short lengths of RNA primer at intervals along the DNA strand
DNA polymerase III	forms short DNA strands (Okazaki fragments), starting from each RNA primer
DNA polymerase I	replaces the RNA primer at the start of each Okazaki fragment with a DNA strand
ligase	joins the DNA stands together

The enzymes that bring about DNA replication

Quick check questions (p.210)

1 a Replication can only proceed by adding nucleotides to the 3′, so one strand of a DNA molecule can be replicated as a single long molecule. The other strand is replicated in short portions that must be joined together.

b In transcription only the coding or antisense strand of DNA is transcribed, creating an mRNA molecule identical in sequence to the sense strand in the DNA.

2 a **Transcription**: first part of gene expression in which a particular section of a molecule of DNA (gene) is copied into mRNA by the enzyme RNA polymerase.

b **Translation**: the process of reading a molecule of mRNA by a ribosome during the synthesis of a polypeptide.

c **Antisense** (coding) strand: this is the strand of DNA that is transcribed by the enzyme RNA polymerase.

d **Sense strand**: the segment of double-stranded DNA running from 5′ to 3′, and complementary to the antisense strand. It has the same base sequence as the mRNA, but with thymine instead of uracil.

3 After the DNA double helix has been unwound and the coding strand exposed, RNA polymerase recognizes and binds to the promoter region. This enzyme now draws on the pool of free nucleotides to complement the DNA sequence (A with U, C with G), and catalyses the reaction that attaches them in a chain. mRNA is formed.

4 **Analysis**: The variation in the levels of methylation between the twins increases with age; hypomethylation is higher away from the ends of the chromosomes; levels of both hypermethylation and hypomethylation increase with age; chromosome 3 shows the greatest variation in methylation at both ages; chromosome 17 shows the least change with age.

Conclusions / deductions: The twins will have experienced different environmental stimuli which will in turn cause different levels of methylation on different chromosomes; genes, in terms of numbers, size, and roles, vary between chromosomes; some chromosomes will vary more than others in their degree of methylation and how they are affected by time and the environment; methylation inhibits transcription: as cells age they becomes more specialized due to higher levels of inhibited and promoted DNA.

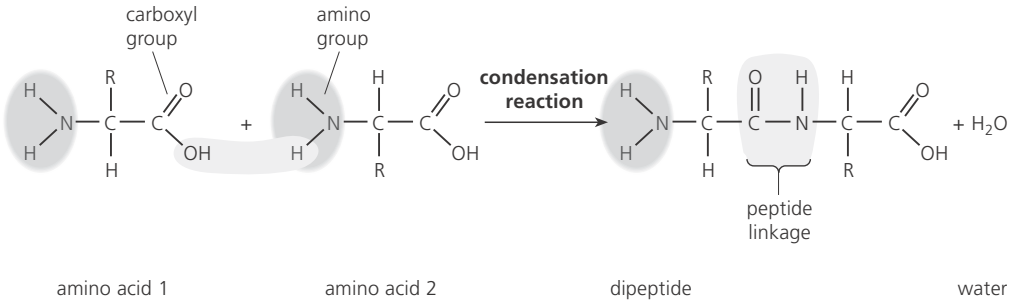
Quick check questions (p.217)

1 Transcription is the process where the DNA sequence of bases is converted into mRNA; information transferred from DNA to mRNA is translated into an amino acid sequence (translation); in transcription, a complementary copy of the information in a part of the DNA molecule (a gene) is made by the building of a molecule of messenger RNA (mRNA); DNA triplet codes are transcribed into codons in the mRNA; this process is catalysed by the enzyme RNA polymerase.

2 a mRNA

b tRNA.

3 amino acids combine together, the amino group of one with the carboxyl group of the other



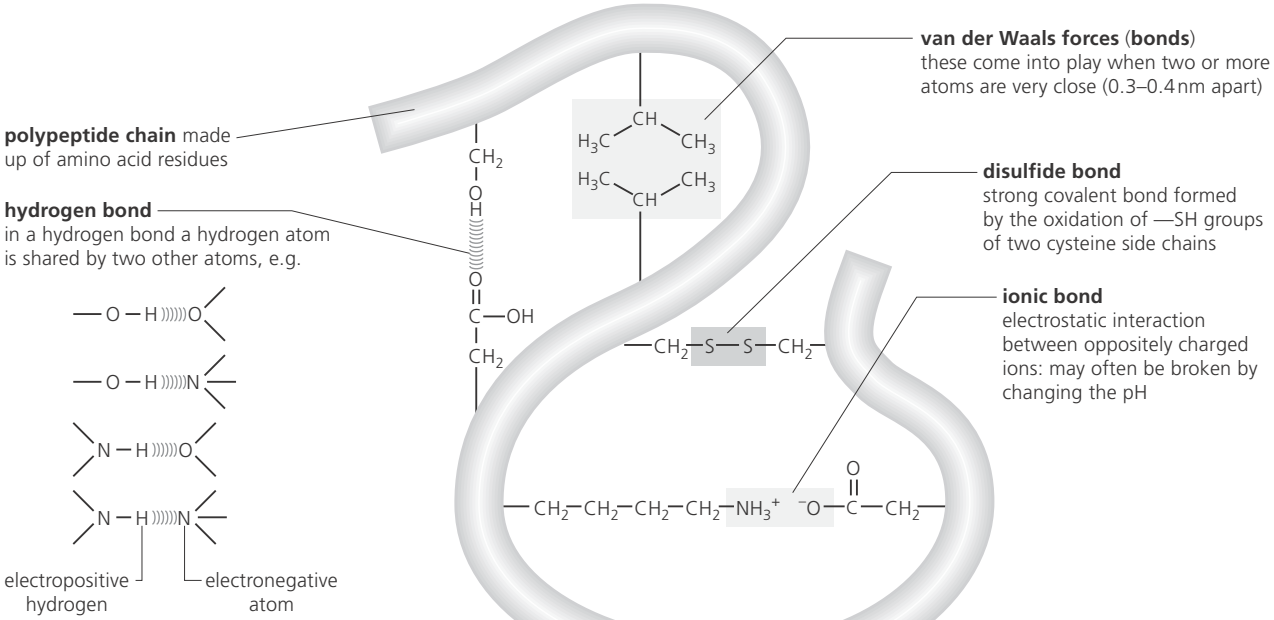
When a further amino acid residue is attached by condensation reaction, a tripeptide is formed. In this way, long strings of amino acid residues are assembled to form polypeptides and proteins.

Peptide linkage formation

4 tRNA delivers amino acids to the polypeptide chain during translation; tRNA is activated by a tRNA activating enzyme; there are 20 different tRNA activating enzymes, one for each different amino acid; for each tRNA activating enzyme, there is a tRNA molecule with a complementary anticodon; ATP is needed for the tRNA to pick up its associated amino acid; the structure of each tRNA molecule is unique and so it minds to only one specific amino acid.

5 Inside the nucleus there are enzymatic proteins that participate in the processes of DNA replication and transcription, such as DNA and RNA polymerases, helicases, topoisomerases, and single strand DNA binding proteins. Also there are histone proteins that help to organize the DNA and participate in the control of transcriptional processes. Other proteins regulate the exit of molecules (e.g. mRNA) from the nuclear envelope.

6 In the tertiary structure of a protein, the polypeptide folds and coils to form a complex 3D shape, caused by interactions between R groups; three different types of bond play a role (see figure): hydrogen bonds, disulphide bridges, and ionic bonds. Hydrophilic and hydrophobic interactions also play a role in determining tertiary structure.



Hydrogen bonds are weak, but are common in many polypeptide chains; they help to stabilize the protein molecule.

Crosslinking within a polypeptide

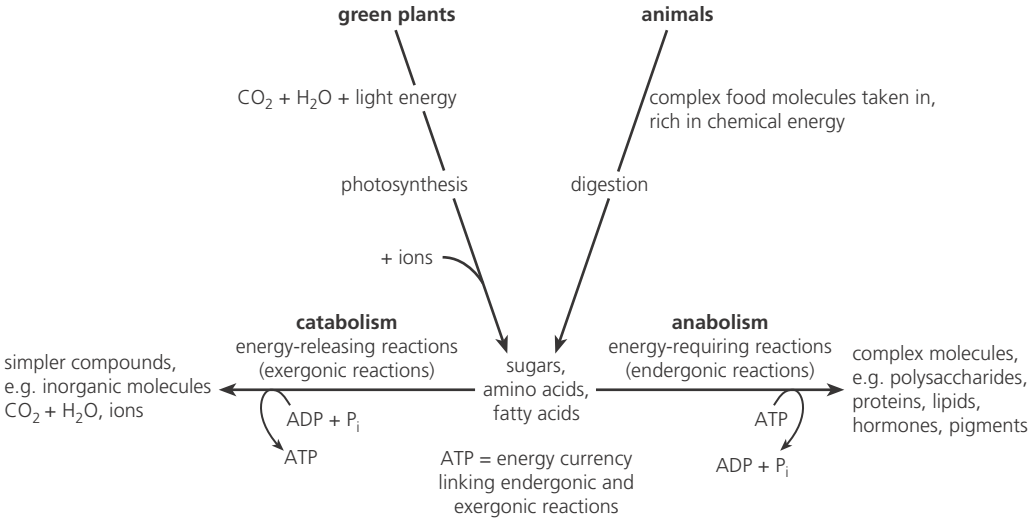
7 Any three of the following:

- **receptors** for hormones (hormone-binding sites): allowing cells to receive a hormonal signal which triggers a set of intracellular reactions
- **transport**: Protein channels (facilitated); protein pumps (active) using energy from ATP – able to move substrates against their concentration gradient
- **anchorage**: cytoskeleton attachments and extracellular matrix
- **cell recognition**: MHC proteins and antigens
- **metabolic pathways**: e.g. electron transport chain, which move electrons from one carrier to another, releasing energy.

Topic 8 Metabolism, cell respiration and photosynthesis

Quick check questions (p.222)

1

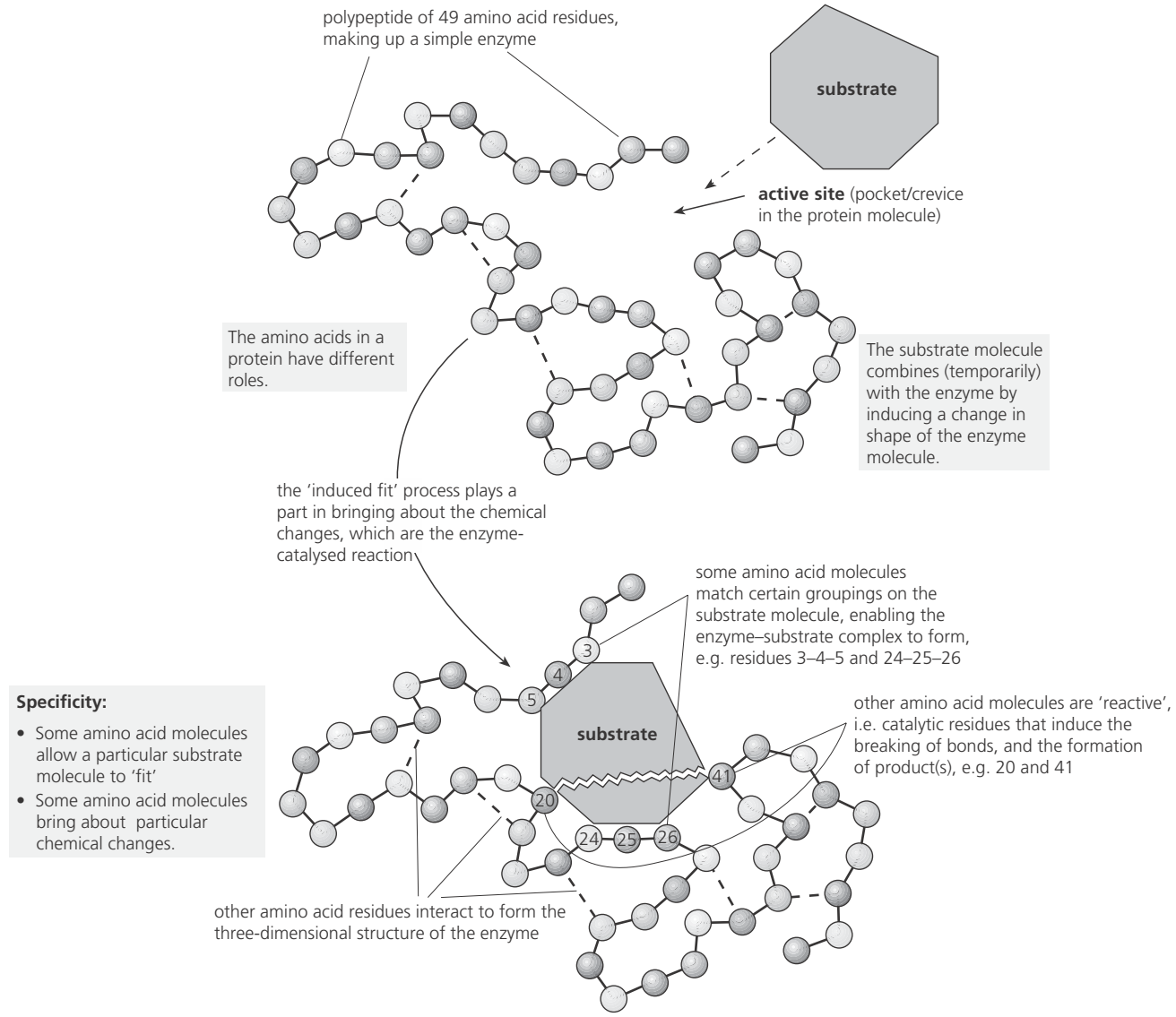


Metabolism = anabolism + catabolism

a **anabolic reactions:** the building up of complex molecules from smaller ones, e.g. photosynthesis

b **catabolic reactions**: the breaking down of complex molecules into smaller ones, e.g. respiration

2 Enzymes are highly specific in their action; enzymes are specific because of the way they bind with their substrate at the active site, which is a pocket or crevice in the protein (see figure below); at the active site, the arrangement of a few amino acid molecules in the protein (enzyme) matches certain groupings on the substrate molecule, enabling the enzyme–substrate complex to form; as it forms, it seems a slight change of shape is induced in the enzyme molecule. It is this change in shape that is important in raising the substrate molecule to the transitional state in which it is able to react; meanwhile, other amino acid molecules of the active site bring about the specific catalytic reaction mechanism, perhaps breaking particular bonds in the substrate molecule and forming others; different enzymes have different arrangements of amino acids in their active sites; consequently, each enzyme catalyses either a single chemical reaction or a group of closely related reactions.



Enzyme specificity and the active site

3

Competitive inhibitors	Non-competitive inhibitors
bind to the active site	bind to other parts of the enzyme, other than the active site
chemically resemble the substrate molecule and occupy (block) the active site	chemically unlike the substrate molecule, but the attachment occurs at some other part of the enzyme, where the inhibitor either partly blocks access to the active site by substrate molecules, or it causes the active site to change shape and so be unable to accept the substrate.
so called because they compete for the active site	so called because they do not do not compete for the active site.
at low concentration, increasing concentration of substrate eventually overcomes inhibition as substrate molecules displace inhibitor	at low concentration, increasing concentration of substrate cannot prevent binding – some inhibition remains at high substrate concentration
Examples: • O_2 competing with CO_2 for active site of RuBisCo in plants • malonate competing with succinate for the active site of succinate dehydrogenase	Examples: • cyanide ions blocking cytochrome oxidase in terminal oxidation in cell aerobic respiration • nerve gas Sarin blocking acetyl cholinesterase in synapse transmission

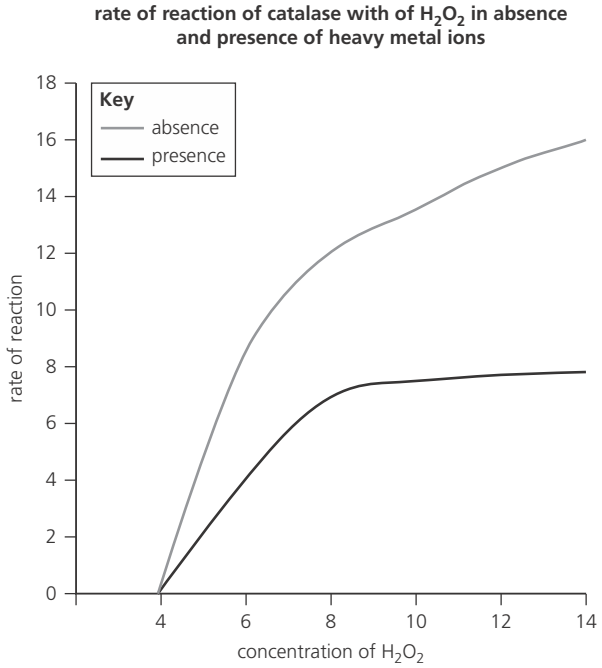
The differences between competitive and non-competitive inhibitors

4 ■ Isoleucine acts as a non-competitive inhibitor by binding to allosteric site of the enzyme threonine deaminase.

■ Threonine deaminase is an essential enzyme in the first stage of the metabolic pathway – its inhibition turns off isoleucine production. This regulates the production of isoleucine.

- Initially, when isoleucine concentration is still low, the metabolic pathway can proceed as noon-competitive inhibition is low.
- As isoleucine concentration increases, non-competitive inhibition takes place and the metabolic pathway is regulated.
- As isoleucine is used in the cell for the protein synthesis, its concentration falls and the allosteric sites of threonine deaminase are no-longer occupied, so the enzyme can once again act in the conversion of threonine to isoleucine.
- End-product inhibition is when the product of the last reaction in a metabolic pathway inhibits the enzyme that catalyses the first reaction of the pathway.
- In this example, the product of the last reaction of the metabolic pathway (isoleucine) binds to the allosteric site of the enzyme that catalyses the first reaction (threonine deaminase; when the product binds to the allosteric site it acts as non-competitive inhibitor and changes the shape of the active site; in this way, the product reduces the chances of the substrate binding to the enzyme; once the inhibitor is released from the allosteric site, the active site returns to its original shape and the substrate is able to bind again.

5 a



b A non-competitive inhibitor binds to a part of the enzyme other than the active site. As the inhibitor does not compete with a substrate molecule for the active site, an excess of substrate does not overcome the inhibition. From the graph we see that an excess of the substrate H_2O_2 has not overcome the inhibition, so copper ions are a non-competitive inhibitor of this enzyme. This is supported by the data in the graph where the rate of reaction levels off even with the increasing concentration of H_2O_2.

Quick check questions (p.230)

1 Glycolysis is the splitting of glucose into pyruvate; it is an oxidation reaction; oxidation occurs removing hydrogen; glycolysis occurs in cytoplasm; a hexose sugar (i.e. glucose) is phosphorylated using ATP; the hexose phosphate is then split into two triose phosphates; the hydrogen is used to reduce NAD to NADH; four ATP are produced resulting in a net gain of two ATP; two pyruvate molecules are produced at the end of glycolysis.

2 In the link reaction, pyruvate is converted to acetyl coenzyme A (acetyl CoA); CO_2 is given off; it connects glycolysis to the reactions of the Krebs cycle; pyruvate (from glycolysis) enters the mitochondrion matrix; enzymes remove one carbon dioxide and hydrogen from the pyruvate; hydrogen is accepted by NAD to form NADH; removal of hydrogen is oxidation; removal of carbon dioxide is decarboxylation; the link reaction is therefore oxidative decarboxylation; the product is an acetyl group which reacts with coenzyme A; acetyl CoA enters the Krebs cycle.

3 In the absence of oxygen, reduced NAD ($NADH_2$) accumulates and oxidized NAD reserves are used up; in the absence of NAD^+, pyruvate production by glycolysis slows and stops, so subsequent steps in respiration stop too.

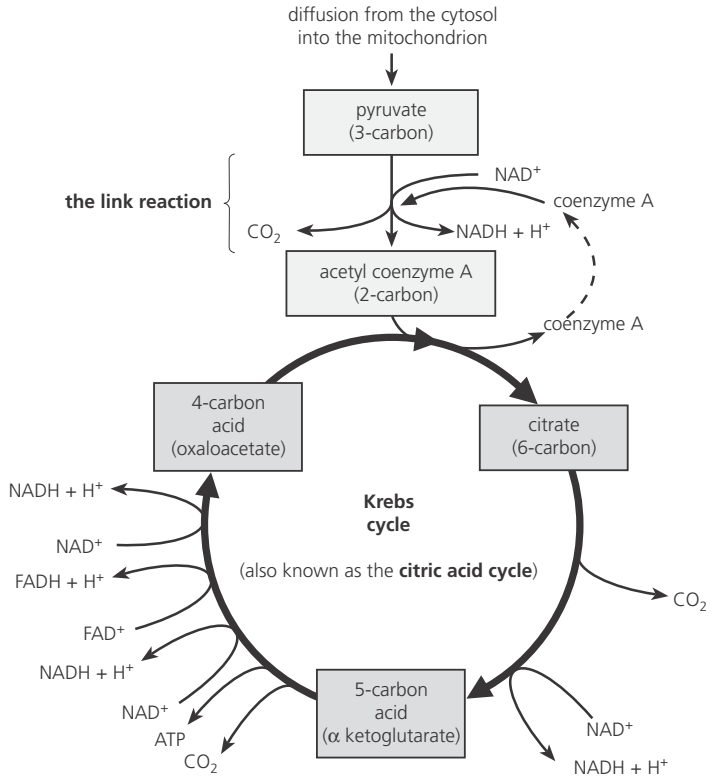
4 a The **substrate** is the molecule that is the starting point for a biochemical reaction; it forms a complex with a specific enzyme. An **intermediate** is a metabolite formed as a component of a metabolic pathway.

b **Glycolysis** is the breakdown of glucose in the cytoplasm, producing a small yield of ATP. The **Krebs cycle** happens inside the mitochondrion and it results in the reduction of electron carriers; it produces one molecule of ATP per molecule of acetyl entering the mitochondrion.

c **Oxidation** is the loss of electrons and **reduction** is the gain of electrons.

