O Level Biology

Teacher's Guide

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Contents

Unit 1: Cell Structure

The Structure of Animal and Plant Cells

This covers the syllabus sections 1(*a*), (*b*), (*c*), (*d*), (*e*) and (*f*).

It is suggested that students first see diagrams of cells, and learn about their structure. This will help them to understand what they see when they later look at cells using a microscope, or when they see photomicrographs of cells. The parts of the cells that are described are those that are required by the syllabus. There is no need to introduce other structures (for example, mitochondria) as these may confuse students at this stage.

The very small size of cells is emphasised here. Ask students to look at a ruler that is marked off in millimetres, and imagine 100 animal cells fitting into one millimetre.

Investigation 1.1 Looking at animal cells

This may be the first time that students have used a microscope. You may need to modify the instructions given so that they relate to the type of microscopes that you have available. In any case, you should demonstrate the use of a microscope to your students, before asking them to carry out this practical.

Safety points

Liver cells may carry bacteria. Dispose of any leftover suspension quickly. Do not pour it down the sink, as the rotting liver will smell badly.

Students should wash their hands thoroughly after carrying out this experiment, to remove any trace of liver cells.

Materials required

Each group of students will need the following:

- a microscope and light source (which can be a lamp or a window)
- a clean microscope slide
- one or two clean cover slips
- a long pin, or a mounted needle, to help with lowering the coverslip
- a pipette
- a small amount of methylene blue solution, with its own pipette
- a piece of filter paper or blotting paper

- a small amount of liver cell suspension. Prepare this by grinding or liquidising some fresh liver with a cold isotonic solution. The suspension should be prepared as close as possible to the time when it will be used, and should be stored in a refrigerator.

Methylene blue is suggested as a stain, because it is taken up by living cells. It is a good idea for you to experiment with different concentrations of methylene blue, to find out the best concentration for staining the liver cells, before the students carry out the practical. The stain should colour the cytoplasm light blue, and the nucleus darker blue.

Students are asked to draw one or two of the cells that they can see. It is very important that they draw what they can see, and not what they think they ought to be able to see. Diagrams that look exactly like Fig. 1.1a are useless!

Investigation 1.2 Looking at plant cells

Safety points

There are no special safety issues relating to this investigation.

Materials required

Each group of students will need the following:

- a microscope and light source
- a clean microscope slide
- one or two clean coverslips
- a long pin, or a mounted needle, to help with lowering the coverslip
- a pipette
- a small amount of iodine in potassium iodide solution, with its own pipette
- a piece of filter paper or blotting paper
- a piece of onion bulb or other source of plant cells—for example, a leaf from which the lower epidermis can be peeled

You will need to show students how to peel a small piece of epidermis from the inside of one of the layers in an onion bulb, or from the lower surface of a leaf. Cut the piece of bulb to size first, rather than peeling off a very large piece of epidermis and then trying to cut it into smaller pieces. The epidermis needs to be put straight into water on the slide, before it begins to dry and curl. You may be able to find a source of material that has coloured cytoplasm or cell sap, which can help students to see the cells more clearly.

Once again, it is very important that students are encouraged to draw what they can genuinely see. It is unlikely that they will be able to see a clear line separating the vacuole from the cytoplasm, for example. They should not be surprised that there are no chloroplasts, if they know that onion bulbs grow underground.

Answers to questions

1.1

Structure	**Animal cells**	**Plant cells**
cell membrane	✓	✓
cell wall	✗	✓
cytoplasm	✓	✓
nucleus	✓	✓
permanent vacuole containing cell sap	✗	✓
chloroplasts	✗	✓

1.2

Structure	**Function**
cell membrane	controls what enters and leaves the cell
cell wall	holds the cell in shape and stops it from bursting
cytoplasm	contains enzymes and other substances; many metabolic reactions take place here
nucleus	contains chromosomes made of DNA, that determine what proteins the cell will make
permanent vacuole containing cell sap	contains cell sap, which is made up of sugars and other substances dissolved in water
chloroplasts	contains chlorophyll and carries out photosynthesis

Special Types of Cells

This covers syllabus sections 1(*g*) and (*h*).

Both the red blood cell and the root hair cell are modified to give them a large surface area to volume ratio, which speeds up the rate at which they can absorb oxygen and water respectively. You could demonstrate this concept to your students using a set of square wooden building blocks.

Demonstration: Shape, Size and Surface Area to Volume Ratios

You will need lots of small square blocks—preferably with sides of 1 cm, as this makes the calculations easier.

(1) First show the students one block, and ask them to tell you:

- its volume
- its surface area—they will need to work out the surface area of each face, and then count the number of faces

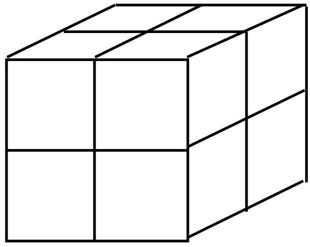
(2) Write these values down on the board, in a table like this:

number of bricks in the stack	volume/cm^3	surface area/cm^2	surface area to volume ratio
1	1	6	

(3) Now add 7 more blocks to the first one to make a cube, and ask the students again for the volume and surface area. Add these values to the table.

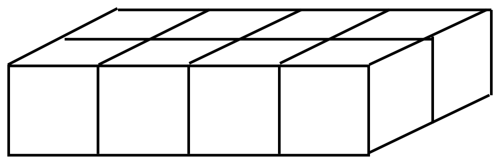
Sizes

Cube made of 8 bricks . . . . . . and so on . . .



(4) Carry on adding bricks to make larger cubes, writing the volume and surface area in the table each time.

(5) Now draw a second table on the board, and repeat the whole thing, using the same number of bricks each time but now arranging them in a long flat shape rather than a cube.



(6) When you have two complete sets of data, show the students how to calculate the surface area to volume ratio. They can then fill in the values for each stack of bricks in the final column.

Discuss results with the students

Ask them what patterns they can see. They should notice that:

- as the volume of the stack increases, the surface area to volume ratio decreases
- for a particular volume, the surface area to volume ratio is always greater for a long, flat shape rather than a cubic one.

Discuss with them what this means. They should be able to see that :

- a small cell has a larger surface area to volume ratio than a large cell
- a flattened cell has a larger surface area to volume ratio than a spherical cell

You can now relate this to the shape of a red blood cell. Its size and shape give it a large surface area to volume ratio. This means that the cell has a lot of surface through which oxygen can get in and out. So more oxygen can pass into or out of the cell at any one moment in time than if the cell was large and spherical—thus speeding up the rate at which oxygen moves in and out.

Answers to questions

1.3 a Red blood cells transport oxygen from lungs to other parts of the body.

b Haemoglobin combines with oxygen in the lungs, and then releases it where it is needed.
The lack of a nucleus makes more space for haemoglobin.
The small size, and the biconcave shape, gives the red blood cell a large surface area to volume ratio. This speeds up the movement of oxygen into and out of the cell. Their small size helps them to squeeze through the tiniest capillary, and get close to the body cells which need oxygen.

1.4 a Root hair cells absorb water and inorganic ions from the soil.

b The shape of the root hair cell gives it a large surface area to volume ratio. This speeds up the rate at which water and inorganic ions can move into the cell.

1.5 a Xylem vessel elements transport water and inorganic ions around the plant. They also help to support the plant.

b Having no living contents makes it easy for water to move through the xylem vessels.
Having lignin in their walls makes the xylem vessel elements very strong, so they help to hold the plant upright.
Having no end walls means that water can easily flow from one xylem vessel element to the next.

How cells are organized

This covers section 1 (*i*) of the syllabus.

Demonstration: different types of cells and tissues

If possible, use a projector and transparencies to show students some different types of plant and animal cells, and the tissues of which they are part. (If you cannot do this, then show the students photomicrographs instead.) You can discuss the function of each tissue that they see, and also consider how the cells that make up the tissue are adapted for their functions. Some suggestions are:

- TS leaf, showing epidermal, palisade mesophyll and spongy mesophyll tissues
- TS stem or root, showing epidermis, cortex, xylem, phloem
- The wall of part of the alimentary canal of a mammal—you may be able to

see the epithelium (which may contain goblet cells to secrete mucus), and also smooth muscle cells

- The wall of the trachea or a bronchus of a mammal—you may be able to see the ciliated cells and goblet cells in the epithelium, and also cartilage and smooth muscle cells

Answers to questions

1.6 eye – organ
nerve – organ
kidney – organ
leaf – organ
epithelium of a leaf – tissue
xylem vessel element – cell

1.7 artery – circulatory system
stomach – digestive system
skull – skeletal system

Unit 2: Diffusion, Osmosis and Active Transport

Diffusion

This covers the syllabus section 2(*a*).

Students need to know something about the kinetic theory before they can understand diffusion, so check that this has been covered in physics or chemistry lessons. Emphasize that the particles are just moving randomly, and not purposefully from one place to another.

You may be able to demonstrate the situation described in 'How diffusion happens'. Choose something with a strong scent, but that is not harmful. A bottle of strong perfume would be ideal.

Investigation 2.1 Diffusion

There are many possible ways to demonstrate diffusion—for example, colour spreading from a copper sulphate crystal in a glass container of water, bromine gas inside a gas jar moving into another held above it, ammonia gradually turning successive pieces of red litmus paper blue as it diffuses down a tube. This example has been chosen as it introduces the idea of membranes which let some things through and not others, and also the starch-iodine test.

Take care, however, to avoid the very common misconception that diffusion only takes place across a membrane.

Students will not understand this investigation unless they understand what a solution is. They need to be aware that the starch solution is a mixture of starch molecules and water molecules, and that the iodine solution is a mixture of iodine molecules and water molecules.

Safety points

None of the materials that are used are toxic. However, iodine solution will stain clothes.

Materials required

Each group of students will need:

- a small beaker or other container
- a piece of Visking tubing, long enough to allow it to be tied into a knot at one end
- a length of strong thread
- a small amount of iodine in potassium iodide solution (as used for starch tests)
- some starch 'solution' (make this using soluble starch)—the concentration does not matter
- two dropper pipettes

Students are asked to explain their results. Encourage them to think about each type of molecule separately – the water molecules, starch molecules and iodine molecules – rather than thinking about the solution moving.

Further work

Assessment Objectives C5 in 'O' Level Biology is to design or plan an investigation, and this investigation provides opportunity for students to develop this skill. When they have done Investigation 2.1, they could be asked how they could modify this procedure to investigate the effect of temperature on the rate of diffusion. You could deal with this as a class discussion, and use it to introduce the idea of variables. In this instance, students should think about:

- what they would need to change (the temperature of the liquids)
- what they would need to keep the same (the volumes of liquids, the size of the Visking tubing, the concentrations of the starch solution)

- what they would measure (the time taken for the blue colour to first appear inside the tubing, or for a particular depth of colour to be reached) and how they would measure it.

Osmosis

This covers syllabus sections 2(*b*) and (*c*).

Do take care that students understand that osmosis is just a special kind of diffusion. They often become very confused with the use of the term 'concentration' to describe how much water is present, and this can lead to erroneous answers to examination questions such as 'Osmosis is the opposite to diffusion, because water moves from a low to a high concentration rather than from high to low concentration'. The use of the term 'water potential' can avoid this confusion right from the start.

Do not be tempted to do anything quantitative about water potential—even A Level students get confused with this! Keep it very simple.

Another common confusion is that the plant cell wall stops water from entering the cell, and this is why it does not burst. Make sure that students realize that the water does move freely through the cell wall, and that the reason it does not burst is because the wall resists the expansion of the cell.

You might like to place some pieces of raw potato or other solid plant tissue into water, and into concentrated sugar solution, some time before the lesson, and then allow the students to find out what a tissue made of turgid cells, and another containing flaccid cells, feels like. This will help them to understand how turgor can help to support the soft parts of a plant, and why plants wilt when they have lost too much water.

Answers to questions

These questions should help students to check their understanding of osmosis. It also helps them to use what they have learnt about osmosis in *single cells*, and apply this knowledge to work out what will happen in *tissues*.

2.1 higher, down, osmosis, membrane, burst, out of, shrink
2.2 tissue, osmosis, water, wall, membrane, turgid, wall, water, flaccid, softer

Investigation 2.2 Osmosis and plant tissues

Any dried fruit can be used for this investigation. It is suggested that students use groups of 10 raisins, but you may need more than this if the balances available cannot mass these with any degree of accuracy.

Safety points

None of the apparatus or materials are potentially harmful. However, make sure that students do not put the raisins into their mouths.

Materials required

Each group of students will need:

- at least 10 raisins or pieces of other dried fruit
- two containers, one containing pure water and the other a sugar-solution (the concentration is not important)
- access to a top pan balance
- blotting paper or filter paper to dry the raisins

The raisins in both groups should gain mass, but those in the water will gain more than those in the sugar solution. As there is bound to be considerable inaccuracy in the results obtained, it is a good idea for all the groups in the class to share their results, so that any patterns can be more clearly seen. Talk these through with the whole group, and try to draw out from them what was happening. They will need to think about the cell membranes around the raisin cells, in which direction there is a water potential gradient, what was happening to the water molecules and what was happening to the sugar molecules. They should also think about the *steepness* of the water potential gradient in the two containers, and how this has affected the results.

Active Transport

This covers syllabus section 2(*d*).

Answers to questions

2.3

	Diffusion	Osmosis	Active transport
Molecules move down a concentration gradient	✓	✓	✗
Molecules move against a concentration gradient	✗	✗	✓
The cell uses energy to make it happen	✗	✗	✓
Can only happen across a partially permeable membrane	✗	✓	✗
Always involves the movement of water molecules	✗	✓	✗

2.4 a The concentration of potassium ions is greater inside the cells than outside. Left alone, the potassium ions would diffuse out of the cell. The cell must have been taking them in against their concentration gradient.

b The cell has to use energy to move the ions into the cell by active transport. It gets this energy from the breakdown of glucose in respiration. If the roots do not have enough oxygen, then they cannot release enough energy from glucose, so cannot carry out active transport.

Unit 3: Enzymes

The introductory paragraphs of this Unit cover syllabus section 3(a).

Students are likely to have met catalysts already in Chemistry lessons. If you know that this is so, you could begin by asking them to tell you what a catalyst is.

