Topic 1 Molecules, transport and health
1A Chemistry for biologists

1A Checkpoint

1A.1 The chemistry of life

1 In some covalent compounds, the electrons in the covalent bonds are not quite evenly shared. This means the molecule has a part that is slightly negative and a part that is slightly positive. This separation of charge is called a dipole, and the tiny charges are represented as δ^+ and δ^-. A molecule containing dipoles is known as a polar molecule. Dipoles are particularly common if one or more hydrogen atoms are involved in the bond.

2 Ionic substances: formed when atoms are joined by ionic bonds. The positive or negative ions formed when the atoms lose or gain electrons form an ionic compound.

Polar substances: compounds formed with covalent bonds where there is a slightly unequal sharing of the electrons across the bond, giving a covalent molecule with slight dipoles that can affect intermolecular bonding.

3 Water is a polar molecule because the electrons are held closer to the oxygen atom than to the hydrogen atoms, so the oxygen has a very small negative charge and the hydrogen atoms have very small positive charges. As a result, the slightly negative region of one water molecule is attracted to the slightly positive region of another water molecule, and this weak electrostatic attraction is a hydrogen bond. Therefore, water has relatively high melting and boiling points and solid water is less dense than liquid water.

4 Excellent solvent: Its covalent nature means water dissolves covalent compounds, its polar nature means it dissolves ionic compounds, so it is an ideal solvent for chemical reactions in biological systems and makes an excellent transport medium.

It is slow to absorb and release heat so is a very stable medium for life.

It is a liquid at room temperature so cannot be compressed, therefore it can be used in hydraulic systems.

Water molecules are cohesive (stick together) and adhesive (stick to other substances). Both are important properties in the movement of water up the xylem of plants.

High surface tension means that the water surface acts as a skin; this is very important in water being drawn up the phloem of a plant and for life at the surface of ponds, lakes and other water masses.

Also award marks for any other sensible points.

1A.2 Carbohydrates 1: monosaccharides and disaccharides

1 Carbohydrates are important in cells as a usable energy source. They are also important for storing energy, and in plants, fungi and bacteria they form an important part of the cell wall. The basic structure of all carbohydrates is the same. They are made up of carbon, hydrogen and oxygen. There are three main groups of carbohydrates with varying complexity of molecules: monosaccharides, disaccharides and polysaccharides.

2 A glycosidic bond is formed by the removal of a hydrogen atom (–H) from one monosaccharide and a hydroxyl group (–OH) from another monosaccharide to form a disaccharide and water.

1A.3 Carbohydrates 2 – polysaccharides

1 Sucrose (a disaccharide) is easily broken down to form glucose. Glucose has a chemical structure which means it can be broken down completely with oxygen to produce carbon dioxide and water and ATP which supplies the energy needed in the chemical reactions in cells. These sugars are not suitable for long-term storage because they are too chemically active and because they are very soluble in water, so they will affect the water balance of the cell.

2 Starch is formed from amylose, which is a straight-chain molecule, and amylopectin, which is a branched-chain molecule. Both are formed from alpha glucose molecules joined by 1-4 or 1-6 glycosidic bonds, and result in compact globular molecules. Cellulose is formed from beta glucose molecules held together by 1-4 glycosidic bonds. As a result, cellulose has hydroxyl molecules sticking out on either side of the molecule, so hydrogen bonds form easily between the individual, long, straight chain molecules, holding them together and making cellulose very strong. Animals can digest starch, breaking it down into glucose, which can be used in cellular respiration. Most animals do not make the enzymes needed to digest cellulose, so it is not usually an energy-providing food for animals unless their digestive system contains bacteria that do have the enzymes needed to break down the cellulose molecules into glucose.

1A.4 Lipids

1 Triglycerides are formed by condensation reactions between one glycerol molecule and three fatty acids. As each of the three ester bonds is formed, one molecule of water is lost.

2 A saturated lipid contains fatty acids that only have single bonds between the carbon atoms in the chain. An unsaturated lipid contains fatty acids that have one or more double bonds within their carbon chain. This means that saturated lipids are more likely to be solids at room temperature. In the body, saturated and unsaturated lipids have different effects, e.g. saturated fatty acids in the diet are more likely to lead to plaque forming in arteries.

1A.5 Proteins

1 The structure of a protein is determined by a variety of bonds between amino acids within the polypeptide chains. Different amino acids can form different weaker bonds (such as hydrogen bonds, sulfide bonds and ionic bonds) with other amino acids, depending on how they are placed in the amino acid chain of the protein. These bonds determine the secondary, tertiary and (possibly) quaternary structure of the protein. So, a change in a single amino acid can alter the structure of the whole protein.

2 There are many more hydrogen bonds because they can form between any two amino acids.

3 The tasks that proteins carry out in the body are often dependent on their three-

dimensional shape. The weak bonds between amino acids in the protein create this shape. These bonds may be affected by changes in conditions, such as temperature and pH, which will change how well the protein works. So, for good protein functioning, conditions need to be kept stable.

1A Exam practice

1 (a) C

(b) (i) hydrogen bond

(ii) It is a polar molecule.

(iii) The cohesion of water molecules in the transpiration stream; producing surface tension that can be a habitat for insects such as pond skaters.

(c) It takes a lot of heat to alter the temperature of a body of water. Therefore, ponds and lakes have a stable temperature which enables life to survive. It was also important for evolution of life.

(d) Polar water molecules surround the sodium chloride. The sodium chloride molecule splits into two ions. The negative chloride ion is attracted to the positive end of the water molecules and the positive sodium ion is attracted to the negative end of the water molecules.

2 (a) D

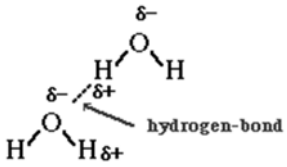
(b) B

(c) Water is a solvent for the water-based ink, so it dissolved the ink causing it to smudge. However, biro is *not* water based, so did not dissolve and therefore did not smudge.

(d) Any **two** from the following:

- Graphite in pencil lead is a non-polar substance.
- Graphite will not dissolve or smudge in water.
- Graphite will not dissolve or smudge in other solvents such as alcohol.

(e)



3 (a) A

(b) C

(c)

	Lactose	**Maltose**	**Amylose**
Component monosaccharides	Glucose and galactose	Glucose	Glucose
Bonds between monosaccharides	β 1–4	α 1–4	α 1–4

4 (a) C

(b) C

(c) Students' answers should include reference to the following:

- breaking of glycosidic bond

- addition of/ using water
- breaking large molecule(s)/ (named) disaccharide/ (named) polysaccharide into smaller molecules/(named) monosaccharide/ (named) disaccharide
- reference to hydrolytic/ named enzyme.

(d) Glycogen stores energy in animals.

It is a polysaccharide made from many alpha glucose molecules.

It is large and insoluble, so will not affect the water potential of the cell.

It is branched and coiled making it compact so it takes up little space.

It has many terminal sugars, so glucose molecules can be released quickly when extra energy is needed.

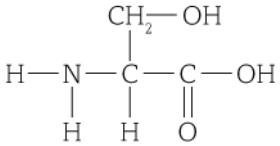
5 (a) B

(b) D

(c) (i) The sequence of amino acids.

(ii) hydrolysis

(d)



(e)

Difference	Collagen	Haemoglobin
1	Fibrous protein	Globular protein
2	Three polypeptides	Four polypeptides
3	Not conjugated	Conjugated with haem groups attached

6 (a)

Description	Level of protein structure (primary, secondary, tertiary or quaternary)
Hydrophobic amino acids such as proline are not found on the surface of the protein molecule.	Tertiary
The molecule contains three polypeptide chains.	Quaternary
The protein molecule contains short helical sections separated by pleated sheets.	Secondary
40% of the amino acids in the molecule are glutamine.	Primary

(b) The R group affects the tertiary structure; attraction or repulsion between R groups; bends or folds the protein; reference to hydrogen/ionic/covalent bonding.

(c) Globular proteins have a specific three-dimensional shape, they have a complementary shape which matches the shape of other molecules. Examples: hormones fit receptor sites, enzymes fit substrate molecules, fibrous proteins tend to be straight and form structures.

1B Mammalian transport systems

1B Checkpoint

1B.1 The principles of circulation

1 The surface area of skin is not large enough in comparison with the volume of the animal (surface area:volume ratio too small) to supply all that the animal needs within its body by diffusion.

The diffusion distances are too long, so substances would take too long to diffuse to the cells in the centre of the body.

The metabolic rate of large organisms tends to be relatively high so their requirements for oxygen and food and amount of waste produced is too high for simple diffusion.

2 Students' answers should include reference to:

- a system of vessels to carry substances – usually tubes, sometimes following specific routes, sometimes widespread and branching
- a way of ensuring that substances move in the right direction
- a means of moving materials fast enough to supply the needs of the organism, e.g. heart, OR a way of maintaining a concentration gradient so substances move rapidly in the right direction, e.g. active transport to move other ions
- a suitable transport medium.

3 Because fish only have a single circulation, where the blood passes through the delicate tissues of the gills before going directly to the rest of the body high pressure would damage the gills. This doesn't matter because fish do not maintain their body temperature above that of the environment, so their rate of metabolism is lower than that of mammals and birds. As a result, their cells need less oxygen and produce less carbon dioxide.

4 These animals need a higher rate of metabolism to provide the energy needed for rapid movement against gravity and to provide heat. They need to supply plenty of oxygen to body cells more quickly in order to maintain a higher rate of respiration (and carbon dioxide needs to be removed from body cells faster too, so it does not build up and become toxic). This raised metabolism means that extra heat needs to be dissipated. A double circulation means that the pressure of blood sent around the body can be higher than that to the lungs. So, the delicate tissue of the lungs isn't damaged, but oxygen is delivered to body cells (and carbon dioxide removed) very efficiently and rapidly.

1B.2 The roles of the blood

1 As red blood cells do not have a nucleus, they have more space within the cell membrane and so can contain more haemoglobin. This makes them more effective as carriers of oxygen to cells. The nucleus contains the instructions for the cell, including its maintenance if it gets damaged. Without a nucleus, there are no instructions for mending blood cells, so they have a shorter life-span than other cells.

2 In the lungs, carbon dioxide diffuses out of the red blood cells and plasma in the

capillaries down a concentration gradient into the alveoli, and oxygen diffuses from the alveoli down a concentration gradient into the red blood cells in the capillaries. In the rest of the body, oxygen diffuses out of the red blood cells in the capillaries down a concentration gradient into the cells, while carbon dioxide diffuses out of the cells down a concentration gradient into the plasma and red blood cells in the capillaries.

3 Fetal haemoglobin has a higher affinity for oxygen than adult haemoglobin, which means that the fetal blood becomes oxygenated when it runs close to the mother's blood in the placenta, as the fetal haemoglobin combines with oxygen from the adult haemoglobin.

4 Similarities:

- Both are precursors – they are converted to another molecule as part of the clotting cascade by enzymes.
- Both are plasma proteins carried around the body in the plasma.

Differences:

- Prothrombin is a precursor of an enzyme. It is converted into the active enzyme thrombin in the clotting cascade. Both molecules are soluble.
- Fibrinogen is the soluble precursor of fibrin, an insoluble protein. The reaction is catalysed by the enzyme thrombin produced from prothrombin.

5 Vitamin K is important in the blood-clotting cascade; for example, it is needed to make prothrombin. The excessive bleeding in the rare condition may be linked to a failure of the clotting cascade as a result of a lack of vitamin K. By supplying all new-borns with vitamin K, the babies who would otherwise suffer severe bleeding and perhaps die are protected because their clotting cascade can function.

1B.3 Circulation in the blood vessels

1 The blood in arteries is constantly being pushed away from the heart by the pressure of more blood coming out of the heart and by the elastic recoil of the arteries themselves. So, there is no backflow in arteries. In veins, blood pressure is much lower, the force of blood leaving the heart has little effect and the blood is mostly flowing against the force of gravity up the body to the heart. As a result, backflow is much more likely. Valves in the veins prevent this by closing as blood tries to flow backwards.

2 Arteries – carry blood away from the heart; usually carry oxygenated blood towards the cells of the body; have relatively high blood pressure, a relatively small lumen, smooth lining, a thick layer of elastic fibres and smooth muscle to absorb the pressure from the pumping of the heart and give elastic recoil so the artery returns to shape after the pulse of blood passes, and an external layer of connective tissue to maintain shape.

Veins – carry blood towards the heart; usually carry deoxygenated blood; have large lumen to carry a large volume of blood, relatively low blood pressure, a thin layer of smooth muscle with few elastic fibres, an outer layer of connective tissue, no pulse, and valves to prevent the backflow of blood.

Capillaries – link the arterial and venous system; provide enormous surface area for the diffusion of oxygen and dissolved food from the blood into the cells and waste products including carbon dioxide from the cells into the blood; have a very small diameter and a wall that is a single cell thick, with relatively loose junctions that penetrate between body cells.

Award marks for any other sensible points.

3 The graph shows that blood pressure is highest in the arteries, drops rapidly in the arterioles and in the capillaries, and remains low in the venules and veins. The velocity of the blood is highest in the arteries, decreases in the arterioles and falls to a low level in the capillaries then increases again in the venules and veins. The total surface area of blood vessels is low in the arteries, increases in the arterioles to its highest level in the capillaries then decreases again through the venules to a low level in the veins.

Velocity is inversely related to surface area which causes friction (resistance to flow). So, it is greatest in the arteries where blood pressure is greatest and surface area lowest, lowest in the capillaries where there is the largest surface area and so greatest resistance to flow, and greater again in the veins where surface area increases again, though not as great as in arteries because blood pressure is lower.

1B.4 The mammalian heart

1 Body capillaries to venules, to veins to venae cavae, to right atrium to right ventricle, to pulmonary arteries (blood is deoxygenated up to this point), pulmonary arteries to lung capillaries (blood is oxygenated in lung capillaries), lung capillaries to pulmonary veins, to left atrium to left ventricle, to aorta to arteries, to arterioles (all oxygenated) and to body capillaries (blood is deoxygenated in body capillaries).

2

(a) Semilunar valves are the valves between the ventricles and the blood vessels leaving them. They are called semilunar because of their shape and are formed from folds of the inner walls. They prevent backflow of blood when the heart relaxes by closing off the lumen.

(b) The muscle walls of the atria are thinner than those of the ventricles because they only have to push the blood into the ventricles, while the ventricles have to push blood out around the two circulations.

(c) The muscle wall of the left ventricle is thicker than that of the right because it has to provide the force that pushes the blood all around the body, not just to the lungs as the right ventricle does. The left side has to provide high pressure and overcome the elastic recoil of the arterial system.

(d) The tendinous cords are tough, to withstand the strain when the ventricles are receiving blood from the atria and the cords are stretched, and to make sure the valves are not turned inside out when the ventricles contract.

1B.5 Atherosclerosis

1 Plaque formation can be caused by damage to the endothelial lining of an artery. This increases blood pressure making further damage more likely, so more plaques form, and so on. Increased blood pressure can result in many problems in the kidneys, eyes and brain, as well as aneurysms. Decreased blood flow through arteries partly blocked with plaques is dangerous in the coronary arteries and in the brain where it may cause damage to tissue beyond the blockage. Clots may form, causing complete blockage of the blood vessel, which can be catastrophic.

2 (a) Atherosclerosis increases the risk of cardiovascular disease in a number of ways:

- Atherosclerosis narrows and/or stiffens the blood vessels, raising blood pressure. Raised blood pressure can damage small capillaries and increases the risk of damage to the endothelial lining.
- Damage to the endothelial lining or an atheroma itself can attract platelets that can trigger the clotting cascade, including the release of

thromboplastin, which catalyses the formation of thrombin from prothrombin, which then catalyses the formation of fibrin from fibrinogen in the blood. The fibrin produces a mesh that traps red blood cells and forms a clot. The clot may then block a blood vessel causing a thrombosis. In a coronary artery, this can lead to a heart attack; in the brain, this may cause a stroke.

- Award marks for any other sensible points, including the impact of high blood pressure caused by atheroma on health.

(b) Similarities: both may be caused by a blood clot (thrombosis) or the formation of an atheroma, or a combination of both; both may be fatal or cause long-term damage to health.

Differences: heart attack produces chest pain and may be triggered by exercise; stroke may affect many parts of the body through the damage caused to the brain and may also be caused by bleeding in the brain after an aneurysm bursts.

3 Students' plans should present the key information of how plaques are formed, how they cause reduced blood flow and increase blood pressure, and what the results of these may be, in a simple and clear way that is appropriate for young people.

1B Exam practice

1 (a) A

(b) Students' diagrams should include the following:

- thick wall drawn
- two/ three/ four layers indicated.