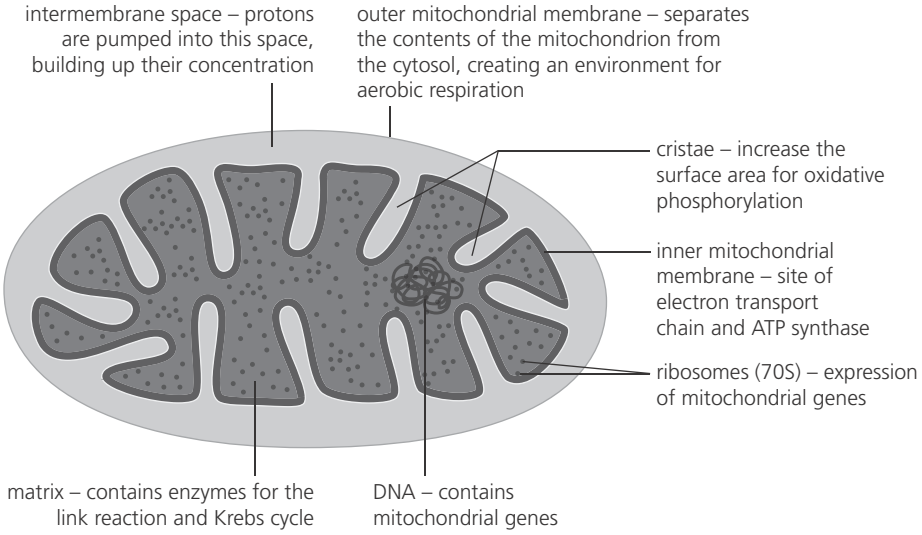
5 Chemiosmosis is a process by which the synthesis of ATP is coupled to electron transport via the movement of protons; the electron-carrier proteins are arranged in the inner mitochondrial wall in a highly ordered way; these carrier proteins oxidize the reduced coenzymes and energy from the oxidation process is used to pump hydrogen ions (protons) from the matrix of the mitochondrion into the space between inner and outer mitochondrial membranes; because the inner membrane is largely impermeable to ions, a significant gradient in hydrogen ion concentration builds up across the inner membrane, generating a potential difference across the membrane (representing a store of potential energy); the protons flow back into the matrix, via the channels in ATP synthase enzyme, also found in the inner mitochondrial membrane; as the protons flow down their electrochemical concentration gradient, through the ATP synthase enzyme, the energy is transferred as ATP synthesis occurs.

6 **Decarboxylation** reactions occur when carbon dioxide is removed from a molecule; **Oxidation** reactions occur when hydrogen (and therefore an electron) is removed from a molecule.



Link reaction and Krebs cycle: a summary

7

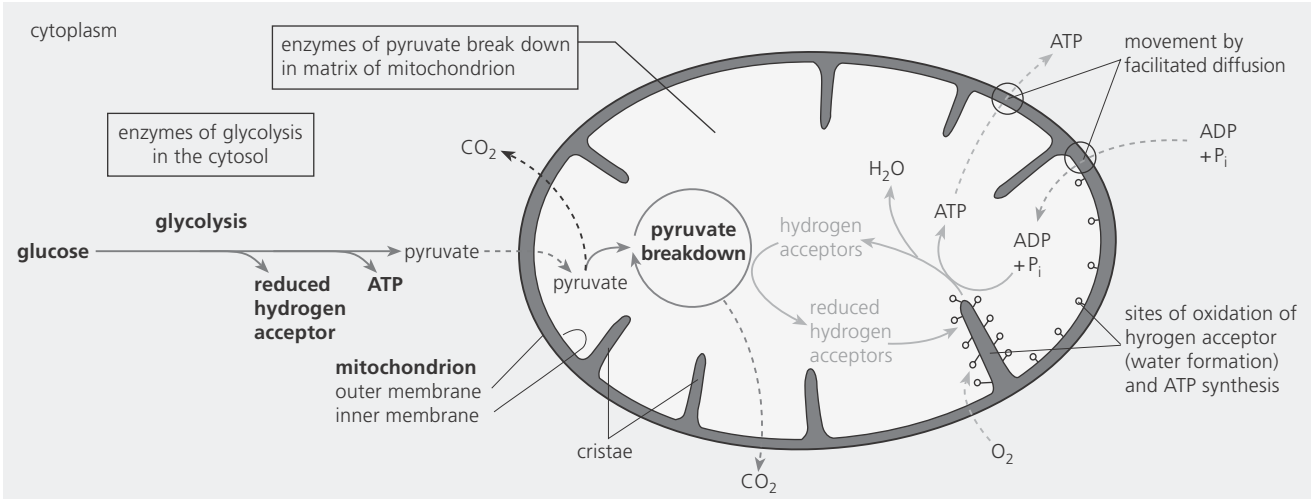


Annotated diagram of a mitochondrion

Structure	Function / role
external double membrane	• permeable to pyruvate, CO_2, O_2 and NAD / NADH + H^+
matrix	• site of enzymes of link reaction and Krebs cycle
inner membrane	• location of electron-transport chain and ATP synthetase enzymes • greatly increased surface area by folding to form cristae, increasing ATP synthesis • impermeable to hydrogen ions (protons), allowing a potential difference between the inter-membrane space and the matrix
inter-membrane space	• small space in which hydrogen ions (protons) can accumulate, generating a large concentration difference with the matrix. This allows chemiosmosis to take place

Mitochondrial structure in relation to function

8



The sites of aerobic and anaerobic respiration in cells. Pyruvate is formed from glucose in the cytoplasm (anaerobic respiration); enzymes concerned with the link reaction, Krebs cycle, and electron transport are all located in the mitochondria (aerobic respiration)

Quick check questions (p.236)

1 a The **light-dependent** reaction happens in the presence of light, whereas the **light-independent** reaction does not require light to occur; it uses the products from the light-dependent one. The light-dependent reactions occur in the thylakoids in the presence of light and the light-independent reactions in the stoma in the absence of light.

b **Photolysis** uses light to break down water, producing hydrogen ions and oxygen, and **photophosphorylation** uses light energy to phosphorylate ADP to form ATP.

2

Components	Photosystem I	Photosystem II
pigment molecules (proteins)	receive the photon of light and pass it to other pigment molecules, until it reaches the reaction centre – these are called pigmented antennae	
reaction centre	an enzyme that uses light of a wavelength 700 nm to reduce molecules	an enzyme that uses light of a wavelength 680 nm to reduce molecules
accessory pigments	constitute part of the pigmented antennae and help in moving photons of light	
electron carrier molecules	ferredoxin and ferredoxin-NADP reductase transfer electrons to reduce NADP into NADPH	plastoquinone, cytochrome and plastocyanin proteins help the excited electron to move hydrogen ions from the stroma into the thylakoid space
oxygen-evolving complex	n / a	with light, performs the photolysis of water to replace the electron excited by the photon of light. Produces hydrogen ions and oxygen
ATP synthase	located in the thylakoid membrane and forms ATP from ADP and P_i	

The components and role of the two different photosystems of the light-dependent reactions of photosynthesis

3 Light energy raises the energy level of electrons in the chlorophyll (photoactivation); electrons displaced from the reaction centre of photosystem II in an excited state are first passed to the reaction centre of photosystem I. Here they are again raised to an excited state and this time they are passed to oxidized NADP ($NADP^+$) to form reduced NADP (NADPH); the vacancies in the reaction centres of photosystem II are filled by from water molecules; the positively charged vacancies in photosystem II cause the splitting of water (photolysis): this event triggers the release of hydrogen ions and oxygen atoms, as well as ground-state electrons.

4 They are formed there as they will be used during the Calvin cycle. This uses enzymes that are located in the stroma of the chloroplasts.

5 Energy from photoactivated electrons from photosystem II is used to pump electrons across the thylakoid membrane, from the stroma to the thylakoid space; hydrogen ions accumulate in the thylakoid space; this generates a high H^+ gradient; protons move through ATP synthase in the membrane back to the stroma, through chemiosmosis; chemiosmosis is the diffusion of ions across a selectively permeable membrane through ATP synthase; the flow of protons from the thylakoid space to the stroma generates ATP.

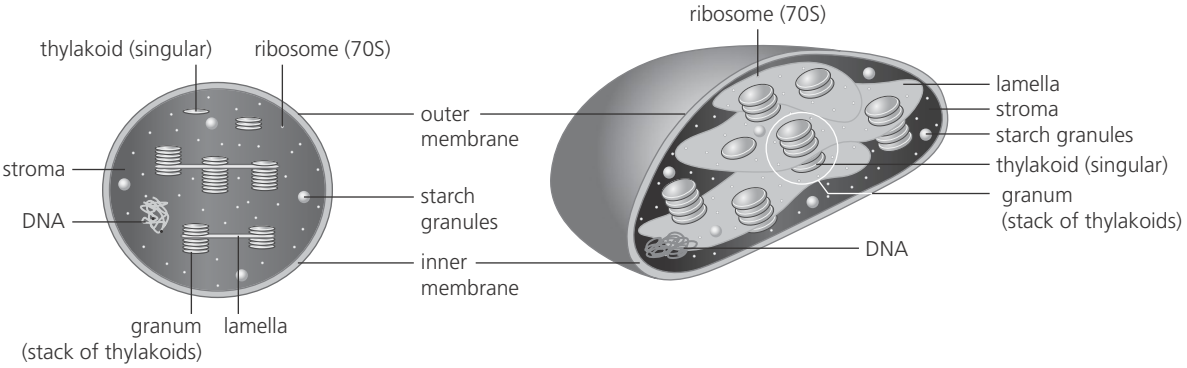
6

Photosynthesis in chloroplasts		Cell respiration in mitochondria
thylakoid space in grana	**site of proton (H^+) accumulation**	space between inner and outer membranes of mitochondria
from water molecules after photolysis has occurred	**origin of protons**	from reduced hydrogen acceptors (e.g. NADH + H^+)
sunlight	**energy source**	glucose and respiratory intermediates
diffuses to stroma and used to sustain reduction of carbon dioxide in light-independent reactions	**fate of ATP formed**	diffuses into matrix of mitochondria and to cytosol and mainly involved in anabolic reactions of metabolism

Chemiosmosis in mitochondria and chloroplasts compared

7 *Chlorella* cells in suspension function biochemically like mesophyll cells but can be cultured in suspension, sampled without interference of the biochemistry of other cells, and supplied directly and quickly with light, intermediates and inhibitors (if required) in such a way that all the cells are treated identically. Gaseous exchange and diffusion occur without the complexity (and delays) of the intact leaf with its air spaces and stomata. In the lollipop chamber the environment of the cells (light intensity, etc.) was more nearly identical for the whole chamber than it would be in a spherical flask, for example.

8



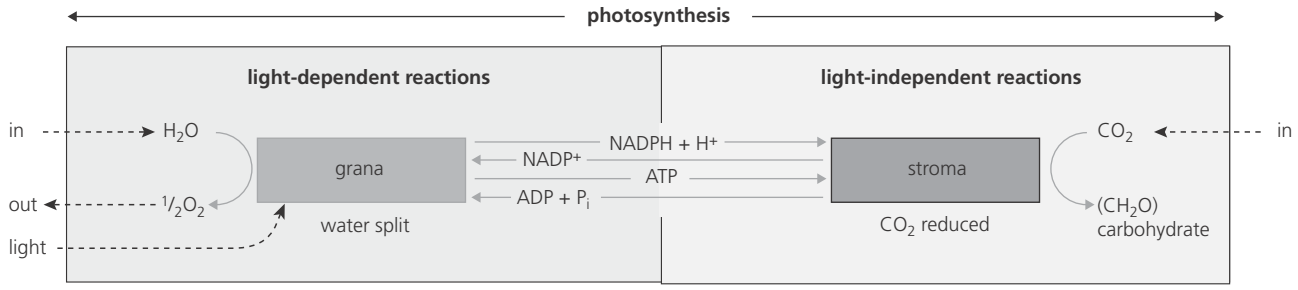
Outer membrane – part of chloroplast envelope; regulates the entry and exit of molecules
Inner membrane – part of chloroplast envelope; regulates the entry and exit of molecules
Thylakoids – extensive system of internal membranes; contain pigment molecules that absorb light. The large area ensures maximum light-absorbing capacity. Thylakoids contain small fluid-filled spaces which concentrate protons pumped there
Granum – a stack of thylakoids
Stroma – contain enzymes for the Calvin cycle together with their substrates
Starch granules – storage of glucose; ensures glucose has no osmotic effect
Lamella – connects grana to each other; maintains efficient distances between grana, maximizing overall efficiency of the chloroplast
Ribosome (70S) – expression of chloroplast genes
DNA – contains chloroplast genes

Adaptations of chloroplasts to their function

Structure of chloroplast	Function / role
double membrane bounding the chloroplast	contains the grana and stroma, and is permeable to CO_2, O_2, ATP, sugars and other products of photosynthesis
photosystems with chlorophyll pigments arranged on thylakoid membranes of grana	provide large surface area for maximum light absorption
thylakoid spaces within grana	restricted regions for accumulation of protons and establishment of proton gradient
fluid stroma with loosely arranged thylakoid membranes	site of all the enzymes of fixation, reduction and regeneration of acceptor steps of light-independent reactions, and many enzymes of the product synthesis steps

Chloroplast: structure and function

9 Photosynthesis is a set of reactions that takes place in illuminated chloroplasts. Photosynthesis is the set of reactions by which light energy brings about the production of sugars, using the raw materials water and carbon dioxide. It takes place in two interconnected stages:



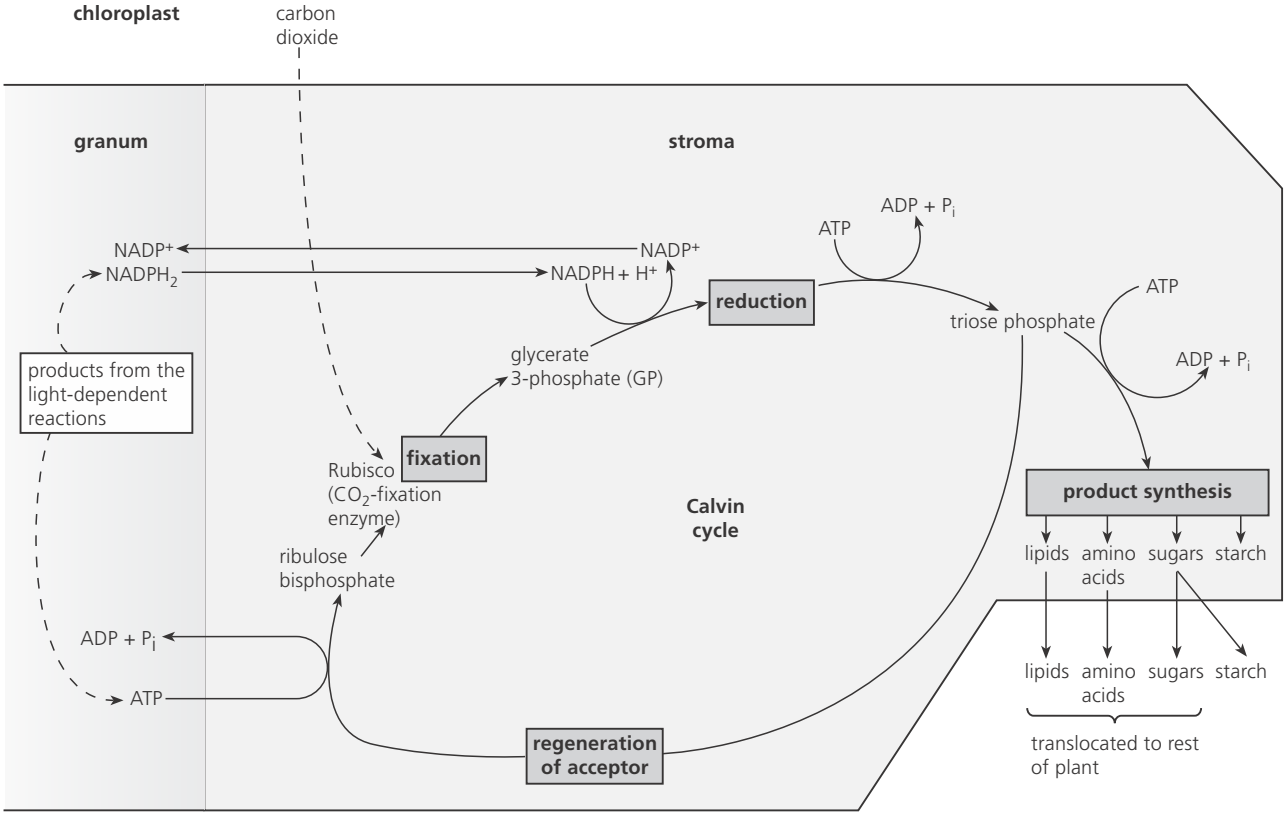
The two sets of reactions of photosynthesis

The light-dependent reactions use light energy to split water (known as photolysis):

- Hydrogen is then removed and retained by $NADP^+$.
- At the same time, ATP is generated from ADP and phosphate, also using energy from light. This is known as **photophosphorylation**.
- Oxygen is given off as a waste product of the light-dependent reactions.
- The reactions occur in the intermembrane space of the thylakoids (i.e. the grana) of the chloroplasts.

The light-independent reactions build up sugars using carbon dioxide:

- The products of the light-dependent reactions (ATP and reduced hydrogen acceptor $NADPH + H^+$) are used in sugar production.
- The reactions occur in the stroma of the chloroplast.
- They require a continuous supply of the products of the light-dependent reactions, but does not directly involve light energy (hence the name).



Summary of the light-independent reactions

Topic 9 Plant biology

Quick check questions (p.244)

1 The features of root hairs that facilitate absorption from the soil are:

- they greatly increase the surface area of the root, increasing the rate of osmosis
- they grow in close contact with the film of soil water that occurs around mineral particles where the essential resources (water and soluble ions) occur
- their walls are of cellulose and are in intimate contact with cells of the cortex in a region that is permeable to water.

2 The **symplast** pathway of water movement is through the cytoplasm (by diffusion), including through the cytoplasmic connections between cells;

The **apoplast** pathway of water movement is the mass flow through the space in the wall cellulose (about 50% of the wall volume) and through the spaces between cells.

3 The Casparian strip is made of a dense, waterproof material that restricts the passive movement of water through the apoplast pathway, forcing it to go into the symplast pathway; this enables the plants to control the flow of water through the root and into the xylem.

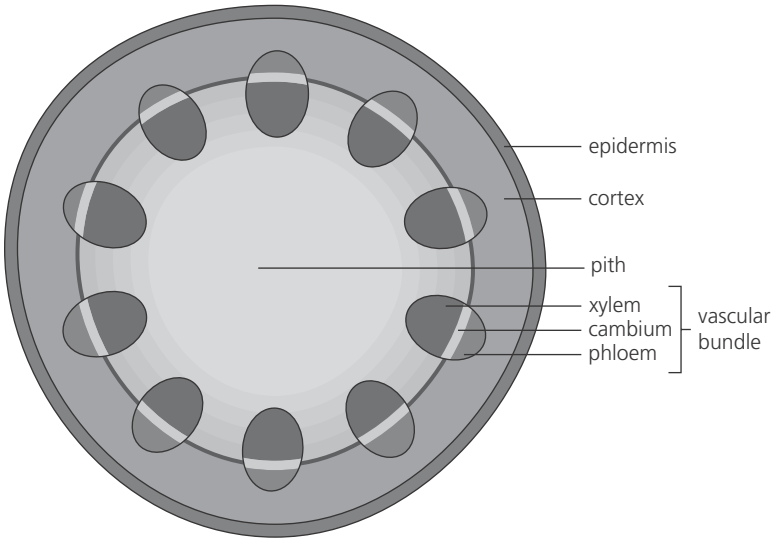
4 Plant growth is dependent on a supply of chemically combined nitrogen (for amino acid and protein synthesis) of which nitrates are typically the most readily available. However, nitrates are also taken up by microorganisms and may be released in the soil at times other than when plant demand is at its peak. They are also very soluble and are easily leached away into ground water in heavy rain. By taking up nitrate whenever it becomes available (and storing it in cells), plants can maintain growth at peak times. Active transport of nitrate from lower concentration in the soil to higher concentration in the root is made possible by active transport.