A very common mistake that students make is to think that all catalysts are enzymes. They need to understand that enzymes are just a particular type of catalyst, found in living organisms and made of protein.

How enzymes work

This section covers syllabus section 3(b).

Maltase is used as an example here because it catalyses a simple reaction in which a molecule is split into two equal parts.

In this section, students are being asked to visualise events taking place that involve *molecules*. It is worth taking a little time to ensure that they do understand that a molecule is the smallest possible particle of a substance. It is quite impossible for any of us to visualise the infinitesimally small size of these molecules, but you could at least ask your students to try!

A number of important new terms are introduced, and Question 3.2 is included to help them to learn them. Similarly, Question 3.1 provides them with a summary table of enzymes, substrates and products. This looks ahead to Chapter 5, in which many of these enzymes will be met again.

Answers to questions

3.1 catalyst – any substance that increases the rate of a chemical reaction without itself being changed
enzyme – a protein that functions as a biological catalyst
active site – the part of an enzyme molecule into which the substrate molecule fits
substrate – the substance that an enzyme can change into something else
intracellular – inside a cell
product – the substance that is formed when an enzyme catalyses a reaction
extracellular – outside cells

3.2

enzyme	**substrate**	**product**
catalase	hydrogen peroxide	water and oxygen
amylase	starch	maltose
protease	protein	amino acids
lipase	fats	fatty acids and glycerol
starch phosphorylase	glucose	starch
maltase	maltose	glucose

Enzymes and temperature

Very often, students are able to explain why enzymes do not work rapidly above their optimum temperature, but cannot explain why the rate of activity increases *up* to the optimum. It is very important that they understand that the increase in activity as temperature rises is seen in many different chemical reactions, even if these are not enzyme-catalysed ones. This first part of the temperature-activity graph should be drawn as an exponential curve; for many reactions, a rise of 10°C produces a doubling in the rate of the reaction.

Do emphasize that enzymes cannot be 'killed'. This is an extremely common error that students make on examination papers, and they will lose marks if they say this. It is probably best for them simply to learn the term 'denatured'. If this is thought too difficult, then 'damaged' would be an allowable alternative.

Another common error is to believe that *all* enzymes have an optimum of 37°C. Encourage students to realise that all living things have enzymes, but that only in birds and mammals that the body temperature is kept constant at around 37°C. In other organisms, enzymes will be adapted to work at different temperatures.

Answers to Questions

3.3 kinetic, quickly, substrate, active site, denatured.

Investigation 3.1

The reaction used in this investigation has been chosen because there is a change in the appearance of the reacting mixture as the reaction takes place. Students often find it easier to understand what is happening here, rather than in the starch-amylase reaction, in which a further test (using iodine solution) has to be carried out before any information is picked up about whether or not the reaction has happened.

Many different types of trypsin are commercially available, most of which are derived from fungi and have a much higher optimum temperature than 37°C. It is suggested that you try this experiment first so that you know approximately what optimum to expect; you may then want to modify the range of temperatures suggested in the student's book. If you do not have thermostatically-controlled water baths, you can maintain approximate temperatures for the short duration of this experiment by adding hot or cold water to containers.

You should also pre-test the best concentration of enzyme and milk to use. Sensible starting points are listed below, but you may need to alter these. The aim is that the contents of at least two of the tubes should have become transparent after 20 minutes.

You may also like to have a tube containing milk to which hydrochloric acid has been added. The acid breaks down the protein and makes the contents clear, and this can show students what they are looking for in their experimental tubes.

Safety points

Trypsin is a protease, and can therefore digest proteins in skin. It may also cause allergies in some people. Students should be advised to wash their hands if they come into contact with the trypsin solution. They should wear eye protection.

Materials required

Each group of students will need:

- 11 clean test tubes or boiling tubes, and something to stand them in
- a pen or other way of labelling the tubes
- access to water baths (see above) containing crushed ice, and water at a range of different temperatures (for example room temperature, 40°C, 60°C and 80°C).
- at least 30 cm^3 of milk made up from fat-free milk powder by dissolving 4 g of skimmed milk powder in 100 cm3 of water. (It is very important that this is *fat-free* milk, as the presence of fat tends to prevent the milk from becoming clear.)
- at least 40 cm^3 of trypsin solution made up by dissolving 0.5 g of trypsin to 100 cm^3 of water
- one or more stirring rods
- a thermometer

There are several important sources of error in this experiment, and students should be expected to discuss these in their write-up. The most important is the impossibility of deciding exactly when the contents of a tube have become ‘clear’. Another significant error is that it is unlikely that the temperatures remained constant in each tube throughout the experiment.

They should *not* describe possible *mistakes* that they have made, such as not measuring out the volumes correctly, as being sources of experimental error.

There are a number of different modifications that could be made to increase the reliability of this experiment, and to give a more precise optimum temperature. These will vary depending on the apparatus that they were able to use, but will probably include:

- carrying out the experiment more than once, and then calculating a mean time for each temperature
- finding a way of standardising the point at which a tube was judged to become clear—for example, using a machine such as a colorimeter, or standing the reacting vessel on a piece of paper with a cross marked on it and looking for the moment at which the cross becomes visible
- using water-baths that were able to maintain a constant temperature throughout
- testing a narrower range of temperature on either side of the apparent optimum, to pin it down more accurately.

Answers to questions

3.3 kinetic, quickly, substrate, active site, denatured

Enzymes and pH

Students are likely to know already what pH measures, but is worth revising it quickly here to make sure.

Investigation 3.2 How does pH affect the activity of an enzyme?

This is presented as an investigation that students design for themselves, in order to help them to develop the skill assessed as Assessment Objective C5. Depending on their progress in this skill, you might like to develop this plan through class discussion, or to ask students to devise a plan in groups.

When students carry out investigations that they have designed themselves, it can sometimes be very difficult to provide the apparatus that they want. Here, however, it is extremely likely that they will ask for the same apparatus as in Investigation 3.1.

By far the best way of varying pH is to use buffer solutions. As a last resort, you could suggest adding acid or alkali to the tubes, and using pH paper to measure the pH obtained. Take care however—proteins may be broken down by strong acids.

Answers to questions

3.4 This question is designed to encourage students to think back over earlier work. They met the starch-iodine test in Unit 1, and diffusion in Unit 2. They now need to bring together these concepts and their more recent work on enzymes.

- a The iodine reacted with starch in the jelly.
- b Amylase catalyses the break-down of starch to maltose.
- c The jelly only turned black where there was still starch present. It did not turn black where the amylase had digested the starch.
- d Amylase spread out of the hole and into the jelly by diffusion. It spread out at an equal speed in all directions. The orange-brown colour is the colour of the iodine solution, and it shows where amylase had digested the starch.
- e The amylase in dish B had been boiled, so it was denatured and could not break down starch.

Unit 4: Photosynthesis

How photosynthesis happens

This covers syllabus sections 4(*a*) and (*c*).

Before introducing the balanced symbol equation, check whether or not the students have used these in their Chemistry lessons. If they have not, then it is best to leave this for the time being, and return to it later in the course. The word equation will be quite adequate in most instances. Students do not need to know anything at all about the light-dependent and light-independent reactions.

The term 'carbohydrate' is used here, and students are going to meet glucose, sucrose, starch and cellulose as types of carbohydrate. You will need to consider whether this will be understandable for them, or if you need to cover some of the material from Unit Five at this stage. A very common error that students make is to say that chlorophyll 'attracts' sunlight. Make sure that they understand the difference between 'attract' and 'absorb'.

Investigating the requirements for photosynthesis

This covers syllabus section 4(b).

The first two of these investigations are described as student experiments, and the last one as a demonstration. They are all directly required by the syllabus, so it is important that all students are familiar with them.

Investigation 4.1 Is chlorophyll needed for photosynthesis?

Choose a plant whose leaves do test for starch quite readily. Some need long boiling, or have very waxy cuticles, which can spoil the results of this investigation. Suitable plants include tradescantia and geranium.

Safety points

Ethanol boils at around 80°C, and is very flammable. Students should therefore turn off flames before taking ethanol to their places. Keep a damp cloth handy, which you can quickly drop over any tube if necessary to extinguish flames. Students should wear eye protection throughout.

Materials required

Each group of students will need:

- access to a plant with variegated (green and white) leaves, which had plenty of water and sunlight.

For the starch test:

- a beaker containing water, and a means of heating it to boiling point (tripod, gauze and Bunsen burner)
- a tube that is large enough to contain a leaf
- forceps and/or glass rod to help with manoeuvring the leaf in and out of hot liquids
- access to ethanol—it is best if the teacher takes charge of this, and students ask for it when required
- a tile or other suitable surface onto which the leaf can be spread
- iodine in potassium iodide solution and a dropper pipette

Investigation 4.2

For this investigation, it is best to use a potted plant, as this can easily be destarched. It is not possible to predict how long you will need to leave it in the dark—you will just have to try it and see!

Safety points

As in Investigation 4.1

Each group of students will need:

- access to a well-watered plant that has been destarched
- thick black paper or card, or aluminium foil
- scissors and paper clips
- materials for testing a leaf for starch, as in Investigation 4.1

Investigation 4.3

This is rather tricky to set up, and it is therefore suggested that the teacher, with involvement from the students, sets this up on behalf of the class.

Safety points

Potassium hydroxide can harm skin. If skin makes contact with it, wash off with plenty of cold water. Eye protection should be worn. The starch test also needs care, as described for Investigation 4.1.

You will need:

- a destarched plant in a pot, well-watered
- two transparent containers, and a way of fastening them around a leaf or small group of leaves – a split cork in the neck of a conical flask often works well
- supports for the containers, so that they do not drag down on the plant
- a small amount of potassium hydroxide solution – pour this into the flask before attaching the flask to the plant. Take care that there is none on the neck of the flask, or anywhere else that might come into direct contact with the plant.

Controls

Having done three experiments in which controls are involved, students are asked to look back at them and identify the control and its function in each case. They should be able to understand that if you are investigating the effect of one variable, then you must keep all others constant. The purpose of a control is to provide a set-up which is in every way identical with the experimental set-up *except for the one factor that is being investigated*. This provides a reference point against which the experimental set-up can be compared.

Answers to questions

4.1 The uncovered parts of the leaf.
4.2 The leaf in the container with water in it.
4.3 The cells in the white parts of the leaf get carbohydrates from the cells in the green parts.

Leaves

This covers syllabus section 4 (*f*) and (*i*).

The structure of a leaf

Before concentrating on the diagram of a cross (transverse) section through a leaf, students could look at whole leaves and think about their structure. They often do not understand what they are looking at in a drawing of a cross-section, as they do not appreciate that the leaf has depth—it looks impossibly thin when viewed edge on, and they may need convincing that there are several layers of cells in there.

If available, show students transparencies of micrographs of leaf sections.

How the leaf's structure is related to its functions

This is dealt with from the point of view of the requirements—first light, then carbon dioxide, then water. Students are asked to turn this round in question 4.4, looking at it from the point of view of a particular feature of the leaf. This should help them to appreciate the many different adaptations and reasons for them.

They may need reminding of how diffusion takes place, so that they realize that the leaf does not do anything active to make it happen. They should appreciate that *more diffusion* can take place at any one time if there is a large surface area present, and that gases can travel from A to B *more quickly* if the distance over which diffusion takes place is small.

Answers to questions

4.4 The upper surface is more likely to have sunlight falling onto it, and will get hotter. It is therefore more likely to lose water by evaporation, and the thicker cuticle helps to stop this from happening.
4.5 Palisade mesophyll cells, spongy mesophyll cells and guard cells have chloroplasts. Epidermal cells, xylem vessels and phloem tubes do not.

4.6 Large surface area: more sunlight hits leaf, in contact with more carbon dioxide so more can diffuse into leaf at any one time.

Thin: sunlight can penetrate all layers of the leaf; carbon dioxide does not have to diffuse far to get into palisade cells.

4.7 It is useful for stomata to open during daylight when the leaf has plenty of light for photosynthesis and needs a lot of carbon dioxide. They usually close the stomata at night when it is dry as this helps too much loss of water vapour from the leaf.

Limiting factors

This covers syllabus sections 4(*d*) and (*e*).

The concept of limiting factors has a reputation for being difficult, but in fact it is not difficult at all if dealt with simply, and most students instinctively understand why graphs such as those in Fig 4.2 and 4.3 level off.

This section is introduced with an investigation, in which students should begin to appreciate how light intensity affects photosynthesis. Take note, however, that:

- the graph they plot will be 'back to front' compared with Fig 4.2, as they will have 'distance' along the x axis, not 'light intensity'
- the results from this investigation are very unreliable! Nevertheless, it is well worth doing, and its unreliability makes it an excellent discussion point to help students to appreciate experimental error.

Investigation 4.4 The effect of light intensity on photosynthesis

You will need a supply of an aquatic plant that photosynthesizes readily in the laboratory and that – preferably – gives bubbles off in a stream from one point. The pondweed *Elodea* is very good for this. If a piece is placed upside down immersed in water, bubbles of oxygen come off from the end of the cut stem, which makes it possible to count them. It helps if you cut the stem at an angle, and keep the plant under water at all times, even while making this cut.

Safety points

If the lamps are plugged into mains sockets, great care must be taken to keep all water away from everything electrical. Wet hands should not touch lamps. If your lamps get very hot, then warn students of this. If you see this as a problem, tell students to switch them off before moving them.

If at all possible, darken the laboratory so that the only light comes from the lamps. Even then, light from one group's lamp can interfere with another group's experiment, so you may want to make 'barriers' from large pieces of cardboard.

Each group of students will need:

- a transparent container of water
- a small piece of water plant
- a way of holding the plant upside down in the water if it will not stay like that on its own, for example, a paper clip to weigh it down
- a stopwatch or clock
- a ruler for measuring distances between lamp and plant
- a lamp that can easily be moved

The **results tables** should clearly show individual results, and also averages. They could look like this:

distance of lamp from plant/cm	number of bubbles in first minute	number of bubbles in second minute	number of bubbles in third minute	mean number of bubbles per minute

The **graph** should have distance of lamp from plant / cm on the *x* axis, and mean number of bubbles per plant on the *y* axis. If there is a clear pattern in the results, then students may be able to draw a best fit line. If the pattern is less clear, then it is better to join each point to the next with a ruled straight line.