Plus two from the following, correctly labelled:

- lumen
- endothelium/ epithelium/ endothelial layer/ epithelial layer/ tunica intima
- (smooth) muscle/ elastic fibres/ elastin/ tunica media
- connective tissue/ tunica adventitia.

(c) Any two from:

- idea of wide wall/ eq (to withstand) blood under high pressure
- reference to narrow lumen to maintain high pressure
- reference to presence of elastic fibres/ eq to allow vessel to stretch
- recoil maintains pressure/ squeezes blood
- reference to (smooth) muscle contracts to squeeze/ eq blood along
- idea that smooth lining/ eq reduces friction
- folded lining/ eq to allow artery to stretch/ eq.

(d) Any two from:

- (walls of) veins more than one layer of cells and capillaries one layer/eq
- (walls of) veins contain connective tissue/(smooth) muscle/collagen/elastic tissue, capillaries do not/eq
- veins have valves in them and capillaries do not/eq
- veins do not have pores but capillaries do/eq
- veins have wide lumen, capillaries have narrow lumen/eq.

2 (a) C

(b)

Name of blood vessel	Carries blood away from the	Carries oxygenated
Aorta	✓	✓
Vena cava	×	×
Pulmonary artery	✓	×
Pulmonary vein	×	✓

(c) A: aorta/ aortic arch; B: tricuspid valve

(d) Students' answers should include the following points:

- reference to coronary circulation

- reference to coronary artery/coronary arteries
- reference to capillaries (in wall of heart)
- oxygen transported/eq by red cells/haemoglobin
- oxygen diffuses out of blood/red cells/capillaries (to heart muscle).

(e) $0.07 \times 72 = 5\ dm^3$

3 (a) D

(b) (i) Any three from:

- (blood flows) from heart to gills
- (blood flows) from gills to (rest of) body/ eq
- (blood flows) from body back to heart
- reference to single circulation.

(ii) Students' answers should include reference to:

- keeps oxygenated and deoxygenated blood separate
- allows higher pressure in systemic circuit
- providing more rapid supply of oxygen to tissues
- mammals can be more active in colder temperatures.

(c) Students answers should include:

- passive filling
- the atria and ventricles are relaxing
- blood enters the atria, passes through the atrioventricular valves into the ventricles
- atrial systole – the atrial walls contract to push extra blood into the ventricles
- ventricular systole – the walls of the ventricles contract. This closes the atrioventricular valves. Pressure rises and pushes the semilunar valves open. Blood is forces from the ventricles into the main arteries.

4 (a) (i) 0.6 to 0.65 for myoglobin and approx. 3 for haemoglobin
(ii) 94 − 24 = 70%

(b) Myoglobin is an extra store of oxygen. Myoglobin has a higher affinity for oxygen than haemoglobin. As oxyhaemoglobin releases oxygen the myoglobin holds its oxygen. Myoglobin releases oxygen when the partial pressure is very low.

(c) Students' answers should include the following points:

- the idea that respiring tissues/cells produce carbon dioxide
- reference to reduced affinity for oxygen
- oxygen is released (more) readily/ (more) oxygen is released/ haemoglobin is less saturated with oxygen/ percentage saturation decreases/ eq
- at a given/ the same partial pressure of oxygen/ eq
- (oxygen released) to tissues/ cells/ muscle/ eq.

5 (a) (i) (11/32) × 100 = 34.4%

(ii) The left ventricle wall is much thicker to create higher pressure. It needs to pump blood further against greater resistance.

(b) Semilunar valves close to prevent backflow of blood from the major arteries to the ventricles. When the ventricles contract the valves are pushed open to allow blood to be forced into the major arteries. When the ventricles relax the ventricular pressure falls below the pressure in the major arteries and this pushes the valves shut again.

(c) The tendinous chords attach the valves to the walls of the ventricles. They prevent the valves from opening the wrong way allowing blood to be forced up into the atria.

6

(a) Clotting factor (thromboplastin) is released when platelets come into contact with collagen from the blood vessel wall. Thromboplastin converts inactive prothrombin to the active form thrombin. Thrombin then catalyses the conversion of soluble fibrinogen to insoluble fibres. These fibres then form a clot. Other clotting factors are required to activate prothrombin.

(b) A clot in a blood vessel is known as a thrombus. It can block a blood vessel, reducing blood flow. In the coronary arteries this can cause a heart attack. In the brain this can cause a stroke.

(c) An aneurism is a swelling or bulge in an artery wall. Continued high blood pressure and a weakened wall will allow the artery wall to bulge.

7 (a) (i) A

(ii) D

(iii) carbonic acid

(iv) H^+ / hydrogen ion

(b) (i) combines with haemoglobin, to produce haemoglobinic acid

(ii) reduces affinity of haemoglobin for oxygen, more oxygen released to tissues.

1C Cardiovascular health and risk

1C Checkpoint

1C.1 Risk, correlation and cause

1 Risk describes the probability that an event will happen; correlation is when two different sets of data appear to be similar or linked in some way; causation is when an event, act or behaviour directly causes a specific result.

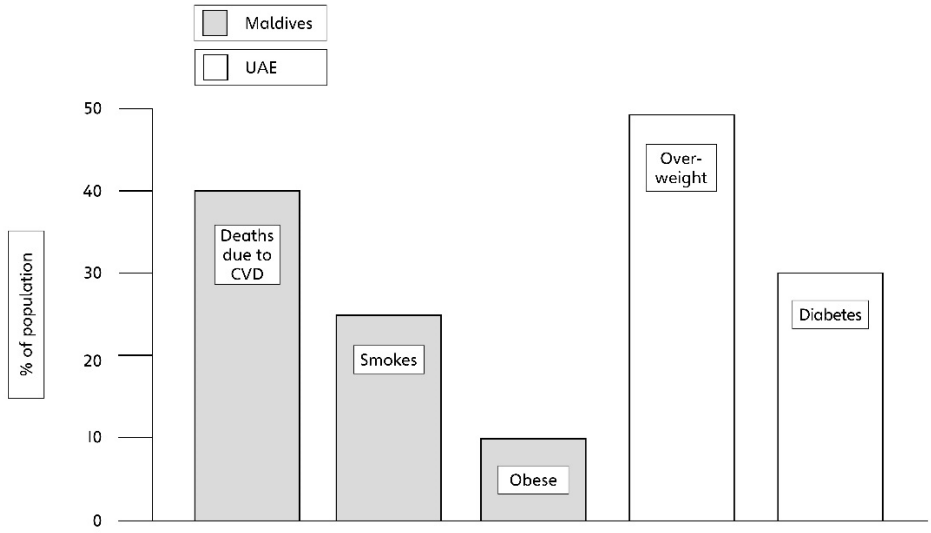
2 There are many other causes of death than those related to smoking. A smoker may die from one of these before a smoking-related disease kills him or her. Some smokers will have their smoking-related disease cured. Not all smokers are adversely affected by smoking – their genetic make-up may mean smoking-related diseases will not affect them.

Award marks for any other sensible points.

3 Stay obese: people stay obese because it is hard to lose weight; they like to eat; it isn't always easy to take exercise; they minimise the risk and assume they will not have problems.

More becoming obese: modern food is often high in fats and so high in calories; people do less physical exercise as they drive rather than walk; many jobs are becoming less physical with computers and machines; people spend a lot of time at computers and TVs, so not doing exercise, etc.

4 Maldives has a higher percentage of the population dying of CVD relative to UAE but a similar incidence of obesity. The data shows that 25% of the population in Maldives smoke, and we also know there are many people who are overweight and with diabetes in the UAE. To make realistic comparisons, we need information about smokers in the UAE and the size of the overweight population and percentage with diabetes in Maldives.



1C.2 Investigating the causes of CVDs

1 Use large sample sizes; carry out the study over many years; try to isolate the factor being studied keeping all other factors constant if possible.

2

(a) A greater proportion of identical twins both die from heart disease than fraternal twins, in all age groups measured. As identical twins have identical genes, and fraternal twins do not, this suggests that there is a genetic link to heart disease, though this is probably not the only factor (otherwise the values for identical twins would be much higher).

(b) Heritability is greater in younger men. The apparent fall as men get older may be due to the chances of them dying from other, age-related diseases or accidents before they die from heart disease. Or the fact that everyone is more likely to be affected by heart disease as they get older.

1C.3 Risk factors for cardiovascular disease

1 Non-modifiable risk factors are beyond your control, while modifiable risk factors are factors you can do something about.

2 (a) Non-modifiable – any two from: genes, age, sex.

Modifiable – any two from: smoking, exercise, weight, stress, diet, or any other sensible lifestyle factor.

(b) For each factor given, students must provide a clear explanation of the link to atherosclerosis and CVDs.

3 (a)

Income of countries	Low	Low/middle	High/middle	High
Deaths per 100,000 population	91	173	235	253

(b) Make a bar graph of the above data with ‘Deaths per 100,000 population’ on x axis.

(c) Three reasons from:

People in poorer countries are …

- less likely to be obese
- more likely to do a lot of physical work
- likely to do a lot more exercise in terms of walking where cars not available, no TVs etc
- less likely to eat rich, fatty food
- may smoke less because of cost
- any other sensible points.

1C.4 Diet and cardiovascular health

1 BMI is body mass index, which is a comparison of weight and height.

2 Ali's BMI is 23.03, which is ideal.

3 (a) About 9 stone 7 lbs to 13 stone (*c*. 60 kg to *c*. 82 kg)

(b) About 7 stone 3 lbs to 9 stone 11 lbs (*c*. 45 kg to *c*. 62 kg)

(c) 6 feet is considered obese from *c*. 15 stone 9 lbs (*c*. 98 kg); 1 m 58 cm is considered obese from *c.* 11 stone 12 lbs (*c.* 75 kg).

4 (a) BMI does not take into account natural changes in body composition with age, does not allow for people who are very fit and active and have high muscle mass and therefore can overestimate risk for some people.

(b) Waist to hip ratio is waist size (cm) / hip size (cm). Easy to measure, obvious changes with gain or loss in weight, good predictor of heart disease risk as measures fat.

5 (a) Apparent correlation between high intake of dietary fat and raised blood cholesterol. However, this is now regarded as over-simplistic as it depends on many other factors including exercise, type of fats, other dietary factors, genetics, etc. Also discovered **low-density lipoproteins (LDLs)**, made from *saturated* fats, cholesterol and protein, which bind to cell membranes before being taken into the cells. If levels of some types of LDLs are high, your cell membranes become saturated and so more LDL cholesterol is left in your blood. **High-density lipoproteins** (**HDLs)** are made from *unsaturated* fats, cholesterol and protein. They carry cholesterol from body tissues to the liver to be broken down, lowering blood cholesterol levels. HDLs can even help to remove cholesterol from fatty plaques on the arteries, reducing the risk of atherosclerosis. So, the balance between HDLs and LDLs seems a better indicator of risk of CVDs than cholesterol alone.

(b) Heart disease is multifactorial – not the result of any one factor in your lifestyle and genetics. The more information scientists have, the more realistically they can estimate the risk of an individual developing heart disease.

6 Confusion – people expect scientists to give them a clear answer, but scientists are constantly changing their ideas in line with evolving evidence. People who had changed their eating habits – e.g. reduced the levels of fat in their diets – to help reduce the risk of heart disease, could be expected to be upset to find they might have made no difference.

People who were pleased – had either never bothered to change to try and eat more healthily or felt they could add fatty food they enjoyed back into their diet. Any other sensible point.

1C.5 Dietary antioxidants and cardiovascular disease

1 (a) 10% reduction
(b) 25% reduction

2 The evidence of the fruit and vegetables shows a correlation between an activity and an outcome. The evidence for the effect of antioxidants on heart disease is trying to find a causal mechanism for the correlation observed.

3 Look for points such as using the same concentration of DCPIP in each case, some volume of fruit juice from each fruit, repeat measurements and taking a mean, etc.

1C.6 Using the evidence

1 Losing weight is easier to organise and fit into daily life than increasing activity levels.

2 The two groups have very different lifestyles and are likely to be genetically different, so there may be other factors that are causing the difference in blood pressure.

3 Some people will overestimate and some underestimate the risk because most people don't know whether their blood pressure is affected by salt or not. Some people will listen to health warnings, or be told their blood pressure is raised, and be very concerned about their salt levels. Others will be unaware of the amount of hidden salt they eat and think they are alright or feel that people have eaten salt for centuries and come to no harm.

4 Whether we like salty foods or not is most likely to affect how much we eat of them. Also, if we eat a lot of processed food, which contains a lot of hidden salt, we may be oblivious to our salt intake.

5 Many possible answers but must be supported by reasonable argument. For example: it is a waste of money as most people do what they feel happiest with and ignore the advice; it is money well spent as the more people who live healthily, the fewer will need treatment for these diseases later.

1C.7 The benefits and risks of treatment

1 If the side-effects of the medication are unpleasant and affect daily life too much, the patient may give up on the treatment because their perceived risk of the reason for taking the medication (in other words, the dangers of the illness) may be much lower than the actual risk. Also, the perceived risk of taking the medication and experiencing side-effects may be much higher than the actual risk.

2 The meta-analysis published in a journal has looked at a large number of studies, which increases the reliability of the findings. A daily dose of plant sterols reduces LDL cholesterol.

3 (a) So that some patients don't receive the treatment (without realising it) and this is the only factor that is different between the treatment group and control group.

(b) Patients taking the placebo don't get the benefits of taking the drug (if there are any). Possible reason for placebos being unethical include where those receiving the placebo suffer more or are more likely to die during the drug trial.

4 (a) People with a high HDL level have plenty of 'good' cholesterol already. So, lowering the level of the LDLs will give them a very healthy balance in their blood.

(b) The best groups to treat are those which will receive the greatest benefit, such as smokers and women in this ethnic group.

1C Exam practice

1 (a) C

(b) Multifactorial means that many factors contribute to the development of a disease, atherosclerosis is not caused by one factor.

(c) (i) C

(ii) No carbohydrate means less energy intake, so weight loss is possible. Fat eaten will replace the energy in the diet. Need to eat polyunsaturated fats, avoid eating saturated fats. Low fibre diet may increase absorption of fats, high saturated fat could cause more atherosclerosis.

2 (a) Correlation means that as one factor changes another factor also changes. Cause means that the change in one factor makes the other factor change. Correlation may be a result of cause, however there may be a third factor that causes both the others to change.

(b) Large numbers of participants; designed and carried out by independent scientists; data come from reliable sources that have been accurately recorded.

(c) area of lumen = πr^2

area = $3.142 \times 0.5^2 = 0.785\ mm^2$

The atheroma takes up approximately half this area – so the area of the atheroma is $0.785/2 = 0.393 mm^2$

3 (a) B

(b) The artery at C supplies blood to a larger part of the ventricle than either B or A. Larger part of ventricle would be starved of oxygen. Larger part of ventricle muscle could die. May cause cardiac arrest.

(c) (i) smoking increases risk; in men of all ages; risk is doubled for men under 45; increase in risk is much smaller for older men.

(ii) not many women of that age smoke OR recoding of data was not reliable.

(iii) A

(iv) % increase in men = $100 \times (8.2 - 6.0) / 6 = 36.7\%$

% increase in women = $1.8 \times 1.367 = 2.5\%$

4 (a) High blood pressure; leads to damage to lining of artery wall; split in endothelium leads to deposition of fatty substances to repair wall.

(b) Reduced lumen of coronary artery; reduces blood flow to ventricle muscle; less delivery of oxygen to muscle; blood clot or thrombus can block artery; stops blood flow and oxygen delivery; muscle dies.

(c) 44.7% = 380, therefore number of people in survey = $100 \times 380/44.7 = 850$ people. 38% of 850 = 323 people had diabetes.

% with high blood cholesterol = $100 \times 212/850 = 24.9\%$

(d) Two of:

- genetic factors (disposition)
- obesity

- smoking
- high salt diet
- diet high in saturated fats
- poverty.

5 (a) Perception of risk depends on how familiar people are with the activity, how much they enjoy the activity and whether or not they approve of the activity.

(b) (i) C

(ii) Lose weight; exercise more; modify diet to eat more vegetables and less red meat.

(iii) Waist to hip ratio.

(c) Student answers could include the following points:

- food is relatively cheap
- many people may eat ready-prepared meals that are often very high in energy content
- advertising
- many people eat out in fast food restaurants
- over dependence on cars rather than walking.

6 (a) They will reduce chance of a thrombus forming, so a clot is less likely to get caught in a narrowed artery.

(b) Student answers should include the following:

- antihypertensives will reduce blood pressure
- so, there is less chance of damaging the artery walls
- statins reduce blood cholesterol levels
- so, less likely to be deposited in artery walls
- these treatments mask the cause
- it would be better to educate people to lose weight, eat more healthily, get more exercise
- this would be cheaper for the health services.