5 In waterlogged soil there are no air spaces and the dissolved oxygen is reduced. Roots need oxygen to respire and perform other metabolic activities; respiration is needed to provide energy for active transport, which enables mineral ions to be brought into the root against their concentration gradient; without sufficient active transport, not enough minerals can be brought into the soil to maintain metabolic processes.

6 The girth of the tree trunk shrinks during the daytime when transpiration occurs at a greater rate and increases at night when transpiration is reduced; in the day, rapid transpiration causes the column of water to narrow: because the water binds to the wall of the xylem (adhesion) the walls of the xylem are pulled inwards, narrowing their diameter; cohesive forces between water molecules enable the column of water to be maintained; water has high tensile strength and so does not break; the reduction in the overall girth of the tree demonstrates the cohesive and adhesive properties of water molecules and the tension within the column of water.

7 Turgor in the guard cells is responsible for the opening of the stomatal pore. In very dry conditions there is insufficient supplies of water to the cells for the pores to reach maximum opening or to sustain open pores for long in the face of continuing water loss by transpiration; the smaller stomatal aperture and shorter duration of opening in dry conditions will lead to reduced transpiration overall.

8



9 If independent variable is **humidity**:

- Hypothesis: Air inside leaf is saturated (relative humidity = 100%): the lower the relative humidity outside the leaf the faster the rate of transpiration as the concentration gradient of water is steeper; high humidity means a higher water potential in the air, so a lower water potential gradient between the leaf and the air, and so less evaporation.
- Suggested experiment: Put a large plastic bag over the plant to create a humid environment.
- Controlled variables: e.g. temperature, light.
- If independent variable is **temperature**:

- Hypothesis: Higher temperature increases the rate of evaporation of water from the spongy cells and reduces air humidity, so transpiration increases.
- Suggested experiment: Use a fan with variable temperature (e.g. a hairdryer); either have hot wind or cold wind (note that the wind speed must be constant, with only the temperature varying).
- Controlled variables: e.g. humidity, light.
- Procedure for either experiment:
- *When using photometer, take care to measure from the right side of the bubble (not the left)*; record the distance moved by the bubble every minute for 10 minutes; repeat each test five times and take an average of your results (to enable reliability of results to be discussed, and to identify anomalies).

Quick check questions (p.249)

1 Rigid cell walls of the sieve tube allow the building of the high pressures needed to generate hydrostatic pressure; ends of sieve element cells are connected with other sieve elements; together they form a sieve tube; sieve plates, found between two sieve elements, contain large pores in the cell walls allowing the transport of substances between sieve element cells; although sieve plates in part obstruct flow of sugar, they allow hydrostatic pressure to build up in the sieve tube element, pushing sucrose and other organic compounds through the sieve tube; sieve plates increase the rate of transport of substances between sieve element cells; sieve tubes have reduced cytoplasm containing low densities of organelles, e.g. mitochondria and SER, distributed along the sides of the cell, allowing space for sugars to move; the relatively empty sieve tubes provide a longitudinal network which conducts phloem sap.

2 **a** Here sugar (delivered by translocation) is converted to starch, lowering the solute potential.

b Here, if photosynthesis in the light produces sugar faster than it can be translocated to sink areas in the plant, the solute potential will be high.

3 Transpiration is the loss of water vapour through the stomata in the leaves of plants, whereas translocation is the movement of solutes, such as organic compounds, from source organs such as leaves to sink organs such as roots and fruits.

4 The companion cells provide all the metabolic functions for the sieve tubes, as well as providing for their own needs, so the ATP demand is very high. Energy is also needed to actively load the sieve tube with the sap containing solutes coming from the source cells.

5 **a** It is generated during the Calvin cycle in photosynthesis in leaves supplied with radioactive carbon dioxide in the light.

b Catkins (flowers) produced during spring and also the stem.

c The distance is determined by the exact location that an individual aphid inserts its proboscis into the phloem.

d Mean = 560 mm

e

Experiment	Rate / mm hr^{-1}
1	242.9
2	260.0
3	300.0
4	308.7
5	300.0

f 282.3 mm hr^{-1}

g slowest is experiment 1; fastest is experiment 4

h As these experiments involved different stems (and separate experiments), it is possible (i) that temperature differences accounted for different rates of translocation, and (ii) the differences in the conditions in the particular source and sink tissues that drive mass flow were responsible.

6 a **Observation 1**: at 50°C, translocation of sugar from the leaf blade stopped – this is above the thermal death point of cytoplasm; **conclusion**: living cells are essential for translocation at 3°C.

Observation 2: compared with 20°C translocation of sugar from leaf blade was reduced by almost 10% of leaf dry weight over a given time; **conclusion**: rate of metabolic activity of phloem cells affects rate of translocation.

b Sample from near the leaves will contain a higher concentration of sucrose than the one taken from the base of the stem. Sugars made by photosynthesis in the leaves will be loaded in to the sieve tubes high up in the tree. The contents are moved down to the sink organs, where there will be a lower concentration of these sugars.

Quick check questions (p.256)

1 Once a plant has grown past the early embryo stage, all later growth of the plant occurs at restricted points in the plant, called meristems; meristem tissue in plants contain cells that retain the ability to divide by mitosis; meristems occur either at terminal growing points of stems and or they are found laterally (to the sides of the plant); mitosis and cell division in the shoot apex provide cells needed for extension of the stem and development of leaves.

Apical meristems: apical meristems occur at the tips of the stem and root and are responsible for their primary growth; cell division and the subsequent growth of the cells produced here lead to formation of the tissues of stem (and root); new cells formed by division rapidly increase in size; following the cell enlargement phase, cell differentiation takes place – the new cells become specialized, forming epidermal cells and cells of the vascular bundle (xylem and phloem); between phloem and xylem of the bundles, a few meristematic cells remain after primary growth, and these form a meristematic tissue called cambium.

Lateral meristems: lateral meristems form from the cambium cells in the centre of vascular bundles, between the (outer) phloem tissue and the (inner) xylem tissue; when the lateral meristem forms and grows, it causes the secondary growth of the plant; secondary growth involves additions of vascular tissue (secondary phloem and secondary xylem), and results in an increase in the girth (width) of the stem; the first stage in secondary growth occurs when the cambium in the vascular bundles grows into a complete cylinder around the stem; growth of the lateral meristem increases the circumference of the stem and also increases the strength of the stem.

Growth due to apical meristem		Growth due to lateral meristem
occurs at tip of stems and roots	**position of meristem**	occurs laterally, between primary phloem and primary xylem
product of embryonic cells	**origin**	cambium – meristematic cells left over from primary growth
produces initial tissues of actively growing plant from the outset	**timing of activity**	functions in older stems (and roots), and in woody plants from the outset
forms epidermis, primary phloem and xylem	**cell products**	forms mainly secondary phloem and xylem
produces growth in length and height of plant	**outcome for stem**	produces growth in girth of stem, plus strengthening of stem

Comparing growth due to apical and lateral meristems

2 Light is required for the manufacture of sugar by photosynthesis; also light inhibits extension growth in stems, triggers a positive phototrophic response in stems, promotes expansion of leaf blades, is required for the synthesis of chlorophyll, triggers the switch from vegetative growth to flowering in many plants (depending upon the length of the light and dark periods within 24 hour cycles) and is required to promote germination in some seeds. Stomatal pores widen in response to increasing light intensity.

3

Stimulus	Tropism	Example
light	phototropism	young stems are positively phototropic
gravity	geotropism	young stems are negatively geotropic; main roots are positively geotropic

Comparing phototropic and geotropic responses in plants.

Phototropism is the response of a plant to the stimulus of light.

Geotropism is the response of a plant to the stimulus of gravity.

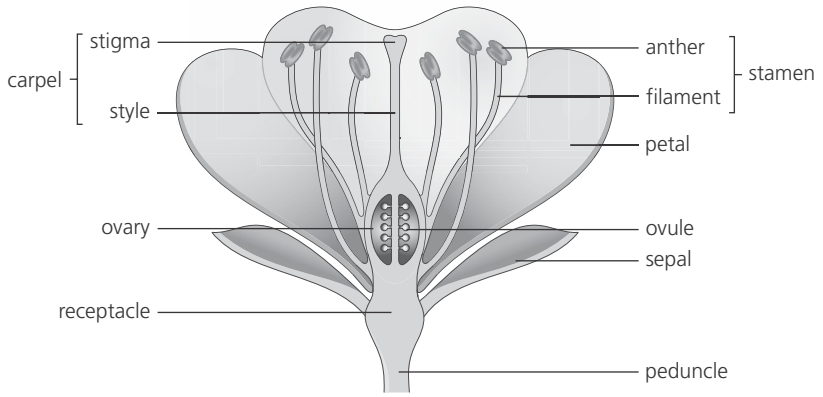
4 An environmental influence, such as unilateral light (light from one direction), is detected by proteins called phototropins, which respond by binding to receptors in the cell; these phototropin receptors control the transcription of specific genes; these genes code for glycoproteins (known as PIN3 proteins) in the plasma membranes of cells that facilitate the transport of auxin; PIN3 proteins are efflux pumps of auxin; PIN3 proteins are involved in: the lateral transport of auxin in unilaterally illuminated stems, and vertical transport of auxin roots exposed to a unilateral gravitational stimulus.

Auxin transport entry into a cell is passive (by diffusion) and its efflux (movement out from the cell) is active (ATP-driven) via PIN proteins; auxin efflux pumps set up concentration gradients in plant tissues; concentration gradients of auxin are necessary to control the direction of plant growth, which requires that auxin is unevenly transported among plant tissues; cells contain auxin receptors; when auxin binds to receptors, hydrogen ions are pumped into cell walls; hydrogen ions loosen connections between cellulose fibres, allowing cell expansion; cell expansion causes the cells to lengthen on one side of the plant relative to the other, causing e.g. the shoot to bend towards the light stimulus.

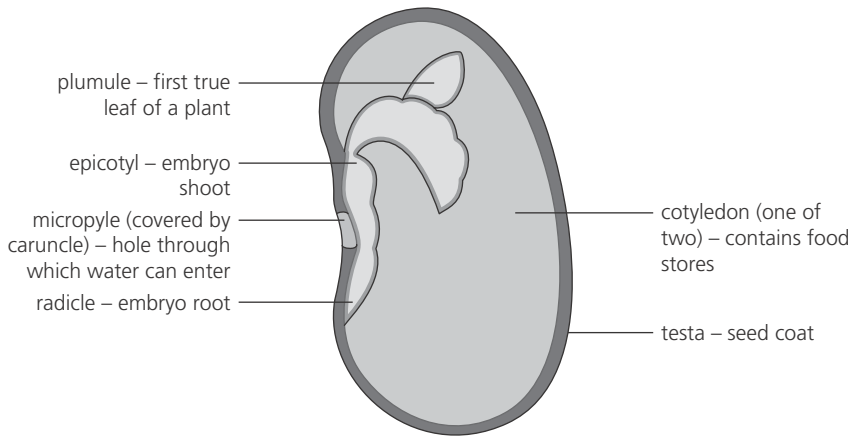
5 Micropropagation is used to produce large numbers of identical plants from stock plants; tissue samples are removed from parent plants; tissues samples are sterilized and cut into pieces called explants; the least differentiated material, e.g. shoot apex, are the best for micropropagation; tissue samples are put on agar growth medium containing nutrients and hormones (auxin); the media is sterile to prevent the growth of fungi and pathogen; plant viruses are transported within the plant through the vascular tissue; the meristem does not contain vascular tissue; propagating plants from sterilized vascular tissue produces virus-free plants; tissue samples grow into small plants (plantlets); once roots and shoots are developed, the cloned plant can be transferred to soil; orchids show a large range of diversity in size, shape, and colour; it is very difficult to get orchids to breed sexually and to maintain desired traits; micropropagation allows orchids to be reproduced in large numbers while maintaining desired traits; this process has been so successful that orchids are now common flowers in markets and shops.

Quick check questions (p.262)

1



2



3 a **Pollination** is the transfer of pollen from anther to stigma.

b **Fertilization** is the fusion of male and female gametes to form a zygote.

c **Germination** is the resumption of growth by an embryonic plant in seed or fruit, at the expense of stored food.

4 Pollination involves the transfer of one (male) gamete whereas fertilization involves the joining / fusing of two gametes; in plants, fertilization refers to the fusion of the gamete cells inside the ovary of the flower.

5 a includes plums, peaches and avocados

b includes pea pods and runner beans

c includes gooseberries, cucumbers and tomatoes

6 When choosing a plant species, it is best to avoid seeds that have long dormancy periods; factors affecting germination (**independent variable**) include: soil temperature, age of the seeds, water availability, and level of light (e.g. some seeds need to be buried and therefore require low light levels). Experiments could also test the requirement for oxygen (needed for respiration).

Factors to consider: **dependent variable** – assessing whether germination has occurred (e.g. first sight of plumule growing from seed), controlled variables – other factors which could affect germination and which need to be kept the same; the experiment needs to be replicated to establish whether results are reliable (i.e. high variation in results indicate less reliability) and whether any results are anomalous.

7 **Short-day plants** – these are plants which flower only if the period of darkness is longer than a certain critical length; phytochrome in $\mathbf{P_{FR}}$ form inhibits flowering in short-day plants; the very long nights required by short-day plants allow the concentration of $\mathbf{P_{FR}}$ to fall to a low level (and $\mathbf{P_R}$ to increase), removing the inhibition.

Long-day plants – these are plants which flower only if the period of uninterrupted darkness is less than a certain critical length each day; phytochrome in $\mathbf{P_{FR}}$ form promotes flowering in long-day plants; the long period of daylight causes the accumulation of $\mathbf{P_{FR}}$, because $\mathbf{P_R}$ is converted to $\mathbf{P_{FR}}$.

In long-day plants: a gene (‘**flowering locus**’ – FT) is activated in leaves of photoperiodically induced plants, high in $\mathbf{P_{FR}}$; **FT mRNA** travels from induced leaves to stem apex, via the plasmodesmata and the symplast pathway; in the cells of the apex, the FT mRNA is translated into **FT protein**; FT protein, bonded to a transcription factor, activates several flowering genes and switches off the genes for vegetative growth.

8 For many varieties of short-day plant, e.g. chrysanthemum, night length needs to be more than 11 hours (i.e. day length needs to be less than 13 hours) for flowers to develop and open; in northern latitudes, during the summer months (April to September) chrysanthemum will not naturally flower because the night length is too short; flowering can be stimulated by covering the plants with opaque black cloth for more than 11 hours per day (i.e. place the cover at 4 p.m. and then remove it again at 7 a.m. to achieve 13 hours of darkness for the plant); plants are covered daily until flower buds begin to show colour.

Exam practice (p.262)

1 a i gid1-1 [1]

ii between 10–8 and 10–7 mol dm^{-3} (units required) [1]

iii (breakdown) of starch to maltose [1]

b 25% / 1 in 4 / 1:3 seeds produced would be homozygous recessive;

no response to / inhibits gibberellin in homozygous recessives results in less germination;

less growth / dwarf plants produced; (*must be in context*)

would produce plants with infertile flowers that cannot produce rice grains;

would lower rice production / less yield because infertile plants cannot produce seeds (that humans can eat) [3 max]

d i *Sub1C* [1]

ii *Sub1A* is expressed strongly / the most / *Sub1A* produces the most RNA;

Sub1B (always) has the lowest expression / produces least mRNA;

Sub1A expressed / produces mRNA for the longest time / days 1 to 10;

Sub1C expressed / produces mRNA for the shortest time / days 3 to 7 [2 max]

e Sub1A;

is only expressed in *indica* / *Sub1B* and *SubC* are expressed in both rice varieties;

indica is the variety showing submersion tolerance / vice versa for *japonica* [2 max]

f i it increases the length of time before flowering [1]

ii long-day light exposure increases time before flowering only if

($OsGI^+$) gene is not overexpressed / in WT and − / −;

long-day light exposure decreases time before flowering for + / − and / or + / +;

length of day does not make much difference / makes least difference for + / +;

overexpression for + / − reduces time before flowering;

− / − acts as a control / has nearly the same length of time before flowering as WT [2 max]

Accept numerical answers if they are making a clear comparison.

iii is a short-day plant because WT has shortest time / shorter time before

flowering in shorter days than longer days / as it takes less time to flower under short day conditions [1]

g codominant alleles show intermediate phenotype when both present;

could be codominant because homozygous + / + shows longer time before flowering than heterozygous;

− / − or homozygous not overexpressed has a slightly longer time before flowering than WT so factors other than codominance could be influencing flowering;

dominance shown with short-day light exposure while codominance in long-day light exposure;

because presence causes overwhelming difference compared with absence in short-day light exposure;

$OsGI^+$ could be dominant because its presence always causes longer time before flowering [2 max]

h the mutant *gid1-1* would not be useful because it produces sterile plants;

genetically modified rice / rice with *Sub1A* is more tolerant to submersion / can withstand seasonal flooding / torrential rain;

$OsGI^+$ varieties adapted to different latitudes / day length could be produced

(*to overcome food shortages)* [2 max]

Topic 10 Genetics and evolution

Quick check questions (p.268)

1

	Mitosis	Meiosis
number of cell divisions	1	2
number of daughter cells	2	4
synapsis of homologous chromosomes	does not occur	occurs, with crossing over occurs during prophase I
genetic composition of daughter cells	genetically identical to parent cell and each other	genetically different from parent cell and each other
location of cells undergoing cell division	body (somatic) cells	germ cells (cells in reproductive organs e.g. ovaries and testes)
number of chromosomes in daughter cells produced by diploid parent cell	diploid (2*n*)	haploid (*n*)
role in body	cells for growth and repair; embryonic development	produces gametes; ensures genetic variation

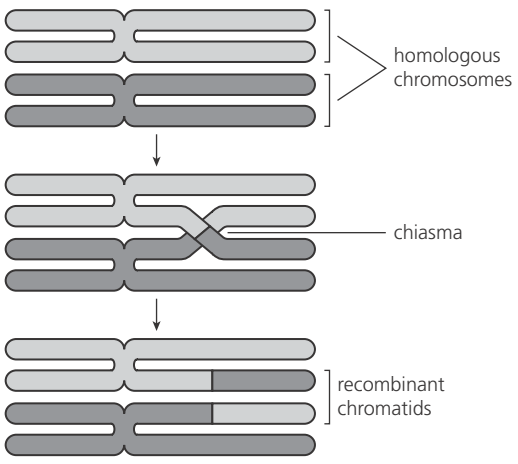
Comparing mitosis and meiosis

2

	Meiosis I	Meiosis II
nature of division	homologous chromosomes separate	sister chromatids separate
role	forms two haploid cells from one diploid cell	splits sister chromatids in haploid cells, creating four daughter cells
homologous chromosomes	homologous chromosomes go through synapsis to form a bivalent / tetrad	no homologous chromosomes (one set of chromosomes present in each cell)
sister chromatids	remain together in a double-stranded chromosome	pulled apart at the centromere and moved into separate cells
crossing over	occurs during prophase I	does not occur

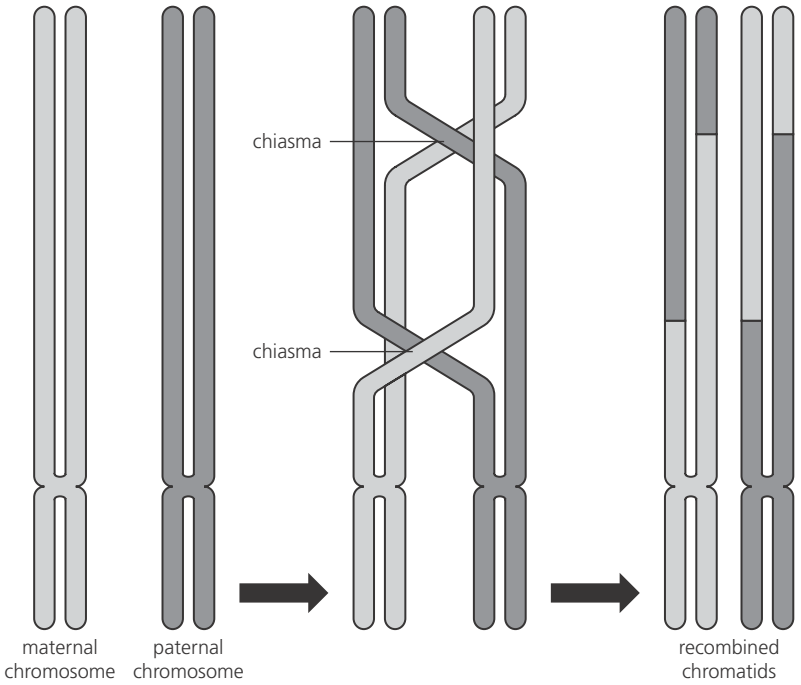
Comparing meiosis I and meiosis II

3



A drawing of one chiasma between homologous chromosomes

A drawing of chiasmata (i.e. more than one crossing over) would be drawn as follows:



Chiasmata between homologous chromosomes

4 **Independent assortment**: The way in which the bivalents line up at the equator of the spindle in meiosis I is random; which chromosome of a given pair goes to which pole is independent of the behaviour of the chromosomes in other pairs; the more bivalents there are in the nucleus, the more variation is possible; in humans, there are 23 pairs of chromosomes, so the number of possible combinations of chromosomes that can be formed as a result of independent assortment is 2^{23}, i.e. over 8 million.