The **conclusion** should be a brief statement about the effect of light intensity on photosynthesis. Students should explain that the closer the lamp is to the plant, the higher the light intensity.

There are some very important **experimental errors** which should be discussed. Probably the greatest of these is that, when varying the light intensity, you are also varying temperature (because of the heating effect of the lamp). Students could try to suggest ways of reducing this error, such as by immersing the tube with the water plant in it in a large tank of water—light will pass easily through this, but heat will not. Other significant errors which reduce the reliability of the results include light from other lamps reaching the plant and varying amounts of carbon dioxide in the water (perhaps the plant uses this up faster than it is replaced, so as the experiment proceeds there is less and less carbon dioxide available for it).

The rate of photosynthesis and light and carbon dioxide as limiting factors

This looks at the theory behind the results students should have obtained in Investigation 4.4. They will need to think about why their graph is not the same shape as in Fig 4.2. They can then go on to think about a similar curve for varying carbon dioxide concentration. The curves are then used to explain what is meant by a limiting factor.

Answers to questions

4.8 It is probably light. You could test it by supplying a plant with that amount of carbon dioxide and more light; if the curve rises then light was limiting the rate of photosynthesis.

Temperature and photosynthesis

This should be related to earlier work on enzymes. Students will know that very high temperatures are detrimental to many plants.

Answers to questions

4.9 It is suggested here that students simply think about how they would do these experiments, rather than actually carrying them out. However, if time is available, there is no reason at all why they should not actually do them.

If each student or group thinks about one of the two investigations, then they can later present their ideas to the class so that everyone thinks about both.

Temperature is relatively easy to vary. However, varying carbon dioxide may not be so obvious. One way of doing this is to add a little sodium hydrogencarbonate to the water surrounding the plant.

The products of photosynthesis

This covers syllabus sections 4(*g*) and (*j*).

This will be difficult for students to understand if they have not yet learnt about carbohydrates and proteins (which is covered in the next Unit). You may prefer to leave this section until after these topics have been dealt with.

Although not directly required by the syllabus, the idea that plants respire all the time is brought in here. There is a very common misconception that 'animals respire but plants photosynthesise', and it is very useful if this can be sorted out at an early stage.

Unit 5: Animal Nutrition – Diet

The early sections of this Unit cover syllabus sections 5(*a*), (*b*), (*c*) and (*d*).

Answer to question

5.1 inorganic: oxygen, nitrogen, calcium ions, iron, water, carbon dioxide
organic: protein, glucose, starch, cellulose

Carbohydrates

If photosynthesis has already been covered, then students will already know something about glucose and starch. Here, the importance of carbohydrates to all organisms – not just in the human diet – is discussed. Note that the terms 'sugar' and 'polysaccharide' are not specifically required by the syllabus, but they are useful terms and will probably help students to understand the range of different carbohydrates.

Information in this section makes links back to earlier units, and forward to ones yet to come. Lactose is introduced here as it will appear in Unit 15. Water potential is revisited, which gives an opportunity to revise this important topic. The iodine test for starch has already been used in the Investigations in Unit 4. Cell structure is also revisited.

Investigation 5.1 Testing for carbohydrates

Provide a range of foods of both plant and animal origin, and which do and don't contain starch and reducing sugar.

Students do not really need to understand the term ‘reducing sugar’. All sugars that they will meet, apart from sucrose, are reducing sugars.

They are provided with a results chart here, but not for the later Investigations in this Unit. In this one, encourage them to write a *colour* in the appropriate columns, not just ‘no change’. So, if a food is tested with Benedict’s solution and is found not to have any sugar in it, the entry in this column should say ‘remains blue’.

Safety points

If at all possible, provide a water bath of very hot (close to boiling) water in which tubes can be partly immersed, rather than allowing students to boil liquids by holding a boiling tube in a flame. Safety glasses should be worn.

Materials required

Each group of students will need:

- access to a range of at least five different foods
- a scalpel, knife or other suitable implement for cutting or crushing pieces of food
- a white tile or other suitable surface for setting out the foods
- several clean test tubes or boiling tubes, and a rack or other container to stand them in
- access to Benedict’s solution, and a pipette to dispense it with access to a boiling water bath
- a spatula or other implement for picking up a small sample of food and transferring it to a tube

Answers to questions

5.2

Carbohydrate	Where found	Functions
glucose	in all living cells in the blood of animals	It is broken down by respiration, to release energy. Glucose is the form in which carbohydrates are transported in animals.

sucrose	in the phloem sap of plants in several plant tissues, for example, in sugar cane and sugar beet	Sucrose is the form in which carbohydrates are transported in plants. Sucrose is an energy store in sugar cane and sugar beet.
starch	in many plant cells, for example, in potato tissues and in seeds; also in leaves	Starch is the form in which carbohydrate is usually stored in plants.
glycogen	in some animal cells, especially liver cells and muscle cells	Glycogen is the form in which carbohydrate is stored in animals.
cellulose	in plant cell walls	Cellulose forms a strong, fully permeable covering around the plant cell.

5.3 Carbon, hydrogen and oxygen.

5.4 Foods made from plants (bread, rice, fruits) contain carbohydrates, as does confectionery and sweets (chocolate, cake). Foods from animals (meat, fish, eggs) do not contain carbohydrates. Milk is the only food of animal origin that contains much carbohydrate.

Fats

Fats have gained the reputation of being 'bad for you'. Here their positive contribution to a balanced diet is emphasised, as well as the harm they may do if consumed in excess. Students do not need to understand the structural difference between saturated and unsaturated fats, but these are mentioned as they will be met again in Unit 8, in relation to cardiovascular diseases.

Investigation 5.2 Testing for fats

The ethanol test makes use of the fact that fat is soluble in ethanol, but not in water. Some of the fat present in the food will dissolve in ethanol. When this is poured into water, the fat forms tiny globules that float in the water, forming an emulsion. This looks cloudy white.

You need to use fairly concentrated ethanol for this test, preferably absolute ethanol. All tubes must be very clean, as any grease on them will affect the results of the test. Fingers that are placed over the ends of the tubes before shaking must also, of course, be very clean!

Safety points

Ethanol is flammable, so there should be no naked flames nearby.

Materials required

Each group of students will need:

- at least five different foods, some that do and some that do not contain fat
- a scalpel, knife or other suitable implement for cutting or crushing pieces of food
- a white tile or other suitable surface for setting out the foods
- 10 very clean test tubes or boiling tubes, and a rack or other container to stand them in
- access to absolute ethanol
- access to water
- a spatula or other implement for picking up a small sample of food and transferring it to a tube

Answers to questions

5.5 Carbon, hydrogen and oxygen

5.6 In plants: as a waxy cuticle that prevents leaves from drying out; as a food store in seeds; as an energy source; to form cell membranes.

In animals: as an energy source; as a food store; as insulation against heat loss; to form cell membranes.

Proteins

The idea of a protein molecule being a string of amino acids, linked together in a particular order, will recur in Unit 20, when the functions of DNA are considered. Proteins themselves will appear in almost every Unit that follows this one, and a number of them and their functions are introduced here. Most students will already know that proteins are important for 'growth and repair', but they should be ready now to absorb and learn the more specific functions described in this section.

Investigation 5.3 Testing for proteins

Safety points

Biuret solution is alkaline, so students should wear safety glasses. If KOH solution is used instead (see below) this is even more alkaline, and care should be taken not to spill it on the skin. If this happens, wash it off with plenty of cold water.

Materials required

Each group of students will need:

- at least five different foods, of both plant and animal origin, some of which do and some which don't contain protein
- five clean test tubes or boiling tubes, and a rack or other container to stand them in
- a scalpel, knife or other suitable implement for cutting or crushing pieces of food
- a white tile or other suitable surface for setting out the foods
- a spatula or other implement for picking up a small sample of food and transferring it to a tube
- access to biuret solution

Biuret solution can be bought ready-made, which is probably easiest for everyone. If not available, provide students with some 20 % potassium hydroxide solution, and 1% copper sulphate solution. They should first add the KOH and then a little $CuSO_4$.

It is not always easy to distinguish the blue colour which indicates absence of protein, from the purple colour which indicates its presence. It will help to set up two 'comparison tubes'—one in which biuret solution has been added to water, and another in which biuret solution has been added to a suspension of something containing protein, such as milk or cheese.

Answers to questions

5.7 This exercise is provided to encourage students to think about the wide range of functions of proteins, and to sort out and simplify for themselves the considerable amount of information in the text on pages 56 to 57.

Protein	Where it is found	Function
enzymes	in all living cells	catalyse metabolic reactions
haemoglobin	inside red blood cells	transport oxygen
antibodies	in the blood and tissues of animals	destroy invading bacteria and viruses
fibrinogen	in the blood plasma	change into fibrin and form a blood clot
insulin	in the blood plasma	cause the liver to remove glucose from the blood, so reducing blood glucose level

Vitamins, Mineral Salts

This section covers the two vitamins and the two mineral salts required by the syllabus. Once again, students are asked to complete their own summary table, bringing together and simplifying the information in the text.

Answer to question 5.8

Nutrient	Foods which contain it	Why it is needed	Symptoms of deficiency disease
vitamin C	fresh fruit (especially citrus) and vegetables	to form the protein collagen, which is found in skin and bones	scurvy, in which skin ulcers form, gums bleed
vitamin D	dairy foods, egg yolks, oily fish, formed in skin when sunlight falls onto it	to allow us to absorb calcium, and so to make strong bones	rickets, in which bones do not grow properly and tend to bend

calcium	milk and other dairy products, fish bones	to make strong bones and teeth; for blood clotting	underdeveloped bones, and teeth with a tendency to crumble
iron	red meat, some dark green vegetables, foods which have been cooked in iron utensils	to make haemoglobin	anaemia, in which insufficient oxygen reaches the tissues, and you feel very tired all the time

A balanced diet

This covers syllabus sections 5(*f*) and (*g*).

It is always an interesting exercise to ask students to make a record of what they eat each day, and then to analyse this in terms of nutrient content and energy content. However, this is very time consuming and difficult, especially as they will not be able to weigh their food, and may not be able to find information about nutrient content for all of it. Probably a qualitative exercise is better, in which they simply find out which nutrients are contained in the food they have eaten, rather than worrying about how much.

The values for energy requirements given in Fig. 5.9 are of course approximations. Individuals can vary tremendously in their requirements, and this is only intended to give an approximate idea of the way in which sex, activity and age affect dietary needs.

Malnutrition

This term is often assumed to mean ‘not having enough to eat’, but its true meaning is broader than this, and includes eating too much as well as not eating enough. Although it is important to discuss issues of under eating or overeating, great care should be taken not to embarrass individuals who are clearly underweight or overweight. In many countries, an obsession with being ‘fat’ is resulting in increasing numbers of young people, especially girls, developing serious eating problems such as anorexia nervosa and bulimia. Take care not to put too much emphasis on anything that might encourage these kinds of feelings amongst the young people in your class.

If they want to calculate their body mass indices, then this should be done individually, with absolutely no attempt to pool results or to let students find out each other's BMIs!

Famine

This topic forms an excellent subject for discussion, either as a whole class or in groups, and an opportunity to encourage students to think widely about social, moral, ethical and economic aspects of the ways in which humans obtain their food. You could perhaps ask them to collect information about famines from newspapers and magazines. They can also find out what appears to be causing food shortages in particular parts of the world, and discuss how these problems might be solved. Particular questions that could be discussed are:

- Should we consider that people are to blame for running short of food? If it is not their fault, is it someone else's? Or is it something that is out of everyone's control?
- What can be done to help people struck by famine? Which is best—providing them with food, or providing them with help to grow their own food?
- In the long term, what can we do to help to prevent famines from happening?
- To what extent is famine a result of a human population that is growing too fast?

At the end of the discussion, students could be asked to write a short piece about their own ideas on famines and how they can be dealt with or prevented from happening.

Answers to questions

5.9 a nitrogen
b Benedict's solution
c biuret solution
d amino acids
e lactose
f scurvy
g vitamin D
h iron
i glucose
j sucrose

Unit 6: Animal Nutrition – Digestion

The structure of the digestive system

The introduction covers syllabus section (5*n*) while this section covers syllabus section 5(*i*). (Note, however, that in early versions of the syllabus, there are three sections (*m*), (*n*) and (*o*).

Students are introduced to the structure of the digestive system (that is, the alimentary canal plus the liver and pancreas) before considering their functions in any detail.

Weaker students often do not understand that the alimentary canal is a long tube. They may suggest that food passes through other parts of the body, such as the liver, pancreas or kidneys. Try to ensure that they can imagine the food moving steadily along through this tube, being gradually digested as it goes.

Teeth

This covers syllabus section 5(*k*).

There is normally little problem for students in understanding and remembering the structure of a tooth, or the names of the different types of teeth. In the investigation, they are asked to think for themselves about the functions of incisors, canines and premolars/molars. (Note that premolars and molars are very similar in structure and function. The difference is that premolars have precursors in the milk teeth but molars do not.)

Investigation 6.1 The functions of teeth

Safety points

As stated in the text, this should not be carried out in a laboratory, as it involves putting food into the mouth.

Materials required

- a small mirror
- a piece of food that can be bitten and chewed

Students should discover that they use their incisors (and possibly canines) for biting off pieces of food. The premolars and molars then grind together to crush the food into small pieces, increasing its surface area before it is swallowed.

Tooth decay

This covers syllabus section 5(*l*).

The role of bacteria in producing acids which dissolve the tooth enamel is often not understood by students. They mistakenly believe that the bacteria themselves eat away at the teeth.

If you can obtain a tooth—for example, a milk tooth that has fallen out—you can demonstrate the effect of acids on it. Tie a piece of thread around the tooth, and immerse it in an acidic solution. This does not have to be a strong acid – a soft fizzy drink such as cola will have a significant effect. Leave the tooth for some days, and let the students look at it every now and then.

If tooth decay is a problem in the area where your students live, and if most of them have had dental treatment, they could collect data from their class about which teeth have the most fillings. They will probably find that these are most common in the premolars and molars, as these have more crevices in which plaque may accumulate.

Digestion

This covers syllabus sections 5(*j*) (part) and (*o*).
Enzymes have already been covered in some detail, in Unit 3. Here the emphasis is on the sequence of events that takes place in successive regions of the alimentary canal.