(c) (i) Student answers should include the following:

- pieces of fruit reduce risk to 0.9 on the relative risk scale
- reduces risk compared to 4 or fewer pieces
- 6 pieces do not reduce risk any further
- therefore 5 pieces seems a suitable number to recommend.

(ii) 7 pieces does reduce risk further, to 0.7 on the relative risk scale; this suggests that recommending 7 pieces of day would bring greater benefits.

Topic 2 Membranes, proteins, DNA and gene expression
2A Membranes and transport

2A Checkpoint

2A.1 Cell membranes

1 Phospholipids make up the main bilayer of the membrane, separating an aqueous layer on one side from an aqueous layer on the other, by a hydrophobic region that makes diffusion difficult for substances that are not lipid-soluble or very small.

Large proteins that sit within or across the membrane act as controls or gates for the passage of ionic and larger molecules across the membrane.

Glycoproteins on the outside of the membrane are part of the cell recognition system.

2 Unsaturated fatty acids contain at least one double bond in the carbon chain. The nature of any lipid is based on the balance of unsaturated and saturated fatty acids – saturated fatty acids make compounds more solid, and unsaturated fatty acids are more flexible molecules and make substances more fluid or even liquid. So, a membrane containing a lot of unsaturated fatty acids will be more fluid than one containing a lot of saturated fatty acids and cholesterol.

3 Any three of the following.

Evidence: lipid-soluble substances pass through membranes more easily than other substances; model: a large part of membranes must be made of lipids.

Evidence: membranes join when cells join together, and most membranes seal themselves after puncturing with a fine needle; model: the membrane must be fairly fluid and the molecules in them able to move about a little.

Evidence: phospholipids at an air/ water surface form a monolayer with hydrophilic ends in the water and hydrophobic tails in the air; model: phospholipids will form layers that arrange the hydrophobic ends in aqueous solutions, keeping the hydrophobic tails hidden away from the solutions.

Evidence: lipids extracted from red blood cells cover an area about twice the size of the cell; model: the membrane must be a lipid bilayer.

Evidence: larger uncharged molecules and ionic molecules can only cross the membrane if protein channels exist; model: there are protein molecules in the lipid bilayer that act as channels or carriers.

2A.2 Cell transport and diffusion

1 The properties of the membrane and the properties of the substances entering or leaving a cell (such as their size, their solubility in water or lipids and their charge), mean that many substances cannot cross cell membranes by simple diffusion. Concentration gradients across cell membranes can also prevent movement by simple diffusion. Any substances that cannot cross a cell membrane by diffusion need a specific transport system, whether carrier molecules or specific pores, to get from one side of the membrane to the other.

2 The molecules need to be able to cross the membrane, and there needs to be a concentration gradient for those molecules from one side of the membrane to the other.

3 Water can't pass across the hydrophobic region in the middle of the membrane, and ions are not lipid-soluble.

4 Simple diffusion is through the lipid part of the membrane, so can happen at any part of the membrane. Facilitated diffusion can only happen where there are suitable carriers in the membrane.

2A.3 Osmosis – a special case of diffusion

1 Students' definitions must include wording that covers the net movement of water/ across a partially permeable membrane/ by diffusion/ down a water concentration gradient, with suitable examples chosen.

2 Isotonic: there would be no change to the cells because as many water molecules would diffuse into the cells from the solution as in the opposite direction.

Hypotonic: the cytoplasm of the cells is more concentrated than the solution outside the cells, so more water molecules would diffuse into the cells than out of them, and the cells would swell up and possibly burst.

Hypertonic: the cytoplasm of the cells is more dilute than the solution outside the cells, so more water molecules will diffuse out of the cells than into them, so the cells would shrink.

3 Students need to demonstrate clear understanding of what turgor is, the role of osmosis in maintaining turgor in plant cells, and the importance of turgor in the normal functioning of the cells and of the plant as a whole. Award credit for any extra understanding based on research including the use of turgor in stomatal opening and closing, the role of turgor in plant growth, role of turgor/ wilting in plant survival strategies, etc.

2A.4 Active transport

1 Active transport makes it possible to take in substances across the cell membrane against a concentration gradient, when diffusion would be impossible. It can also move substances that could not otherwise pass through the membrane.

2 ATP provides the energy needed for active transport. The carrier protein may need ATP to move a substance through the membrane, or to return to the original position. The enzyme ATPase is associated with active transport sites in the cell membrane.

3 Endocytosis and exocytosis involve the breaking and fusing of parts of the cell membrane. This is only possible because the membrane is fluid.

2A.5 The need for gas exchange surfaces

1 Large animals need a lot of oxygen and produce a lot of carbon dioxide. The surface area:volume ratio of a large animal is relatively small and so they cannot absorb everything they need from their surroundings and pass it to every cell by diffusion fast enough to survive. This is why specialised exchange surfaces are needed.

2 The lungs provide a specialised exchange surface for oxygen, which is needed by the body, and carbon dioxide which must be removed from the body. They are ventilated

which brings in air rich in oxygen and removes air with a relatively high carbon dioxide concentration, helping to maintain a steep concentration gradient to speed up diffusion.

The lungs are made up of alveoli which have several adaptations for rapid, efficient diffusion of gases e.g., short diffusion distances and rich blood supply to maintain steep concentration gradients.

Surface area is very large, allowing enough oxygen to diffuse in and carbon dioxide to diffuse out to supply the needs of the cells.

2A.6 The mammalian gas exchange system

1 Humans are large multicellular organisms with a high metabolic rate to maintain body temperature and all the processes that keep cells alive. They need a rapid exchange of gases with all cells in the body to maintain the rate of respiration needed to support this metabolism. A complex internal respiratory system is needed to provide the large surface area required for this rapid rate of gas exchange with the body.

2 The nose has a larger surface area with a good blood supply and a lining covered in mucus and hairs. So, the air entering through the nose is warmed, moistened and cleaned of dust and other particles before passing into the lungs. Air entering through the mouth gets little of this preparation and so will change conditions in the lungs more than air entering through the nose. It will be easier for pathogens to get to the lungs if air is breathed through the mouth than through the nose.

3 Breathing replaces air inside the lungs with air from outside that has a higher concentration of oxygen and a lower concentration of carbon dioxide. This maintains steeper concentration gradients for these gases between the air in the lungs and the blood, so that diffusion rates are maintained.

4 In normal breathing, only part of the alveolar air mixes with inhaled air to form the exhaled air. So exhaled air contains a slightly higher proportion of oxygen and lower proportion of carbon dioxide than alveolar air.

2A Exam practice

1 (a) B

(b) C

(c) (i) Any three from:

- (at beginning) there is a concentration gradient/ eq
- as concentration of A decreases on outside, it increases on inside/ eq
- substance A moves from outside to inside
- as concentration gradient/ difference gets smaller, rate of change decreases
- no change in concentration/ eq when equal on both sides/it reaches equilibrium.

(ii) Students' answers should include the following:

- rate of change would be (almost) linear/ constant/ eq
- (changes) would occur faster/ eq
- the idea that (overall) movement of molecules would not stop when concentrations equal, e.g. equilibrium would not be reached, concentration inside would be greater than outside.

2 (a) C

(b) Award up to 4 marks for any of the following:

- thin/ eq cells
- decreases diffusion distance
- permeable (to respiratory gases)
- (collectively) have a large surface area
- increases diffusion
- of respiratory gases/ oxygen/ carbon dioxide
- (surrounded by) capillaries
- idea that movement of blood maintains diffusion/ concentration gradient
- reference to the presence of/ a description of surfactant.

(c) Students' answers should include the following.

- The external intercostal muscles contract and raise the rib cage up and out.
- The muscle of the diaphragm contracts and the diaphragm is lowered/ flattened.
- These increase the volume of the thoracic cavity and the lungs are pulled outwards as the pleural membranes covering them and lining the inside of the rib cage are joined.
- The volume of the lungs increases so the air pressure inside them decreases and is lower than atmospheric pressure, so air enters from outside, down the pressure gradient, down the trachea and bronchi and bronchioles into the alveoli, which expand.

(d) 8.1 (dm^3)

3 (a) D

(b) 'Water loving' – the head part is able to dissolve in water/be surrounded by water molecules.

(c) They form a bilayer at the interface between the watery cytoplasm and the outside of the cell. They line up so that the hydrophilic heads dip into watery cytoplasm and watery exterior and the hydrophobic (water-hating) tails are on the inside of the bilayer, away from water.

(d) Diagram should show phospholipid bilayer with proteins in it: intrinsic, extrinsic and some glycoproteins. See diagram in student text

4 (a) Students' answers should include:

- Fatty acids/tails are hydrophobic/ non-polar…
- … so orientate themselves away from water/ polar environment/ eq.
- Phosphate/ heads are hydrophilic/ polar…
- … so can interact with water/ polar environment/ eq.
- Reference to cytoplasm/ tissue fluid/ eq as the polar environment.

(b) (i) Students' answers should include:

- A is the most and D is the least likely to cross/ eq
- reference to same ability of B and C to cross membrane
- manipulation of permeability figures to quantify one of the above points.

(ii) Students' answers should include:

- substance A has a high (oil-water partition) coefficient/ eq
- therefore, can dissolve in the lipid portion of the membrane/ (phospholipid) bilayer
- (more specifically) dissolves in the inner part of bilayer/ hydrophobic region of bilayer/ fatty acids
- (can then pass through) by diffusion.

5 (a) (i) Any two from: temperature, surface area/ volume (of beetroot), part, age, variety, storage, source, volume of ethanol, same wavelength/ filter.

(ii) Students' answers should include the following points:

- cells/ membranes/ eq damaged (by cutting up of pieces)/ eq
- (as a result, pigment) could leak out of vacuoles/ cells.

(iii) Rinse pieces (thoroughly)/ dab pieces dry/ eq.

(b) (i) Increased ethanol concentrations, increases intensity/ eq

(ii) Students' answers should include:

- reference to disruption/ eq of membrane
- ethanol is a (non–polar/ organic) solvent
- the idea that lipids/ eq dissolve (in alcohol)

- the idea that increase in ethanol causes solution to be less polar
- the idea that orientation of phospholipids depends on water around it.

2B Proteins and DNA

2B Checkpoint

2B.1 Enzymes

1 Yeast cells.

2 An intracellular enzyme is produced by a cell for action within the cell. An extracellular enzyme is produced by a cell and then excreted so that it acts outside the cell.

3 Students should cover as a minimum:

- Sumner's work in crystallising proteins and his relatively simple process (took nine years to develop).
- Controversy over the nature of enzymes.
- A relatively young researcher managed something other very prestigious scientists had failed to do.
- e.g., Richard Willstätter; won Nobel prize for chemistry of chlorophyll, working on extracting enzymes with very complex process, couldn't get yield, declared enzymes were a new, unknown class of compounds, tried to say Sumner's extract was merely an inert carrier etc.
- Brief explanation of how the reservations were overcome through practical demonstration.

2B.2 How enzymes work

1 (a) The key characteristics of enzymes:

- globular protein with complex 3-D shape and a critical shape to the active site
- catalysts: speed up the rate of a reaction but are left unchanged at the end of the reaction and don't affect the reaction in any other way
- form an enzyme/ substrate complex where the substrate(s) fits the active site of the enzyme by inducing a change in the shape of the enzyme; the shape of the active site makes it easier to break existing bonds within the substrate(s) or to form new bonds between products
- present in very small amounts
- specific to one or small number of reactions of similar-shaped substrate molecules
- rate of reaction affected by concentration of substrate only up to a certain point
- rate of reaction affected by temperature and pH because these affect the shape of the enzyme and its active site.

(b) How each characteristic provides evidence for the induced-fit hypothesis:

- 3-D shape needed for the shape of the active site to be critical

- the shape of the enzyme is left unaffected when the products are released at the end of the reaction
- the role of the active site is to make the formation of bonds between substrates, or the breaking of bonds within the substrate, easier
- only small amounts are needed because they catalyse the reaction so quickly
- specific because the substrate(s) fits within the active site, so shape of molecules important
- substrate concentration increases rate of reaction up to the point where all active sites on enzyme molecules are occupied. After this point, increase in substrate concentration has no further effect.
- temperature increases the rate of reaction by increasing the energy in all molecules up to the point where it starts to affect the weak bonds within the enzyme and so the shape of the active site. After that point, further increase in temperature denatures the enzyme and so slows the reaction rate.
- pH also affects the weak bonds within a protein molecule, so affecting its 3D shape and the shape of the active site. Different weak bonds are affected differently by changes in pH, so different enzymes work better at different pHs.

2 Students' plans should include suitable method, identifying equipment, variables measured and controlled to increase reliability and validity of results. Look for the following:

- awareness of need for control, reliability, etc.
- consideration of maintaining all other factors constant
- need for water bath
- suitable temperatures chosen – awareness of normal biological range, etc.
- appropriate and manageable number of temperatures
- appropriate number of repeats of each temperature
- suitable enzyme with simple test to illustrate activity, etc.
- risk assessment.

2B.3 The structure of DNA and RNA

1 A mononucleotide is a pentose sugar (either ribose or deoxyribose) with an attached phosphate and an attached organic nitrogenous base (either adenine, thymine, guanine or cytosine in DNA, or adenine, uracil, guanine or cytosine in RNA).

2 (a) The complementary base pairs in DNA are adenine and thymine, and guanine and cytosine. Hydrogen bonds link the bases in a complementary pair that are bonded to opposite strands. This makes the 'rungs' of the DNA helix. As there are many base pairs in a DNA molecule, and therefore many hydrogen bonds, the two strands are held firmly together in the helical structure by the hydrogen bonds.

(b) The size of the combination of the two molecules is crucial. If a purine and a pyrimidine base join by hydrogen bonds, they fit between the two sugar/ phosphate backbones of the two strands of the DNA molecule. Pyrimidine bases (cytosine and thymine) are too small for hydrogen bonds to form between a pair of them; they would be far apart. Purine bases (adenine and guanine) are too large to pair up together; they would overlap and hence not make effective hydrogen bonds.

2B.4 How DNA works

1 DNA helicase breaks the hydrogen bonds between complementary base pairs of DNA.

→ The molecule of DNA is unzipped.

→ Free DNA nucleotides form hydrogen bonds with matching exposed bases on the DNA molecules.

→ DNA polymerase and DNA ligase cause bonds to form between the nucleotides.

→ A new DNA strand results on each exposed DNA strand.

2 Meselson and Stahl showed that after one replication in a medium containing light nitrogen, the density of the DNA produced was halfway between that of DNA containing all heavy nitrogen and DNA containing all light nitrogen. This could only be explained by the DNA having one strand containing light nitrogen and one containing heavy nitrogen; which is what you get after semi-conservative replication. If there had been conservative replication they would have found half the DNA all heavy and the other half all light. After this work no reasonable scientist could support any theory other than semi-conservative replication.

2B.5 The genetic code

1 The sequences of three base pairs in the DNA that carry the genetic information from one generation to another.

2 Areas of DNA that do not code for proteins; this makes up about 98% of the genome.

3 (a) It allows for any arrangement of amino acids to be coded for – there are no limitations from an overlap of the code. Also, point mutations would only impact a single amino acid rather than two or three if the code overlapped.

(b) Often only the first two of the three nucleotides in a codon determine which amino acid is added to a protein. As a result, if the final base in a codon is lost or damaged by mutation, the amino acid structure of the proteins remains the same. So, having part of the code that doesn't really code helps protect organisms from the damage caused by mutations.

2B.6 DNA and protein synthesis

1 DNA contains the sugar deoxyribose and the bases adenine, guanine, cytosine and thymine. The molecule forms a very large, complex double helix.

RNA contains the sugar ribose, the bases adenine, guanine, cytosine and uracil. It forms a single helix and does not form the enormous structures of DNA, but it can form different shaped molecules to carry out different functions in the cell.

2 (a) The DNA contains the genetic code for the protein.

(b) The DNA unwinds at the point where the gene for the protein occurs. The coding (antisense) strand of the gene attracts nucleotides to matching base pairs and these join to form a strand of messenger RNA (mRNA). When it is released from the DNA, the mRNA molecule passes out of the nucleus and attaches to a

ribosome, taking the information coded on the DNA molecule out from the nucleus into the cytoplasm of the cell.

(c) Transfer RNA molecules bring matching amino acids to the ribosome and attach to the messenger RNA so that the amino acids are aligned correctly to form the polypeptide chain.

(d) Ribosomal RNA makes up around 50% of the ribosome and it holds together the mRNA, the tRNA and the enzymes controlling the process of protein synthesis on the surface of the ribosome.