Crossing over: results in new combinations of genes on the chromosomes of the haploid cells produced by meiosis; the process generates the possibility of an almost unimaginable number of new combinations of alleles; e.g. if there are 30 000 individual genes on the human chromosome complement, all with at least two alternative alleles, and that crossing over was equally likely between any of these genes, there would be 2^{30000} different combinations of alleles; recombination is the reassortment of alleles into different combinations from those of the parents; recombination occurs for genes located on separate chromosomes (unlinked genes) by independent assortment in meiosis, and for genes on the same chromosomes (linked genes) by crossing over during meiosis.

Quick check questions (p.275)

1 a W = allele for normal wing, w = allele for vestigial wing

N = allele for normal body, n = allele for ebony body

P generation must be: wwnn × WWNN, because all F_1 are normal wings and normal body

F_1:

	Normal wing and normal body (WWNN)
Vestigial wing and ebony body (wwnn)	All heterozygous, normal wings and normal body (WwNn)

F2: Possible gametes for both parents: **WN, Wn, wN or wn**

Genotypes:

	WN	**Wn**	**wN**	**wn**
WN	WWNN	WWNn	WwNN	WwNn
Wn	WWNn	WWnn	WwNn	Wwnn
wN	WwNN	WwNn	wwNN	wwNn
wn	WwNn	Wwnn	wwNn	wwnn

Genotype ratios: 1 WWNN : 2 WwNN : 4 WwNn : 2 WWNn : 2 Wwnn : 1 WWnn : 2 wwNn : 1 wwNN : 1 wwnn

	WN	**Wn**	**wN**	**wn**
WN	normal wings and normal body	normal wings and normal body	normal wings and normal body	normal wings and normal body
Wn	normal wings and normal body	normal wings and ebony body	normal wings and normal body	normal wings and ebony body
wN	normal wings and normal body	normal wings and normal body	vestigial wings and normal body	vestigial wings and normal body
wn	normal wings and normal body	normal wings and ebony body	vestigial wings and normal body	vestigial wings and ebony body

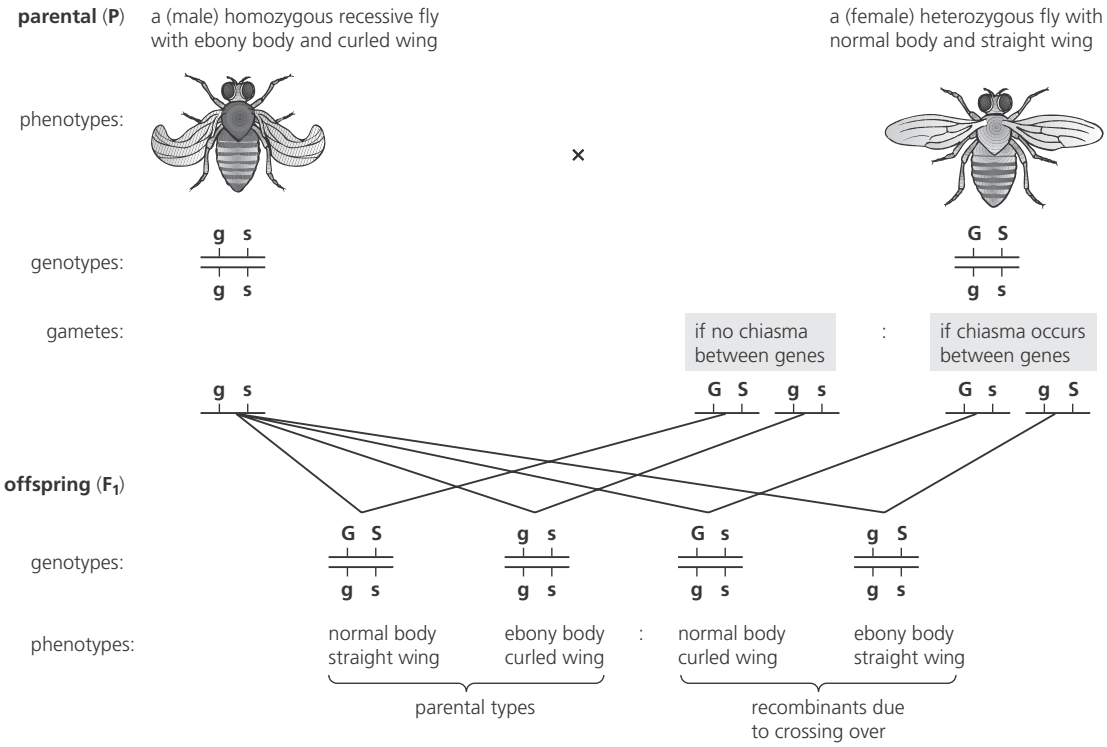
Phenotype ratios: 9 normal wings and normal body: 3 normal wings and ebony body: 3 vestigial wings and normal body: 1 vestigial wings and ebony body

b Natural variation means that predicted outcomes may be slightly different from actual observed outcomes; a prediction of the likely outcome of a breeding experiment represents the probable results, provided that: fertilization is random; there are equal opportunities for survival among the offspring; large numbers of offspring are produced; what is actually observed in a breeding experiment may not necessarily agree with the prediction, for example, there is a chance in this particular cross that: more pollen grains of one genetic constitution may fuse with egg cells than another; more developing seeds of one type are predated and destroyed by insect larvae of species attacking the plant (so fewer zygotes of one type complete development); the cross produces too few progeny in total.

2 a

Offspring	**Phenotypes**	**Genotypes**
parental types	normal body straight wing	**G S** / **g s**
	ebony body curled wing	**g s** / **g s**
recombinants	normal body curled wing	**G s** / **g s**
	ebony body straight wing	**g S** / **g s**

b **test cross**



c If no crossing over occurred we would expect parental types only, in the ratio 1:1.

d If these genes were on separate chromosomes we would expect these offspring in the ratio 1:1:1:1.

3 expected results are equal to ¼ = 50 pea plants

Calculating χ^2

	Predicted	O	E	O –E	$(O - E)^2$	$(O - E)^2 / E$
tall, axial	1	55	50	5	25	0.5
tall, terminal	1	51	50	1	1	0.02
dwarf, axial	1	49	50	1	1	0.02
dwarf, terminal	1	53	50	3	9	0.18
Total		208	$\Sigma(\chi)^2$			0.72

Degrees of freedom = 4 − 1 = 3

Critical value of χ^2 = 7.81

The difference observed is due to chance (i.e. there is no significant difference between observed and expected results).

4 *Drosophila melanogaster* (the fruit fly) was used by Thomas Morgan as an experimental organism to investigate Mendelian genetics; crosses between *Drosophila* resulted in phenotype ratios that did not match predicted results obtained using Mendelian ratios; Morgan's experiments (1909–1914) with fruit flies produced results that could not be explained by Mendel's work on heredity as it stood; anomalous data were repeated and found to be predictable.

Morgan's key experiment involved breeding a white-eyed male mutant with red-eyed female flies; the 1st generation offspring all had red eyes (consistent with Mendelian theory concerning dominant and recessive traits); the 2nd generation contained a small number (ca. 25% of flies) with white eyes (again consistent with Mendelian theory); however, all the white-eyed flies were male in the second generation – this is inconsistent with Mendelian theory and suggested that the two traits (sex and eye colour) are linked.

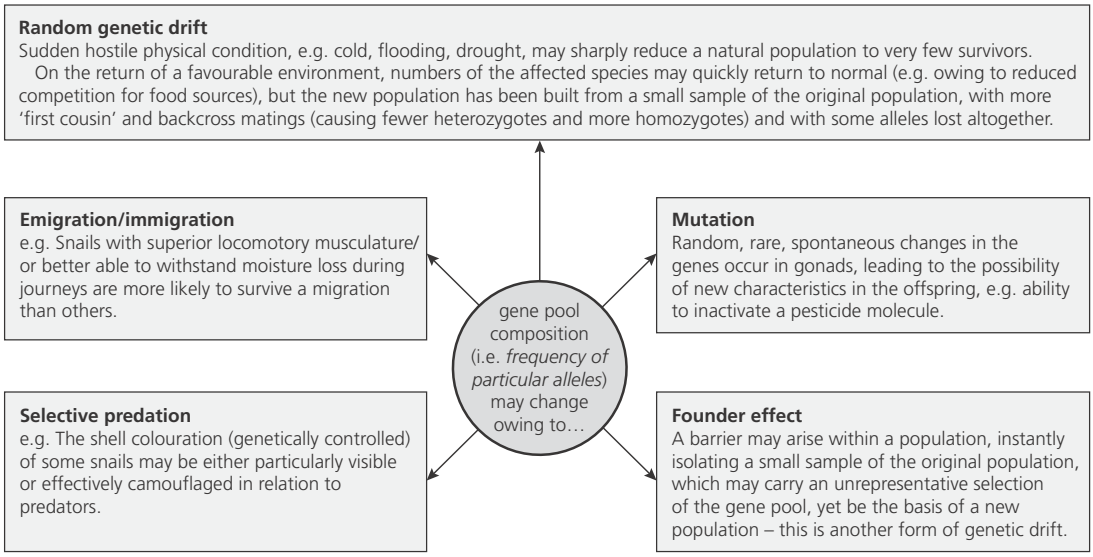
The experiments led Morgan and his colleagues to revise Mendelian heredity (1915): i.e. discrete pairs of factors (later to be called genes) are located on chromosomes, certain characteristics are sex-linked, and other characteristics are also sometimes associated (i.e. linked); his work also demonstrated crossing over and the exchange of alleles between chromosomes, resulting from the chiasmata that form during meiosis.

Quick check questions (p.281)

1 Gene pool: all the genes and their different alleles present in an interbreeding population.

2 The following factors affect the composition of a gene pool:

- whole population level: founder effect; random genetic drift, and emigration and immigration
- members of a population: mutations and selective predation.



The compositions of gene pools can change

3 A **mutation** is a change in the sequence of bases in DNA that results in an altered polypeptide and has the potential to change the characteristics of an organism or an individual cell as a result of alterations in, or non-production of, proteins specified by the mutated DNA. Mutations occurring in body cells of multicellular organisms, i.e. somatic mutations, are only passed on to the immediate descendants of those cells, and disappear when the organism dies.

However, mutations occurring in ovaries or testes (or anthers or embryo sac of flowering plants) – germ line mutations – are mutations that may be passed to the offspring and persist from generation to generation.

As a result of this source of genetic variation, the individual offspring of parents may show variations in their characteristics. Some of these changes may confer an advantage. Favourable characteristics expressed in the phenotypes of some of the offspring may make them better able to survive and reproduce in a particular environment. Others will be less able to compete successfully, survive and reproduce. This is the principle of **natural selection**.

4 **Reproductive isolation**: occurs when two potentially compatible populations are prevented from interbreeding; reproductive isolation of populations can be temporal, behavioural or geographic.

Temporal isolation is caused by changes in activity; it occurs when organisms produce gametes at different times or seasons; e.g. rainbow trout a reproductively active in the spring and brown trout in the autumn; angiosperms produce flowers at different times of year so as to avoid interspecific competition.

When **behavioural isolation** occurs, organisms acquire distinctive behaviour routines, such as in courtship or mating, not matched by other individuals of their species; e.g. the birds of paradise, where different species of males have difference dance displays.

Geographic isolation between populations occurs when barriers arise and restrict the movement of individuals (and their spores and gametes in the case of plants) between the divided populations; barriers can be natural (e.g. mountain ranges or rives / seas) or made by humans; an example of geographical isolation is shown by species on the Galápagos Islands, about 500–600 miles from the South American mainland; each island has a separate flora (see Topic 5).

5 **Gradualism**: evolution occurs at a constant pace over a long period of time (due to the accumulation of mutations); evolution that takes place through a long sequence of continuous intermediate forms; e.g. the change in size and hoof of the modern horse.

Punctuated equilibrium: Long periods of stability are interrupted by rapid evolutionary changes; during periods of stability, well-adapted organisms have no reason to evolve until large environmental changes (e.g. meteor strikes) cause selection pressures to shift; the rate of change is rapid and so no sequence of intermediate forms exist, i.e. there are no gaps in the fossil record but rather this indicates that speciation has occurred abruptly.

6 **Directional selection** is natural selection in which an extreme phenotype is favoured over other phenotypes, causing the allele frequency to shift over time in the direction of that phenotype; in these situations, the majority form of an organism may become unsuited to the environment because of change; some other phenotypes may have a selective advantage; an example of directional selection is the development of resistance to an antibiotic by bacteria.

Stabilizing selection occurs where environmental conditions are largely unchanging; stabilizing selection does not lead to evolution; it is a mechanism which maintains a favourable characteristic and the alleles responsible for it, and eliminates variants that are useless or harmful; most populations undergo stabilizing selections; human birth weight demonstrates stabilizing selection: there is optimum birth weight for babies, and those with birth weights heavier or lighter are at a selective disadvantage.

Disruptive selection occurs when particular environmental conditions favour the extremes of a phenotypic range over intermediate phenotypes; as a result, the gene pool will split into two distinct gene pools; new species may be formed; this form of selection has been shown by plant colonization of mine waste tips: spoil heaps at many locations show local populations of plants that have evolved tolerance to heavy metal ions such as copper and lead; one example is the grass *Agrostis tenuis* (bent grass), populations of which are tolerant of otherwise toxic concentrations of copper.

7 Polyploidy is an abrupt alteration in the number of whole sets of chromosomes; a polyploid organism is one that has more than two sets of homologous chromosomes; it can occur after total non-disjunction, when one of the two cells produced during Meiosis I gets all of the chromosomes (the other cell is not viable and is reabsorbed), resulting in two ($2n$) daughter cells from meiosis instead of the usual four (n); self-fertilization of two $2n$ gametes results in tetraploid offspring ($4n$); tetraploid offspring cannot mate with diploid organisms, resulting in speciation; polyploidy is largely restricted to plants, although can occur in less complex animals; many crop species are polyploids; an economically important example is the cultivated potato, *Solanum tuberosum* ($2n = 48$), a polyploid of the smaller wild variety, *Solanum brevidens* ($2n = 24$).

Topic 11 Animal physiology

Quick check questions (p.291)

1 **Immunity** is the ability of the body to resist an infection by a pathogen; it is resistance to the onset of disease after infection by harmful microorganisms or internal parasites.

2 Similarities: both originate in the bone marrow, where they are formed from stem cells; many lymphocytes are stored in lymph nodes.

Differences:

T lymphocytes	B lymphocytes
migrate to the thymus gland to complete maturation	complete their maturation in the bone marrow
T cells that would react to the body's own cells are removed and destroyed; surviving T cells are released and circulate in the blood plasma	await activation by T calls, leading to clonal selection
the role of T cells is to reactivate B cells after 'activation' by contact with antigens of a particular pathogen or other foreign matter	the role of the majority of B cells, after activation by T cells, is to form clones of plasma cells that then secrete antibodies into the blood system
form killer, helper and suppressor cells	form plasma cells and memory cells
surface antibodies absent	surface antibodies present
T cells form cell-mediated immune system	B cells form humoral or antibody-mediated immune system
killer cells react against transplants and cancer cells	Plasma cells do not react against transplants and cancer cells
80% of lymphocytes	20% of lymphocytes

3 The function of the thymus gland is to receive immature T cells (produced in the bone marrow) to select only those that (i) attack antigens of foreign cells, and (ii) exclude any T cells that also attack the body's own cells. The remaining T cells are allowed to mature and pass out of the thymus gland. These cells are able to protect the body against invasion, normally without danger of autoimmune diseases being triggered by the immune system.

4 **1** When a specific antigen enters the body, B cells with (antibodies) that recognize the antigen bind to it.

2 On binding to the B cell, the antigen is taken into the cytoplasm by endocytosis. Then it is expressed and displayed on the cell surface membrane of the B cell.

3 Macrophages (phagocytic white blood cells) engulf any antigens they encounter. (Macrophages occur in the plasma, lymph, or tissue fluid.) Once antigens have been taken up, they are presented externally, attached to the MHC antigens, on the surface of the macrophages. T cells respond to antigens that are presented on the surface of other cells, as on the macrophages. This is called **antigen presentation** by a macrophage.

4 As T cells come into contact with these macrophages and briefly bind to them, they are immediately activated. They are now called **activated helper T cells**.

5 Activated helper T cells bind to B cells with the same antigen expressed on their cell surface membrane (step 2 above). As a result, the B cell is activated. It is now an **activated B cell**. Plasma cells develop from B cells that have been activated.

6 Activated B cells divide rapidly by mitosis, forming a clone of **plasma cells** (plasma cells develop from B cells that have been activated, and release antibodies into the blood). The generation of a large number of plasma cells that produce one specific antibody type is known as **clonal selection**.

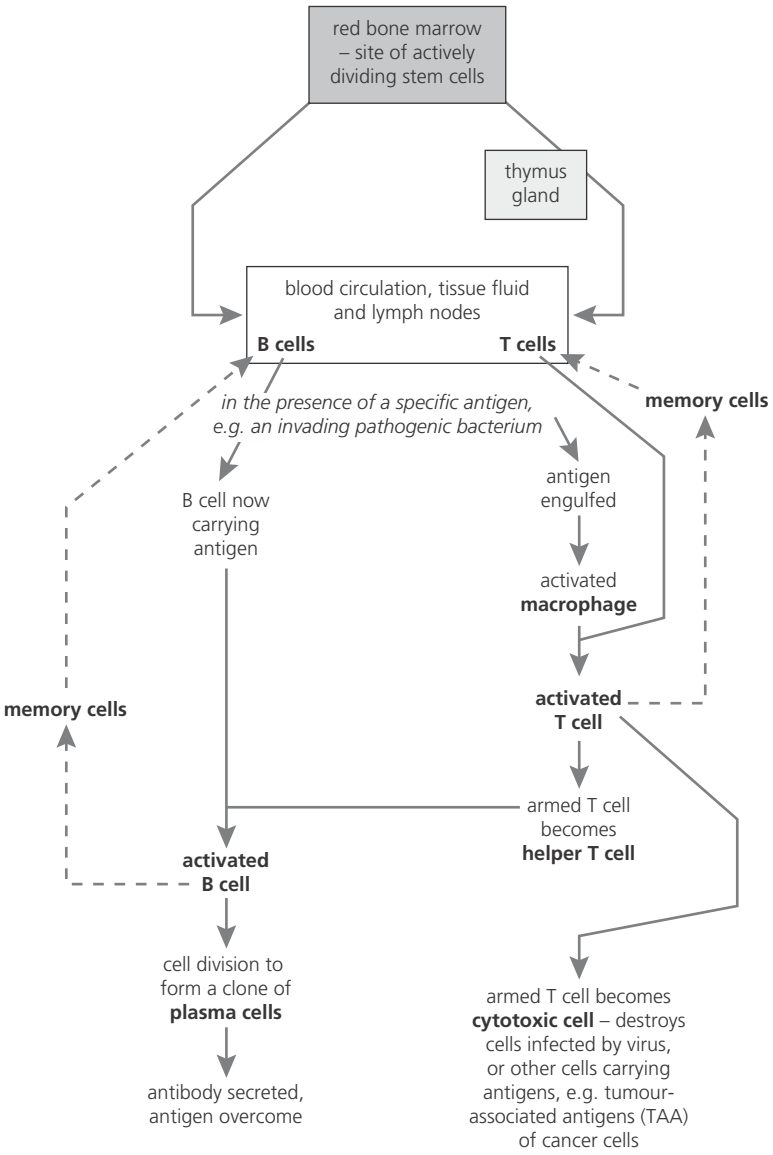
7 The antibodies are produced in such numbers that the antigen is overcome. The action of antibodies is to bind to antigens, neutralizing them or making them clear targets for phagocytic cells.

8 After antibodies have tackled the foreign matter and the disease threat is overcome, they disappear from the blood and tissue fluid. So, too, do the bulk of the specific B cells and T cells that were responsible for their formation.

The antibody can destroy the pathogen in a number of ways:

Agglutination	Antibodies attach to pathogens, causing them to stick together – clumped in this way they more easily ingested by phagocytic cells
Complement activation	Complement proteins in the plasma destroy the plasma membrane of pathogen cells causing lysis, after antibodies have identify them by binding
Toxin neutralization	Antibodies bind to toxins in the plasma, preventing them from affecting susceptible cells
Opsonization	Antibodies make pathogens instantly recognizable by binding to them, and then linking them to phagocytic cells

How antibodies aid the destruction of pathogens



The roles of B and T cells in the immune system–a summary

5 The first priority in combating TB is to make sure that the quality of people's housing ensures that they are not exposed to conditions favouring the transmission of TB and also that their diet and lifestyle choices enable them to be healthy. The first group to receive the vaccine is children. Then people at high risk, such as those living in poverty or in economically depressed zones where access to a hospital is not possible. After this, treat older people and patients with respiratory problems or with immunodeficiency syndromes. Finally, apply the vaccination programme to people who are located near reported areas of infection and then start extending the vaccination programme to the rest of the population.