Investigation 6.2 The effect of temperature on the activity of amylase

You may like your students to carry out this investigation using amylase, or you may feel that they have already done enough 'enzyme experiments'. Another possibility would be to carry out the experiment that is described in Question 3.4 in Unit 3.

It is possible to use students' own saliva as a source of amylase, but many teachers now prefer to avoid doing this for reasons of hygiene. Amylase can usually be readily obtained from biological suppliers.

In general, a 10% starch solution and 1% amylase solution are likely to provide results in a suitable length of time. However, as amylase from different sources can vary greatly in its activity, you will need to check that these concentrations are suitable, and adjust them if necessary.

Materials required per group of students

- starch solution; make this up using 'soluble' starch
- amylase solution
- 6 clean boiling tubes
- dropper pipettes
- a thermometer
- access to water baths containing ice, water at room temperature and boiling water
- iodine in potassium iodide solution
- three glass rods
- a stopwatch

Students will need to think carefully through this experiment, and get themselves well organized before they begin. If you have spotting tiles with three or four rows of dents, they can use one row per tube. If you have plenty of spotting tiles, then you could provide each group with two or three, which will avoid them needing to quickly clean the tile and refill it with iodine solution spots in the middle of their series of tests.

They should be encouraged to think carefully about sources of error. (You may like to remind them again that this does not include mistakes that they should not have made.) Here, the most important one is the impossibility of deciding the exact moment at which there was no starch present, as the colour of the starch-iodine spots changes gradually.

Answers to questions

6.1

Region of alimentary canal	Enzymes present	Substrate	Product
mouth	amylase	starch	maltose
oesophagus	none	none	none
stomach	protease	proteins	peptide
small intestine	amylase	starch	maltose
	protease	peptides	amino acids
	lipase	fats	fatty acids and glycerol
large intestine	none	none	none

Absorption and assimilation

This covers the remaining parts of syllabus section 5(*f*), and also the second syllabus sections (*m*), (*n*), and (*o*) plus section (*p*).

Investigation 6.2 Absorption of carbohydrates

Students may need to be reminded about diffusion, in order to interpret the results of this investigation.

Safety points

There are no particular hazards in this investigation.

Materials required

Each group of students will need:

- a glass beaker or other container to hold water and the tubing
  (Note that the smaller the volume of water, the higher the concentration of glucose that will be produced, and the better the result of the Benedict's test)
- a piece of Visking tubing

- a length of thread
- a solution containing a mixture of starch and glucose (concentrations are not important, but a relatively high concentration of glucose will produce best results)
- two clean dropper pipettes
- iodine in potassium iodide solution
- a white tile or other surface for carrying out the starch tests
- Benedict's solution, and access to a boiling water bath
- a test tube for carrying out the reducing sugar tests

Answers to questions

6.2 glycogen – glucose
protein – amino acids
fats – fatty acids and glycerol

6.3 a hepatic portal vein
b deamination
c villi
d glycogen
e fat

Unit 7: Transport in Flowering Plants

Uptake by root hairs

This covers syllabus section 6(*a*).

Students may need reminding about osmosis and water potential, covered in Unit 2. They may already have looked at the structure of root hairs, and how they are adapted for their functions of absorbing water and mineral ions, in Unit 1.

They should be encouraged to think about the movements of water and of ions taking place independently of each other, rather than thinking of a 'solution' moving into the root hairs.

The transpiration stream

This covers syllabus sections 6(*b*), (*c*),(*d*), (*e*) and (*f*).

There are good arguments for dealing with this topic either from the root upwards, or from the leaves downwards. Here, having already looked at how water enters the roots, attention is then moved up to the leaves, as it is from here that water is pulled upwards through the xylem vessels. Make sure that students understand that water usually passes out of the leaves in the form of *vapour*, not as a liquid.

Investigation 7.1 How wind speed affects transpiration rate

The syllabus does not specify an understanding of how wind speed affects transpiration, but it is the easiest of these factors to investigate, so it is included here. If you prefer, you could investigate the effect of light or temperature, but these do not give such good results on the whole.

Safety points

Ensure that the glass tubing is strong enough not to break when stems are pushed into the rubber tubing attached to it. Both ends of the tubing should be smoothed off, so that there is no risk of cuts.

Materials required

Each group of students will need:

- a long piece of glass tubing—but not so long that it cannot be completely immersed in a large container of water—with a length of rubber tubing firmly fixed over one end (see the diagram in the student's book)
- a large container of water, in which the glass tubing can be completely immersed
- a means of supporting the tubing in a vertical position, for example a retort stand, clamp and boss
- a scale that can be placed against the glass tubing, for example a metre ruler, and a means of supporting it
- a leafy plant shoot, with a stem of a diameter that will fit tightly into the rubber tubing
- a stopwatch or other means of timing
- access to a fan

If you have more elaborate potometers than the glass tubing suggested here, then do use these instead. Their only real advantage is that they are easier to refill with water.

Investigation 7.2 Finding the positions of xylem vessels in a root, stem and leaf

Whether you attempt to look for xylem vessels in all three of these places will depend on the plants you have available. The best type of a plant is a small annual weed that you can pull up from the soil with its root system intact. It should have leaves with obvious veins, and a stem that is easy to cut into thin sections. If you cannot find plants with suitable roots, then confine this investigation to the positions of the xylem in the stems and leaves.

Safety points

The only possible source of danger is the instruments used for cutting thin sections.

Materials required

Each group of students will need:

- a small herbaceous plant, as described above
- a beaker or other container, with a small amount of red dye (Eosin solution works well.)
- a sharp knife or scalpel for cutting thin sections
- a piece of cork or other material on which the cutting can be done
- two or three microscope slides and cover slips
- access to a microscope

Students should be able to see red spots in the centre of the roots, and in a circle in the stem. They can compare what they see with Figs 7.4 and 7.5.

Transport of sugars

This completes the coverage of syllabus section 6(*g*).

Answers to questions

7.1 a liquid
b liquid
c liquid
d liquid
e gas
f gas

7.2 root hairs
xylem vessels evaporate
water vapour diffusion
stomata
transpiration

Unit 8: Transport in Humans

The heart

This covers syllabus sections 7.1(*a*), (*b*), (*c*), (*d*), (*f*) and (*g*).

Here, the topic of transport is begun with a consideration of the heart. You could equally start with blood, then move on to looking at the heart and blood vessels. However, most students are familiar with the idea of the heart as a pump, and so this topic provides a secure starting point for them.

Students normally have little trouble in learning to label a diagram of a vertical section through the heart, but they are often less sure about the way in which it functions. Make sure that they understand that the diagrams in Figure 8.1 and 8.2 are drawn as though you were looking at a person facing you, so that the right side of the heart is on the left side of the diagram.

The functioning of valves often causes confusion, largely because many students falsely believe that they open and close actively. Try to ensure that they realise that it is the blood itself which pushes them open and closed.

Another common error is to think that the two sides of the heart beat one after the other, rather than simultaneously.

Investigation 8.1 The effect of exercise on the rate of heartbeat

Although students will not yet be able to explain why the heart rate does not return to normal immediately after exercise finishes, this is probably the best point at which to carry out this practical. They can think back to it when they have covered respiration, in Unit Nine.

Safety points

Make sure that none of the students has a condition which makes it unsafe for them to carry out exercise. Choose a form of exercise that is unlikely to lead to injuries in a laboratory, such as running on the spot.

Materials required

A stopwatch, stop clock or sight of a clock with a seconds hand.

Students could work individually, or in pairs. The normal place to find a pulse is on the inside of the wrist, but is usually easier to locate in the neck.

They are expected to devise their own results chart and graph. Careful thought will be needed when deciding how to record time—it is probably easiest if the first two readings (at rest) have a 'break' after them while the exercise is done, and then a fresh start is made in recording time from the moment that exercise stops. This can be shown on the graph by a 'break' (perhaps a zig-zag line) on the x (time) axis of the line graph.

Further work

Students could obtain practice in Assessment Objective C5 by planning and carrying out their own investigation into the effect of a chosen factor on the time taken for heart rate to return to normal—for example gender, age or fitness. It is not easy to control variables in such an investigation, but it is nevertheless a worthwhile experiment to do.

Answers to questions

8.1 The walls of the heart are made of cardiac muscle, and their thickness is directly related to the force they need to generate.

- a The walls of the atria need only to push blood into the ventricles, so they do not need to generate much force. The walls of the ventricles push blood out of the heart, towards the lungs or the rest of the body.
- b The walls of the left ventricle push blood into the aorta, from where it will flow to all parts of the body. High pressure must be generated to make sure the blood will travel all this way. The walls of the right ventricle push blood to the lungs, which are very close to the heart, so the blood can flow at a lower pressure.

8.2 Oxygenated blood will mix with deoxygenated blood. So the blood in the aorta will not be as fully oxygenated as normal, and will deliver less oxygen to body cells.

Blood vessels

This covers syllabus sections 7.1(*c*) and (*e*).

The differences in the structure of the walls of arteries, capillaries and veins are related to their functions. A very common misconception is that the muscle in the walls of arteries contracts and relaxes to help to pump the blood around the body, but this is simply not true! The pulse is explained by the elastic stretching and recoil of the artery wall as blood pulses through it in time with the heartbeat.

The smooth muscle in the walls of arterioles may contract to narrow the lumen of these vessels, and this is the way in which the volume of blood flowing to different organs can be adjusted. Students will meet this idea in relation to the arterioles supplying the blood capillaries in skin when looking at temperature control in Unit 11.

Answers to questions

8.3 pulmonary vein, left atrium, left ventricle, aorta, renal artery.

8.4

	Arteries	**Capillaries**	**Veins**
function	carry blood away from the heart	deliver blood to the tissues	carry blood back to the heart
thickness of wall	very thick, with muscle and a lot of elastic tissue	extremely thin, often only one cell thick; no elastic tissue or muscle	thin, with some elastic tissue
width of lumen	narrower than in veins	tiny—often just wide enough to allow a red blood cell to squeeze through	wide, so allowing low pressure blood to flow through easily
presence of valves	none (except in the entrances to the pulmonary artery and aorta from the heart)	none	valves present to ensure one-way flow of blood

8.5 The pulmonary artery is the only one that carries deoxygenated blood.

8.6 Blood in an artery is at much higher pressure than in a vein, so blood loss is much greater from a cut artery than from a cut vein.

Blood

This covers syllabus sections 7.1(*h*), (*i*) and (*j*).

If possible, show students projector slides of light micrographs of blood, so that they become familiar with its appearance under the microscope. They should realise that blood plasma is not itself coloured, and that the red colour of blood comes from the red blood cells.

An extremely common error (even among A level students) is to confuse red blood cells and haemoglobin. This is highlighted for them in the margin, and is revisited in question 8.11 at the end of the Unit.

Red blood cells as an example of specialized cells were covered in Unit One, so this makes a good opportunity to revise this earlier work. Another very common error is to think that the large surface area to volume ratio of red blood cells increases the amount of oxygen they can carry—this is entirely wrong!

The functions of white blood cells are dealt with fairly simply, and there is no attempt to describe any more different types than are required by the syllabus. There is no need to distinguish between T and B lymphocytes, for example.

Answers to questions

8.7
- they are smaller than most cells—this gives them a relatively large surface area to volume ratio, which speeds up the rate of diffusion of oxygen into and out of them.
- they have a biconcave shape—this again increases the surface area to volume ratio, which speeds up the rate of diffusion of oxygen into and out of them.
- they contain haemoglobin—this combines reversibly with oxygen, so that oxygen is picked up at the lungs and released in the tissues which need it.
- they have no nucleus—this makes more room for haemoglobin and so increases the amount of oxygen that each red cell can carry.

8.8 Iron. Good sources are red meat, egg yolks and dark green vegetables.

8.9 a Lymphocytes, which could make the antibody to the antigens carried by the disease-causing organism will have multiplied, and some of these will remain in the blood. If the same kind of organism invades the body again, these lymphocytes will be able to produce the antibody very quickly, destroying the organisms before they have a chance to breed and cause infection.

b A close relative is more likely to have similar antigens on their cells to the recipient. This reduces the chances of tissue rejection.

Tissue fluid

This covers syllabus section 7.1(*k*).

This topic is covered very simply, as required by the syllabus. There is no need to mention lymph.

Answers to questions

8.10

Component of blood	Structure	Functions
red blood cells	small cells with no nucleus, shaped like a biconcave disc	oxygen transport (also transport some carbon dioxide)
white blood cells – phagocytes	cells with lobed nucleus	engulf and destroy bacteria
white blood cells – lymphocytes	cells with little cytoplasm and a large, round nucleus	produce antibodies in response to contact with their particular antigen
platelets	small cell fragments	help to stimulate fibrinogen to change into fibrin and so form blood clots
plasma	pale yellowish liquid	blood cells float in it and are carried around the body; contains many different substances in solution, such as glucose and hormones

8.11 a Blood is plasma plus red and white blood cells. Tissue fluid is plasma without the cells.

b Phagocytes are white blood cells with a lobed nucleus, which engulf and destroy bacteria. Lymphocytes are white blood cells with a large, round nucleus, which produce antibodies.

c Fibrin is an insoluble, fibrous protein which helps to form blood clots. Fibrinogen is a soluble protein found in blood plasma, which changes into fibrin when a blood vessel is damaged.

d The pulmonary artery carries deoxygenated blood from the right ventricle of the heart to the lungs. The pulmonary vein carries oxygenated blood from the lungs to the left atrium of the heart.

e Antigens are proteins on the surface of anything which is 'foreign' to the body, such as bacteria or cells in a transplanted organ. Antibodies are proteins made by lymphocytes, which destroy antigens.

Unit 9: Respiration

The introduction covers syllabus sections 8 (*a*) and (*d*). Students should already have met energy in science lessons, and they will normally not have problems with the concept of energy being required for various activities and processes to be carried out. No mention of ATP is made here, as this is often confusing for students at this level and is not required by the syllabus.

They may, however, have preconceptions about what 'respiration' is, and confuse it with breathing. Care will be needed to ensure that they understand that respiration takes place in *every living cell*, not just in animals. Another error is the belief that respiration takes place only in the lungs.

Aerobic respiration

This covers syllabus sections 8 (*b*), (*c*), (*h*), (*j*), (*k*) and (*l*).