2B Exam practice

1 (a) D

(b) C

(c) (i) Limiting factor is starch concentration because as it increases, so does the rate of reaction.

(ii) Maximum rate/ V_{max} (with copper ions present) is lower (than without inhibitor)/if it was active site-directed it would take longer to reach same maximum rate.

(iii) Students' answers should refer to:

- overall decrease in activity
- increasing concentration (of copper ions) up to 4 au increases the activity of amylase
- increasing concentration from 4 au (to 32 au) reduces activity
- reference to change in activity at 20 au
- correct manipulation of data (this means students have worked out the *difference* between two named concentrations, or some kind of percentage change, not just stated the values on the graph).

(iv) Drops from 5.4 au to 3.4 au, so percentage decrease of 2/5.4 = 37%.

(v) Students' answers should refer to:

- inhibition
- likely to be non-competitive
- ions may interfere with tertiary structure of enzyme/attach to allosteric site/break disulphide bonds
- and subsequently change shape of active site
- substrate molecules no longer fit properly
- fewer enzyme-substrate complexes made per unit time.

2 (a) (i) Activation energy: the idea that energy is needed for a chemical reaction to being/ eq; enzymes reduce it.

(ii) Curve shows same energy levels at start and finish as on original graph; activation energy is lower.

(b) (i) Hydrolysis reaction; peptide bond.

(ii) 126; correct division by 36 to give 3.5 (arbitrary units per hour).

(iii) Although the rate of reaction is greater at 30°C than at 40°C, there are no data for between 30 and 40°C. As the optimum could lie between these temperatures this is not a valid conclusion. More investigations need to be carried out.

3 (a) B

(b) B

(c) A phosphate group B; pentose group.

(d) Adenine 29%; Guanine 21%; Cytosine 21%.

(e) (i) in the nucleus

(ii) RNA nucleotides from the nucleoplasm align next to the exposed DNA strand. DNA-directed RNA polymerase catalyses the formation of phosodiester bonds between the sugars and phosphate groups of the RNA nucleotides. The mRNA chain then separates from the DNA strand.

(f) (i) translation

(ii) transcription

4 (a) (i) Unwinds the two DNA strands; breaks hydrogen bonds between bases.

(Note: those students who have done background reading might talk about 'active' and 'passive' helicases: the 'active' helicases require ATP, e.g. ATPX.)

(ii) Adds new nucleotides to new strand semi-conservative replication pairing complementary bases; works from 3' end to 5' end of DNA strand.

(iii) Joins phosphate group of new nucleotide to (deoxyribose) sugar of growing strand forms phosphodiester bond.

(b) (After first round, ^{14}N:hybrid ^{14}N/^{15}N:^{15}N is 0:2:0, second round is 2:2:0, third round therefore is 6:2:0, six double helices out of eight. It's easier if you draw it out first!) proportions of strands is ¾.

(c) Radioactive isotopes lose mass/ become different atoms.

(d) Students' answers should include:

- semi-conservative replication produces two molecules of DNA
- each containing one old and one new strand
- conservative replication produces two molecules of DNA
- one consisting of two old strands and one consisting of two new strands.

2C Gene expression and genetics

2C Checkpoint

2C.1 Gene mutation

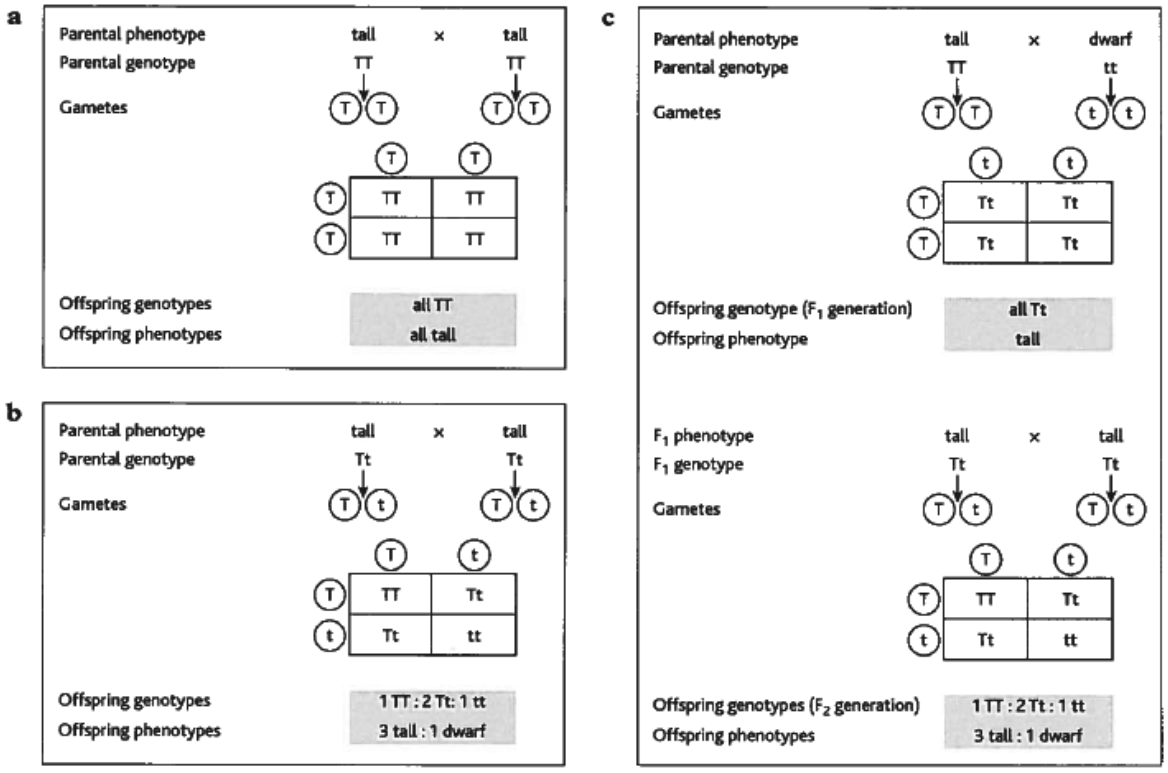
1 A point mutation is a change within a gene. This may be a deletion of a single base pair or a change to a base pair. A change may not affect which amino acid is coded for, so this won't have any impact on the organism, as the protein formed will have the same amino acid arrangement. A change to a base pair may change the amino acid coded for, and if this amino acid doesn't form the same bonds as the original one, then the protein will not have the same 3-D shape and will not work in the same way as the original one, which will affect the organism. A deletion will affect not only the triplet in which it occurs but also all the triplets following it and so change many of the amino acids coded for. This will change the protein formed and so affect how the body works.

2 The change in a single base in one codon changes one amino acid in the chain of 147 amino acids in the haemoglobin molecule. This is enough to change the nature of the protein and the way it folds in the red blood cells, so it forms rigid rods. As a result, the red blood cells have a sickle shape and cannot pass through the small blood vessels and cause blockages, which in turn can lead to pain and even death.

2C.2 Patterns of inheritance

1 Homozygous, both alleles for a gene code for the same version of the characteristic; heterozygous, the two alleles for a gene code for different versions of a characteristic; dominant, an allele which is expressed whether the individual is homozygous or heterozygous; recessive, an allele that is only expressed in the phenotype when the individual is homozygous for the allele.

2



3 It distinguishes a heterozygous individual from a homozygous dominant individual, which phenotypically are the same, because when crossed with a homozygous recessive organism, if one parent is homozygous dominant, all the offspring will have the dominant phenotype. On the other hand, crossed with a heterozygous individual about half of the offspring will show the recessive phenotype.

4 They reproduce quickly, produce many offspring, are cheap to culture and have easily distinguishable characteristics. There are no ethical issues with using them in this way.

(a) White x golden orange cross – only one parent has a dominant gold colour allele as the white parent has two recessive alleles. So, any cubs which are golden in colour are heterozygous.

In the cross between the two golden tigers – both are heterozygotes as they both have a recessive allele to produce a white cub. Therefore, any golden cubs could have inherited a dominant allele from both parents, or a dominant allele from one parent and a recessive allele from the other. You cannot tell from their phenotype if they are homozygous or heterozygous.

(b) When they are adults, cross the offspring with a white tiger – homozygous recessive. If any white cubs are produced, you know the golden cubs are heterozygous.

Limitations are that tigers don't have many offspring and take a long time to reproduce, and gametes fuse at random so it would be very difficult to have enough offspring to be decide that a golden tiger was either homozygous or heterozygous if it produced golden cubs.

2C.3 Sex linkage

1

(a) Gene for colour vision carried on X chromosome. Means if a man inherits an allele for colour-blindness he will demonstrate the trait as no corresponding allele on the Y chromosome. Women have to inherit faulty allele from both parents – much less likely so much lower incidence in the population.

(b) No: demonstrate using Punnett square or other genetic diagram, for example, mother carried colour-blind allele, but has normal vision XCXc, father has normal vision: XCY:

X^C X^c
X^C X^C X^C X^C X^c
Y X^C Y X^c Y

(c) Yes: demonstrate using Punnett square or other genetic diagram, for example, mother carried colour-blind allele, but has normal vision XCXc, father has normal vision: XCY:

X^C X^c
X^c X^C X^c X^c X^c
Y X^C Y X^c Y

A colour-blind woman has to inherit an allele for colour-blindness from both parents to be affected as colour-blindness is a recessive phenotype.

2

(a) A sex-linked genetic disease (carried on the X chromosome) that affects the ability of the blood to clot. Affected individuals cannot produce clotting factor VIII.

(b) Girls have two X chromosomes so may be homozygous for haemophilia A. They are so badly affected that they do not usually survive the trauma of birth.

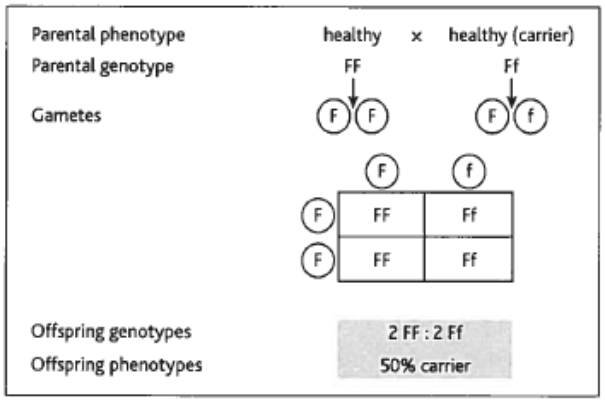
(c) There may have been carriers in the family, but carriers have always by chance had daughters who have themselves become carriers. The faulty allele only showed itself when it was inherited by a son – the lack of a second X chromosome meant that he was affected by the condition.

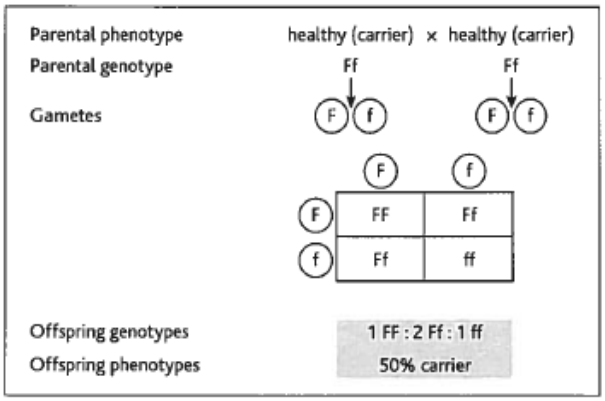
A new mutation may have occurred in the germ line cells of one of the parents.

Look for clear diagrams and/ or pedigree.

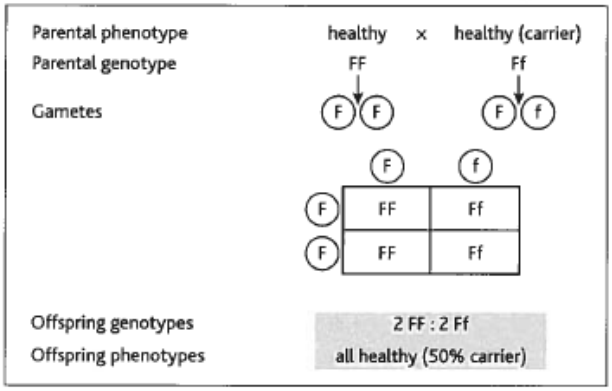
2C.4 Cystic fibrosis: a genetic disease

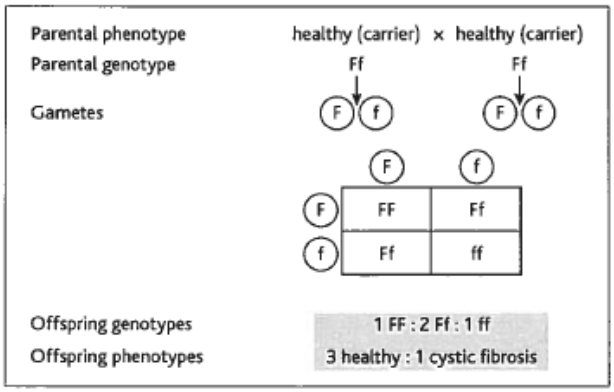
1 At least one of Nuala's parents is a carrier for cystic fibrosis, which is why Nuala is obviously a carrier. There is a 1 in 2 chance that Nuala's brother or sister might also be carriers. This will be true even if both of Nuala's parents are carriers themselves (see genetic diagrams).





2 Every conception has a certain chance of inheriting a particular combination of alleles, so they could follow the theoretical possible pattern, or by chance all be affected, or all not be affected. The diagrams show the theoretical possible patterns.





3

(a) Without the CFrR protein channels, chloride ions build up in the cells instead of moving out through the channels of the mucus-secreting glands. As a result, water moves into the cells by osmosis from the mucus and fluid surrounding the cells. This makes the mucus thick and sticky, and this blocks, or narrows, small airways and fills the lungs, reducing surface area for gas exchange. This means less oxygen is available making the person feel tired. Also, can't be moved out of lungs by cilia so pathogens trapped in lungs making infections more likely. Repeated infections make you tired and lethargic.

(b) Pancreatic duct is blocked by mucus so lack of enzymes in gut – food not digested properly so less food available to be absorbed to provide energy for the cells, therefore tired, lack energy. Also, thick mucus lining gut is barrier to digested food being absorbed into blood which again reduces digested food available in blood to be used for energy.

4 Excess salt excreted as pump won't remove chloride ions from sweat - electrolyte (salt) balance upset. This affects the contraction of the muscles, the heart, the nervous system, the kidneys, movement into and out of cells by osmosis – the whole way the body works is less efficient.

2C.5 Genetic screening

1 Simple blood test available and people with CF live longer so need many medicines for longer – cost more to keep alive. Therefore, cost:benefit calculation is in favour of testing new babies and keeping them as healthy as possible. In the past only prenatal testing available – expensive and intrusive – and people affected didn't live very long.

2 Carried out earlier, results sooner, less invasive. Amniocentesis needed if someone doesn't realise they are pregnant until later, or risk of genetic disease not recognised until further in the pregnancy.

3 It takes place before the woman is pregnant. Involves process of IVF but can be certain baby is free of disease and not a carrier. No risk of miscarriage. No need for termination. Less emotionally traumatic and more effective.

Any appropriate ethical points.

2C Exam practice

1 (a) A

(b) D

(c) There is a change to the sequence of nucleotide base pairs/triplets of bases in the DNA/gene. This leads to a change in the sequence of codons in the mRNA at transcription and so, during translation, there is a change to the sequence of amino acids assembled. This is therefore a change to the primary structure of the CFTR protein, which leads to it not being able to fold into its correct tertiary structure.

(d) The non-functioning (wrong tertiary structure) proteins form chloride ion channels that are not the correct shape and so do not transport chloride ions across the membrane, out of the epithelial cells. This leads to lack of sodium ions leaving the epithelial cells and subsequently not enough water leaving the cells by osmosis, so there is not enough water in the mucus secreted by the goblet cells. The thick, sticky mucus is difficult to be moved by the cilia (which also lack hydration), so it builds up in the airways leading to difficulties with gaseous exchange and the pathogens trapped in it stay in the airways and cause infections. This accumulation of thick, sticky mucus also happens in the digestive and reproductive tracts. It can lead to infertility and lack of absorption of digested food.

(e) Pre-implantation genetic screening. Mother given hormones, so her ovaries release more than one egg (secondary oocyte) and these eggs are collected by a doctor. The eggs and sperm are mixed in a Petri dish, so fertilisation happens *in vitro* (IVF). When the fertilised eggs have reached the 8-cell stage (after mitotic divisions) then one cell can be removed and the DNA extracted and multiplied using the PCR reaction. Then this can be tested for the presence of faulty CFTR alleles. Only embryos without the faulty alleles, usually two of them, are inserted into the mother's uterus

2 (a) Copying errors occur during the replication process, wrong bases are inserted.