6 The data supports the use of vaccines, as it is shows that there was a decrease in the number of cases after the vaccination programme started. This reduction was then maintained.

7
- Generate antibody-producing cells by immunizing a mouse against the antigen of interest.
- Perform a blood test to determine the presence of the desired antibody.
- Remove the spleen from the mouse and culture the B cells with myeloma (cancer) cells that divide indefinitely.
- Allow the cells to produce hybridoma cells in the culture and then eliminate the B cells which did not fuse with the myeloma cells.
- Allow each hybridoma cell to divide, creating a clonal culture, where by all cells are clones from the first one.
- Check, after some weeks, that the desired antibody is produced by the hybridoma cloned cells.
- Clones that produce the desired antibody are mass cultured and frozen for future use.

Quick check questions (p.298)

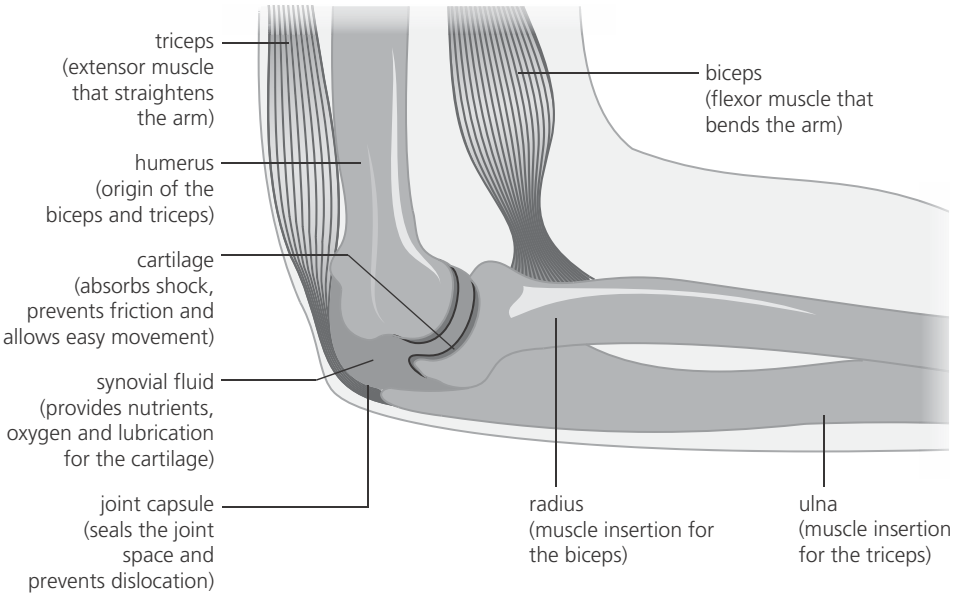
1 Muscles can only contract: when one muscle of an antagonistic pair is contracting, the other is relaxing; the controlled movement of a limb in any direction depends on the balance of opposing contraction of antagonistic pairs of muscles.

2 The **exoskeleton** is the external skeleton that supports and protects an animal; it is made of chitin in insects and deposits of calcium carbonate in shelled animals. An **endoskeleton** is an internal support structure in animals, such the skeleton in humans.

A **bone** is a rigid organ, made of dense connective tissue, which provides support to organs and produces blood cells and blood components. **Cartilage** is a flexible connective tissue that cushions bones at joints, in order to reduce friction between the endings of the bones. It is also found in other parts in the body, such as the outside of the ear and in the larynx.

A **ligament** is a fibrous connective tissue that connects bones to other bones, and also helps to support internal organs. A **tendon** is also a fibrous connective tissue, but one that connects muscles to bones and transmits the mechanical force from muscles to bones, being able to withstand the tension.

3



4 a **Muscle fibre**: a long, multinucleated cell that forms the basic unit of a muscle.

b **Myofibril**: tubular structures that are contained by the muscle fibre. They are composed of actin and myosin proteins, organized into thin and thick filaments, and are responsible for the muscle contraction.

c **Myosin filament**: a motor protein that uses ATP for muscle contraction, generating a force in skeletal muscle by means of a power stroke mechanism.

5 Labelled diagrams of the structure of a sarcomere should include: Z lines, actin filaments, myosin filaments with heads, and the resultant light and dark bands.

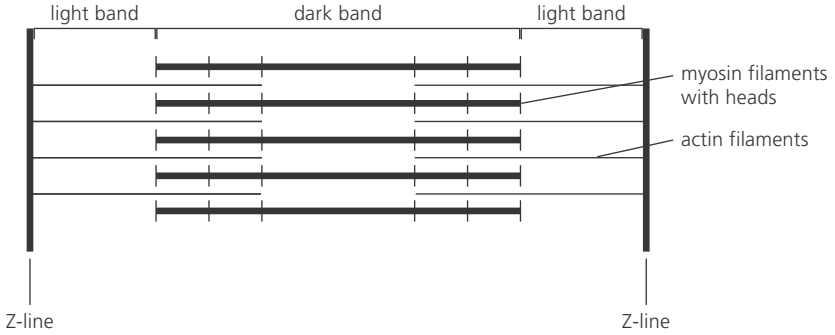


Diagram of a sarcomere

6 **a** This is a relaxed sarcomere; light bands are wide.

b This must show a shorter sarcomere, but with the same length of dark band (thick myosin). The Z lines from both sides must be closer than in the original picture; light bands are narrower.

7 **1** The myofibril is stimulated to contract by the arrival of an action potential

a This triggers release of calcium ions from the sarcoplasmic reticulum.

b Calcium ions react with troponin, triggering the removal of the blocking molecule, tropomyosin. The binding sites are now exposed.

2 Each myosin bulbous head has an ADP and P_i are attached (called a charged bulbous head). The charged bulbous head reacts with a binding site on an actin molecule. The phosphate group (P_i) is shed at this moment and a **cross-bridge** is formed between the myosin and actin filaments.

3 The ADP molecule is released from the bulbous head. This triggers the rowing movement of the cross-bridge, which tilts by an angle of about 45°, pushing the actin filament along. At this step, the **power stroke**, the myofibril has been shortened (contraction).

4 A fresh molecule of ATP binds to the bulbous head. The protein of the bulbous head includes the enzyme ATPase, which catalyses the hydrolysis of ATP. When this reaction occurs, the ADP and inorganic phosphate (P_i) remain attached, and the bulbous head is now 'charged' again. The charged head detaches from the binding site, breaking the cross-bridge, and straightens.

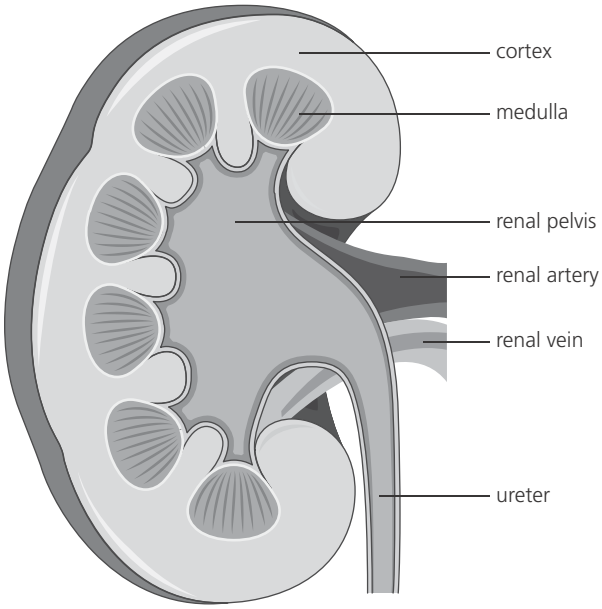
Quick check questions (p.309)

1 **Excretion** is the process by which waste products from metabolic activities are moved outside the body (for example, during urination), whereas **egestion** is the discharge of undigested material during defecation.

Osmoregulation is the regulation of the osmotic potential body fluids by controlling the amounts of water and of salts present in the blood and tissue fluid.

Secretion is the production of useful substances outside the cell for a particular function in an organ. For example, gland cells secrete hormones into the bloodstream.

2



Cross-section through a human kidney

3

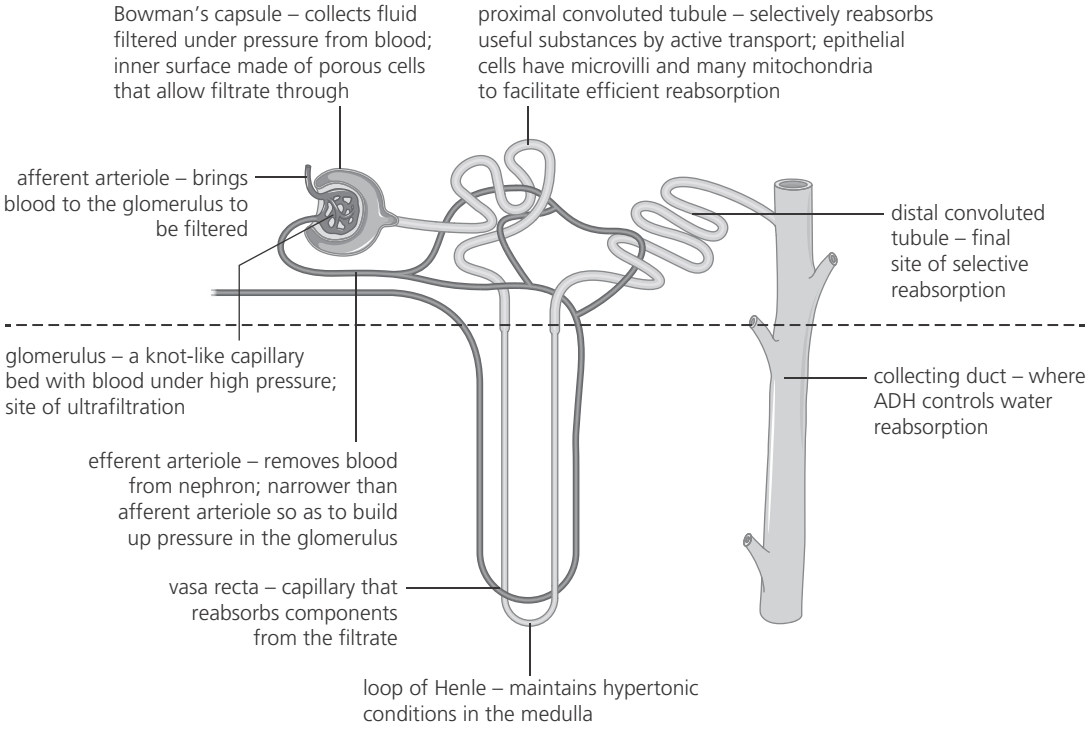


Diagram of a nephron

4 Ultrafiltration occurs when high hydrostatic pressure forces small molecules such as water, glucose, amino acids, sodium chloride, and urea through tiny pores in the capillaries of the glomerulus and into the Bowman's capsule; in the glomerulus, many small molecules present in the blood plasma, including ions, glucose, water, amino acids, and urea are forced out of the capillaries into the lumen of the Bowman's capsule; the blood pressure in the glomerulus is high enough for ultrafiltration because the input capillary (afferent arteriole) is wider than the output capillary (efferent arteriole); small molecules are forced through small pores in the capillary wall under high hydrostatic pressure; there are three parts to the ultrafiltration system:

- **capillary walls** of the glomerulus: small pores or fenestrations exist between adjacent cells; these allow small molecules through, but not blood cells or larger molecules
- **basement membrane** of the capillaries: this structure surrounds and supports the capillary walls; it is made from a mesh-work of negatively charged glycoproteins; filtration gaps in the membrane are very small; it allows small molecules through but retains almost all of the plasma proteins due to their negative charge and size

- **podocytes**: specialized cells that form the inner wall of the Bowman's capsule; they have foot-like extensions which wrap around the capillaries of the glomerulus; a network of small slits between extensions allow the filtrate to pass into the lumen of the Bowman's capsule.

5 Same concentration of both blood cells and plasma proteins; same or almost the same concentration of glucose; urea concentration will be different with 30 mg 100 ml^{-1} of urea in the renal artery and a lower amount of this waste product in the renal vein.

6 The proximal convoluted tubule is the longest section of the nephron and it is here that a large part of the filtrate is reabsorbed into the capillary network; the walls of the tubule are one cell thick and their cells are packed with mitochondria; active transport is a key part mechanism in reabsorption: mitochondria provide the energy for this; the cell membranes of the cells of the tubule wall (in contact with the filtrate) all have a 'brush border' of microvilli: these enormously increase the surface area where reabsorption occurs.

7 The function of the loop of Henle is to enable the kidneys to conserve water; it is important that mammals are able to form urine which is more concentrated than the blood; human urine can be five times as concentrated as the blood, due to the action of the loop of Henle.

The descending limb is permeable to water but not to Na^+ and Cl^-; ascending limb is permeable to Na^+ but not to water; Na^+ and Cl^- diffuses and then is actively transported from the ascending limb into the medulla tissue; this generates an osmotic potential between the fluid in the nephron and the medulla tissue; some water leaves the descending limb by osmosis; output is reduced in volume, and there is reduced salt content.

Exchange in this counter-current multiplier is a dynamic process that occurs in the whole length of the loop:

- At each level in the loop, the salt concentration in the descending limb is slightly higher than the salt concentration in the adjacent ascending limb.
- As the filtrate flows, the concentrating effect is multiplied and so the fluid in and around the hairpin bend of the loops of Henle is saltiest.
- The movement of sodium chloride out of the tubule helps maintain the osmolarity of the interstitial fluid in the medulla.

8 Osmoreceptors in the hypothalamus detect that the water content of the blood is low; ADH is secreted from the posterior pituitary gland; ADH travels through the blood plasma; the hormone binds to receptor molecules in the collecting-duct membrane, causing the protein channels in the membranes to open; water diffuses out from the urine into the medulla; the water entering the medulla is taken up and redistributed in the body by the blood circulation; only a small amount of very concentrated urine is formed; the liver continually removes and inactivates ADH, which means that the presence of freshly released ADH has a regulatory effect.

9 **Dehydration** is due to loss of water from the body so body fluids become hypertonic; effects include: thirst, small quantities of dark coloured urine; lethargy (exposure to higher levels of metabolic waste, reduced muscle efficiency); low blood pressure (reduced blood volume); raised heart rate (low blood pressure); inability to lower body temperature (lack of sweat); in severe cases: seizures, brain damage, and death.

Overhydration (less common) occurs when there is an over-consumption of water; effects include: clear urine; swelling of cells due to osmosis (from hypotonic body fluid); headache, disruption of nerve function; in more serious cases: delirium, blurred vision, seizures, coma, and death.

10 This is due to the nature of the kidney as a highly vascular tissue that contains endothelial cells with antigens belonging to the major histocompatibility complex or MHC. This can induce an immune response, leading to a critical rejection of the transplanted kidney. The MHC will be the same in identical twins.

Quick check questions (p.320)

1 Compare gametogenesis in males and females.

Spermatogenesis	Oogenesis
spermatogonia are formed from the time of puberty, throughout adult life	oogonia are formed in the embryonic ovaries, before birth
all spermatogonia develop into sperm, nurtured by the nutritive cells of the seminiferous tubules of the testes	oogonia become surrounded by follicle cells, forming tiny primary follicles, and remain dormant within ovary cortex. Most fail to develop further – they degenerate.
millions of sperm are formed daily	from puberty, a few primary oocytes undergo meiosis I to become secondary oocytes each month. Only one of these secondary oocytes, surrounded by a much enlarged follicle, forms a Graafian follicle – the others degenerate
four sperm are formed from each spermatogonium	one ovum is formed from each oogonium (the polar bodies degenerate)
sperm are released from the body by ejaculation	the Graafian follicle releases a secondary oocyte into the oviduct at ovulation
meiosis I and II go to completion during sperm production	meiosis II reaches prophase and then stops until a male nucleus enters the secondary oocyte, triggering completion of meiosis II
sperm are small, mobile gametes	a fertilized ovum is non-motile and becomes lodged in the endometrium of the uterus, where cell divisions lead to embryo formation

Comparing gametogenesis in males and females

2 a

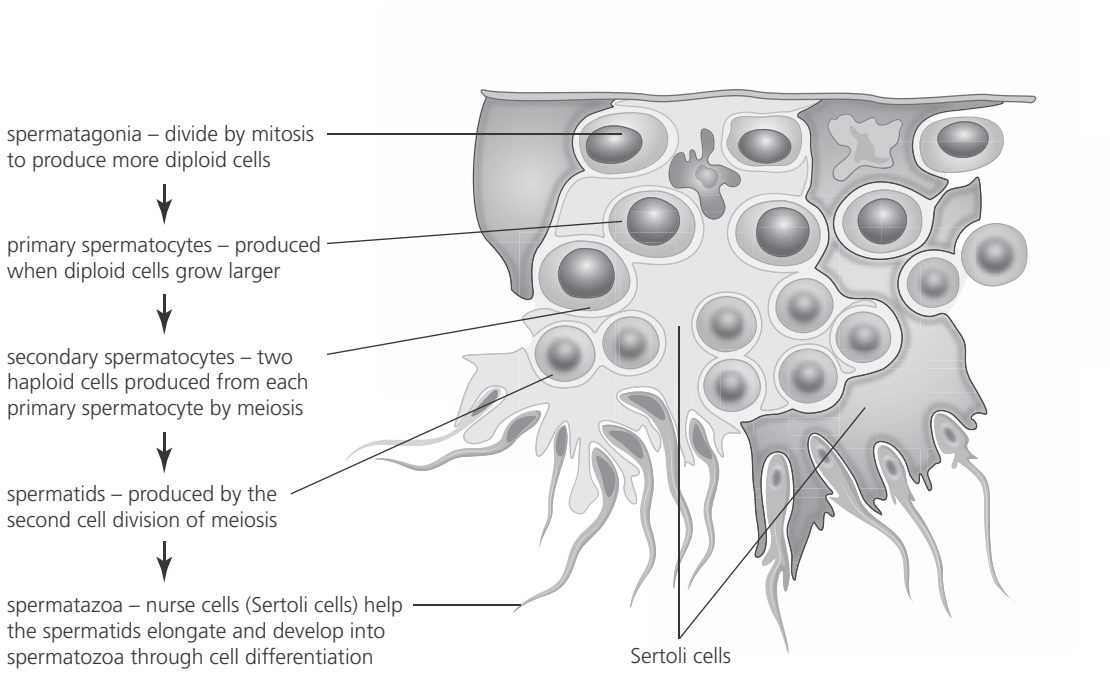


Diagram of a seminiferous tubule showing the stages of gametogenesis

b

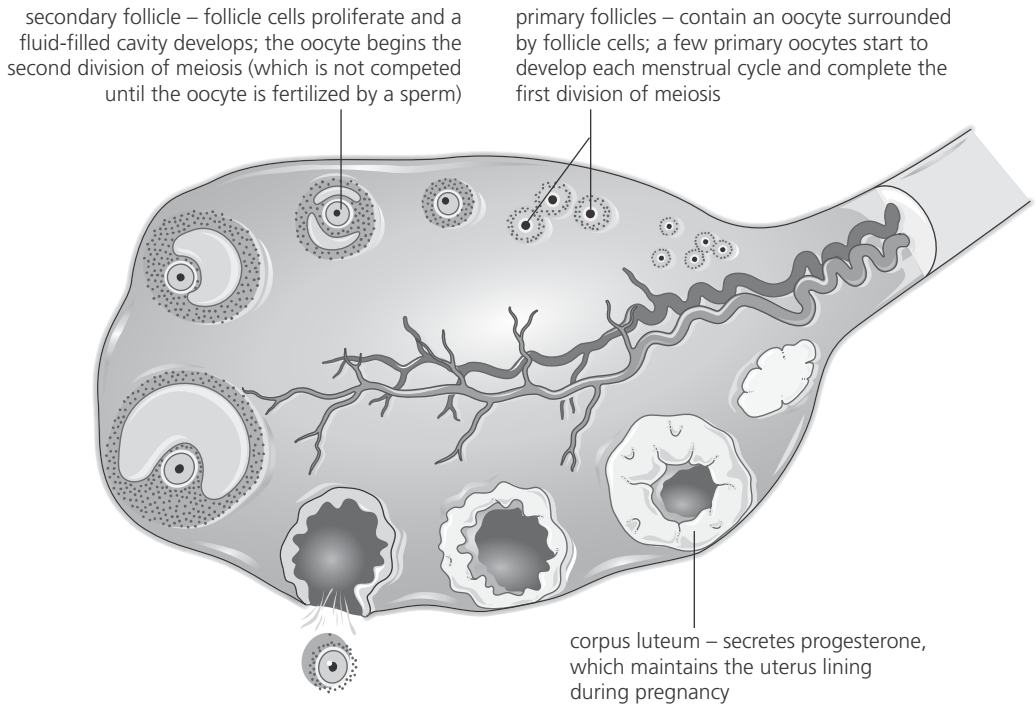


Diagram of an ovary showing the stages of gametogenesis

3 a

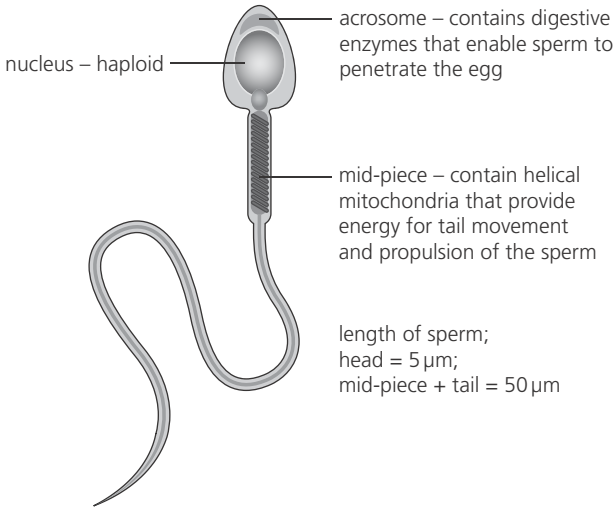


Diagram of a mature sperm

b

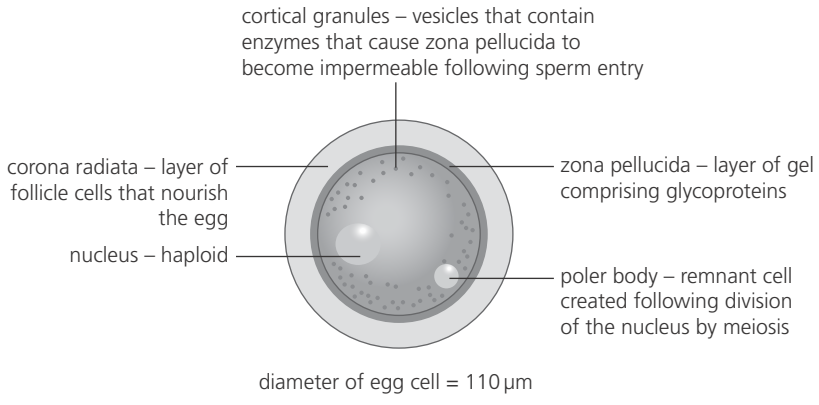


Diagram of a mature egg

4 The fetus is 'foreign' tissue to the mother (for example, fetus and mother may not be of the same blood group) and carries antigens foreign to her. Ensuring the separation of the maternal and fetal blood supplies avoids an immunological response of the mother against the presence of the embryonic tissue. Such a response could lead to the end of pregnancy.