The words 'aerobic' and 'anaerobic' need to be taught carefully, so that they are not muddled in answers. Do ensure that students realize that energy is not made or produced in respiration—they should already understand from earlier science lessons that energy is *transferred* or *changed* from one form to another, not produced or lost entirely. Keep using the syllabus terminology, that is, that energy is *released* from glucose or other nutrients during respiration.

Questions

9.1 All living cells respire.

9.2 Energy is not made during respiration. The energy is already there, locked up inside the molecules of glucose or other foods. Respiration simply releases this energy from the food.

9.3 If the apple is respiring, then it will release carbon dioxide. The apple could be placed in an airtight container, with a small container of lime water or hydrogencarbonate indicator. If respiration takes place, then the lime water will go cloudy and the indicator yellow. A control should be set up with an inanimate object (such as a rubber ball) in place of the apple.

Investigation 9.1 Releasing energy from food

This classic experiment illustrates how oxidation releases energy from food. Like respiration, this involves the combination of the foodstuff with oxygen. Unlike respiration, it takes place in one rapid reaction in which a lot of heat is released as energy all at once. In respiration, the reaction takes place more steadily, and only a little of the energy released is in the form of heat.

Any food that will burn can be used in this experiment. Usually, a nut of some kind is used, and this could also be done here if you do not want to cope with the problems of burning oily bread.

Safety points

Students should wear goggles throughout. The oily bread will burn with a black, smoky flame, and extremely hot oil will drip from the burning bread. Great care is needed not to let it touch anyone's skin.

Materials required

Each group of students will need:

- apparatus as shown in the diagram, plus a spare, clean boiling tube
- a syringe or measuring cylinder for measuring 20 cm^3 of water
- Of course, much of the energy in the bread or oil is not transferred to the water. A lot is lost to the air, and some remains in the unburnt parts of the food. If the original masses of the bread and the bread plus oil are known, then the energy released per gram can be calculated. This will be a much lower figure than is given in reference tables. (Bread contains between 200 and 300 kJ per gram, and oil contains about 900 kJ per gram.) However, the results may be good enough to indicate that the energy content of the oil is considerably greater than that of bread.

The structure of the gas exhange system, **Breathing and Gas exchange in the lungs** describe how the oxygen that is required for aerobic respiration is obtained, and how carbon dioxide is removed by the lungs. Of these topics, by far the most difficult is that of breathing. Many students find it very difficult to understand how muscles between the ribs and in the diaphragm bring about breathing. It is very common to find descriptions of breathing with cause and effect completely reversed—with the air going in and making the chest expand, for example. Try to ensure that any descriptions they give begin with the *muscles* involved, and that they remember for breathing in, *both* sets of muscles contract.

Investigation 9.2 Comparing inspired and expired air

Safety points

Use clinical thermometers if at all possible, and make sure that no one puts these into the mouth.

It is important to *breathe gently* into the apparatus used for comparing carbon dioxide content. Sucking could bring lime water or hydrogencarbonate indicator into the mouth.

The results of this experiment will give students the information that they need in order to compare inspired and expired air in terms of water content, carbon dioxide content and temperature. Afterwards, you could give them a quantitative comparison, as shown in this table:

	Inspired air	**Expired air**
oxygen content	about 20%	about 16%
carbon dioxide content	about 0.03%	about 4%
water vapour content	very variable	always high
nitrogen content	78%	78%
temperature	very variable	at about body temperature, that is 37 °C

It is worth emphasizing that a very small amount of carbon dioxide there is in the air. However, this is rising steadily at the moment, and 0.04 per cent may be a better estimate than 0.03. Students may also be surprised to see that expired air contains far more oxygen than carbon dioxide! Try to ensure that they do not believe that 'inspired air contains oxygen, but expired air contains carbon dioxide'.

The section on **Keeping the lungs clean** will be revisited in Unit 14, where the effect of tobacco smoke on this mechanism will be described.

Questions

9.5 Respiration is a metabolic reaction which releases energy from food, and which takes place in every living cell.

Breathing is a rhythmic series of movements, brought about by the contraction and relaxation of muscles, that moves air into and out of the lungs.

Gas exchange is the diffusion of oxygen and carbon dioxide between the air in the alveoli and the blood.

Anaerobic respiration

This covers syllabus sections 8 (*e*), (*f*), (*g*) and (*i*).

In this Unit, only anaerobic respiration in humans is dealt with. Later, in Unit 15, students will learn that yeast also respires anaerobically, in a different way. You may like to deal with this subject here, and to carry out Investigation 15.1.

Investigation 9.3 The effect of exercise on breathing rate

This is essentially a repeat of Investigation 8.1. Now, however, students should be able to explain their results more precisely, especially the reason for the breathing rate remaining high for some time after exercise has finished.

The same safety points apply, and the materials required are the same as for Investigation 8.1.

Questions

9.6

	Aerobic respiration	**Anaerobic respiration**
is oxygen used?	yes	no
what is produced?	carbon dioxide and water	lactic acid
how much energy is released?	large amounts	small amounts

9.7 (a) digested food; small molecules such as glucose and amino acids.
(b) oxygen
(c)
- Large surface area. The ileum has folds and villi. The alveoli are very small, and there are huge numbers of them.
- Thin surface across which the substances must travel. Villi are very tiny, and there are only a few cells between the inside of the ileum and the capillaries inside the villi. Alveoli and blood capillaries in the lungs have walls only one cell thick.
- Gradients maintained. Blood capillaries take absorbed nutrients away from the villi. In the lungs, blood capillaries take oxygen away from the alveoli, while breathing brings in new supplies of air.

Unit 10: Excretion

The introduction covers syllabus sections 9(*a*) and (*b*).

The removal of carbon dioxide from the lungs has been described in Unit 9, but is revisited here to ensure that students realize that this is an example of excretion. The questions which follow are designed to help students to realize that not only animals, but *all* living organisms excrete.

This is also an opportunity to reinforce understanding of the two terms *organ* and *organism*, which often cause confusion.

Answers to questions

10.1 a Carbon dioxide is a waste product of respiration, and all living organisms respire. So carbon dioxide is an excretory product for all living organisms.
(Some students may point out that the carbon dioxide produced by respiration during the day is all used in photosynthesis, and therefore is not excreted. However, during the night this does not happen, and carbon dioxide is excreted through the stomata.)
b The lungs.

10.2 a Oxygen.
b Photosynthesis.

Excretion of urea

This covers syllabus sections 9 (*c*) and (*d*).

The production of urea in the liver has already been dealt with in Unit 6, so this should be revision for most students. Fig 10.1 may help them to revise earlier work and to follow the whole chain of events which leads to the excretion of urea by the kidneys.

There is frequently confusion between *urea* and *urine*, which can lead amongst other errors to the belief that urea is made in the kidneys. The margin note here points out this distinction to students, and it is reinforced in question 10.7 at the end of this chapter.

Note that the syllabus specifically states that no detail of kidney structure or function is required. It is strongly recommended that you do not teach this topic in any more detail than is given here, as the syllabus is already quite large and it is better to spend time on other topics which are definitely required.

Question 10.4 b requires students to appreciate that sweating on a hot day will increase the rate of water loss from the body. Although this topic has not yet been covered (it is dealt with in the next Unit) most of them will already know this so should be able to answer this question.

Answers to questions

10.3

Substance	Where it is produced	How it is produced	Where it is excreted
oxygen	in plant cells during daylight	by photosynthesis	from plant leaves, through the stomata
carbon dioxide	in all living cells	by respiration	from plant leaves through the stomata; from the lungs of animals
urea	in the liver of animals	by deamination	from the kidneys, in urine

10.4 a This would increase the amount of water in the blood. The kidneys will therefore excrete a large volume of dilute urine.

b Sweating would take place, so that a lot of water is lost from the blood. The kidneys will therefore excrete a small volume of concentrated urine.

Kidney dialysis is again dealt with simply. This topic revisits diffusion and osmosis, covered in Unit 2. The opportunity is also taken to revise tissue rejection in the context of kidney transplants.

Answers to questions

10.5
- ureter carries urine from the kidney to the bladder
- kidney produces urine by removing urea and excess water from the blood
- liver makes urea by the deamination of excess amino acids
- bladder stores urine
- urethra carries urine from the bladder to outside

10.6a Lymphocytes will recognize the antigens on the transplanted kidney cells as foreign. They will make antibodies which destroy them. (In fact, tissue rejection is largely caused by T lymphocytes, but students do not need to know about the two major types of lymphocytes.)

b The patient could be treated with immunosupressant drugs. The kidney should be taken from a close relative or someone else who has very similar antigens on their cells.

10.7a Urea is a chemical which is made in the liver by the deamination of excess amino acids. Urine is a liquid made in the kidneys which contains urea dissolved in water.

b Excretion is the removal of toxic materials and waste products of metabolism from organisms. Egestion is the removal of undigested food material from the alimentary canal, in the form of faeces.

c The bladder is an elastic-walled sac, linked to the kidneys by the ureters, which stores urine. The gall bladder is a sac within the liver, which stores bile.

Unit 11: Homeostasis

The introduction covers syllabus section 10(*a*).

Answers to questions

11.1 a Kidneys.

b When there is too much water in the body, the kidneys excrete some of it in large volumes of dilute urine. When there is too little water in the body, the kidneys keep most of it back, only excreting small volumes of concentrated urine.

The skin and temperature control

This covers syllabus sections 10(*b*), (*c*) and (*d*).

The syllabus states precisely which parts of the skin need to be known, and students should be prepared to label these on an unlabelled diagram. It is worth presenting them with a completely different diagram from that in Fig 10.1 and asking them to label it, to ensure that they can recognize the structures and not just remember where the different labels go! There are actually more structures labelled on Fig 10.1 than they need to know.

The central role of the hypothalamus in the control of body temperature is emphasized, and also the way in which it receives and sends information in the form of nerve impulses. Students may also like to know that the hypothalamus is involved in the control of water content, sending information to the kidneys about the water content of the blood. (However, it is probably best not to mention ADH, as this is not required by the syllabus and often causes confusion in students at this level.) But the hypothalamus plays no role at all in the control of blood glucose, as will be explained in the next Unit.

Students find it difficult to appreciate that if they 'feel cold' or 'feel hot', this does not mean that their core temperature is too low or too high. These 'feelings' usually result from the temperature being sensed by receptors in the skin, and represent the temperature of the skin or the air immediately around it.

Another extremely common error is to state that the capillaries move up and down in the skin. Even AS and A level candidates often write this, and it is very important to try to ensure that students do not think this to be the case. Moreover, when they describe how temperature is controlled, they will often just mention 'capillaries', without stating that they mean the ones *near the surface of the skin*. It should be possible to ensure that most students are aware of these errors, so that they can take care to avoid them.

Investigation 11.1 The effect of sweating on body temperature

Many students think that sweat is a cold liquid, which cools the body by lying on the skin. In this Investigation, *hot* water is used to soak the cotton wool in the second tube, which may help them to avoid this error.

Safety points

Results will be better if very hot water is used, rather than water at body temperature. Care must be taken not to scald skin. It may be best if you have hot water available in several kettles, which students can carry to their places when they are ready to pour the water into the tubes.

If the tubes are exactly the same size then they do not need to measure the volume of water, but can just fill each tube up to exactly the same level.

Materials required

Each group of students will need:

- two boiling tubes of the same dimensions
- two thermometers
- supports for the tubes, which allow the tubes to be kept separate from each other
- a stopwatch, stop clock or sight of a clock with seconds hand
- cotton wool, sufficient to wrap around both tubes
- elastic bands or cotton to secure the cotton wool firmly in place
- access to water at about 80°C

There are a number of points which could be discussed when the results have all been collected and graphed. For example, could the temperature in either of the tubes be expected ever to drop below room temperature? How do these results relate to the problems that could result if someone fell into a river on a cold day?

Answers to questions

11.2

Structure	What it does when your body temperature rises	What it does when your body temperature drops
sweat gland	secretes sweat	stops secreting sweat
arterioles supplying capillaries at the skin surface	dilate	constrict
erector muscle	relaxes	contracts
other body muscles	relax	shiver

11.3 a Sweating. As the water in sweat evaporates, it takes heat from the skin and so cools it.

b Drink cold drinks. Go into a shady place or an air-conditioned room. Wear loose, light-coloured clothes. Get your body or clothes wet, e.g. by swimming, then allow the water to evaporate from your skin.

Unit 12: Coordination

The nervous system

The introduction to this Chapter covers syllabus section 11(*a*).

The central nervous system

This covers syllabus sections 11(*b*) and part of (*c*).

Students are often very interested in the brain, but then disappointed when they find that they will learn so little about it (apart from a rather large number of new technical terms!). You may be able to find diagrams or photographs of the results of brain scans—a search on the Internet should find several such pictures, together with information about how they are obtained and what they mean.

Answers to questions 12.1

Part of brain	Function
cerebrum	conscious thought, language, emotions
cerebellum	control of automatic body movements
hypothalamus	control of body temperature
medulla oblongata	control of heart rate and breathing movements

Neurons

Although the syllabus does not specifically require knowledge about the structure of a neurone, it is helpful to students to look at this here.

Answers to questions

12.2 A neuron, like all cells, has a cell membrane, cytoplasm and a nucleus. It is unusual, however, in having many dendrons to pick up impulses from other neurons, and a long axon to carry impulses very quickly over long distances.

A reflex arc and the pupil reflex

This covers syllabus sections 11(*g*), (*h*) and (*f*).

Students often confuse the actions of the iris and those of the ciliary muscles, so it is well worth warning them about this possibility when they deal with focusing a little later on.

You may like to get them to demonstrate the pupil reflex. Working in pairs, one person covers their head or eyes with something dark and waits for several minutes. The dark covering is then removed and the person looks towards bright light. The other member of the pair will be able to see the rapid change in the size of the pupil.

Answers to questions

12.3

Stimulus	Receptor which detects the stimulus	Response	Effector which carries out the response
bright light	cells in the retina of the eye	pupil gets smaller	circular muscles in the iris
ant bite	pain receptor in skin	hand pulled quickly away	muscle in hand and arm
loud noise just behind you	cells in the ear	jump or move away quickly	muscles in the legs

12.4 Reflex actions are helpful when we need to carry out an action very quickly, for example when danger threatens. Our reaction can be quicker, because there is no need for any conscious thought to take place before we react.