(b) 28

(c) 1.4×10^3

(d) The mutation might be in some non-coding DNA or only one allele of a gene may be affected, and DNA has repair mechanisms.

3 (a) B

(b) A

(c) Three of:

- they have many different mutant forms
- short life cycle (three weeks from egg to adult at 20°C)
- easy to keep and manipulate
- small number of giant chromosomes.

(d) Students answers could cover haemophilia (A or B), red-green colour-blindness or fragile X syndrome. Explanation should include:

- Gene is on X chromosome…
- … so a male, who has only one X, who inherits the recessive /faulty

allele, will exhibit symptoms as he does not have a functioning allele to produce functioning protein

- he will only produce abnormal protein for that gene
- for a female to have the symptoms she must have a faulty allele on both X chromosomes and as faulty alleles are rare in the population, there is a very small chance of inheriting two of them.

4 (a) (i) Y = allele for yellow; y = white; S = allele for smooth and s = wrinkled.

(ii) YYSS yyss

(b) (i) D

(ii) Parental phenotypes both yellow seeds

Parental genotypes Yy × Yy

Gametes (Y) (y) × (Y) (y)

F_1 genotypes YY Yy Yy yy

F_1 phenotypes 75% yellow 25% white

(c) A

5 (a) Where two alleles of a gene both contribute to the phenotype.

(b) (i) Students' answer should include:

- The cell's altered shape prevents it from travelling in capillaries/ means they get stuck in capillaries and prevent any normal shaped blood cells, carrying oxyhaemoglobin, reach the cells to deliver their oxygen.
- The sickled shape may also reduce the surface area so less diffusion of oxygen across the membrane.

(ii) Both parents would be heterozygous genotype Hb^AHb^S. Both have gametes Hb^A and Hb^S

Hb^A Hb^s × Hb^A Hb^S

Offspring genotype probabilities:

25% Hb^A Hb^A

50% Hb^A Hb^S

25% Hb^S Hb^S

(c) If a nucleotide base (pair) in a base triplet on the DNA coding strand, coding for a particular amino acid is changed so that the new base triplet now codes for another amino acid, the primary structure (amino acid sequence) of the protein will be changed. This may lead to the protein not being able to fold into its usual tertiary structure (3D shape) so it cannot now carry out its function.

6 (a) B

(b) (i) A

(ii) Mother is homozygous and has two alleles for normal colour vision, one on each X chromosome. So all eggs have genotype X^N. Males inherit their one X chromosome from their mother so all males would have an X^N (and a Y).

(iii) parental genotypes $X^N Y$ x $X^N X^n$

Gametes (X^N) (Y) x (X^N) (X^n)

Offspring genotypes	$X^N X^N$	$X^N X^n$	$X^N Y$	$X^n Y$
Offspring phenotypes	25% female Not colour-blind	25% female colour-blind	25% male not colour-blind	25% male colour-blind

(iv) 25%/1 in 4/0.25. Genetics diagram as above.

7 (a) A version of a gene.

(b) Both alleles contribute to the phenotype.

(c) There are two alleles which are codominant. RR produces red coat. WW produces white coat. RW produces roan coat.

P RW x RW

G (R) (W) x (R) (W)

F_1 RR RW RW WW

1 red : 2 roan : 1 white

Probability of first offspring being roan is 50% or 1 in 2, or 0.5.

Topic 3 Cell structure, reproduction and development

3A Cell structure

3A Checkpoint

3A.1 Observing cells

1 Magnification is a measure of how much bigger the image is than the original object and it is very important. But the other important factor is resolving power (or resolution), which is a measure of how close together two objects must be before we see them as one – or how far apart before we see them as two. If the resolution is poor, the image will appear fuzzy and so we cannot see the details of cells clearly.

2 Light microscope: cells and tissues are stained with dyes, which are taken up by different parts of the cellm making it easier to see them, e.g. the nucleus, chromosomes, lignin-containing material. It is the biological material itself that is stained.

Electron microscope: colour is used to make it easier to identify cell components, but it is added to the image after it has been taken – it does not reflect staining on the cells themselves.

3 5 mm/40 = 0.125 mm

12mm/100 = 0.120 mm

13mm/100 = 0.130 mm

Mean diameter = (0.125 + 0.120 + 0.130)/3 = 0.125 mm (125 µm)

3A.2 Eukaryotic cells 1: common cellular structures

1 Organelles enable different functions to be carried out in different areas, making the cell more efficient. Enzymes can be held next to each other in sequence. Membrane folding gives increased surface area for enzyme action. Avoids substances/ enzymes interacting and causing problems. Accept any other valid points.

2 Transmission EM: high magnification, detail. Scanning EM: 3-D image.

Advantages: Transmission EM gives you detailed information about internal parts of organelles, etc. E.g., useful for finding out about detailed internal structures of mitochondria and chloroplasts; scanning EM gives 3-D picture of the cell and the relationships of one organelle to another, e.g., finding the 3-D shape of protozoa or organelles.

3 Apoptosis is programmed cell death. It is used to get rid of cells that are ageing and coming to the end of their life, as well as those which contain mutations, damaged cells, etc. So healthy levels of apoptosis allow new cell growth and prevent the development of cancers and other problems from damaged cells. If there is too much apoptosis, this can lead to arthritis, damage after heart attacks and probably many other conditions. If there is too little apoptosis, this can lead to cancers, as cells containing mutations are not destroyed. Also accept any other valid points based on students' own research.

3A.3 Eukaryotic cells 2: protein transport

1 Likely questions and ways of finding the answers include:

- What is the detailed structure? Using electron microscopy helps us understand more about the structure of the different types of ER.
- Are substances made in the ER or do they travel through it? Using radioactive labels to track substances through the different areas of ER, e.g., labelled proteins would show up in RER but not in SER, labelled lipids in SER and not in RER. Centrifuge tissue to investigate different areas of ER - check for labelled substances, etc.
- Accept any other sensible suggestions.

2 RER – enzyme proteins formed on ribosomes, then moved into cavities of RER and transported through the system. Vesicles containing the enzymes are pinched off from the RER and moved by cytoskeleton to Golgi stacks. Membrane of vesicles fuse to form Golgi. Enzymes move through the Golgi and may be modified. Finally enclosed in another membrane vesicle. Some remain in the cell as lysosomes containing digestive enzymes or are released into the cytoplasm (intracellular enzymes). Others move to cell surface membrane, fuse and release enzymes by exocytosis to the outside of the cell (extracellular enzymes).

3 Packaging products within a cell is important as it means that enzymes only work in the appropriate place. Chemicals do not mix when they shouldn't. Controls enzyme cascades and makes sure all the reactions of metabolism occur in the right sequence. Allows materials to be transported to specific regions.

3A.4 Prokaryotic cells

1

Structural features	Eukaryotic	Prokaryotic
Average size μm	10–100	0.5–10
Genetic material	DNA	DNA
Outer layers	Lipoprotein cell surface membrane. May have cell wall containing cellulose or chitin.	Cell surface membrane and bacterial cell wall made of peptidoglycan, with other compounds such as teichoic acid, lipopolysaccharides. May have slime capsule or layer.
Main inclusions	Nucleus containing genetic material (DNA), 80S ribosomes, mitochondria, Golgi body, lysosomes, vesicles, cytoplasm, centrioles, cytoskeleton, vacuoles, endoplasmic reticulum (RER and SER), etc.	Cytoplasm, genetic material (DNA), plasmids, mesosomes, 70S ribosomes.
Movement	Varies – may not move, may be amoeboid, may use cilia, flagella, etc.	May have flagellae.

2 Gram-positive bacteria (e.g. methicillin-resistant Staphylococcus aureus, MRSA) cell walls contain a thick layer of peptidoglycan containing chemicals such as teichoic acid within their net-like structure.

The cell walls of Gram-negative bacteria (e.g. E. coli) have a thin layer of peptidoglycan with no teichoic acid between the two layers of membranes. The outer membrane is made up of lipopolysaccharides.

The way they infect cells and cause disease is different and the way they react to antibiotics is different, so need to know to treat bacterial diseases effectively.

3A.5 The organisation of cells

1 (a) Squamous epithelium lining an alveolus: very thin and flat, so diffusion distances are kept to a minimum.

(b) Ciliated epithelium lining a bronchus: cilia move mucus carrying bacteria away from the lungs.

(c) Muscle tissue in the biceps muscle: contracts to allow muscle to move bone.

2 (a) Any system – correct naming of cells, tissues and organs.

(b) Clear and accurate explanation relating to the body system chosen.

3A Exam practice

1 (a) C

(b) A

(c) Students' answers should include: production of ATP/ eq; reference to aerobic respiration; reference to Krebs cycle/electron transport chain/oxidative phosphorylation.

(d) Award marks for:

- correctly drawn shape of mitochondrion
- several non-stylised cristae drawn
- correct size (double length of photograph: the original was 7.2 cm long, so 14.0–14.6 cm is fine)
- matrix *and* crista labelled correctly.

2 (a) (i) C

(ii) High magnification and high resolution and has depth/ 3-D.

(b) (i) Contains (most of) the genetic information/ DNA and RNA/ chromosomes or chromatin and controls events in the cytoplasm.

(ii) Allows messenger RNA, made during transcription, to pass out of nucleus to cytoplasm/ribosomes; allows sub units of ribosomes, made in nucleolus, to pass out of nucleus into cytoplasm; allows some chemicals into nucleus.

(c) (i) C

(ii) 314 μm^2

(iii) area of nucleus in photo = $3.5 \times 3.5 = 12.25\ \mu m^2$

Number of times this area fits onto surface of nucleus = 314/12.25 = 25.6

Number of pores = $25.6 \times 230 = 5888$

3 (a) Award marks for:

- envelope/ double membrane clearly shown
- granum clearly shown
- granum/ thylakoid(s) labelled
- stroma/ ribosomes/ starch grain/ DNA/ lipid droplet/ double/ inner/ outer membrane/ envelope/ intergranal lamellae correctly labelled.

(b) (i) Award marks for: correct length (50 mm); divided by 50 000; correct length in μm (1 μm).

(ii) Acceptable answers include: vacuoles/ vesicles/ lysosomes/ glycogen granules/ ribosomes/ lipid droplets/ centrioles/ spindle fibre/ microtubules.

(iii) Acceptable answers include: resolution not high enough/ eq/ damage/ angle of section/ eq/ poor printing of photograph/ eq.

(iv) Lysosome – membrane bound sac containing chemicals, e.g. enzymes

4 (a) Answers are shown below.

Name of cell structure	Description of cell structure	Diagram of cell structure
Nucleolus	1. Darkly stained region in the nucleus. 2. Where ribosomal RNA is made.	
Centrioles		Pair of cylinders; at right angles to each other.
Lysosome	1. Spherical (structures). 2. Single membrane. 3. Containing hydrolytic/ eq enzymes.	
Microtubules	1. Hollow cylinders made of protein. 2. Form spindle fibres.	

(b) (i) Award marks for: use of single unbroken lines, with a sharp pencil. No shading. Scale should be shown and structures nucleus, cytoplasm and cell surface membrane labelled with ruled label lines.

(ii) Magnification of cell A in photo is x1800. Magnification of their drawing is their diameter in μm divided by 10.

5 (a) Three from: centrioles, microtubules, microfilaments, lysosomes, rough and smooth endoplasmic reticulum, Golgi body.

(b) Two from: nucleus, chloroplasts and mitochondria.

(c) Sections in electron microscopes have to be extremely thin (transmission microscope) or fractured (scanning microscope). A vacuum is also needed for the electron microscope to work, which precludes the ability of cells to successfully respire.

6 (a) Award 1 mark for each two correct responses.

Feature	Prokaryotic cell	Eukaryotic cell
Nuclear envelope	×	✓
Cell surface (plasma)	✓	✓
Mitochondria	×	✓
Golgi apparatus	×	✓

(b) Bacteria have a single membrane, and when they are absorbed a vacuole forms around them, like a second membrane. This could explain through endosymbiotic theory why mitochondria and chloroplasts have double membranes.

7 (a) C

(b) They are single celled.

(c) Larger size, cells can specialise to become more efficient, cells can work together in tissues.

(d) Award marks for: diagram is large, clear lines drawn not sketched, ciliated and goblet cells drawn, annotation stating goblet cells secrete mucus, annotation stating cilia can move mucus.

3B Mitosis, meiosis and reproduction

3B Checkpoint

3B.1 The cell cycle

1 When the cell is not dividing, the chromosomes are very diffuse and the DNA is translucent, so it cannot be seen.

As the cell goes into mitosis the chromosomes condense. The DNA molecule winds around positively charged proteins known as histones to form dense clusters, which then coil around each other. These coils form supercoils that produce very dense structures, which will take up stain and become visible under the microscope.

2 (a) 79.2% 16.7% 4.1%

(b) Interphase: 38 hours; mitosis: 8 hours; cytokinesis: 2 hours.

3B.2 Mitosis

1 Interphase: stage before mitosis begins when DNA replicates.

Prophase: chromosomes coil and condense so take up stain and become visible as a pair of chromatids held together by a centromere. Nucleolus breaks down and centrioles begin to separate to form a spindle.

Metaphase: nuclear membrane breaks down, spindles formed by centrioles, chromatids line up on equator/metaphase plate of spindle.

Anaphase: centromeres separate and chromatids move to opposite poles along spindle tubules. Telophase: chromatids reach poles of cell and are now chromosomes again. Nuclear membrane reforms, cytoplasm begins to divide. Nucleoli reform, centrioles present; two separate cells result.

2 Root tips are particularly suitable because they contain many rapidly dividing cells in growing region. The cells contain no pigment, so it is easy to see the stain taken up by the chromosomes. As plant material is used there are no ethical issues.

3 12 actively dividing cells

54 cells in total

MI 12/54 = 0.2 (1sf)

3B.3 Sexual reproduction and meiosis

1 Climate change; introduction of new predator; new disease; shortage of food or water; any other sensible idea.

In any situation where conditions change, the majority of organisms are adapted for status quo. Different phenotypic features are needed to survive in changed conditions. Sexual reproduction introduces variety and so an increased possibility that at least some of the offspring will have adaptations that increase the chance of survival in the new situation.

In very stable conditions, asexual reproduction removes any risk of not finding a mate and ensures that advantageous adaptations are passed to offspring.

2

Stage of meiosis	Main events
Prophase 1	Each chromosome appears in the condensed form with two chromatids. Homologous pairs of chromatids associate.
Metaphase 1	Spindle forms and pairs of chromosomes line up along the metaphase plate. Crossing over takes place.
Anaphase 1	The centromeres do not divide and pairs of chromatids move to each end of the cell, resulting in a halving of the chromosome number or each new cell.
Telophase 1	The nuclear membrane reforms and the cells begin to divide which may continue to full cytokinesis with a brief or even prolonged interphase but no further DNA replication.
Metaphase 2	New spindles form and the chromosomes, still made up of pairs of chromatids, line up on the metaphase plate.
Anaphase 2	The centromeres now divide and the chromatids move to opposite ends of the cell.
Telophase 2	Nuclear envelopes reform; the chromosomes return to their interphase state and this is followed by cytokinesis to give four daughter cells, each with half the chromosome number of the original cell

3 Variety introduced in a number of ways:

- replication of the DNA – scope for errors (mutations) which introduce variety
- crossing over where internal chromatids cut and re-joined by enzymes, which introduces different arrangements of alleles
- mutation possible during crossing over when mistakes are made
- random assortment of the chromosomes as the new cells form, which means each gamete contains a different mixture of chromosomes.

3B.4 Gametes: structure

1 Gametes carry the genetic information from male and female parents, which joins together to form a new individual.

2 Meiosis introduces variety and reduces the chromosome number by half. In animals, meiosis takes place in the ovary and the testis – it takes place constantly in testes throughout life in humans, and it takes place in the ovary every month in the production of mature ova. In ova, meiosis isn't completed unless fertilisation occurs.

In plants, meiosis only takes place in the anthers and ovary. It takes place in the formation of pollen grains and ovules and is followed by a number of mitotic divisions that produce a number of different types of haploid nuclei.

3 Human male gametes: there are many of them, so there is huge wastage as very few reach the fertile ovum; they are very small as they only need to carry genetic material to egg; the nucleus contains condensed genetic material so it takes up minimum space and needs minimum energy to transport it; they have a long whip-like tail to produce movement and keep sperm in suspension; microtubules of contractile proteins produce whip-like movements of the tail to move the sperm and keep it in suspension; the middle section contains many mitochondria to provide the ATP needed for the movements of the tail; the acrosome contains enzymes, which break down the protective layers around the ovum prior to fertilisation.