5 It has finger-like projections (villi), providing a large surface area for exchange of substances between the embryo's blood and the mother's blood. It has spaces around the villi (lacuna) that contain maternal blood to pass nutrients and oxygen to the embryo's blood.

6 In **negative feedback** the effect of a deviation from the normal or set condition is to create a tendency to eliminate the deviation. Negative feedback is a part of almost all control systems in living things. The effect of negative feedback is to reduce further corrective action of the control system once the set-point value is reached.

In **positive feedback** the effect of a deviation from the normal or set condition is to create a tendency to reinforce the deviation. Positive feedback intensifies the corrective action taken by a control system. Biological examples of positive feedback are rare, but include the generation of an action potential at the post-synaptic membrane: when a wave of depolarization takes effect in the post-synaptic membrane, the entry of sodium ions triggers the entry of further sodium ions at a greater rate.

At parturition:

- estrogen initiates contraction of the muscular wall of the uterus
- contractions of the uterine wall stimulate stretch receptors which signal the brain to release the hormone oxytocin from the posterior pituitary
- oxytocin levels increase
- oxytocin stimulates the wall of the uterus and the contractions become stronger. This stimulates the stretch receptors causing more oxytocin release (**positive feedback**)
- the rate and strength of the contractions increase, until they expel the offspring.

Exam practice (p.320)

1 **a** on Day 1 / at end of Day 1 / after one day / after the first day / at start of second day [1]

Award [0] for on Day 2 or after Day 1.

b two oral doses daily of saline (for ten days);

one saline injection on Day 1 / at end of Day 1 / after one day / after the first day / at start of second day [2]

Award [0] for on Day 2 or after Day 1.

c PAN + early edaravone group received edaravone for the first five days / first half of experiment / from Day 0 to Day 4 and PAN-only group did not [1]

To award [1] reference to both groups is required. Award [0] for 4 or 4 1 / 2 days.

d 205 mg day $^{-1}$ (units required) [1]

Allow answers in the range of 200 to 21 mg day $^{-1}$.

e on Day 3 little / no difference / both levels very low;

protein increases in both during the experiment; (*Can be mentioned in separate parts of the responses.*)

protein higher in PAN-only group by an increasing amount / increases faster in PAN-only group;

protein levels are higher in the PAN-only group on all days / after Day 3 / on Day 6 and day 9; (*Accept comparative statements such as more than double.*)

145 versus 45 on Day 6 / 350 versus 110 on Day 9 / increase from Day 3 to Day 6 is 130

versus 35 / increase from Day 6 to Day 9 is 205 versus 65; (*Allow answers in the range of* ±5%. *Accept numerical comparisons expressed as percentages.*) [3 max]

f lower (increase in) protein / greater reduction / best results with early dose rather than with continuous; more (increase in) protein / smaller reduction / worse results with late dose than with continuous; differences may not be significant;

partial support / does not fully support / comparison of continuous with late supports hypothesis but continuous with early does not;

timing of dose more important than duration [3 max]

Option A 12 Neurobiology and behaviour

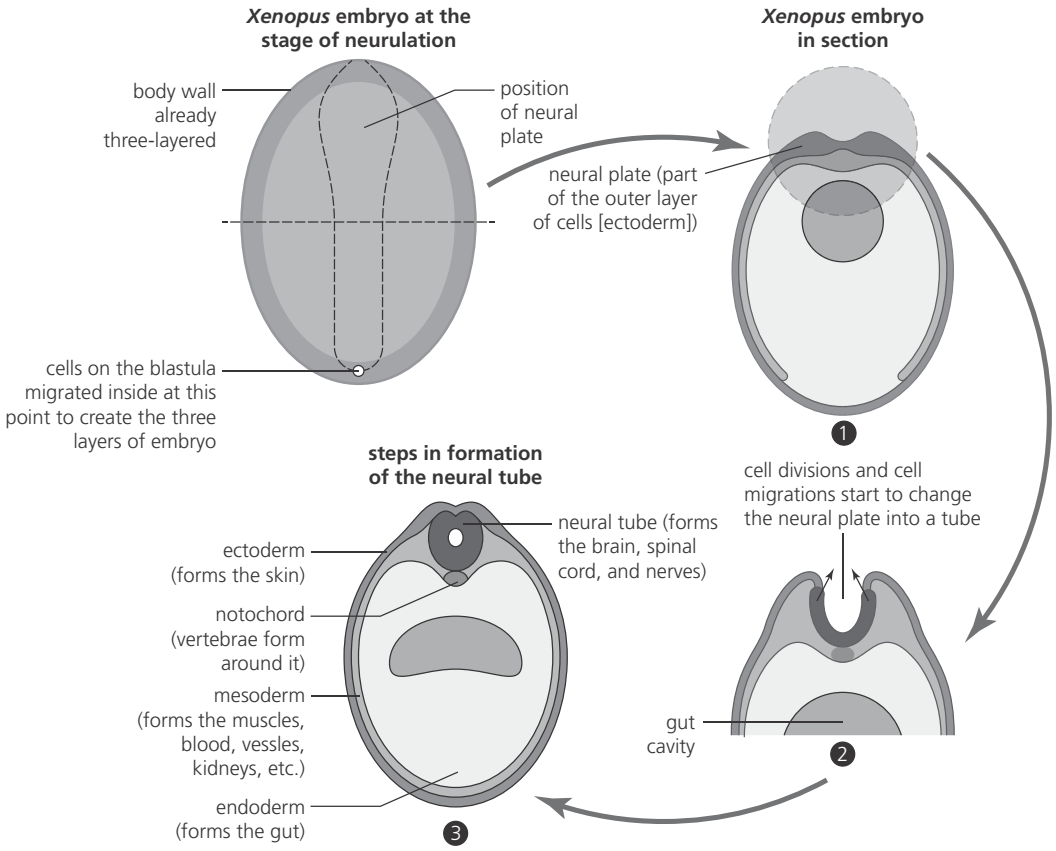
Quick check questions (p.6)

1 **Advantages**: animal models offer the opportunity to investigate new pharmaceuticals and research new procedures, medical protocols or techniques without harming or risking an actual human life. They also allow researchers to identify unique features and mechanisms of a certain disease (models of diseases) or phenomenon. Much of the physiology and biochemistry of the human body also occurs in other animals, particularly in other mammals. Consequently, when drugs are administered to an animal model, the outcomes are likely to be comparable to those in a human.

Drawbacks: since the model organisms are in captivity, they have a sedentary and highly stressed life. These conditions do not necessarily produce accurate data and sometimes do not allow researchers to test a hypothesis in a fair way. In addition, some human conditions are very complex and involve behavioural problems that in most cases cannot be simulated with model organisms. Ethical considerations must be taken into account as there are some procedures considered illegal when experimenting with animals.

2 *Xenopus* is an appropriate model organism in the sense that the embryos allow investigations related to simple single cell development and specialization. The model has been thoroughly studied, so facilitating the investigation of gene knock-out experiments, for example. In addition, it is relatively straightforward to insert a wide range of molecules such as proteins, nucleic acids, and others into the cells. It is also appropriate to use other vertebrates to model early steps in human embryology because all vertebrates proceed through remarkably similar stages.

3



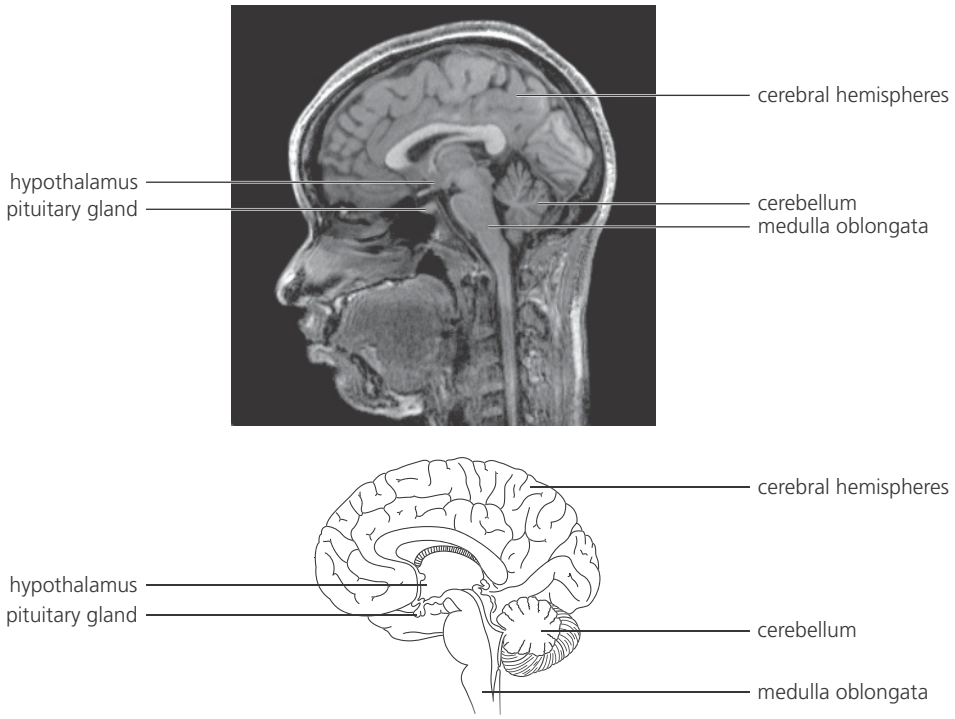
Neurulation in *Xenopus* – formation of the neural tube

4 Programmed cell death (PCD) allows organisms to develop following a certain predetermined path. PCD also facilitates flexibility in development by allowing vastly more cells to form than will ultimately survive, while efficiently removing all cells that fail to find a role, and this without harming developing tissues and organs. Advantages of PCD include: in the nervous system, it allows an adequate innervation by removing cells that could compromise adequate communication between nerve cells or that innervate incorrectly (connecting the wrong target cells). In early embryonic development, fingers and toes form by PCD in cells that will allow the digits to separate.

Quick check questions (p.13)

1 The medulla oblongata (in the hindbrain) contains control centres for vital body functions such as heart function and breathing.

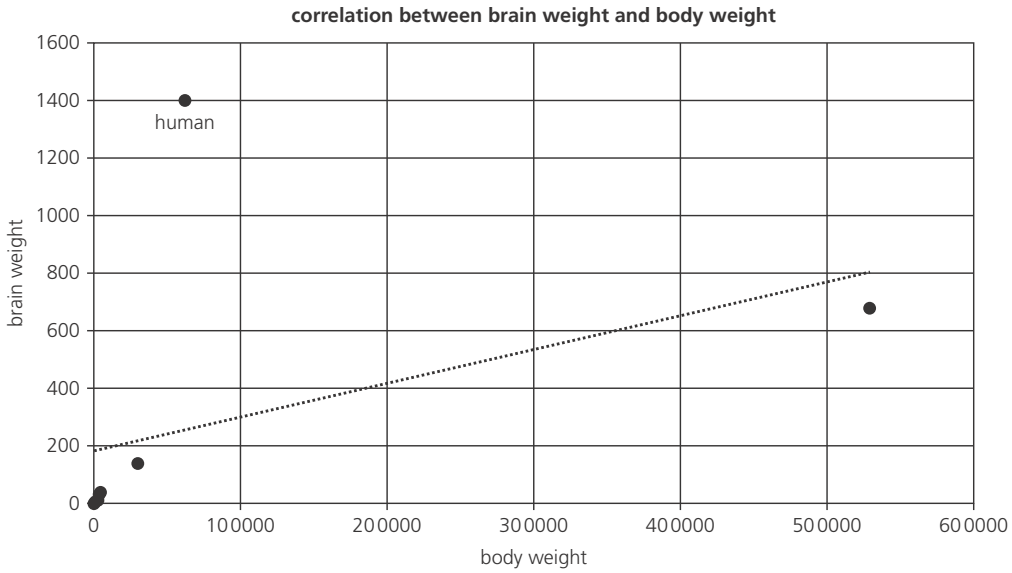
2



The human brain

3 In the medulla oblongata.

4

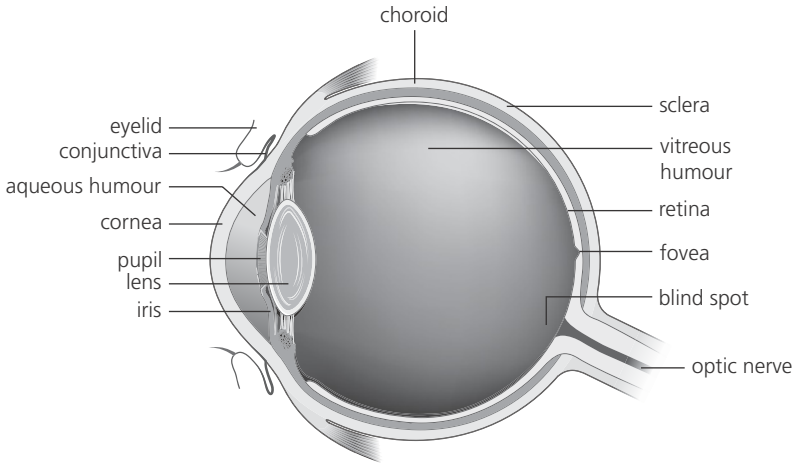


Graph showing correlation between brain weight and body weight

There is a positive correlation between body weight and brain weight; animals with greater body mass have heavier brains; humans are an exception to this correlation: they have a heavier brain compared to body mass than other animals; the cerebral hemispheres are more highly developed in humans than in other animals; the human cerebral cortex has become enlarged, principally by an increase in total area, with extensive folding to accommodate it within the confines of the bony cranium, allowing higher brain functions (e.g. self-awareness, language, problem solving, and abstract thought).

Quick check questions (p.21)

1



The human eye

2

Rods		Cones
human retina contains about 10–12 million rods	**relative numbers**	human retina contains about 7 million cones
evenly throughout majority of the retina, but not found in the fovea	**distribution**	throughout the retina, but particularly concentrated in and around the fovea
sensitive to low light intensities	**light sensitivity**	sensitive to high light intensities
used in dim light and night vision	**type of vision they facilitate**	used in high light intensities (bright light)
synapse with several bipolar neurons	**relationship to bipolar neurons**	synapse with a single bipolar neuron
poor resolution	**resolution**	high degree of resolution
one type of rod cell	**types of cell present**	three types of cone cell
visual purple (rhodopsin)	**visual pigment**	idopsin – three different forms
'black and white'	**vision facilitated**	colour

Comparing rods and cones

3 a White light stimulates all three types equally, but different colours are produced by the relative degree of stimulation of the three types of cone; this is known as trichromatic vision.

b Red–green colour-blindness is believed to be due to partial function failure in two of the three types of cone – those receptive to red and to green.

4 Olfactory receptors, located in the nose, detect chemicals in the air; they allow for the sense of smell.

Quick check questions (p.29)

1

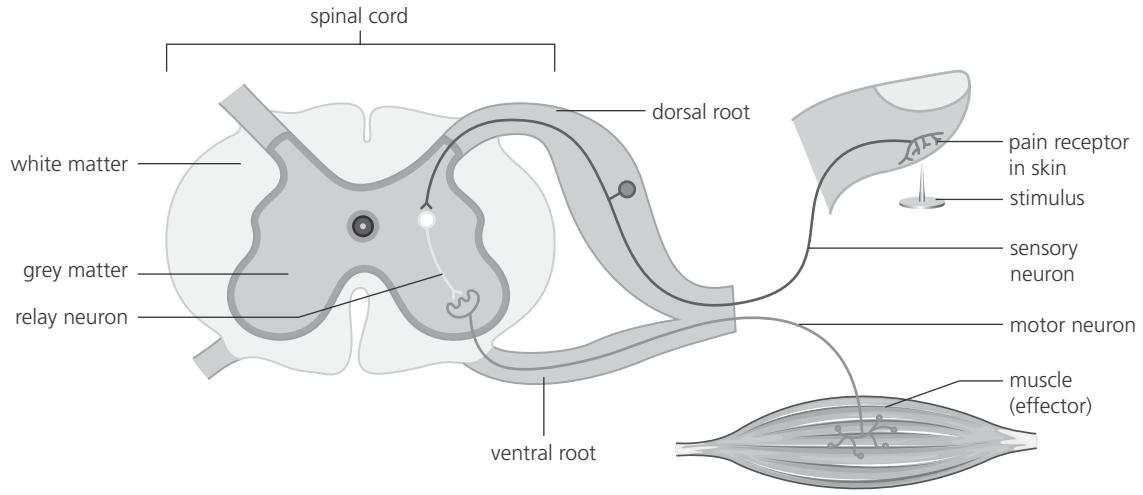


Diagram of a reflex arc for a pain reflex

The diagram should show: the receptor cell, sensory neuron, relay neuron, motor neuron, and effector.

2 Reflexes are immediate, quick, and short-lived responses; such responses are automatic and involuntary (unconscious); a reflex is a rapid, unconscious response, such as the pain reflex; the pain reflex acts to protect the body from further harm.

3 The behaviour shown by the data on woodlouse activity over a 24-hour period directly favours their chances of survival because the woodlouse is less active during the daylight hours, so avoids many predators. The woodlouse can remain in shaded damp or humid conditions during the day to reduce the probability that it will become desiccated or encounter too much heat. When it is dark, however, there are greatly increased numbers of active woodlice. They come out to find food when there are fewer predators around. In addition there is increased reproductive potential as there is a greater probability of woodlice meeting if they are active during the same time period.

Quick check questions (p.36)

1 a The saline only group acts a control group to be compared with the other experimental groups receiving the MDMA drug.

b The data support the hypothesis that more serotonin is released than dopamine in the presence of MDMA for the wild-type mice as the graphs show there are approximately 7500 serotonin units compared with less than 1000 dopamine units for a dose of 3 mg MDMA and approximately 17 000 serotonin units compared with less than 3000 dopamine units for a dose of 10 mg MDMA.

c At treatment levels of 3 mg MDMA, the effect of the absence of a gene for dopamine-release protein on the levels of dopamine in the brains of mice during the experiment was not very marked, although the total level of dopamine was slightly lower than for wild-type mice (but both levels were around 500 units). At treatment levels of 10 mg MDMA, however, there were marked differences in the dopamine levels, with GM mice that lacked the gene for making dopamine transported protein having levels of approximately 700 units, compared with levels in wild-type mice of around 3000 units. Thus increasing the treatment levels of MDMA did not greatly increase dopamine levels in these mice, compared with wild-type mice where the dopamine levels increased 5- or 6-fold with an increase of MDMA treatment level of 10 mg versus 3 mg.

d The effect of the absence of a gene for serotonin release protein on the levels of serotonin in the brains of mice during the experiment was that the levels of serotonin were very low or zero at both treatment levels of MDMA (3 mg and 10 mg) compared with wild-type mice where the total serotonin levels were approximately 6000 and 18 000 units, respectively.

e Hormones originating in the endoplasmic reticulum of a cell are effectively released by being packaged in vesicles which then discharge their contents at the plasma membrane by the process of exocytosis. The ways 'release proteins' may work are by (i) facilitating vesicle formation, (ii) vesicle transport across the cytosol or (iii) the exocytosis process itself – or all of these, for example.