The eye

This covers syllabus sections 11(*d*) and (*e*).

An understanding of the structure of the eye requires learning a lot of new terminology, and this is reinforced and tested in questions 12.5, 12.6 and parts of 12.8. If you can obtain an eye from a butchered sheep or other animal, your pupils may enjoy seeing this dissected.

Demonstration The structure of a sheep's eye

You will need:

- an eye from a sheep or other animal
- a board or other surface on which you can dissect the eye
- a pair of very sharp, small scissors
- other dissecting equipment such as forceps and a mounted needle

1. First, examine the outside of the eye. You should be able to see the **muscles** which hold the eye in position in the orbit, and which can move the eyeball around in its socket. The **optic nerve** will also probably be visible at the back of the eye; it is a creamy-white colour, paler than the muscles.

Looking at the front of the eye, the **pupil** and **iris** can be seen. Usually, the cornea will have become cloudy after death.

2. Using the sharp points of the scissors, cut into the eye about half way down, in order to make a **horizontal** section of it. This is very difficult to do, and illustrates the strength of the **sclera** which surround the eye. Once you have cut through it and begun to cut around the eye, you will notice that the eye collapses as the **vitreous humour** leaks out. This illustrates how the vitreous humour helps to maintain the shape of the eye.

3. The two halves of the eye can now be studied. In the posterior half, you may be able to pick out the black **choroid layer**, although very often the black material has leaked into the vitreous humour after death. The retina is not usually visible, as it breaks down very quickly.

In the anterior half, you should be able to find the **lens**. It may have become rather cloudy, but it is usually possible to hold it (using forceps) over some writing and to see how it acts as a magnifier. Almost certainly, the lens will have become detached from the suspensory ligaments and ciliary muscle, which are not usually easily visible.

Demonstration

How the eye focuses light

The way in which lenses of different sizes refract light can be demonstrated as follows.

You will need:

- a large, round-bottomed flask filled with **fluorescin**. This is a liquid in which light rays can be clearly seen as they pass through it.
- two or three different types of lenses (you may be able to borrow these from the Physics department), and a way of fixing these temporarily onto the flask (such as Blu-Tack)
- a source of bright light such as a bench lamp

1. Arrange the lamp and flask so that a band of light falls onto the front of the flask and travels through the fluorescin.

2. Take a convex (converging) lens and place it on the front surface of the flask, where the light hits it. You should be able to see how the light rays are bent by the lens. Try different lenses until you can see that the light

rays are coming to a focus on the back surface of the flask, which represents the retina.

3. Students who wear glasses may also like to try out the effect of their lenses on the light rays. You can discuss the problems of long and short sight, and demonstrate the effects of different types of lenses on the focusing of light rays onto the retina.

Answers to questions

12.5 conjunctiva, cornea, aqueous humour, pupil, lens, vitreous humour, retina.

12.6 a iris
b lens
c cornea
d ciliary muscles (and suspensory ligaments)
e dark cells behind the retina (choroid layer)

The endocrine system

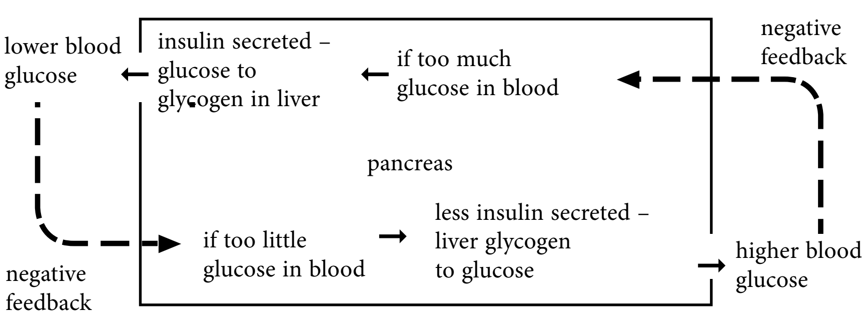
This covers syllabus sections 11(*i*), (*j*) and (*k*).

The hormones and glands dealt with here are the ones required by the syllabus, and there is no need to mention others. Testosterone, oestrogen and progesterone will be mentioned in Unit 19.

The syllabus does not require knowledge of the hormone glucagon, so this is not mentioned in the text.

Answers to questions

12.7



12.8 a The nervous system is made up of the central nervous system (brain and spinal cord) and nerves. However, the endocrine system is made up of glands.

The nervous system transmits information in the form of electrical impulses which sweep along neurons. The endocrine system transmits information in the form of chemicals that are carried in the blood all around the body.

b The aqueous humour is a runny liquid which fills the part of the eye in front of the lens. The vitreous humour is a more jelly-like liquid which fills the part of the eye behind the lens.

c The cerebrum is the large, folded part of the brain in which conscious thought takes place. The cerebellum is much smaller and lies behind and beneath the cerebrum, and this is where control of movement and balance takes place.

d A neuron is a specialized cell which transmits information in the form of electrical impulses. A nerve is a group of many axons and dendrons belonging to many different neurons.

e A sensory neuron carries impulses from receptor cells towards the central nervous system. Its cell body is in the dorsal root of a spinal nerve. A motor neuron carries impulses from the central nervous system to an effector. Its cell body is in the spinal cord or the brain.

f The ciliary muscles form a circle of muscle around the lens, connected to it by the suspensory ligaments. They contract and relax to change the shape of the lens. The iris muscles are in the coloured part of the eye, which lies in front of the lens. They contract and relax to change the size of the pupil.

Unit 13: Support, Movement and Locomotion

This short Unit covers syllabus sections 12 (*a*), (*b*) and (*c*).

The structure of the whole skeleton is shown in Fig 13.1, even though the syllabus does not require all of the bones to be known. The only names which students need to learn are the humerus, radius, ulna and scapula.

If at all possible, allow students to see real bones, such as those from a small mammal. They need to be able to recognize the four bones listed above from diagrams, photographs or real specimens.

Demonstration
How calcium phosphate and collagen affect the properties of bone

You will need:

- at least two fairly fresh bones
- a container of hydrochloric acid (approximately 2 mol dm^{-3} should work well)
- a method of burning a bone at a high temperature

1. Take one of the bones and place it in the hydrochloric acid. Leave it there until the bone has become soft and bendy. The acid dissolves away the calcium phosphate in the bone, but does not destroy the collagen.

2. Heat the other bone to a very high temperature. You could leave it in a very hot oven for several hours, or – if it is fairly small – in a hot Bunsen flame. The heat destroys the collagen, and leaves the bone very brittle.

When studying joints, students can try moving the elbow joint and the shoulder joint for themselves, and should be able to recognize the very different range of movement that is allowed at a ball and socket joint compared with a hinge joint.

You will be able to find information and photographs of artifical joints on the Internet. Students may be interested in the different designs of these joints, and the different materials from which they are made.

Answers to questions

13.1 a A tendon joins a muscle to a bone, and does not stretch. A ligament joins a bone to another bone, and can stretch more than tendons.

b A ball and socket joint has a ball on the end of one bone fitting into a socket on the other. It allows movement in all directions. An example is the joint between the humerus and scapula at the shoulder. A hinge joint allows movement in one plane. An example is the joint between the humerus and radius at the elbow.

c Bone is a strong, hard material made from calcium phosphate and collagen. Cartilage is also very strong, but is more flexible than bone.

13.2 Muscles obtain their energy by breaking down glucose in respiration. Glucose and oxygen are brought to the muscles in the blood.

Unit 14: The Use and Abuse of Drugs

The introduction covers syllabus section 12(*a*).

Antibiotics

This covers syllabus section 12 (*b*).

Most students will be familiar with antibiotics, but many will not realize that they are completely ineffective against diseases caused by viruses.
All of the early antibiotics were produced by fungi, but in recent years, as the search for different antibiotics continues, other sources are being investigated, such as the skin of amphibians. The continual increase in the range of bacteria that have become resistant to one or more antibiotics means that it is essential to keep searching for new ones. In hospitals in many parts of the world there are worrying increases in infections with strains of bacteria, such as *Staphylococcus aureus*, which are resistant to so many different antibiotics that it is becoming extremely difficult to find any way of controlling them. The current worldwide increase in cases of tuberculosis is also at least partly due to the development of antibiotic resistance in the bacteria which cause it.

Ensure that students use the term **resistance** and not 'immunity' in this context. Immunity refers to the immune system, which, of course, bacteria do not have.

It is also important for students to understand that bacteria do not 'purposefully' become resistant to antibiotics, but that this happens just by chance. This concept will be discussed again in Unit 20.

Answers to questions

14.1 An antibiotic is a drug which can be taken to kill bacteria in the body. An antibody may also kill bacteria, but it is produced by a person's white blood cells—in particular the lymphocytes. Most antibiotics are effective against several different kinds of bacteria, but each kind of antibody is very specific for one particular type. Antibiotics only act against bacteria, but antibodies can act against any antigens that enter the body, including bacteria, viruses or cells in a transplanted organ.

14.2 a The antibiotics destroy bacteria in the animal's body, which may have been slowing the rate of growth.

b The widespread use of antibiotics increases the risk that bacteria will become resistant to them. If a person becomes infected with these resistant bacteria, then antibiotics will not be able to cure their disease.

14.3 Influenza and colds are caused by viruses. Antibiotics are useless against viruses.

Heroin

This covers syllabus section 13(*c*).

Alcohol

This covers syllabus section 13(*d*).

Anwers to questions

14.4 Anaerobic respiration (sometimes also known as fermentation.)

Tobacco

This covers syllabus sections 13(*e*) and (*f*).

Heroin, alcohol and tobacco can be discussed in general and their adverse effects on the society.

Discuss the sources of drugs in general and hard drugs such as heroin, cocaine and marijuana in particular. Ask the pupils if they know of any one who smokes, drinks or is a heroin addict. Discuss their appearance and behaviour towards their family and friends. Discuss the bad effects of taking any kind of additives. Take the pupils to rehabilitation centre in your city. Show them the condition of the inmates. Discuss with a doctor or a carer and make their case histories. Other examples of drug addicts and the after-effects of these things on their lives can be discussed.

Answers to questions

14.5 There are no 'correct' answers to this question, and it might be best to treat it as a discussion rather than requiring written answers from individual students. Possible reasons they may suggest include:

- peer pressure – needing to feel 'one of the crowd'
- wanting to rebel against advice given by older people
- advertising by cigarette companies, and association of cigarettes with exciting lifestyles (for example, motor racing .....)

Unit 15: Micro-organisms and Biotechnology

The term 'biotechnology' does not have a very precise meaning, but the definition given here is one which is widely used. Note that further examples of biotechnology, in genetic engineering, are covered in Unit 20.

Types of micro-organisms

This covers syllabus section 14(*a*).

The influenza **virus** is given as an example here, as it has a relatively simple structure and a relatively straightforward method of reproduction. The human immunodeficiency virus, HIV, is described in Unit 19.

Students may like to discuss whether or not viruses can be said to be 'alive'. Certainly they do not possess all of the characteristics normally expected to be seen in living things, but it could be argued that their ability to reproduce is the one most important characteristic that distinguishes living from non-living things.

There is a great deal of interesting information on the Internet about viruses, including those which affect plants and which can be responsible for significant reductions in crop yields.

Bacteria will be met with again in Unit 16, where their roles in the carbon and nitrogen cycles are discussed, in Unit 19 in relation to the disease syphilis, and yet again in Unit 20 in relation to their use in the industrial production of insulin. You may be able to show your students micrographs of different kinds of bacteria.

Many **fungi** are not truly micro-organisms, as they produce from time to time large fruiting bodies which we know as 'mushrooms' or 'toadstools'. However, the main body of these fungi, as with most others, is the mycelium made up of very fine hyphae. Yeast, which will be described later in this Unit, is an unusual fungus as it is unicellular.

Students are asked to summarize the information given here in order to build up a list of the main characteristics of these three groups.

Answers to questions

Virus	Bacteria	Fungi
Not made of cells	Made of cells with cell walls	Made of cells with cell walls
Can only reproduce by taking over a living cell		
	Cells do not contain a nucleus	Cells contain a nucleus
	Cells are much smaller than plant or animal cells	Body is called a mycelium, and is made up of many hyphae
		Always feed by saprotrophic nutrition

Making use of micro-organisms

Decomposition

This covers syllabus section 14(*b*).

Students should gain a better understanding of this topic when they have covered the carbon and nitrogen cycles.

Using yeast for making bread and alcohol

This covers syllabus section 14(*c*).

Students can be explained about this topic by giving them examples of breads, *sheermals* where yeast is used to make them.

Production of yoghurt and cheese

This covers syllabus section 14(*d*).

The Latin name of a bacterium, *Lactobacillus*, is introduced here. The use of binomials is not required by this syllabus, but it is difficult to avoid them completely. You may like to explain briefly to your students that each kind of organism is given a two-word Latin name which is used all over the world by all scientists, no matter what language they speak.

Students may remember that they have met lactic acid before, in the context of anaerobic respiration in muscles.

Investigation 15.1 Making yoghurt

Students may be asked to do the experiment with different types of milk (like cows' and buffaloes') at their homes. Later they can share and exchange their observations based the quality of yoghurt formed.

Making penicillin

This covers syllabus section (*f*) and part of (*e*).

The use of antibiotics was described in the previous Unit. You may be able to show students blue mould growing on bread (leave some moist bread, loosely covered so that it doesn't dry out, for a few days.)

Answers to questions

15.2 (This is a difficult question, but definitely worth asking your students to try!) The nitrate ions supply nitrogen, which is needed to make proteins. Carbohydrates, such as the sugar that is supplied to *Penicillium*, contain only carbon, hydrogen and oxygen.

15.3 Sterilization kills all living organisms. This means that no micro-organisms other than *Penicillium* will grow inside the fermenter, so the penicillin that is obtained will not be contaminated by anything else.

Single-cell protein

This covers the remainder of syllabus section 14(*e*).

It was once thought that SCP could become a major food source for people, but this has not yet happened. However, in some parts of the world filamentous cyanobacteria have long been grown and harvested for food, and it may be that the development of more appealing and better-tasting types of SCP will eventually capture people's imagination and become popular.