4 Female gametes in mammals: these are relatively large compared to male gametes; there are no adaptations for movement as they are moved by cilia in the female reproductive tract; they contain food reserves for the early embryo; they have protective layers around the outside to prevent the penetration of more than one sperm; they contain a single nucleus suspended at metaphase of meiosis 2; meiosis is only completed if fertilisation occurs when haploid chromosomes fuse with haploid sperm nucleus; polar bodies all die at fertilisation.

Female gametes in plants: they are large compared to male gametes, which are simply nuclei within a pollen grain; they contain no food stores for the embryo – these form later after fertilisation; they contain a number of different nuclei, which fuse with pollen nuclei to form the embryo but also to form the endosperm; they attach to the wall of the ovary to allow the seed to develop securely once the ovule is fertilised.

3B.5 Fertilisation in mammals and plants

1 It ensures that pollen grains only germinate when on the stigma of the same species of plant, and often only when on a different plant than that from which they originated. This helps to ensure variety, but also that there isn't cross-fertilisation, which would waste both pollen and ovule if they were from different species. If the pollen grain does not develop when it is on a different species, the ovule is still available to be fertilised, and this is to the advantage of the species as a whole.

2

(a) Mammals: enzymes in mitochondria release energy for the movement of the tails of the sperm; enzymes in the head of the sperm (acrosome) digest away the protective follicle cells and zona pellucida around the ovum to allow a sperm to penetrate.

(b) Plants: hydrolytic enzymes in the pollen tube break down the stigma and digest the tissues of the style and ovary to allow the pollen tube to penetrate the ovule.

3 Polyspermy is prevented initially by the opening and closing of various ion channels in the membrane, so that ions move to make the inside of the ovum positive with respect to the outside rather than negative. This repels the entry of further sperm. Then a tough fertilisation membrane forms around the fertilised ovum to completely block the entry of other sperm. If more than one sperm entered the ovum, it would become triploid or polyploid and unviable, so that an embryo would not develop, or if development started, the embryo would die and not develop. This would waste the resources put into the egg and the sperm and would waste an opportunity for successful reproduction on both the individual and the species level.

3B Exam practice

1 (a) (i) C

(ii) B

(iii) one

(iv) 100% as visible chromosomes present in all cells.

(b) Students' answers should include reference to the following:

- during prophase chromosomes/ chromatids become visible
- centrioles move to opposite poles (of cell)
- formation of spindle/ spindle fibres/ microtubules
- disappearance of nucleolus/nucleoli
- breaking down of nuclear envelope/ membrane (in prophase) or nuclear envelope is broken down by metaphase/ eq
- (at metaphase) chromosomes/ centromeres attached to spindle fibres
- chromosomes/chromatids lined up at equator.

(c) Chromatids (when DNA replicates); new mitochondria when each one divides.

2 (a) D

(b) B

(c) Interphase. G_1 when cell grows and develops. Protein synthesis will be occurring.

(d) B has a longer gap phase so may be less metabolically active than cell A. The process of mitosis takes longer in cell B (3.4 hrs compared to 2.4 hrs).

(e) 1.5 au

3 (a) (i) A = acrosome B = tail/ undulipodium/ cilium

(ii) When an egg and sperm nucleus join at fertilisation, the full chromosome number (diploid) will be restored, and the zygote will contain genetic information from two unrelated individuals, adding to genetic variation.

(iii)

Feature	Spermatozoa	Ovum
size	50 μm	100 μm
number of chromosomes	23	23
motility	very motile	None
number needed for fertilisation	one	one

(b) Enzymes released from the acrosome digest the follicle cells of the jelly-like zona pellucida. One sperm reaches and touches the ovum membrane. The second meiotic division of the ovum (secondary oocyte) completes and the sperm nucleus fuses with the resulting haploid ovum nucleus (the cytoplasm division at ovum meiosis is uneven, resulting in polar bodies and one haploid nucleus). When the two nuclei fuse, the ion channels in the ovum membrane close, so it becomes depolarised and this prevents entry of other sperm. As the sperm nucleus enters, the ovum absorbs water and swells and the ovum chromosomes pair with those of the sperm, forming a zygote with a diploid nucleus.

4 (a) Chemicals on the surface of the pollen grain interact and if they recognise each other (are compatible) then a pollen tube grows down through the stigma and style to the ovary. This involves secretion of digestive (hydrolytic) enzymes. The pollen tube nucleus and generative nucleus travel down with the pollen tube. The generative nucleus divides by mitosis to give two haploid male nuclei. The tip of the pollen tube passes into the ovule through the micropyle and the two nuclei pass into the ovule.

(b) (i) To act as an energy source/respiratory substrate.

(ii) Axes correct (time on horizontal axis); axes labelled with units; all points plotted correctly; suitable curve drawn – ideally all points joined dot to dot with straight lines, or a good line of best fit (any line on a graph is called a curve even it if is straight!).

(iii) Increases during first 60 minutes (0.156 to 0.169 to 0.182 mm per 30 min) then decreases greatly to 0.169 mm per 30 min by 2 hours, then decreases to 0.52 and 0.32 by end of the 3-hour period.

(iv) 0.76 mm.

(c) (i) Award marks for the following:

- 90 (mean length at 12 hours) – 45 (mean length at 6 hours) = 45
- 45 ÷ 6 (to get the 'per hour'; 6 hours have elapsed between 6 hours and 12 hours)
- = 7.5 (units not needed).

(ii) Award marks for any two points from:

- (with boron) pollen tubes grow faster/ longer/ eq
- (with boron) keep growing/ no levelling off AND (without boron) stops growing/ levels off/ eq;
- manipulated quantitative comparison, e.g. at the end of experiment, pollen tubes are 3 times longer.

3C Mitosis, meiosis and reproduction

3C Checkpoint

3C.1 Cell differentiation

1 (a) Man: AA or AO; Woman: BB or BO

(b) 1 in 4

2 (a) Multiple alleles – a single pair of genes code for a characteristic BUT there are a number of different possible alleles.

(b) Polygenic – a characteristic is the result of many different genes found on the same and/or different chromosomes.

3 The genes for the two characteristics are found close together on the same chromosome and so are linked and inherited together almost as one gene. Experimental error – not enough flies crossed, some of the offspring escaped, etc.

3C.2 Interactions between genes and the environment

1 (a) The rabbit has a mutation that means the enzyme which produces the dark colour is inactive at normal body temperature. When the fur is removed and a cool pack in place the temperature in that area is lowered. So, the enzyme remains active and melanin pigment is produced.

The skin is cooler and loses heat easily. When fur is removed there is enough of a drop in temperature to allow the enzyme to work, so dark pigment is produced and the fur is dark. However, once the dark fur has grown, the skin is kept warm so at the next moult, as new fur grows, the enzyme is inactive as the skin is at normal body temperature under fur – so new fur is cream again.

(b) A mutation in Siamese cats results in a version of tyrosinase that is inactive at normal body temperatures and only works at lower temperatures. After surgery, the shaved area of skin will be cooler than normal, so the enzyme is not denatured and as a result the fur that regrows over the patch is dark. However, when the cat next moults, the new fur grows under the insulating layer of existing dark fur, so the skin is warmer, the tyrosinase is inactive and the fur grows pale.

2 Identical twins reared together have the same genes and similar environment. This allows scientists to see how closely they are the same and can compare pairs of identical twins in different environments. However, twins reared apart have the same genes but different environment, so looking at similarities and differences gives an even clearer picture of how strongly phenotypic characteristics are affected by genes and by environment.

3 Fairly reliable, as they are from twin studies. However, numbers in the study are relatively small, particularly of the separated twins. Data from larger studies (such as the 2008 study) give more reliable evidence.

4 Because there are multiple combinations of the different genes interacting with almost infinite variations in an environment, which means there will be huge amounts of variation across a population for those characteristics and no two (or more) simple forms will be found.

3C.3 Controlling gene expression

1 When RNA is transcribed from the DNA of a gene in the nucleus both the introns and the exons are transcribed. The introns and sometimes some of the exons must be removed from this pre-mRNA before it can be translated at the ribosomes. This cutting and pasting of the pre-mRNA is carried out by enzymes called spliceosomes. Once the introns have been removed, the spliceosomes may join up the exons in a variety of ways to produce different strands of mRNA for translation. This is known as RNA splicing, and the variations in the mRNA that result may code for different amino acids in the amino acid chain and so for different proteins. This is one of the ways in which a single gene in the DNA can code for a number of different proteins at the ribosomes.

2 Epigenetics is the study of genetic control by factors other than the base sequences of the DNA and ways in which environmental factors can result in changes that affect future generations, for example, RNA splicing, DNA methylation, DNA demethylation and histone modification.

3 In a multicellular organism, every cell contains the same genetic information which codes for the proteins that will be made, but different cells perform different functions. They differentiate and develop into different tissues and organs and different types of cell produce more and more proteins which are specific to their cell type. So, all cells in an organism have the same genetic make-up, but different genes are expressed in different types of cell. Gene switching may be controlled internally, but it can also be affected by the environment of the organism. The impact of the environment on the phenotype might be quite straightforward – the availability of food, water, light, etc. But environmental factors can also trigger gene switching in epigenetic changes which may be passed on to future generations. So, the phenotype of an organism is the result of a combination of genotype and environment.

3C.4 Stem cells

1

Embryonic stem cells	Adult stem cells
Pluripotent – can form most cells. Sourced from embryos either from abortions or unwanted in IVF – or produced by therapeutic cloning. Relatively easy to obtain. Difficult to control differentiation into specific cell types. Risk of cancer developing. Ethical issues with use of embryos as the source.	Multipotent – can form a limited number of specific cells. Sourced from adult tissues (small numbers). Relatively hard to extract and difficult to grow in the laboratory. Differentiate into limited number of cells types. If an individual has a genetic problem it will be present in their own adult stem cells. No rejection issues as own cells used. No ethical issues as no embryonic tissue involved.

2 Totipotency is the potential to form all known cell types in an organism. Animal cells are totipotent in the earliest embryo cells, plant cells remain totipotent throughout life.

Pluripotency is the potential to form most of the cell types needed in an organism. Animal cells are pluripotent slightly later in embryo development.

Multipotency is the potential to form a limited number of differentiated cell types within a mature organism.

Adult stem cells are multipotent.

3 If you understand how differentiation works you can intervene if things go wrong in embryonic development. If you understand control mechanisms you can use them in embryonic stem cells or adult stem cells to produce new tissues or organs for people with different diseases, to grow new neurones, etc.

Any other sensible points.

3C.5 Using stem cells

1 Being able to direct stem cells to make a particular type of differentiated cell or tissue.

2 Umbilical cord – advantages: no ethical issues of embryo involvement; reduced problems of rejection; any other valid point.

Disadvantages: umbilical blood has to be stored (cost implications); carries any genetic disease.

Adult tissue: multipotent rather than pluripotent unless new technique develops successfully; adult stem cells rare; technique for converting to iPS very new.

Any other valid points.

3 Look for clarity in arguments, factual detail and accuracy, awareness of need to spend money efficiently, techniques at early stages so difficult to know which will end up most effective etc. Any points of view acceptable as long as well and scientifically, rather than emotionally, argued. Look for evidence that the student understands both the biological advantages and disadvantages, and potential benefits and pitfalls, of different methods, and the current consensus on chances of success, etc. Look for clarity of thought, good expression and clear communication.

3C Exam practice

1 (a) (i) A

(ii) C

(iii) Chiasma/chiasmata

(b) (i) Not all ovules are fertilised; more pollen/ male gamete nuclei with alleles for white and wrinkled may have fertilised ovules also carrying recessive alleles (genetic lottery); some seeds may not have germinated.

(ii) 48%/0.48; (750 + 1953) divided by 5600.

2 (a) (i) Both alleles contribute to the phenotype.

(ii) The gene for ABO blood group has three alleles, but any individual will only have two alleles for this gene.

(b) (i) C1 is $I^A I^B$ C2 is $I^B I^0$ C3 is $I^A I^B$

(ii) P1 has genotype $I^A I^B$ and if P2 also has genotype $I^B I^O$ then the chances of a child being group O is 1 in 4/25%. If P2 is genotype $I^B I^B$ then there is no chance of the child being group O as group O is a recessive characteristic and only genotype $I^O I^O$ will be group O.

3 (a) B

(b) B

(c) (i) Mitosis

(ii) Not all/ different genes are switched on or off/ active/ activated; correct and appropriate reference to factors/ mechanisms for gene switching; for example, reference to promoters/ transcription factors.

(iii)

- if you (suffered an accident/disease/deterioration) and needed to replace damaged brain cells
- would be genetically the same as the rest of your cells
- able to replace more than one kind of brain cell
- goes on generating new cells as required.

(d) (i) For:

- Embryonic cells are easier to work with than adult stem cells.
- Embryonic cells are (relatively) undifferentiated whereas adult stem cells are/appear to be less so.
- Embryonic stem cells are totipotent/ pluripotent/ able to become any kind of cell in the body, but adult stem cells are multipotent/ able to become only a limited number of cell types.
- Embryonic stem cells have a wider range of clinical applications/adult stem cells have a narrower range of clinical applications.

(ii) Against:

Credit any three of the points below:

- Embryonic stem cells (are taken from embryos) which (are to be considered) unborn children.

- Use of stem cells is thus effectively murder/ lack of respect for the embryo as a (potential) human.
- A lot of current (embryonic) stem cell treatment is fraudulent/ badly regulated/ exploits suffering/ encourages IVF clinics to 'create' more 'spare' embryos.
- If we wait a few years longer we shall have the same benefits through adult stem cells.
- Not enough funding for alternatives, for example adult stem cells;
- An embryo becomes a new human at the moment of conception.

The fourth mark is for attempting to balance opposing points of view whilst thoughtfully coming down on one side, for example, 'Even though it may benefit people, this does not justify taking the life of an unborn child'.

For:

Credit any three of the points below:

- offers prospect of treatment to many suffering people
- research using alternatives, for example adult stem cells, is progressing more slowly than that with embryonic stem cells
- if we ban it in the UK it will still happen in other countries
- it uses spare IVF embryos which would alternatively be destroyed
- research with embryonic stem cells is needed to develop use of adult stem cells
- an embryo is not a new human until it is viable.

The fourth mark is for attempting to balance opposing points of view whilst thoughtfully coming down on one side, for example, 'Alleviation of suffering in people (who have already been born) is (ethically) more important than not destroying embryos'.

4 (a) D

(b) 1. Protein released from ribosome;

2. enters the rER lumen;

3. becomes packaged into (rER) vesicles;

4. vesicles/proteins move to Golgi (apparatus); vesicles fuse with/ protein enters Golgi;

5. protein modified/ carbohydrate added/ named carbohydrate added;

6. then become packaged into (secretory) vesicles;

7. glycoprotein becomes part of (vesicle) membrane;

8. vesicles move towards/ fuse with the cell (surface) membrane.

(c) (i)

- Totipotent (stem cells) can give rise to all/ any/ 216 cell types.
- (Stem cells) are undifferentiated/unspecialised.
- They can keep dividing.

(ii) They can give rise to white blood cells.

(iii) Possible route to infection/ rejection by recipient/ increased chance of becoming cancerous.

5 (a) (i) Can give rise to different types of cells/ all types other than embryonic cells.

(ii) Bone marrow

(iii) Depending which genes are switched on/off different structural proteins and enzymes will be produced in that cell so different structures will be present and different metabolic pathways will be operating so cell can carry out different functions and will have different appearance.

(b) B

Topic 4 Plant structure and function, biodiversity and conservation

4A Plant structure and function

4A Checkpoint

4A.1 The cell wall

1 Cell walls provide strength to the plant and prevent cells from bursting when they are bathed in a solution that is more dilute than their contents. The cellulose microfibrils are strong and not easily stretched, so they help to maintain cell size and shape. The matrix of hemi-celluloses and other carbohydrates hold the microfibrils in position but keep the structure flexible, so that the plant can bend with the wind, etc.

2 The primary cell wall formed when the cell divides is flexible and can stretch in some directions as the cell swells and the plant grows. As the cell gets older, more cellulose microfibrils are laid down at angles to each other, to make a more rigid box that prevents the cell changing shape any further but provides extra strength for the plant. If the cell wall becomes lignified later, this makes the structure even stronger and more rigid.

3 Plasmodesmata are cytoplasmic connections between cells though the cell wall. This means that substances from one cell can pass more easily into another cell without having to pass through the cell surface membrane and cell wall. This allows communication between the cells.