2

Examples of stimulants	
pramipexole	acts on the dopamine receptors in post-synaptic membrane of neurons in the brain, and has the same effect as dopamine used to treat the Parkinson's disease in the early stages
cocaine	also acts on dopamine synapses, blocking the uptake mechanism of dopamine into the pre-synaptic membrane, causing dopamine to build up in the synaptic cleft, so that post-synaptic neurons remain continuously excited a state of euphoria results
Examples of sedatives	
diazepam (valium)	binds to GABA (γ-aminobutyric acid – an inhibitory neurotransmitter) receptors, causing chloride channels to open in the post-synaptic membranes, leading to hyperpolarization and the inhibition of nerve impulse transmission panic attacks and other forms of anxiety are reduced
THC (tetrahydrocannabinol)	a component of cannabis binds to receptors in pre-synaptic membranes, inhibiting the release of excitatory neurotransmitters a sedative that acts in the cerebellum, hippocampus, and cerebral hemispheres of the brain

Comparing the effects of stimulants and sedatives

3 An anesthetic is a drug that can bring about reversible loss of consciousness; the action of anesthetics is due to interference with neural transmission between areas of the brain concerned with sensory perception and the CNS; they inhibit synaptic transmissions; depresses the excitability of the whole CNS; a general anaesthetic is a medication administered to cause total loss of consciousness, so that a patient is unaware of surgery and feels no pain, and is administered by an anesthetist – a specially trained doctor – to bring about a medically induced coma.

Quick check questions (p.43)

1 Ethology is the study of animal behaviour in natural conditions.

2 Behaviour can be inherited or learnt; learnt behaviour is behaviour such as following migration routes, using tools for feeding, improving signing patterns, other valid examples; inherited behaviour is controlled / expressed by genes; individuals in a population show differences / variability in their genome; some behaviours can provide an advantage; the fittest organisms will survive / individuals showing an advantage in their behaviour will survive; these individuals will be able to pass this behaviour to their offspring thus changing the frequency of those alleles in the population.

3 Learnt behaviour is acquired during the animal's lifetime and innate behaviour is inherited; learnt behaviour uses life experiences and depends on the circumstances / environment; if learnt behaviour confers a competitive advantage it is likely to be adopted by others and so spread rapidly through a population; when it is no longer useful it will be lost quickly as well; in order to remove an innate behaviour the gene frequency must decrease and this takes time / generations as it requires mutations / evolution to occur; innate / instinctive behaviour develops independently of the environment.

Option B 13 Biotechnology and bioinformatics

Quick check questions (p.53)

1 Pyruvate.

2 By substrate level phosphorylation during glycolysis only (as opposed to the additional and substantial formation of ATP by oxidative phosphorylation, by the electron transport chain, occurring during aerobic respiration only).

3 Antibiotics are contained in the arms of the mast ring so that sensitivity to many antibiotics may be tested simultaneously; there is evidence that growth of the bacterium is more sensitive to certain antibiotics (e.g. CM, A) than to others (e.g. S, I).

Quick check questions (p.58)

1 The species' proteome depends on the genome. If the plant has been genetically modified, it means that a new gene has been inserted in order to translate a novel protein which is not part of the species' proteome.

2 A target gene is a gene that possesses a biological / experimental importance; a promoter is required to ensure that the sequence will be expressed; a terminator section located downstream of the gene in order to terminate / stop the expression of the gene; a marker gene that identifies the presence of the target gene / provides confirmation / recognition for the presence of the target gene.

3 An open reading frame (ORF) is used in the identification of genes; an ORF is a long base sequence; it is found between a start codon (ATG) and the stop codons (TGA, TAG or TAA); an ORF can be used to determine if a similar nucleotide sequence exists in other species; if found in other organisms the ORF is likely to be a gene; the ORF is used in a BLAST search for similarities with other species; a BLASTx search is performed to find out the sequence of amino acids and find a protein that matches with the ORF; a BLASTn search can be performed in order to find sequence of nucleotides and locate the gene in different genomes.

4 a Between 1996 and 2001 the method used to reduce weed growth (tillage) changed considerably. In 1996 the 'no tillage' method was less common (at approximately 5.5 million hectares) and almost 8 million hectares were conventionally tilled to remove weed growth. By 2001 the situation had changed so that no tillage was used on over 11 million hectares and under 4 million hectares were conventionally tilled. (The number of hectares undergoing reduced tillage also increased over this time period, from just over 6 million hectares in 1996 to just under 8 million hectares by 2001.) This is due to the fact that by 2001 GR soya was grown in almost 70% of the total area cultivated, increasing from about 5% in 1996, so one or two post-emergent applications of glyphosate herbicides were typically required instead of tillage to suppress weed growth.

b The data establish that there had been a resurgence of the practice of weed control by tillage (almost 50% of the total crop grown) and a reduction in the practice of weed control by 'no tillage' (a process of relying on the weeds being non-glyphosate resistant but the crop being glyphosate-resistant, so that chemical weed control remains effective – now reduced to about 30% of the total crop grown).

c The greater impact of using this technology could be that the GR crops have become weeds themselves or the GR transgenes could have escaped into wild plants and weeds, creating 'super weeds' that are resistant to glyphosate herbicides, so requiring increased tillage to suppress weed growth.

5 a one

b two: TAA and TGA

c 33 in total including the start and the last stop codon

d 29 amino acids up to the first stop codon (TAA)

e proline: P

f cysteine: C

g glycine: G

h serine: S

Quick check questions (p.66)

1 Bioremediation is the process of exploiting microorganisms in the removal of pollutants from the environment.

Bioremediation	
microorganisms are used to remove environmental contaminants, combined with physical and chemical procedures	
Physical procedures	**Chemical procedures**
pumping the surface oil slick (an expensive procedure); re-extraction of the oil; detergents and dispersants are deployed on oil spills	contaminants can be burnt, removed by dissolving or destroyed by oxidation

Different forms of bioremediation

2 Bacteria of the *Pseudomonas* genus are the most efficient of the hydrocarbon-degrading microorganisms; *Pseudomonas aeruginosa*, which is widespread in the environment, can utilize crude oils as its sole carbon source; its efficiency in oil degradation is greatly improved by the presence of a surfactant; certain strains of *P. aeruginosa* synthesize their own surfactants (rhamnolipids), and this increases their usefulness to the industries concerned with bioremediation; *P. aeruginosa* can also become an opportunistic human pathogen, causing serious infections; *Pseudomonas putida*, however, is an entirely safe microorganism that has a very diverse metabolism and the ability to degrade a wide range of organic solvents. It has been used widely in bioremediation work.

3 Biofilms are microorganisms that are stuck to each other and, usually, to a surface; frequently embedded in and held by a polysaccharide matrix, secreted by the cells of the biofilm; cooperative aggregates of microorganisms form biofilms showing emergent properties; emergent properties are the result of complex interactions between the parts of an organisms where the whole is greater than the sum of its parts; bacteria attach to the biofilm using their pilli, creating colonies of several or unique bacteria; microorganisms in biofilms cooperate through quorum sensing by sending signals into the colony; quorum sensing is a behaviour that is a function of the density of the colony, where signalling induces the expression of genes that are not active when the population has a low density; colonies increase their complexity based on the types of interactions / signalling between the bacteria present in the colonies; emergent properties observed include the secretion of an extracellular polymeric substance (EPS) creating the matrix that holds the colony together; formation of channels within the colony that facilitate water flow / nutrients into the biomass of bacteria; microorganisms growing in a biofilm are highly resistant to antimicrobial agents.

4 Potential environmental problems caused by biofilms include: contamination of surfaces in food production; once *Salmonella* bacteria, for example, get into a food processing facility and form a biofilm on surfaces, it is very difficult, if not impossible, to kill them; biofilms can also lead to clogging and corrosion of pipes; transfer of microorganisms in ballast water.

Microorganisms growing within the biofilm become highly resistant to antimicrobial / antibiotic agents; the EPS (extracellular polymeric substance) matrix between the cells provides a physical barrier to the entry of the antibiotic agent; antibiotics attack / affect cells division mechanisms; cells in a biofilm are metabolically active but may not be dividing, making it difficult to eliminate them for example in hospitals.

5 While the bacteria in biofilms are difficult to attack using disinfectants (disinfectants attack surface members of a biofilm colony, but those within remain unharmed), they are vulnerable to viruses; viruses as disease-causing agents; viruses that are specific to the species of bacteria present may quickly spread through all members of the biofilm; the viruses that parasitize bacteria are known as bacteriophages; inside their host cell, viruses function as endoparasites and the bacterial cells are quickly destroyed; the use of bacteriophages specific to the biofilm bacteria present, together with chlorine disinfectant, has been effective against these biofilms in water pipes.

Quick check questions (p.73)

1 A genetic marker is a gene or DNA sequence (such as a single nucleotide polymorphism (SNP) or tandem repeats); has a known location on a chromosome; the marker is associated with a predisposition for a genetic disease; markers that are part of a coding sequence contribute to the disease / non-coding markers are linked to the gene that causes the disease; non-coding markers must be very close to the defective gene (so that they are not separated by crossing over) to be useful in diagnosis; detection of markers usually involves PCR techniques and DNA profiling; for diagnosis purposes the inherited variation must be polymorphic / with a number of possible genotypes at the gene locus; examples of marker genes are *BRCA 1* found in chromosome 17 / *BRCA 2* on chromosome 13; individuals with mutations in these have a higher risk of developing breast and ovarian cancer.

2 A DNA microarray is a collection of microscopic DNA spots on a solid support typically made of glass; it is used to measure the expression level of large numbers of genes in a genotype; microarrays with clusters of genes related to a particular cancer / disease are used to identify cancerous cells which express unique set of genes / oncogenes; RNA expressed from cancerous cells is used together with RNA expressed from normal cells in order to produce cDNA; cDNA from cancer cells is tagged with red fluorescence / cDNA from normal cells with green fluorescence; red, green, and yellow fluorescence indicates the level of expression of the genes in different tissues; red fluorescence for the expression of cancer cells / green for normal tissue / yellow for when level of expression in both tissues is the same; the level of fluorescence is compared and the ratio between red, green, and yellow light is calculated / the degree of the difference of expression is calculated.

3

Advantages	Disadvantages
viruses are made of simple structures that can carry a single gene or group of genes that can be designed under laboratory conditions	some errors created during the design of the virus could be multiplied when the virus is implanted in the bacteria; these would then convert the viral particles into antigens that activate the immune system unexpectedly
their manipulation is easy and bacteria can be used to multiply viral particles at a relatively low cost	the insertion of an additional gene into the individual's genome may activate other genes already present, resulting in for example a fatal cancer
some viruses may only trigger a minimal immune reaction, for example, the AAV virus that infects human cells does not generally cause disease	some of the AAV viruses can elicit an immune response when patients' medical histories are not fully studied
the low cost of creating the viral particles may allow for future booster injections	the treatment involves some expensive procedures and it would have to be regularly repeated as body cells are replaced

Potential advantages and dangers of using viral vectors for human gene therapy

Quick check questions (p.80)

1 Scientists can perform a BLASTp search in order to compare the amino acid sequence of a novel protein with that of other reported species in the database. If the sequence presents differences, an evolutionary tree can be produced, allowing them to identify species closed related to the species whose amino acid sequence has been identified.

2 BLASTp uses a sequence of amino acids as the original search and BLASTn uses sequences of nucleotides. BLASTn does not always enable an evolutionary relationship to be established, whereas BLASTp does, since BLASTp compares sequences of amino acids from the expression of the gene, whereas BLASTn compares nucleotide sequences and these can present slight variations that do not indicate an evolutionary adaptation.

3 The higher the percentage of nucleotide or amino acid sequence similarities is, the closer the relationship between two species is, as this indicates that their genome has a similarity in the genetic sequence.

4 The primary sequence is the expressed sequence of nucleotides. Since the DNA contains introns and exons, these could vary among species and do not give a clear insight of the evolutionary relationship between the species to be studied.

5 A model organism is a widely studied non-human species and it is easy to maintain / breed under laboratory conditions; it gives insights about the way the experimental procedure will work in other species.

6 Gene function can be studied using model organisms with similar sequences; model organisms offer experimental advantages in order to understand simple and complex biological functions; studies for a particular gene / disease can be applied to humans; this is possible due to the universality of the genetic code / similar biochemistry among organisms; some of these model organisms can be produced in large quantities and have a short generational time allowing for large amounts of data to be collected / compared with other species.

e.g. the zebra fish (*Danio rerio*) provides clues about the way genes in cancer cells get activated before metastasis. The study helps human cancers to be more clearly understood.

Name and type of organism		Example of its use
Caenorhabditis elegans (*C. elegans*)	Nematode (soil roundworm)	Understanding organ development and programmed cell death, or apoptosis
Drosophila melanogaster	Insect (fruit fly)	A high homology with human cells, means that the fruit fly is being used to study Parkinson's disease and Alzheimer's disease in humans
Danio rerio	Vertebrate (zebra fish)	Embryos are transparent, allowing non-invasive *in vivo* imagery to obtain data about the circulatory system; also useful in the understanding of the process of metastasis
Arabidopsis thaliana	Angiospermophyte (flowering plant)	First plant to have had its genome sequenced; used in a variety of studies, such as understanding floral production and the effects of environmental stress in plants

Some of the most common model organisms used

7 Gene knockout uses a model organism, such as the mouse (*Mus musculus*). This technique has led to an understanding of metabolic disorders, such as those leading to obesity in humans. Researchers knock out or destroy the function of a particular gene and observe the effect on the phenotype. In order to knock out a gene: a stem cell is used in which the gene of interest is replaced with a homologous non-functional sequence; the cell is fused with an embryo, creating a chimera; the adult mouse is bred until a pure breeding offspring is obtained; once homozygous mice are obtained, it is possible to study the function of the knocked out gene.

This technique has been used to create the p53 KO mouse, which has a mutated version of the p53 gene; normally, the p53 gene translates into a protein that regulates the cell cycle; when the protein is absent, tumour cells are created, increasing the risk of bone cancer in mammals.

Another example of this technique is the Methuselah KO mouse; increased longevity is shown in mutants, allowing researchers to study the complexity of ageing; this has led to prevention of human ageing diseases and better treatments.

8 BLAST can be used with multiple species by selecting them from the list of available organisms. In order to obtain a phylogenetic relationship, a genomic or proteomic sequence is used and the algorithm will find the correlations between the species depending on the number of targets or identities found. The tree will show the relationships between the species by means of a cladogram.

Option C 14 Ecology and conservation

Quick check questions (p.90)

1 a At the end of the experiment at 55°C, all worms were dead and all showed very serious damage of their tissues and cells. The worms at 55°C also showed high mortality of circulating cells. In the 20°C experiment, cell mortalities were significantly higher in animals compared with the ones kept at 42°C. Survival of individuals was also lower in the 20°C experiment compared with the 42°C one. The 42°C experiment displayed the highest survival rates at both organism and cellular levels, with no observable structural damage in the tissues.

Specimen survival and cell mortality data show that *A. pompejana* endured more damage from the 20°C exposure compared with the 42°C experiment. These findings show that *A. pompejana* is a thermophilic species (extremophile organisms thrive at relatively high temperatures of between 45 and 122°C). The results of this study provide experimental evidence that *A. pompejana* cannot withstand prolonged exposure to temperatures in the 50–55°C range, and that its thermal optimum lies below 55°C, and above 20°C.

b The mRNA extracted from the tissues of these animals contained a significantly higher quantity of transcripts for the *hsp70* gene compared to normal (not heat-treated) animals. The activation of the *hsp70* gene confirms that thermal exposure up to 55°C is harmful for *A. pompejana*. The animals did trigger a mild heat stress response, but with a level of *hsp70* gene expression significantly lower than for the 55°C specimens. The stress gene expression showed values significantly higher in animals subjected to the 20°C compared with the 42°C treatment.

2 a Exposure brings the threat of desiccation and wider extremes of temperature than those experienced during submersion. Exposure is an abiotic factor that influences distribution of organisms on the seashore.

b

Location	Plant	Animal
i a high water location	spiral wrack	rough winkle
ii a low water location	oar weed	acorn barnacle

3 a Both *Galium* species grow healthy populations on both soil types when grown by themselves. In experiments where both plant species are grown together, one species outcompeted the other, as they do in the wild.

b These results demonstrate that the fundamental niche of both species of *Galium* included a wider variety of soil types than they inhabit in the wild. Interspecific competition restricts the realized niche of each species, so that they are limited to a narrower range of soil types.

4

Feeding relationship	Description of relationship	Example
herbivory	an organism feeds on a plant	caterpillars of the monarch butterfly feeding on milkweed leaves
predation	one animal (or sometimes a plant) eats another animal	African lion feeding on prey (kudu – a savannah herbivore)
parasitism	one organism – the parasite – benefits at the expense of another – the host – from which it derives its food	tick (an ectoparasite) feeding on the blood of a sheep
mutualism	interaction in which both species derive benefit. This is a specific type of symbiotic relationship	mushroom of fly agaric fungus taking sugars and amino acids from a tree's roots in return for essential ions, via its hyphae attached below ground

Different feeding relationships

Quick check questions (p.104)

1 a mean annual temperature

b mean annual precipitation

2 Primary succession is on bare land, devoid of soil, whereas secondary succession occurs in an environment after an ecosystem has been disrupted or destroyed due to a disturbance that reduces the population of the original inhabitants: soil already exists in this type of succession. Initial colonizers of primary succession on e.g. rocky shore are algae, whereas colonizers in secondary succession include small rooted plants from seeds carried in from surrounding land, or that survived the fire in the soil.

3 Your results will indicate a higher diversity index with increasing age of dune. A high diversity index suggests the community is ecologically stable. A low diversity index is typical of a community of recent origin.

4 Pioneering species are algae, mosses, lichens, and some ferns; the climax community is made of mature trees like oak and other woodland trees.

Quick check questions (p.112)

1 Initially, a small number of a large population of rabbits had immunity. As their vulnerable relatives were killed off, the immune rabbits prospered from the diminished competition for grass. Rapidly, the bulk of the population were immune and any that failed to develop immunity were quickly taken out. The eradication programme was ultimately unsuccessful.

2 Run-off from agricultural land can carry very dilute solution of pesticides, e.g. DDT; DDT can enter the cells of phytoplankton in the water; herbivorous non-vertebrates eat phytoplankton and accumulate DDT; carnivorous fish eat the herbivores and are in turn eaten by the top carnivores, such as predatory birds; as a result, at each stage of the food chain, DDT has become concentrated (biomagnification); the end result can be that a top predator may have an accumulation that is several thousand times greater than that of a primary producer; DDT concentrations sometimes reach toxic levels in top carnivores.

3 When DDT was used as an insecticide, it was probable that this pesticide would bioaccumulate at each trophic level in the food chain where it was used, and biomagnify in the top carnivore. In the eggshell thickness study of British sparrowhawks 1870–1970, more than 2000 clutches of eggs were measured, each dot representing the mean shell thickness of a clutch (typically five eggs). Although DDT is not a nerve poison in birds and mammals, in breeding birds it inhibits the deposition of calcium in the egg shell. Affected birds lay thin-shelled eggs that easily crack. There was a rapid decline in numbers of birds of prey in areas where DDT had become widely used in agriculture. Once the wider effects of organochlorine pesticides on wildlife were recognized, a ban on DDT's agricultural use in the United States was imposed in 1972, after which thickness of eggshell started to recover.

Quick check questions (p.123)

1 a For habitat B, Simpson's reciprocal index:

$$\frac{100(99)}{50(49) + 30(29) + 15(14) + 5\,(4)} = \frac{9900}{3550} = 2.79$$

b Habitat A has the greatest diversity and habitat E the lowest. Habitat A has the greatest evenness between species (i.e. all species are equally abundant), with habitat E dominated by one species (i.e. lowest evenness). Species diversity is a combination of the number of species and their relative abundance – higher diversity indices are recorded when all species are equally abundant, indicating a large range of available niches, whereas low species diversity indicates a low number of available niches.

c Habitat A is more complex with a greater array of niches than habitat E, indicating a more complex habitat, whereas habitat E is simpler with fewer available niches. Habitat A may be older than habitat E. Other habitats lie between the extremes demonstrated by habitats A and E.