Answers to questions

15.4 The carbon dioxide is produced by the anaerobic respiration of *Fusarium*.

15.5 a In some parts of the world, for example where there is famine, foods containing protein (such as meat, fish, eggs, pulses and milk) may be in short supply. Mycoprotein is a very rich source of protein, and so could make a valuable contribution to a growing child's diet. Protein is required for growth and repair of cells, as it is a major component of cell membranes and cytoplasm. It is also needed to make other proteins in the body, such as haemoglobin, enzymes and antibodies.

b Fibre is needed to keep the alimentary canal working well, and to prevent constipation.

c A diet containing high levels of fat may increase the risk of heart disease.

Unit 16: Organisms and Environment

The introduction encourages students to think about real living organisms in their natural environment. If at all possible, try to take your students outside to look at one or more habitats, even if only into the school grounds.

Energy flow

The introduction to this section covers syllabus section 15(*a*). This is essentially revision—students will probably have come across the idea that the Sun is a source of energy in food chains, and should remember from earlier in their O Level course that photosynthesis incorporates some of this energy into carbohydrates.

Answers to questions

16.1 a In respiration. Glucose or other substances are broken down by combining them with oxygen.

b For active transport (for example for the absorption of mineral ions by the root hairs.) For translocation (that is, the transport of sucrose in the phloem tissue). For building large molecules from small ones (for example, making protein molecules from amino acids). For cell division.

Food chains

This begins coverage of syllabus section 15(*b*) and (*c*).

This is probably a familiar idea already. However, do encourage students to think of the arrows as representing *energy flow*, not just 'is eaten by'. They may like to think of some food chains of their own.

This section introduces quite a bit of new terminology, which needs to be learnt with care.

Answers to questions

16.2 a grass
b hog deer
c tiger
d hog deer and tiger

Food webs

This continues coverage of syllabus section 15(*c*).

There is normally no problem at all in moving on from food chains to food webs. Once again, make sure that everyone understands what the arrows mean, and that they are pointing in the direction in which energy is flowing. You may be able to build up a food web for a habitat that you visit with your students.

Answers to questions

16.3 a desert fox or honey badger

b any two of black beetles and other insects, gerbils, hares

c any two of spiny-tailed lizard, short-toed eagle (desert fox and honey badger are also possibilities)

Energy losses along food chains

This begins coverage of syllabus section 15(*d*).

Students who have studied energy transfers in physics lessons will already appreciate that energy is lost as heat, each time it is transferred from one form or from one place to another. However, take care that they do not infer that the quantity of energy in one desert fox is less than that in one gerbil, for example! They must think about the whole *population* of each kind of organism in the ecosystem, not just individuals.

Decomposers

This completes coverage of syllabus section 15(*c*).

These have been met before, in Unit 15, where the roles of micro-organisms in decomposition were first mentioned. The roles of decomposers in the carbon and nitrogen cycles are dealt with later in this Unit.

Pyramids of numbers, pyramids of biomass and advantages of short food chains

This covers syllabus section 15(*e*).

These pyramids illustrate the consequences of the losses of energy along food chains, and most students have no problem in dealing with them at this level. The ideas developed here then lead into thinking about advantages of short food chains. However, this is not at all straightforward, and students should not be led to think that if everyone became vegetarian then we could solve the world's food problems!

Answers to questions

16.4 Depending on the food chain chosen, it is likely that both pyramids will be of the 'classic' shape shown in Fig 16.2.

Nutrient cycles

You could point out to your students that, whereas energy flows *through* an ecosystem, nutrients tend to cycle around it. It is worth spending a short time on revisiting the reasons why carbon and nitrogen are important to living organisms, before embarking on descriptions of the cycles themselves.

The carbon cycle

This covers syllabus section 15(*f*).

The central role of photosynthesis as being the only way in which carbon enters ecosystems quickly becomes obvious. Students may need reminding that every organism respires, including plants and decomposers as well as animals.

Avoid the statement that respiration 'turns oxygen into carbon dioxide' or that photosynthesis 'turns carbon dioxide into oxygen'. Neither of these statements are correct.

Answers to questions

16.5 Carbon dioxide enters the leaf of a plant, where it is combined with water to form a carbohydrate molecule, for example starch. A hog deer eats the plant and digests the starch to produce glucose, which is absorbed into its blood in the digestive system. It is taken to the liver and stored as glycogen. A tiger eats the hog deer, and digests the glycogen to produce glucose, which is absorbed into its blood and taken to the liver. Here the liver cells link many glucose molecules together to form glycogen.

The nitrogen cycle

This covers syllabus section 15(*g*).

This is not an easy topic for most students, who do not appreciate the meaning of all the different molecules in which nitrogen is found. Try to remember to use the word 'nitrogen' to mean a nitrogen *atom*, not nitrogen *gas*, as this can be a great source of confusion. Encourage students to name the compound involved when they describe something happening to it. For example, they should say that *nitrates* are absorbed through root hairs, not *nitrogen*.

Note that there is absolutely no need for students to know the names of any of the bacteria involved, nor the details of denitrification.

Answers to questions

16.6 Nitrogen gas from the air could combine with oxygen when lightning flashes through the air to produce nitrates, *or* nitrogen-fixing bacteria in a plant's roots change nitrogen gas into ammonium.

A plant uses the nitrate or ammonium to make proteins. The hog deer eats the plant, and digests the proteins to amino acids which are absorbed into its blood and then used by a cell to make protein molecules. The hog deer is eaten by the tiger, which digests the proteins into amino acids and absorbs them. The amino acids are carried in the blood to the muscles, where they are linked together to form proteins.

Malaria

This covers syllabus sections 15(*h*) and (*i*).

Try to avoid confusion between the *pathogen* and the *vector* here. The actual cause of the disease is *Plasmodium*, not the mosquito which transmits it.

Note that no details of the life cycle of *Plasmodium* are required.

The term 'vector' also occurs in mathematics and physics, where it is used to describe a factor which has both magnitude and direction, such as velocity. Here it means something very different, and it is probably worth reminding students of these two very different meanings. Confusion is quite common, and resulted, in one examination paper which I have marked, in the wonderful statement that 'A vector is a mosquito with speed and direction.'

It is worth keeping an eye on the media for news of new developments in the control of malaria. Both the mosquito and the parasite have evolved resistance to chemicals used to control them, and new ones are always being sought. It is possible that a vaccine for malaria will be developed in years to come.

Answers to questions

16.7 a A producer is a plant, which produces organic materials by photosynthesis. A consumer is an organism which feeds on other organisms, such as fungus or an animal.

b A herbivore is an animal that eats plants. A carnivore is an animal that eats animals.

c Nitrogen fixation is the combination of nitrogen gas with some other substance, producing a more reactive compound such as nitrate ions or ammonium ions. Denitrification is the breakdown of nitrogen-containing compounds to produce nitrogen gas.

d A pathogen is an organism that causes disease, for example the malaria pathogen *Plasmodium*. A vector is an organism that transmits a pathogen from one organism to another, for example the *Anopheles* mosquito that transmits the malarial pathogen.

16.8 *For example*:

Carbon dioxide diffuses through the stomata of the leaf of a bean plant, through the air spaces and into a chloroplast in a palisade cell. Here it is made to combine with water, using energy from the beam of sunlight which the green pigment chlorophyll has absorbed. The energy in the sunlight is now trapped in the glucose molecule.

The plant converts some of the glucose it has made into sucrose, which is transported in the phloem into a growing seed. In the seed, the sucrose molecules are converted to starch molecules, which still contain the energy from the sunlight.

The seed grows into a bean, and you eat it. In your mouth, amylase breaks down the starch into maltose, and the maltose is broken down in your small intestine to produce glucose. This glucose, still containing the sun's energy, is absorbed into your blood.

16.9 Energy is lost each time. It is transferred from one organism to another in a food chain. Therefore, there would not be enough energy left to support a population of animals that always fed at the fifth trophic level in a food chain.

16.10 a The only way a mosquito can pick up malarial pathogens is by biting someone who has the pathogen in their blood. If it cannot do this, then it cannot transmit the disease to someone else.

b Fish will eat mosquito larvae. So there are fewer mosquito vectors which can transmit the disease.

c Adult mosquitoes lay their eggs in pools of water, such as those that collect in rubbish. By removing these, the mosquito population will be kept smaller.

Unit 17: Human Effects on Ecosystems

This is a huge topic, and the syllabus quite rightly concentrates on particular examples, rather than asking students to cover everything that could be studied in this area. The emphasis is on issues of international importance. However, throughout this topic, try to introduce local examples wherever possible.

The syllabus section 15(*j*) is largely subsumed within the detailed coverage of particular issues covered in the later sections.

Deforestation

This covers syllabus section 15(*k*). Here the focus is on tropical rain forests, as these are specifically mentioned in section 15(*j*). However, students should understand that deforestation on a huge scale has already happened in many of the temperate forests of Europe, Asia and North America.

A search on the Internet can provide detailed satellite photographs of areas where deforestation is taking place. Students may also enjoy researching data on specific instances of deforestation, and the effects this has had on local biodiversity and on humans who live in that area.

Answers to questions

17.1 For timber (for building houses and furniture). For clearing space for agriculture. For clearing space for building towns and roads.

17.2 The loss of trees reduces the amount of water vapour that goes back into the air after rain. The air, therefore, becomes drier, and less rain falls.

Pollution

This covers syllabus section 15(*l*). Once again, only a few examples are touched on here, and there are very many others which are also very important. You might ask your students to research one instance in detail, for example the Minimata Bay mercury pollution. They could also look at pollution of local waterways.

The process of eutrophication is often misunderstood. A common error is to think that the *plants* use up oxygen, rather than the bacteria that feed on them. Students also often wrongly suggest that pesticides or heavy metals cause eutrophication.

Another common misconception is that all insecticides are persistent and accumulate along food chains. This is by no means so. DDT is the most famous example of a persistent insecticide, but there are now a large number of insecticides that do not show bioaccumulation.

Answers to questions

17.3 a The bacterial population becomes very high just below the point at which the raw sewage enters, because the sewage contains organic materials on which they can feed. As you go further downstream, the amount of these organic materials gets less, so only small populations of these bacteria are found there.

b The bacteria respire aerobically, using up oxygen from the water. The greater the population of bacteria, the less oxygen there is in the water.

c Fish respire aerobically, and therefore need oxygen. They cannot survive in parts of the river where oxygen concentrations are low.

17.4 The sewage may contain pathogens, such as the polio virus or the cholera bacterium. People who come into contact with water containing these pathogens may be infected with these very dangerous diseases.

17.5 a If it rains just after the fertilizers have been applied, they are very likely to be swept off the land by the water and carried into rivers and streams.

b If there are growing crops present, they will quickly take up the fertilizer. If there are no plants on the land, then the fertilizers will be washed down into the soil next time it rains, and may be carried into rivers and streams.

17.5 a Calcium carbonate reacts with acids, neutralizing them.

17.6 Application of insecticides often kills predatory insects as well as the ones which are causing crop damage. Thus there are no natural predators to destroy these harmful insects, and their numbers will increase.

Another problem is that insects develop resistance to insecticides. In a population of insects, there may be one or two that have a gene that makes it resistant. All the others die when exposed to the insecticide, leaving the resistant ones to breed and eventually produce a whole population of resistant insects.

Conservation

This covers syllabus sections 15(*m*) and (*n*).

This is a huge topic, and can only be touched on here. Once again, try to find local examples to illustrate the concepts described here if at all possible.

Answers to questions

17.7 It is the duty of humans to care for planet Earth. Tropical rainforests have very high biodiversity. Rainforests may be the source of as yet unknown drugs. Their loss would lead to lower rainfall which could cause droughts.

17.8 a A broad-spectrum insecticide kills all insects. A narrow-spectrum insecticide kills only the pest insect.

b A biodegradable insecticide breaks down soon after it has been applied. A persistent insecticide does not break down, and may be passed along food chains.

17.9

Pollutant	Source	Harmful effects
raw sewage	houses, industry	eutrophication spread of water-borne diseases
nitrogen-containing fertilizers	run-off from farmland	eutrophication
inorganic waste	runs-off from industries and mining operations	kills aquatic animals, as it contains toxic heavy metals
sulphur dioxide	burning fossil fuels, especially coal	acid rain, which weakens trees and kills aquatic organisms
insecticide	from farmland, or villages where it is used to kill mosquitoes	kills organism other than the pest, especially if it accumulates along food chains

Unit 18: Reproduction in Plants

The sequence of the material covered in this Unit follows that in the syllabus, but you may prefer to do this differently. There are good arguments for beginning with the details of human or plant reproduction, and then using that knowledge to help to explain the features of asexual and sexual reproduction (syllabus sections 16(*a*), (*c*) and (*d*)).

This topic will need to be covered at a time when suitable flowers are likely to be available.

Asexual reproduction

This covers syllabus sections 16 (*a*) and (*b*). You may prefer to use a different example of a commercially important application of asexual reproduction, depending on what materials you have available. If desired, students could try growing cuttings, or you could do this as a demonstration.

Sexual reproduction

This covers syllabus sections (*c*) and (*d*).

Notice that there is no need whatsoever to use the terms 'mitosis' or 'meiosis', nor to provide any descriptions at all of how these processes occur.

There are a number of common misconceptions which commonly arise in this topic. The two most important misconceptions are:

- the idea that sexual reproduction always involves two parents. This is simply not true, and there are many plants which reproduce sexually but use self-fertilization.
- the idea that all organisms have cells with 46 chromosomes.

Answers to questions

18.1

Sexual reproduction	Asexual reproduction
cells undergo a reduction division, in which the number of chromosomes is halved	there is no reduction division; cells divide to make new cells with the same number of chromosomes as the parent cell
gametes are involved	there are no gametes
gamete nuclei fuse in a process called fertilization	there is no fertilization
a zygote is formed	there is no zygote
offspring are genetically unalike	offspring are genetically identical

Avoid comparison points which suggest that sexual reproduction always involves two parents, and asexual one, as sexual reproduction may occur with only one parent (eg. in many flowering plants).

Sexual reproduction in flowering plants

The structure of a flower

This covers syllabus sections 16(*e*), (*f*) and part of (*h*).

Once again, there are very common misconceptions which arise here, the most common being that pollen grains actually *are* the male gametes. Similarly, students should learn that ovules contain female gametes. Yet another problem is that many students use the terms ‘plant’ and ‘flower’ to mean the same thing.