4A.2 Plant organelles

1 Amyloplasts are structures that store starch in plant cells. Chloroplasts have a complex structure of folded membranes that contain chlorophyll, which traps the energy from sunlight so that the plant can make its own food.

2 Typical plant and animal cells have a nucleus, mitochondria, a cell surface membrane and cytoplasm. Animal cells may have temporary vacuoles, but a typical plant cell has a cell wall, permanent vacuole, sometimes chloroplasts and sometimes amyloplasts.

3 Chloroplasts trap sunlight, so plant cells that don't receive enough light would be wasting energy if they made chloroplasts. If a potato tuber, which is usually underground and so is white, is removed from the soil it starts to turn green. The cells on the surface of the potato must be able to make chloroplasts and the green pigment chlorophyll that is found in them.

4A.3 Plant stems

1 Similarities:

- both are plant transport tissues
- both have a lot of water moving through them

- both found together in vascular bundles in plant.

Differences:

Xylem:

- water and mineral ions are transported in the xylem
- xylem cells are living when first formed but become heavily lignified, so cell contents die
- comprises hollow tubes running through plants
- water moves through xylem in transpiration stream carrying minerals with it
- water leaves xylem through pits
- provides important structural support for plant.
- (Award marks for any other sensible points.)

Phloem:

- contains products of photosynthesis, e.g. sucrose transported in the phloem in solution in water
- phloem sieve tubes are made of many cells joined together to form tubes with perforated sieve plates between them
- phloem sieve elements are not dead but have lost most of their functions; they are a tube filled with phloem sap – cells have no nuclei
- phloem cells only survive because they are supported by companion cells, which are very active and linked to phloem cells by many plasmodesmata.
- (Award marks for any other sensible points.)

2 The epidermis protects the stem, reducing water loss and making it more difficult for pathogens to get into the plant. Parenchyma is packing tissue that holds everything in place. Collenchyma and sclerenchyma are strengthening tissues that help support the plant. In a young stem there is more collenchyma because this tissue can stretch as the stem grows taller. More sclerenchyma is formed as the stem matures – the cell walls are lignified so they can't stretch, but they provide more strength than collenchyma and can support the plant more firmly.

3 Collenchyma cells have thick cellulose primary cell walls, which are even thicker at their corners which gives the tissue its strength. These cells are found around the outside of the stem, just inside the epidermis, and they give plenty of support but remain living, so they stretch as the plant grows and provide flexibility.

As the plant gets bigger and older, sclerenchyma cells are formed. This tissue develops, as the plant grows, to support the increasing weight of the upper part of the plant. Sclerenchyma tissue is found around the vascular bundles in older stems and in leaves. All sclerenchyma cells have strong secondary walls made of cellulose microfibrils positioned at right angles to each other. Some sclerenchyma makes fibres, very long cells often found in bundles or cylinders around the outside of a stem or root. As the plant grows, lignin is deposited on the cell walls of these fibres in a spiral or a ring pattern, and this makes the fibres strong but also flexible. The strength of the fibres depends on their length and how much they are lignified (how much lignin they contain). When the fibre is fully lignified, the cell contents die because water cannot pass through lignin, and so the fibres become hollow tubes. Once this has happened, these cells can no longer grow, so plant growth must take place higher up the stem. Sclerenchyma cells can also become completely impregnated with lignin and form sclereids. These very tough cells can be found in groups throughout the cortex of the stem or individually in plant tissue.

4 This is to prevent animals nibbling the soft young bark and destroying the transport tissue. If the bark is destroyed all around the trunk the plant will die, as no water can move up the trunk, and no food can move down to the roots

4A.4 The importance of water and minerals in plants

1 Solvent for cell reactions.

For photosynthesis.

For turgor to support the stems and leaves.

2 Minerals are needed by plants to make critical molecules such as chlorophyll, amino acids, calcium pectate and ATP, without which the plant cannot grow or function well.

3 When investigating mineral uptake in the lab, you would need to exclude just the mineral being investigated, keeping all other variables the same as far as possible. Repeats will increase reliability of results. A control of all minerals in the solution would be appropriate.

4A.5 Using plant starch and fibres

1 They store substances such as starch which are good energy sources for us. They also contain vitamins and minerals, such as vitamin C and iron, that we need to keep our bodies healthy. They may contain oils which are rich in energy. May have high protein levels.

2 They are easily accessible from a range of plant species, which means they are also a sustainable resource.

3 Advantages: biodegradable so less damaging to the environment than oil-based plastics when discarded; a renewable resource so potentially supplies shouldn't run out.

Disadvantages: more expensive than oil-based plastics currently; can be conflict between use of crops for food and for bioplastics.

4 Accept any answer that includes data that compare performance, and a suitable assessment of that comparison.

Judgements on importance should depend on a critical assessment of the quality of the data found. Accept other factors that are suitably justified.

4A.6 Plant-based medicines

1 (a) The right nutrients; the right temperature; water.

(b) Aseptic techniques keep the experimental apparatus sterile and free from contamination with microorganisms other than those you are choosing to grow. This is very important because otherwise your cultures could be contaminated by dangerous bacteria or you could accidentally contaminate your environment with potentially dangerous microorganisms.

2 Plants are frequently attacked by bacteria, which grow on or in the plants and damage or destroy them. The plants make antibacterial chemicals which kill invading bacteria and so protect the plant from harm.

3 Levels of chemicals vary in plants, so by using manufactured drugs you can give known, repeatable doses of the active ingredient every time. Plant extracts contain many other things apart from the desired drugs and some of these may be harmful. Using manufactured drugs, the active ingredient is pure and only mixed with known inert substances to make the pill or medicine. Any other sensible point.

4A.7 Developing new drugs

1 Modern techniques: identification of active ingredient, lab preparation of active ingredient including modification for improved effectiveness, testing on cell/ tissue cultures first for effectiveness, then on animals for safety and effectiveness, then on limited human trials before large-scale trials on patients. This includes use of double-blind tests to avoid the placebo effect. Careful recording at all stages to identify correct dosage, side-effects including level of risk to patient and assessment whether new drug is worth putting into production.

Withering's method: identification of active ingredient by guesswork (and trial and error), no tests before trials on patients, careful recording of all tests and their effectiveness and side-effects to identify the best treatment.

2 Identification of active ingredient → lab preparation of active ingredient → possible modification for improved effectiveness → testing on cell/tissue cultures → tests on animals →phase 1 trials on human volunteers → phase 2 trials on small number of patients → phase 3 trials on large number of patients → licensing of new drug – continuing monitoring of side-effects.

3 Any appropriate ethical statements suitably argued – any view expressed must be backed up by explanation, e.g., carrying out phase 1 trials on healthy volunteers is ethical because people volunteer to take part, or because it has the potential to give great benefit to many people. Alternatively, carrying out phase 1 trials on healthy volunteers is not ethical because some people may be persuaded to take part because they need the money.

All suggestions must be supported by explanation, e.g., carry out phase 1 trials on people who have the disease, because the drug might work effectively in people who are ill but cause problems for healthy people who have a different body chemistry.

4 Arguments for: e.g., it may save that person's life, even if it does not help the individual, they had nothing to lose and it will give information that may help others.

Arguments against: it may risk that person's life more than not using the treatment as it may have terrible side-effects. It is never ethical to use people as experimental organisms.

4A Exam practice

1 (a) B

(b) C

(c) Award marks for: alpha glucose has OH group on C1 below the line and H above. Beta glucose has OH group on C1 above the line and H below.

(d) Every other glucose molecule flips through 180 degrees (see Figure C on page 226).

2 (a) B

(b) D

(c) D

(d) X–Y is 62 mm = 62000 µm, so magnification is 62000/5 = 12400.

Award marks for:

- correct measurement between line X and Line Y (ideally in mm)
- correct division by 5
- correct magnification (originally 99–104 mm, so 19,800 to 20,800).

(e) palisade/ guard/ spongy/ mesophyll

(f) Source of lipids for synthesising membranes such as thylakoid membranes or chloroplast envelope.

3

(a) Long, straight cellulose chains, held together by many hydrogen bonds, bundled into microfibrils which are deposited in layers and held together by a matrix of hemicelluloses.

(b) (i) Award marks for: drawn using single unbroken lines, using a sharp pencil; no shading; show and label cellulose cell wall, cell surface membrane, nucleus and cytoplasm; indicate scale.

(ii) Length of one of their cells in mm, × 1000 to convert to µm and divide by 40 to obtain magnification.

4 (a) See Figure A on page 230.

(b) Root and stem are subject to different stresses and strains. Bundles around edges of stem make it resistant to bending in wind; in the centre of the root makes it resistant to compression

(c) Students' answer should include:

- contents of cells dead
- forming long hollow tubes to carry water
- walls strengthened with lignin to resist forces as water is pulled upwards
- pits to allow some sideways movement of water.

5 (a) (i) Award marks for any four points from:

- lignin gives strength but is lightweight
- wood is renewable/ sustainable
- means less concrete and steel are used
- does not expand in heat but dries out and gets stronger
- good heat and sound insulator
- there are many types of wood to suit different purposes
- aesthetic value
- composite material
- resists compression forces
- doesn't crack when cut or nailed and keeps its strength.

(ii) Award marks for any three points from:

- cotton fibres are very strong
- good heat insulator
- breathable
- allows sweat to evaporate
- flexible
- cotton is renewable/ sustainable
- cotton plants while growing remove carbon dioxide from atmosphere.

(b) Bioplastics are biodegradable so less pollution; also sustainable/ renewable.

6 (a)

Xylem	**Phloem**
Transports water and minerals	Translocates sucrose, some minerals and amino acids
Dead tissue	Living tissue
Carries water up the stem	Transport up or down the stem
Transport as mass flow	Transports as mass flow
Transport depends on pull from transpiration.	Transport depends on active loading of sucrose at sources.

(b) (i) They have the mitochondria to make ATP to actively load sucrose into the sieve tube elements.

(ii) They contain a nucleus and organelles such as mitochondria; there are connecting plasmodesmata between them and the sieve tube elements.

7 (a)

Mineral	Function
Magnesium	part of chlorophyll molecule
Calcium	used to build the middle lamella of plant cell walls
Nitrates	used to make amino acids/proteins

(b) Many in water up the xylem vessels.

(c) (i) To make middle lamella between newly formed cells at meristems where cell division occurs.

(ii) To make proteins for new cell membranes, organelles, enzymes, electron carriers in the new cells.

8 (a) (i) C

(ii) A

(iii) Use a plant pot with soil but no plant in it, repeat same procedure.

(b) Award marks for: axes correct way round and labelled (time on horizontal axis); scales on axes correct with units; correct plotting; smooth line drawn of best fit or points joined dot to dot with straight lines.

(c) It is dark, less water loss as stomata closed.

(d) Set up apparatus in same way, use a suitable (10°C–40°C) range of temperatures.

4B Classification

4B Checkpoint

4B.1 Principles of classification

1 To give scientists a universal naming system so people of all languages know what organism is being discussed, and to make it possible to quantify biodiversity.

2 Students may organise diagrams differently but should show the following relationships:

Domain → Kingdom → Phylum/division (plants) → Class → Order → Family → Genus → Species

3 Domestic cat: Eukaryota; Animalia; Chordata; Mammalia; Carnivora; Felidae; Felis; catus: *Felis catus.*

Maize: Eukaryota plantae; Aniospermophyta; Monocotyledoneae; Commelinales; Poaceae; Zea; mays: *Zea mays*.

Honeybee: Eukaryota; Animalia; Arthropoda; Insecta; Hymenoptera; Apidae; Apis; mellifera: *Apis mellifera*.

Human being: Eukaryota; Animalia; Chordata; Mammalia; Primates; Hominidae; Homo; sapiens: *Homo sapiens.*

4B.2 What is a species?

1 To give scientists a universal naming system so people of all languages know what organism is being discussed, and to make it possible to quantify biodiversity.

2 To measure genetic diversity, to identify relationships between different species, to track the process of evolution, to monitor effects of human activities, etc.

3 Classic morphology: advantage – easy to see and measure differences; difficulty – visible differences don't always indicate different species, or lack of visible differences doesn't mean they are the same species.

Reproductive capability: advantage – successful breeding with fertile offspring is unequivocal in animals if it occurs; difficulty – can be very difficult to get evidence, particularly in slow-breeding organisms and those that live in different localities, different species of plants often crossbreed and produce fertile offspring.

DNA analysis: advantage – gives unequivocal evidence of organisms in same species, and of relationships between species; disadvantages – still expensive, needs high-tech equipment, generates huge amounts of data.

Any other valid points.

4B.3 Domains, kingdoms or both?

1 Molecular phylogeny involves analysing the DNA, RNA and other chemicals in organisms which may appear similar or very different. This analysis can be used to demonstrate genetic diversity between apparently similar organisms, or it may reveal surprising similarities.

2 Fairly general points are acceptable as an answer to this type of question. Answer could include: enables scientists to see how similar and different key chemicals are in different species and so to work out how closely related they are, allows us to distinguish the three

domains.

3 There is a lot of different evidence that can be interpreted in different ways. Not all of the evidence supports all of the theories: fossil evidence and DNA evidence may point in different directions, for example; it depends on what you are looking for, what you are trying to prove, how you interpret data, etc.

Students may provide evidence (e.g., from the Natural History Museum, etc.) that scientists are beginning to think there should only be two domains – Archaea and Bacteria – with Eukaryotes and a branch of the Archaea that include some Bacteria. They may use the similarities and differences between Bacteria, Archaea and Eukaryote to discuss the problems of deciding which is more closely related. Any sensible discussion, and evidence of reading around the subject, should be credited.

4 The development of the three-domain system made the old five-kingdom classification system redundant because the prokaryotes were in two domains, destroying the old kingdom of the Monera and demanding a six-kingdom classification system. Students may cite evidence from the Natural History Museum and other sources that scientists are beginning to think there should only be two domains – Archaea and Bacteria – with Eukaryotes and a branch of the Archaea that includes some Bacteria.

4B Exam practice

1 (a) D

(b) A

(c) Three of:

- no membrane-bound nucleus/ DNA not in a nucleus
- no other membrane-bound organelles
- 70S ribosomes
- mesosome
- capsule
- plasmids
- flagellum (structurally different from cilia/ undulipodia in eukaryotes)
- walls containing peptidoglycan(murein).

(d) Some similar features may not have had the same origins, e.g. bird, bat and insect wings. This could lead to putting unrelated organisms into the same group and lead scientists to think organism were related when they were not; could lead to wrong evolutionary relationships being described.

2 (a) C

(b) A generic name which shows the genus to which the organism belongs and a specific name shows the species.

(c) Members of the same species can interbreed and produce fertile offspring; they also have similar morphology, anatomy, physiology and behaviour.

(d) Can indicate how closely related organisms are, informing us of evolutionary relationships and can support/ refute previous classification.

3 (a) (i) Q

(ii) Q and R

(iii) Students should place a cross in the far-right box.

(b) (i) (QWC – Spelling of technical terms must be correct and the answer must be organised in a logical sequence). Answer should include the following terms: cellulose; as microfibrils; cellulose molecules held together by hydrogen bonds; details of microfibrils (e.g. bundle/ correct stated number of cellulose molecules); correct reference to arrangement of microfibrils (in primary cell wall); reference to matrix/ hemicelluloses/ pectins; reference to primary and secondary cell walls; detail of different laying down arrangement (in secondary cell wall)/ reference to lignin.

(ii)

Feature described	Name of feature
Site where there was no cell wall and the cytoplasm linked the two adjacent cells.	plasmodesmata/ plasmodesma
Dark line that is the boundary between one cell and the next cell.	middle lamella

4 (a) C

(b) (i) C; because mitochondria are present (and only Eukaryota possess mitochondria)

(ii) B; because it has more/most/three/any two named characteristics in common (with the eukaryotes/Group C) OR due to the idea that because A is sensitive to antibiotics, A must be Bacteria therefore B is Archaea/eq.

(c) (i) Students' answers should include reference to the following:

- stacks/ eq
- cisternae
- smooth membranes/ no ribosomes/ eq
- (cisternae) curved/ flattened
- idea of different sizes (cisternae)
- presence of vesicles.

(ii) Award up to 5 marks for the following points:

- protein/ polypeptides produced by ribosome
- ribosomes held on/ attached to/ eq rER
- proteins stored/ transported/ within rER/ eq
- proteins folded/ assume 3-D shape/ tertiary structure within (lumen of) rER/ eq
- (rER) produce vesicles/ packages proteins/ eq
- vesicles fuse with Golgi (apparatus)/ eq
- Golgi modifies/ processes protein
- details of modification, e.g. glycoprotein/ carbohydrate added, trimming of carbohydrate
- water removed (to concentrate)/ eq
- Golgi produces lysosomes/ secretory vesicles
- up to 1 mark for quality of written communication – spelling of technical terms must be correct; answer must be organised in a logical sequence.