2 The minimum value of the Trent Biotic Index is 6.

3 The maximum value of the Trent Biotic Index is 4.

4 You will need to discuss your ideas with a conservationist in your country and area. Are there national or local reserves or conservation areas, with voluntary or professional management who can give you guidance?

Quick check questions (p.133)

1 (14 + 5) − (11 + 7) = 1

This population, growing at this rate over a year, will increase by 1 individual for every 1000 in the population.

2 Population size = (natality + immigration) − (mortality + emigration).

Natality: without birth the population cannot grow; density independent limiting factors affect the very young, the old and the weak individuals the most, with population growth as individuals of reproductive age affected the least.

Mortality: if individuals die before reproducing the population size of the next generation will be reduced / population growth is negatively affected; the more genetically diverse a population is the more likely individuals are to survive (e.g. disease) to reproduce.

Immigration: increasing population density in one area promotes immigration to other populations.

Emigration: increasing population density and the associated competition promotes emigration from a population.

A population faces one of three possible situations:

1 Immigration and natality are, when combined, higher than emigration and mortality combined. This leads to population growth. This can be represented by the equation:

I + N > E + M

2 Immigration and natality are, when combined, the same as emigration and mortality combined. This leads to population stability. This can be represented by the equation:

I + N = E + M

3 Immigration and natality are, when combined, lower than emigration and mortality combined. This leads to population decline. This can be represented by the equation:

I + N < E + M

3 Use the Lincoln index / capture–mark–release–recapture method; organisms are captured, marked, released and then recaptured; marking varies according to the type of organism, e.g. wing cases of insects can be marked with pen, snails with paint, and fur clippings used for mammals; markings must be difficult to see – high visibility increases predation risk; the number of individuals of a species are recorded at each stage; the total population size is estimated using the following equation:

$$N = \frac{n_1 \times n_2}{m}$$

where: N = total population of animals in the study site

n_1 = number of animals captured (marked and released) on first day

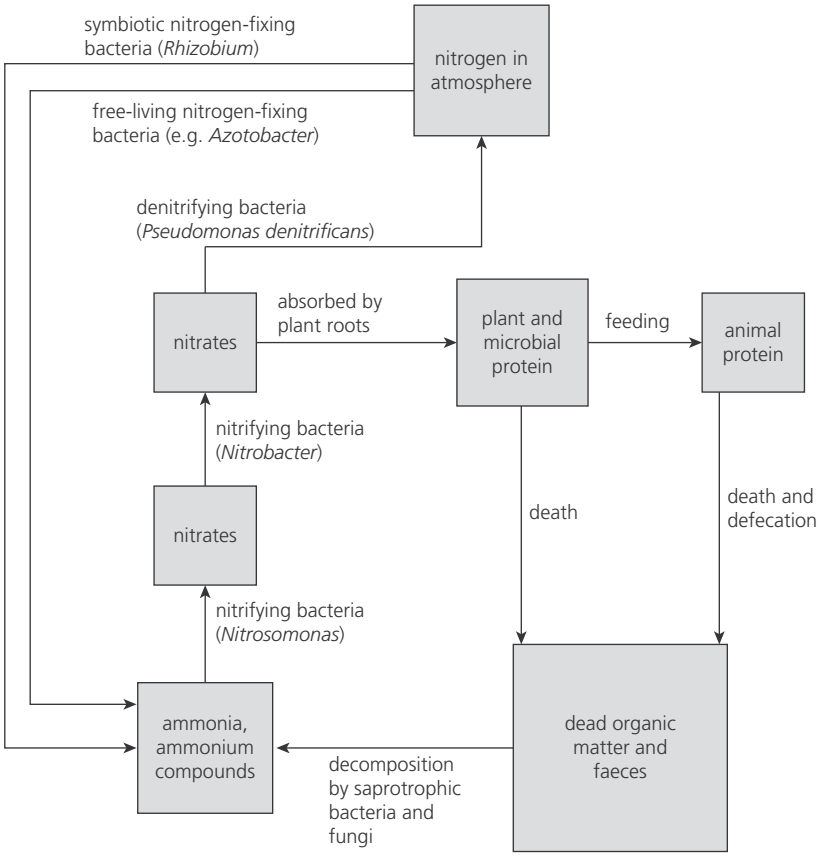
n_2 = number of animals recaptured on second day

m = number of marked animals recaptured on second day

4 **Top-down** factors are pressures applied by other organisms at higher trophic levels; **bottom-up** factors are those that involve resources or lower tropic levels; excessive algal growth in water bodies can be controlled by bottom-up control: reduction in fertilizer use and use of slow-release sources of nutrients such as manure will lead to a reduction in the supply of nutrients (a limiting factor) will reduce algal growth, as there will be less raw material to construct proteins. Top-down control of algal growth can be achieved using herbivores (biomanipulation) to consume the excessive algal growth: biomanipulation of fish-eaters (piscivores) leads to a reduction in planktivores and a corresponding increase in herbivore biomass – the result is an overall reduction in phytoplankton (algal) biomass.

Quick check questions (p.141)

1



The nitrogen cycle

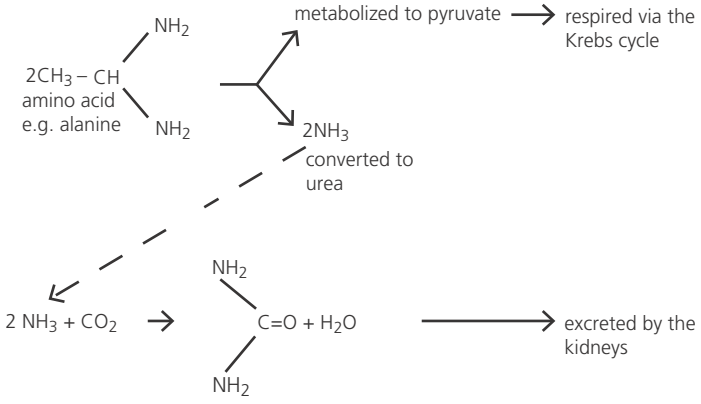
2 Biological oxygen demand (BOD) values increase with increasing eutrophication as the bacteria present have access to an increasing quantity of dead organic matter, and their numbers multiply. Increased bacterial respiration leads to increased BOD, which causes a lowered oxygen content of water (hypoxia).

3 Many of the species present fail to survive conditions of increasing eutrophication because of falling oxygen concentration and the reduction in sunlight penetration.

Option D 15 Human physiology

Quick check questions (p.154)

1 Proteins are been hydrolysed to amino acids, and then excess amino acids are deaminated – by the removal of the amino group to form ammonia; in humans, ammonia is converted to urea and then excreted, whereas the remaining part of the amino acid is fed into the Krebs cycle:



Deamination

2 Anorexia is a multisystemic disease where the body loses muscle mass; the heart's muscle cells starve, losing mass and leading to a drop in blood flow and pressure and dangerous heart rhythms; the heart, if eating disorders go untreated, may be left permanently damaged; a serious symptom of anorexia is a slower heart rate and lower blood pressure, which can reflect the changing, and weakening, heart muscle.

3 Collagen is the key structural protein in connective tissues; it makes up about 30% of the total of protein in the body; ascorbic acid (vitamin C) is involved in the synthesis of collagen; the elastic and collagen fibres of the *tunica externa* in the wall of blood vessels prevent rupture as blood surges from the heart; if body collagen is not maintained, the outer layer of the arteries or veins may leak blood (hemorrhage); collagen forms connective fibres in tissues such as skin, ligaments, cartilage, bones, and gums; breakdown of connective tissue in gums leads to them becoming swollen; teeth loosen and fall out as the gums and the connective tissue holding teeth also begin to break down.

4 Lipids are insoluble in water, and so are transported about the body in association with proteins, in components which are either low-density lipoproteins (LDLs) or high-density lipoproteins (HDLs) according to the relative proportions of protein and lipid; diseases of the blood vessels are mainly due to a condition called atherosclerosis, which develops after LDLs are deposited under the endothelium of arteries; if such atheromas / plaques form in arteries to the heart (coronary arteries), heart disease can result; atheromas can block flow of blood to heart muscle, leading to cell death; high levels of LDLs in the blood are therefore an indicator of the risk of coronary heart disease.

5 Vitamin D is involved with the absorption of calcium and phosphorus by the body; in the absence of sufficient vitamin D, calcium and phosphorus pass out with the faeces rather than being absorbed; lack of vitamin D or calcium can affect bone mineralization; infants who are deprived of vitamin D or calcium develop rickets and have deformed bones; in the elderly, deficiency in vitamin D or calcium leads to a disease, osteomalacia, in which the bones soften.

Quick check questions (p.165)

1

Endocrine glands	Exocrine glands
These secrete hormones directly into the bloodstream. At target organs, hormones typically work by triggering changes to specific metabolic reactions	These deliver their secretions via ducts, typically into the lumen of the gut or onto the body surface
Examples • islets of Langerhans – secrete insulin, targeted at muscle and other tissues • posterior pituitary gland – secretes anti-diuretic hormone (ADH), targeted at collecting ducts of kidney tubules • gonads – secrete sex hormones, targeted at the gonads and other body tissues • pineal gland – secretes melatonin, targeted at tissues and organs that respond to our 'body clock'	Examples • sweat glands – secrete sweat onto the skin's surface • salivary glands – secrete saliva into the mouth • gastric glands – secrete gastric juice into the stomach • exocrine glands in pancreas – secrete digestive juice (of several digestive enzymes) into the duodenum

Comparing endocrine and exocrine glands

2 This avoids the risk of digestion of the body's own tissues (autolysis); active protease would digest the muscle wall of the stomach (made of protein); another example of this is the enzyme chymotrypsin produced by the pancreas, which is only active in the duodenum in the small intestine.

3 The cholera bacteria attach to the epithelium membrane, and release enterotoxin; the enterotoxin causes a loss of ions from these cells; the cholera enterotoxin consists of a 'two-protein' complex: one part is the binding protein, which attaches the toxin complex to a particular binding site – a glycolipid on the plasma membranes of intestine epithelial cells, whereas the other part is an enzyme that activates the enzyme systems of the plasma membrane of the epithelium cell to which it is attached, causing secretion of chloride ions into the gut lumen and inhibiting any uptake of sodium ions; hypersecretion of chloride ions results, and is followed by water loss; the patient loses a massive amount of body fluid; 15–20 litres may drain from the body as watery diarrhoea; this leads to severe dehydration.

4 Adaptations of the villi include: microvilli – foldings of the cell surface facing the lumen of the gut greatly increase the surface area in contact with material to be absorbed; mitochondria – present in large numbers, used to provide a significant demand for ATP in these cells; pinocytotic vesicles – the site of pinocytosis, with fluid is taken up or released in tiny vesicles across the plasma membrane of a cell; tight junctions between cells – bind together the individual epithelial cells so that the only way into the tissues of the body is through the epithelium.

Quick check questions (p.171)

1 The liver receives a dual blood supply from the hepatic portal vein and the hepatic arteries; the hepatic artery supplies the liver with oxygenated blood from the lungs; the hepatic portal vein brings blood from the stomach and small intestine, containing nutrients from digested food; most of the blood circulating in the liver comes from the hepatic portal vein.

2 Sinusoids are blood-filled channels where arterial blood mixes with blood from the hepatic portal vein as it flows through; blood flowing through the sinusoids comes into contact with liver cells (hepatocytes), and allows proteins (e.g. albumen) to enter or leave the blood; in the sinusoids, blood and liver cells are in direct contact whereas capillaries keep blood separate from the cells they pass by; sinusoids are without walls separating blood from the liver cells; sinusoids are wider than capillaries; many phagocytic cells line the sinusoids.

3 The hepatic portal vein has lower oxygen content than the hepatic artery because the blood has already travelled through other organs.

4 Glucose is converted to glycogen in the liver; raised blood glucose level causes β cells in the pancreas to be stimulated; β cells secrete insulin into the capillary network; insulin causes the uptake of glucose into cells of the liver; insulin triggers the conversion of glucose to glycogen in cells (glycogenesis).

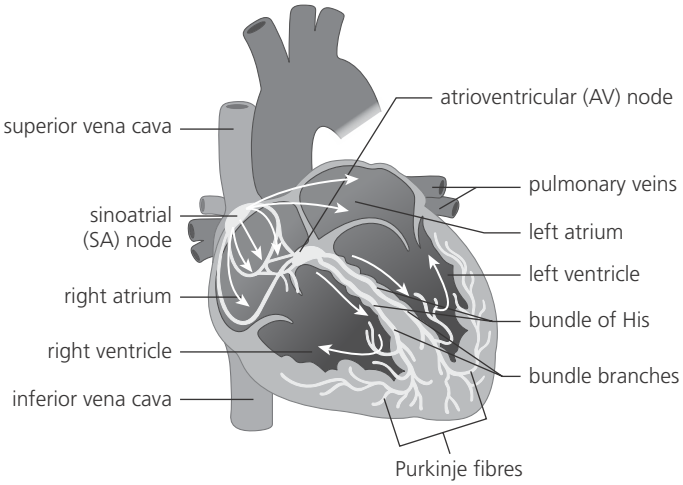
5 The rough endoplasmic reticulum (RER) with its associated ribosomes is involved in the synthesis of proteins. When proteins have been translated in the RER, they are packaged within its group of cisternae (flattened, membrane-enclosed tubes). At this stage, the proteins are non-functional. The cisterna then buds, creating vesicles that transport and deliver the proteins into the cis face of the Golgi apparatus. Once at the Golgi apparatus, the proteins will be further modified and then activated for delivery within or outside the cell.

6 Jaundice is a condition in which the skin develops a yellowish tinge along with the whites of the eye (sclera); the immediate cause of jaundice is the presence of the bile pigment bilirubin, which is formed in the liver from the heme part of hemoglobin after the iron has been removed; possible causes of this condition are: the breakdown of red blood cells at an abnormal (accelerated) rate, damage or disease of the liver, e.g. by alcohol-induced cirrhosis or due to malaria, a blocked bile duct.

   Newborn babies may suffer from jaundice briefly; the hemoglobin of the fetus, produced during its time in the uterus, is different from the hemoglobin our body forms after birth and for the rest of life; immediately after birth, the breakdown of fetal hemoglobin occurs at an accelerated rate, and bilirubin is formed more quickly than it can be broken down; this problem self-corrects quickly.

Quick check questions (p.182)

1



The structure of the heart

The drawing of the human heart must have the following considerations: atria are smaller than ventricles; thicker walls in ventricles than atria; the wall of the left ventricle is thicker than that of the right ventricle, but the cavity (blood-filled chamber) of both ventricles have the same volume; the septum clearly divides the heart into two sides; AV valves must be clearly drawn; three lines for the tricuspid and two for the mitral valve; semilunar valves in the aorta and pulmonary artery as they exit the heart.

2 a There is a direct correlation between the levels of cholesterol and the deaths caused as a result of CHD. The correlation is strong due to the increasing slope in the curve as the serum cholesterol / mmol l^{-1} increases the number of deaths. However, there could be other causes associated to the increased number of deceases.

Alternatively: Although the frequency of the highest levels of serum cholesterol in males is relatively low, the four highest bands progressively attract by far the highest levels of mortality due to CHD. However, there may be other, or additional, causes of these high levels of mortality.

b The heart rate increases as result of a vigorous exercise due to an increase in materials required by tissue cells such as oxygen and nutrients. Also, the body needs to get rid of the waste products released as a consequence of increased metabolic activity such as carbon dioxide. Levels of carbon dioxide and oxygen in the body are detected by sensors located in the carotids that send impulses to the medulla oblongata. Lower levels of oxygen cause the medulla oblongata to stimulate the pacemaker in the sinoatrial node, thus increasing the heart rate.

3 Hypertension is a condition of persistently high blood pressure.

The causes of hypertension are:

- the deposition of fat in arteries and the formation of fibrous tissue:
  - blood flow is impeded
  - the thickening of the artery wall also leads to loss of elasticity, further contributing to raised blood pressure;
- high salt content in the diet:
  - leads to greater retention of water in the body
  - as volume of blood increases, blood pressure increases;
- smoking:
  - nicotine is a vasoconstricting drug
  - when arterioles constrict, blood pressure is temporarily elevated;
- obesity and lack of exercise:
  - particularly a problem in abdominal obesity

- the direct effect on blood pressure of being overweight is not clear, but blood pressures fall again when weight is lost;

- excessive alcohol consumption:
  - the direct relationship between high alcohol consumption and hypertension is not clear, but a reversal of an alcohol drinking habit leads to lowered blood pressure.

The consequences of hypertension are that it: damages the heart, blood vessels, brain, and kidneys, without causing noticeable discomfort; accelerates onset of atherosclerosis; increases the workload of the heart and makes a brain hemorrhage more likely.

Quick check questions (p.189)

1 Hormones influence the metabolism of target cells in different ways, depending on whether the hormone is a lipid-soluble steroid hormone or a water-soluble hormone, typically a peptide; steroid hormones are lipid soluble, they diffuse from the bloodstream, through the lipid bilayer of plasma membranes and into the cytoplasm of cells; if the cell is a target cell, the steroid hormone binds to a receptor molecule which may be present in the cytoplasm or may be within the nucleus; the receptor molecule is activated and alters the expression of particular genes; peptide hormones bind to receptors in the plasma membrane of a specific target cell.

2 The binding of the hormone causes the activation of an enzyme in the membrane, called adenylate cyclase; adenylate cyclase converts ATP into cyclic AMP (cAMP) in the cytoplasm of the cell; cAMP (the second messenger) activates one or more protein kinase enzymes, present in the cytoplasm or attached to a membrane; the action of protein kinase is to add a phosphate group (from a molecule of ATP) to one or more enzymes: sometimes this activates an enzyme, whereas sometimes it inactivates the normal action of an enzyme; after a brief period, cAMP is inactivated by another enzyme, and the impact of the hormone on the cell is terminated, unless new hormone continues to bind to the plasma membrane receptors.

3 Milk secretion is controlled by oxytocin and prolactin.

Prolactin, secreted by the anterior pituitary, promotes milk secretion; during pregnancy, the concentration of prolactin starts to build up, but progesterone inhibits its effects on the mammary glands; immediately after birth of the baby, the estrogen and progesterone levels in the blood fall; the inhibition of prolactin now ends; the stimulus of the sucking action of the baby on the mother's nipples maintains prolactin secretion for as long as breastfeeding continues.

Oxytocin, secreted from the posterior pituitary, causes release of milk into the mammary ducts, from where it can be sucked out by the baby; stimulation of touch receptors in the nipple initiates sensory nerve impulses that are relayed via sensory neurons and the spinal cord to the hypothalamus; as a result of nerve impulses, release of oxytocin increases.

Quick check questions (p.198)

1 The oxygen dissociation curve is S-shaped; the amount of oxygen held by hemoglobin depends on the partial pressure of oxygen; significant changes in oxygen saturation of hemoglobin occurs over a narrow range of oxygen partial pressures; the range represents oxygen partial pressure surrounding cells undergoing normal metabolism; at low partial pressure (in e.g. respiring tissues) oxygen will dissociate from hemoglobin; at high partial pressures (e.g. in the lung alveoli) the hemoglobin will become saturated; the curve is sigmoid because the binding of the first O_2 increases the affinity of other hemoglobin binding sites for oxygen; the steep part of the curve indicates that a small reduction in the partial pressure of oxygen will lead to an increase in oxygen unloaded; where the curve is flattest means that a large reduction in the partial pressure of oxygen will lead to a reduction in O_2 saturation of hemoglobin (e.g. at high altitude); the hemoglobin in red cells in the capillaries around the alveoli in the lungs will be about 95% saturated; in respiring tissues, the oxygen partial pressure is much lower due to aerobic respiration there; the oxygen partial pressure in actively respiring tissues may be 0.0–4.0 kPa: at these partial pressures, oxyhemoglobin breaks down and oxygen is released in solution which rapidly diffuses into the surrounding tissues.

2 **Pneumocytes**: extremely thin cells made of squamous tissue cells; they have a nucleus, clustered mitochondria, RER, and Golgi apparatus, with a clear, almost transparent cytoplasm.

Capillary endothelium cells: extremely thin layer of cells but with strong walls due to the presence of collagen fibres; the endothelium is made of a monolayer of cells with a clear and distinguishable nucleus located in the middle region of the cell.

Blood cells: red blood cells have a biconcave disc shape; they lack nuclei and have wider edges with a depressed central area.

3 At a pressure of 1 kPa, the percentage of saturation in hemoglobin is lower than 10%; myoglobin on the other hand, is close to an 80% of saturation; for a partial pressure of 5 kPa, hemoglobin is approximately 70% saturated and myoglobin has a value near to 100% (plateau); these differences allow muscles to contract using aerobic respiration with its large yield of energy; myoglobin works as an oxygen store that is used when the pressure is lower than 5 kPa, releasing the oxygen into the tissue and allowing for prolonged muscular contractions.

4 This training method allow competitors to produce more red blood cells per volume of blood and, when they return to lower altitudes their body will have a greater oxygen saturation due to the greater number of blood cells. This effect lasts for only a short period of time (days) and it is debatable whether it does give athletes an advantage, as they have a higher heart rate when training at high altitudes to get sufficient oxygen to their muscles.