(d) (i) B

(ii) C because there are least differences in the sequence

(iii) $100 \times 5/783 = 0.64\%$

5 (a) Based solely on appearance of the organisms. Organisms with similar

appearance are put in the same group. For example: all cats look similar, but we know that domestic cats are not the same species as tigers, although they are related.

(b) (i)This states that only members of the same species can interbreed and produce fertile offspring.

(ii) Members of closely related species can interbreed and sometimes the offspring are sterile (e.g. mule), but sometimes they are fertile; some species do not reproduce sexually (e.g. bacteria).

(c) (i) Cell wall containing chitin; heterotrophic nutrition.

(ii) Not animal, plant, fungi or prokaryote; mainly reproduce asexually.

6 (a) Gorilla: Domain – eukaryote; genus – *Gorilla;* species – *gorilla*.

Fruit fly: domain – eukaryote; genus – *Drosophila*; species – *melanogaster.*

(b) (i) Greatest level of agglutination.

(ii) Proteins of a similar shape as both fit the variable regions of the antibody. Protein in each species coded for by a gene. In each case the base triplet sequence of the DNA is very similar/almost the same, between the two species.

(iii) The more distantly related the two organisms the longer the time they have had to become diversified and more mutations in the gene have accumulated, so the amino acid sequence of the proteins are now more different from each other and so the 3D shape/tertiary structures are more different and one no longer fits so well into the variable regions of the antibody.

4C Biodiversity and conservation

4C Checkpoint

4C.1 Biodiversity and endemism

1 Because it doesn't take into account the genetic variation in populations, which is also important.

2 High bird biodiversity means a large number of different species; high endemism means a large number of species that evolved in that place. High biodiversity may be the result of high endemism, but it may also be due to bird species from other areas moving into the area. An area of high endemism may only include a few species of bird that evolved in situ and not a large number of different species, as on islands, which might explain the high levels of endemism on the Indonesian islands which are not areas of high species richness.

3 Because they were founded by a small number of individuals that would have had a small gene pool. Allele frequencies would not necessarily reflect a normal population. As all subsequent generations are descended from this small number of individuals, genetic diversity is lower than in a population in which there can be genetic movement in and out of the population.

4C.2 Measuring biodiversity

1 Because it doesn't take into account the genetic variation in populations, which is also important.

2

Species	**Number of organisms**	**(*n* – 1)**	***n* (*n* – 1)**
holly	9	8	9 × 8 = 72
bramble	3	2	3 × 2 = 6
oak	3	2	3 × 2 = 6
butcher's broom	5	4	5 × 4 = 20
ivy	3	2	3 × 2 = 6
yew	1	0	1 × 0 = 0
Total number of organisms	24	18	24 × 18 = 432

$$\frac{D = N(N-1)\,o}{\sum n(n-1)}$$

Using the data from the table:

$$D = \frac{432}{72+6+6+20+6+0}$$

$$D = \frac{432}{110} = 3.93 \text{ (to 2 d.p.)}$$

Diversity index = 3.93, which is relatively high.

3 The number of species and the amount of genetic variation within species are both important. The number of different species and the number of individuals of each species is key information for understanding an ecosystem and how it can best be conserved. However, genetic diversity is also important – it gives an indication of how robust a species will be at surviving changes. Using both measures is the best way to understand biodiversity.

Award marks for any other valid points and clear examples.

4C.3 Adaptation to a niche

1 A niche is the way an organism lives, including what it eats, whether it moves, etc. To be successful (i.e. grow and produce offspring), the organism needs to be well adapted to the conditions around it, and therefore its niche, so that it can find food and a mate.

2 (a) Time before the dive.

(b) Approximately 4.5 minutes.

(c) $\frac{160 - 20}{160} \times 100$ = c. 88%; without bradycardia = 4.5 min × 12% = c. 32 seconds

(d) It is a physiological adaptation – which enables the seal to stay underwater and hunt for food in a harsh environment where food is scarce, giving it a survival advantage over animals that do not have this bradycardic response.

3 Summary of how anatomical adaptations help camels survive in their hot, dry, plant-grazing niche:

- Large eyes give good vision in many directions and are protected by long lashes which protect the eyes against the sandy environment.
- Long, slit-like nostrils can be closed to protect against sand and wind.
- The upper lip is split, hairy, extensible, slightly prehensile and sensitive. This allows camels to identify and gather food and avoid the thorns that are a protective adaptation of many desert plants.
- A hump on the back helps insulate the animal from the heat of sun. The fat concentrated in the hump allows easy evaporation of sweat over the rest of the skin surface as there is little fatty insulation under the skin. This is important in cooling down.
- The feet are large and flat with tough pads. These spread out the weight of the camel as it walks over sand and prevent heat damage.
- Tough pads on the knees prevent damage from hot sand when the camel rests.

Summary of how physiological adaptations help camels survive in their hot, dry, plant-grazing niche:

- The camel can withstand a wide variation of internal (core) body temperature. Most mammals – and camels under ideal conditions – maintain their body temperature within a 2°C range. Under heat stress, or when a camel is dehydrated and cannot afford to lose water in thermoregulation, a camel can allow its body temperature to vary over 6°C. This saves energy and water as it does not need to produce so much sweat.
- Camels can lose 30% of their bodyweight through water loss and then make it up in 10 minutes drinking water, without changing the osmotic potential of the blood. Consequently, the blood does not become thick and unable to flow when the camel

is extremely dehydrated enabling it to survive in very dry conditions.

- As the fat in the hump is broken down to release energy during cellular respiration, water is produced as a by-product and this metabolic water means camels can survive longer than most mammals without actually drinking water.
- Camel body tissues can withstand a loss of up to 30% of the body water without being damaged – it can go without water in the desert heat for up to 10 days, vital for survival in the desert niche.
- Camels can withstand big temperature variations which means that they minimise water loss by sweating. They have kidneys adapted to produce very concentrated urine – this reduces water loss and enables camels to drink quite salty water. The production of urine is also slowed down to a minimum when a camel is dehydrated – again reducing water loss and maximising the ability to survive in the hot, dry, grazing niche.

4C.4 Gene pool and genetic diversity

1 (a) 95/200 × 100 = 47.5% have the recessive phenotype.

(b) The two equations needed to find the percentage of the population that are recessive are:

$p + q = 1$

$p^2 + 2pq + q^2 = 1$

The frequency of the homozygous recessive trait is 0.48. So, $q^2 = 0.48$, therefore $q = \sqrt{0.48} = 0.69$.

Now we can find p as, $p + q = 1$ so, $p = 1 - 0.69 = 0.31$

Frequency of heterozygote = $2pq = 2\ (0.31 \times 0.69) = 0.43$

So, percentage of heterozygotes = 43%

(c) Frequency of homozygotes with dominant phenotype = $0.31^2 = 0.1$

2 126/150 have brown fur so, 150 – 126 (or 24) have grey fur (recessive phenotype).

24/150 × 100 = percentage homozygous recessive = 16%

Frequency = 0.16

$q^2 = 0.16$ so, $q = \sqrt{0.16} = 0.4$

Now we can find p as, $p + q = 1$ so, $p = 1 – 0.4 = 0.6$

Frequency of heterozygotes = $2pq = 2\ (0.6 \times 0.4) = 0.48$

Frequency of homozygous dominant = $p^2p = 0.6$ so, $p^2 = 0.36$

3 The Hardy-Weinberg equation is only valid if it is applied to a large population, with a minimum of several thousand individuals. The population must exist in isolation with no

migration of organisms either into or out of the population and all alleles must have the same level of reproductive advantage or disadvantage. These conditions are rarely if ever met in a natural environment.

4C.5 Reproductive isolation and speciation

1 Ellis-van Creveld syndrome homozygous recessive

43/8000 × 100 = percentage homozygous recessive = 0.5%

Frequency = 0.005

q^2 = 0.005 so, q = √0.005 = 0.07

Now we can find p as, $p + q = 1$ so, $p = 1 – 0.07 = 0.93$

Frequency of heterozygotes = $2pq = 2(0.93 \times 0.07) = 0.13$

Frequency of homozygous dominant = p^2. p = 0.93 so, p^2 = 0.86.

2 Genetic bottleneck: when an event or series of events dramatically reduces the size of the population through the deaths of many organisms. This is called a population bottleneck and it causes a severe decrease in the gene pool of the population. Many of the gene variants present in the original population are lost so the gene pool shrinks and the allele frequency changes dramatically. In almost all cases, genetic diversity is greatly reduced.

Founder effect: the loss of genetic variation that occurs when a small number of individuals leave the main population and set up a separate new population, producing a voluntary 'population bottleneck'. The alleles carried by the individuals who leave the main population may be a random selection of the gene pool, but it is unlikely that they will include all the alleles, or at the same frequencies, as in the original population. Any unusual genes in the founder members of this new population may become amplified as the population grows.

3 Ngorongoro crater: lions suffered population bottleneck due to disease. Many alleles wiped out and some alleles increase in frequency as breeding pool small and inbreeding likely. This can lead to infertility as damaged genes increase in frequency in the population, etc.

Outside crater: population has much bigger gene pool, greater genetic diversity, no loss of frequency or artificial selection of narrow range of alleles, therefore more likely to remain healthy and breed effectively.

Any other sensible points.

4C.6 Conservation: why and how?

1 Conservation involves keeping and protecting a living and changing environment – it is dynamic and encompasses change, whereas preservation is static and keeps things exactly the same.

2 (a) In situ conservation takes place in the natural habitat of the organism; ex situ conservation is the conservation of living organisms away from their natural habitat – often in a different country.

(b) Ex situ conservation can be used to support in situ conservation in the following ways.

- Organisms can be removed from breeding in a safer environment and then returned to the wild to support the organism being conserved in situ.
- Ex situ conservation can increase the gene pool of a dwindling wild population.
- Ex situ conservation can keep the numbers going until such time as in situ conservation is viable.

3 Plants can be conserved as seeds. Plants make many seeds, so collecting a few does not harm population numbers. When cooled and dried, most seeds will last several hundred years. If not seeds, tissue cultures can be conserved that will produce more plants when desired. These techniques do not take up much space and are not very expensive.

Animals are much harder to conserve. DNA is being conserved but so far, we have no way of bringing that back into being a living animal. Conserving and breeding whole animals is very expensive, takes up a lot of space and is very time consuming.

Award marks for any other sensible points; there are many.

4 Advantages:

- It helps save some of the rarest animals and plants.
- Some species have been saved from extinction and returned to the wild.
- Genetic variety can be maintained as much as possible to support captive breeding and wild populations.

Disadvantages:

- Ecosystems, once lost, may never be restored – animals may not have somewhere to return to so reintroduction to the wild becomes impossible.
- Animals are expensive to keep.
- It is difficult to provide the right conditions for breeding.
- Animals bred and fed in captivity may be unable to adapt to life in the wild.
- Expensive reintroduction programmes may fail.
- Award marks for any other sensible points.

4C Exam practice

1 (a) (i) A

(ii) D

(b) Species richness is the number of different species per unit are in a location; biodiversity is a measure of the variety of living organisms and their genetic differences within a location.

(c) (Quality of written communication – Spelling of technical terms must be correct and the answer must be organised in a logical sequence.)

General points include: to increase numbers/ population size; to maintain/ increase genetic diversity or reduce genetic drift; protect from predators/ poachers; for captive breeding; inter-zoo animal movement; selection of mates/ use of stud books/ records kept of breeding programme; process involved described, e.g. IVF/ AI/ use of surrogates/ DNA profiling; for reintroduction: preparation for reintroduction described, e.g. idea of reinforcing wild behaviour/ idea of hacking out/ reduce food intake to encourage hunting; select habitat/ reserves; raise awareness/ educate local population.

2 (a) (i) Award: 1 mark for each total (up to 3 max); 1 mark for correct *n* – 1; 1 mark for correct *n* (*n* – 1).

Species	Number of plants growing in 0.25 m^2 quadrat (*n*)	*n* – 1	*n* (*n* – 1)
Daisy (*Bellis perennis*)	2000	1999	3 998 000
Dandelion (*Taraxacum officinale*)	3000	2999	8 997 000
Red clover (*Trifolium pratense*)	3500	3499	12 246 500
Yarrow (*Achillea millefolium*)	2000	1999	3 998 000
Grass (*Agrostis spp*)	4000	3999	15 996 000
Grass (*Festuca spp*)	4500	4499	20 245 500
Bee orchid (*Ophrys apifera*)	1	0	0
Totals	19 001	18 994	65 481 000

(ii)

- 1 mark for the equation $\frac{N(N-1)}{[\Sigma n(n-1)]}$
- 1 mark correct substitution $\frac{19\,001 \times 19\,000}{(65\,481\,000)}$
- 1 mark correct resolution $\frac{5.51}{5.5}$

(b) (i) Probably as the plant was rare and one was found in one of the quadrats which seems to be representative. Sampling should be random and not set out to find any particular specimens.

(ii) When calculating Simpson's Diversity, the 'n – 1' part of the calculation removes this one bee orchid from the calculation.

(c) More grass plants *and* less broad-leaved plants; therefore, *lower* biodiversity (2.26 is less than 5.5). (Note: There are many ways of calculating Simpson's Index. The way in the specification goes from low numbers (= low biodiversity) to high numbers (= high biodiversity). Other methods do exist, including:

$$D = \Sigma\left(\frac{n}{N}\right)^2$$

This last method goes from 0 to 1, where (confusingly) 1 means *low* biodiversity, and smaller numbers means *high* biodiversity. It's important to know which Simpson's Index you're using!)

3 (a) B

(b) B. *p*2 is only the individuals who have the homozygous dominant genotype, DD (not Dd or dd).

(c) (i) You are told in the question that MSUD is 1 out of 200. So, this means that q = 1/200, which is 0.005

Since $p + q = 1$, this means that $p + 0.005 = 1$

Therefore $p = 1 - 0.005$, which is 0.995

(ii) Using $p2 + 2pq + q2 = 1$, and knowing that $p = 0.995$ and $q = 0.005$:

(I) Homozygous dominant is *p*2 which is (0.995)2

in population of 100000, (0.995)2 × 100000 = 99002.5.

(II) Heterozygous is 2*pq*, which is 2 × (0.995 × 0.005)

in population of 100000, 2 × (0.995 × 0.005) × 100 000 = 995.

(III) Homozygous recessive is *q*2, which is (0.005)2

in population of 100000, (0.005)2 × 100000 = 2.5.

HINT: you can check you have your calculations correct by making sure the numbers of each genotype all add up to your total population: 99002.5 + 995 + 2.5 = 100000. Do not round your *p*2, 2*pq* or *q*2 until you multiply by the total population.

(iii) In the general population the MSUD allele remains at a very low frequency. The Amish are an isolated population with a small number of founder members. By chance at least one founder member of the original Amish population carried the recessive allele for MSUD. Due to the small gene pool available in an isolated population the frequency of the MSUD allele is amplified, resulting in a higher proportion of affected individuals in the population over time. This is the founder effect.

4 (a) One from:

- DNA/point mutation
- error passes on to mRNA
- during transcription
- (incorrect tRNA bound) during translation.

(b) (i) African: q = 1/3, so *q*2 is (1/3)2 = 0.11; as a percentage this is 11%

African descent in America: q is 1 in 13, so $q = 0.077$, $q2 = 0.0059$ so 0.59%

Northern European: 1 in 63, so $q = 0.016$, $q2 = 0.00025$, so as a percentage = 0.025%.

(ii) Homozygous normal and homozygous sickle cells both least likely to survive to produce children; heterozygous individuals do not get sickle cell disease AND less likely to die from malaria; so can survive to produce children.

5 (a) C

(b) D

(c) More risk of inbreeding depression – increased chance of related individual mating and could lead to decrease in fertility or greater incidence of genetic abnormalities; may be more difficult for individuals to find mates.

(d) Three from:

- prevent poaching
- not eat bush meat
- not encroach on their territory
- not take their food
- educate children/ next generation to appreciate gorillas and understand the need to protect them.

(e) Establish captive breeding programmes between unrelated individuals and release some back into the wild, may prevent extinction of the species.

(f) Students' answers could include:

- In botanic gardens plant species/ varieties may interbreed.
- Competition from other species may cause selection pressures and lead to change in allele frequencies in the population.
- Climate changes may also drive changes in allele frequency in the population.
- In seed banks no such changes occur.
- Seeds in seedbanks kept at low temperatures remain viable for a long time (hundreds of years).
- They may be used to repopulate an area after humans have solved climate change and pollution problems.