Investigation 18.1 The structure of an insect-pollinated flower

If at all possible, choose a simple but large flower for this exercise. Fused petals and stamens can be very confusing at this stage.

The guidelines for the drawing are general advice for all biological drawings. You may have other features that you expect your students to include, such as using double lines to represent cut surfaces. Calculating and stating magnifications of diagrams is something which biology students should always expect to include.

They may enjoy looking at pollen grains from different species of flowers.

Safety points

The only possible source of risk here is the use of a sharp blade for cutting the flower.

Materials required

Each group of students will need:

- at least one simple, brightly coloured flower, or preferably a flower spike containing several flowers at different stages of development
- a scalpel, safety razor blade or sharp knife
- a surface on which cutting can be done
- a hand lens
- a ruler to measure in mm
- a microscope slide and cover slip
- access to water
- a microscope

Answers to questions

18.2

Structure	Function
sepals	protect the flower while it is in bud
petals	attract insects to the flower, by their colour and/or their scent
nectary	contains a sugary liquid called nectar which attracts insects to the flower
stamens – anther filament	makes pollen grains supports anther in a position where insects will rub against it
carpel – ovary ovule	contains the ovules contains the female gametes
style	connects the ovary to the stigma
stigma	provides a sticky surface on which pollen grains can be trapped

Wind-pollinated flowers

This covers syllabus sections (*g*) and (*i*).

Investigation 18.2 Comparing a wind-pollinated and insect-pollinated flower

Safety points

None, unless some members of the class have severe allergies to grass or other pollen.

Materials required per group

- an insect-pollinated flower; this could be the same one as was used in Investigation 18.1
- a wind-pollinated flower, such as a grass flower
- a hand lens
- a microscope slide, coverslip and microscope

Self-pollination and cross-pollination

This covers part of syllabus section 16(*h*).

Fertilization

Do not try to teach too much detail here; at this stage, it is best if the process is dealt with simply. Try to ensure that students do not become confused between pollination and fertilization. Also, try to avoid the extremely common misconception that the entire pollen grain goes down the style to the ovule.

You may like to try growing pollen tubes.

Demonstration
Growing pollen tubes

You will need:

- a number of flowers with fresh, ripe pollen
- sucrose solutions with a range of concentrations
- a little boracic acid or borate
- cavity microscope slides *or* ring slides, coverslips and a microscope

Pollen grains need ample access to air if they are to germinate and grow tubes. You, therefore, need to make a slide in which they are in contact with air. This can be done in one of two ways:

1 Using cavity slides

Place a drop of your chosen liquid into the cavity on the slide, making sure that the cavity is not completely filled. Dust a few pollen grains onto the surface of the liquid, then cover with a cover slip. You may like to use a small ring of vaseline around the edge of the cavity, to support the coverslip above the surface of the liquid.

2 Using ring slides

Place a drop of your chosen liquid onto the centre of a coverslip. Invert this, so that the drop is hanging downwards (it should stay in place if the coverslip is clean) and place it on the ring on the slide. Once again, vaseline may prove helpful.

It is suggested that you trial a range of sucrose concentrations, to see which is most successful for the species of plant that you are intending to use. Having made your slides, keep them in a warm but not hot environment (once again, optimum temperature may vary between species) and look at them every 10 minutes or so.

Seeds and fruits

This – together with the two Investigations which follow—covers syllabus sections 16(*k*), (*l*) and (*m*).

Yet another extremely common source of confusion exists here. Many students regularly confuse movement of *pollen* and dispersal of *seeds or fruits*.

Investigation 18.3 The structure of a seed

Safety points

There are few risks here. Do not use seeds which may be poisonous, such as those from *Ricinus* (castor oil).

Materials required per group

- a large seed which has been soaked in water to soften the testa—bean seeds are recommended
- a lens
- a ruler to measure in mm
- food tests reagents and equipment

Investigation 18.4 Fruits

Use whatever fruits are available to you locally, either from markets or from local plants. Try to find at least one example of self-dispersed, wind-dispersed and animal-dispersed fruits.

It is not advisable to teach the names of all the different kinds of fruits (berries, drupes etc.), as this is not required by the syllabus and can be an unnecessary source of confusion at this level. Nor do students need to know the names of different parts of a fruit, although the term 'pericarp' *is* required.

Both this investigation and the previous one give opportunity for practising drawing skills and the calculation of magnification.

Germination

Students will already have met the roles of enzymes in germination, so this is an opportunity to revise that part of the syllabus. They may like to germinate large seeds such as beans to watch the growth of radicle and plumule, even if they have this before.

Investigation 18.5 The conditions necessary for germination

Safety points

There are no risks involved in this Investigation.

Materials required per group

- five glass tubes, large enough for a number of small seeds to fit into
- cotton wool
- a little oil and a dropper pipette
- access to a refrigerator
- a number of small, quickly-germinating seeds (e.g. mustard)—they should all be of the same age and have been stored under the same conditions

The results should indicate that the seeds require moisture, a warm temperature and access to air (oxygen) in order to germinate. It is likely that the seeds will not require light. However, it is a fact that the majority of seeds do require light for germination; humans have inadvertently selected for non-sensitivity to light in the seeds of crop plants.

Ensure that students do not confuse *germination* – the breaking of dormancy of the seed - with its subsequent *growth*.

Answers to questions

18.3 a A plant is a whole organism, made up of many organs including roots, stems, leaves and flowers. A flower is an organ in which sexual reproduction takes place.

b Stamens are the male parts of a flower, consisting of a filament and anther. Male gametes are made inside pollen grains in the anthers. Stigmas are part of the female parts of a flower, on which pollen grains are trapped.

c Pollination is the transfer of pollen from an anther to a stigma. Fertilization is the fusion of the nuclei of the male and female gametes inside the ovules.

d Wind-pollination is the transfer of pollen from an anther to a stigma. Wind-dispersal of fruits is the movement, by the wind, of a fruit from the plant where it was formed to a different place away from the parent plant.

e A seed develops from an ovule after fertilization. It contains an embryo plant. A fruit develops from an ovary after fertilization. It contains seeds.

Unit 19: Reproduction in Humans

The Unit begins with a brief summary of the whole process of sexual reproduction in humans, using the knowledge that students will already have from the introduction to the differences between sexual and asexual reproduction in the previous Unit.

The term ‘sperm’ is very commonly used for both singular and plural, although, of course, if you or your students would prefer to use ‘sperms’ or ‘spermatozoa’, that would be perfectly acceptable.

The term ‘ovum’, for the female gamete, is intentionally avoided. An ovum is a female gamete which has undergone both meiotic divisions, and this stage is not reached in the development of the human female gamete until after fertilization has occurred. The cell which leaves the ovary at ovulation is technically a secondary oocyte. So a term with a broader meaning, 'egg', has been used throughout this Unit. However, if you prefer to use the term 'ovum', this would be acceptable.

The human reproductive organs

This covers syllabus sections 16(*p*) and (*q*).

It is a good idea for students to learn the appearance of both male and female reproductive organs when viewed either from the front or from the side.

Several of the organs in Figs 19.1 and 19.2 have at least two alternative names. The ones used here are the ones used in the O Level syllabus, and students must know these terms as they will appear on examination papers. However, it would be acceptable for a student's answer to contain other correct biological names—i.e. vas deferens, Fallopian tube.

Answers to questions

19.1

Part of reproductive system	Function
testis	where sperm are made
sperm duct	a tube that carries sperm from the testes to the urethra
prostate gland	a gland which secretes a sugary fluid to mix with sperm and produce semen
scrotum	a protective sac around the testes
ovaries	where eggs are made
oviduct	a tube that carries eggs from the ovaries to the uterus; this is where fertilization can take place
uterus	the organ in which an embryo develops
cervix	a ring of muscle around the entrance to the uterus

The menstrual cycle, fertile and infertile phases

This covers syllabus section 16 (*s*).

Note that the syllabus does not require knowledge of how hormones control the menstrual cycle, or the changes in the levels of progesterone or oestrogen throughout the 28 days. However, these hormones will be met later, in the section on hormonal methods of birth control, so it may be a good idea to at least mention them here. There is, however, absolutely no need to mention FSH, LH or the role of the pituitary gland in the control of the menstrual cycle.

The fertile and infertile phases of the cycle will be dealt with again in the section on natural methods of birth control.

Answers to questions

19.2

fertile phase – days 12-22
infertile phase – days 22-10
ovulation – day 14
menstruation – days 1-7

Gametes and fertilization

This covers syllabus sections 16 (*r*) and part of (*t*).

The syllabus does not require any knowledge of how sexual intercourse takes place, but this is covered very briefly here as it is difficult to make any sense of how fertilization occurs without this knowledge.

Answers to questions

19.3

Feature	Sperm	Egg
size	about 0.05 mm long	about 0.1 mm in diameter
numbers produced	100 million to 200 million each day	one each month
motility	can swim actively	unable to move by itself

The development of the embryo, implantation, the placenta

This covers part of syllabus section 16(*t*), and also 16(*u*) and *v*).

The term 'fetus' used to be spelt 'foetus', but the Institute of Biology has recommended that the *o* should be dropped. The reason for this is the derivation of the word from ancient Greek; there never should have been an 'o'! It is difficult to make this change if you have been using the spelling 'foetus' all of your life. The spelling 'fetus' will be used on the examination papers, but it would be quite acceptable if students used the older spelling instead.

You may like to draw parallels between the adaptations of the ileum and the placenta for the rapid exchange of materials.

Students should be precise if asked to name substances that pass across the placenta. The answer 'food substances' or even 'nutrients' is unlikely to be sufficient; specific soluble nutrients should be named.

Answers to questions

19.4 a carbon dioxide, urea
b glucose, amino acids, fatty acids, glycerol, any named vitamins, any named minerals
c oxygen

19.5 a amnion
b umbilical cord
c placenta

Pregnancy and birth, breast milk and bottle milk

This covers syllabus sections 16(*w*) and (*x*).

The syllabus expects knowledge of special dietary needs during pregnancy, but nothing else about prenatal care. You may like to talk about this in more detail than is given in the text. Similarly, the syllabus does not require knowledge about birth, and this is, therefore, treated very briefly.

The advantages of feeding a young baby on breast milk are numerous, but it is important not to make students feel that anyone who chooses to bottle-feed is somehow failing their baby. However, some of the manufacturers of formula milk are very aggressive with their advertising campaigns, and it is important for students to realize that breast milk is actually better for a baby than formula milk.

Answers to questions

19.6 a to form bones and teeth
b to produce haemoglobin in red blood cells
c to form new cytoplasm, cell membranes, and chemicals such as enzymes and haemoglobin
d to help to form bones and teeth

Birth control

This covers syllabus section 16(*y*).

There is a lot of information to take in here. Question 19.7 asks students to summarize it into a form in which it should be easier to learn.

Answers to questions

19.7 This question intentionally leaves it to individual students to think about how they will design their table, and what they will include in it. It is, therefore, not possible to provide a standard answer that can be matched against each student's work. All of the information necessary to construct this table is included in the preceding text and diagrams.

Sexually transmitted diseases

This covers syllabus sections 16(*z*), (*aa*) and (*bb*).

Although syphilis is not one of the commonest sexually transmitted diseases (the incidence of gonorrhoea and chlamydial infections is much greater) it is perhaps the most dangerous.

Everyone has now heard of AIDS, and knows that it is caused by HIV. There are many misconceptions about how it can be passed from one person to another, so it is important that students gain a clear understanding of this. Patterns of transmission seem to vary considerably between one country and another. For example, in sub-Saharan Africa, by far the most important method of transmission is through normal heterosexual activity, whereas in other countries homosexual activity or the sharing of hypodermic needles by intravenous drug users are the major methods of infection.

Treatment with drugs such as AZT can greatly improve the quality and length of life of a person with AIDS, but there is as yet no cure for the disease.

Answers to questions

19.8 a If people understand what AIDS is and how it is transmitted, then they are able to take decisions about what they do which can reduce their chances of getting the disease.

b This can ensure that no one is given blood containing the HIV virus. It could also ensure that anyone who gives blood can find out whether or not they are infected with the virus; if they are, then they can make sure that they do not pass it on to anyone else.

c A used hypodermic needle will have come into contact with someone's blood, and so it may contain HIV viruses. If this needle is used again by someone else, then the virus could be passed on. Sterilizing the needle, or – better still – disposing of it and using a new one, can make sure that this does not happen.

d All the partners can be tested for HIV, and if any of them are infected with it they can begin treatment which could slow the onset of the symptoms of AIDS. They can also make sure that they do not pass the virus on to anyone else.

19.9 a The testis is one of the organs in which sperms are made. The prostate gland makes a sugary fluid which mixes with sperms to produce semen.

b The ovary is one of the organs where eggs are made. The oviduct is a tube along which the egg travels from an ovary to the uterus.

c HIV is the virus which causes AIDS. AIDS is the illness which is caused by HIV. A person infected with HIV is said to be HIV-positive. They may or may not have AIDS.

d The fertile phase of the menstrual cycle is the time in which fertilization could occur. It lasts between about day 12 to day 22 of the cycle. The infertile phase is when it is very unlikely that there will be an egg in the oviduct, which is between about day 22 to day 10 of the cycle.

Unit 20: Inheritance

This Unit follows a slightly different order from that of syllabus section 17. Most of the new terminology is introduced and practised before thinking about inheritance. The idea of mutation is left until inheritance has been covered.

The introduction begins to consider syllabus section 17(*a*). It asks students to think about examples of variation, and what may cause them. They will already be aware, though perhaps without having thought about it specifically, that who and what we are, is influenced both by genes and environment.

Investigation 20.1 Variation

It is suggested that finger length is measured, but of course there are many other possibilities. Another idea would be to use plant material—for example, measuring the length of a number of leaves. This has the advantage that each student could measure at least 10 leaves, which will provide more data and, therefore, a more meaningful graph.

Safety points

There are no hazards in this investigation.

Materials required

A ruler to measure in mm.

Types of variation, the causes of continuous and discontinuous variation

These complete coverage of syllabus section 17(*a*).

A common misunderstanding is that continuous variation is something which changes throughout your life. Unfortunately, this is true of several of the examples which you might consider using, such as a person's height or the length of a leaf, so you may need to emphasize the idea that this is not the true meaning of the term.

Answer to questions

20.1 a Degree of exposure to sunlight
b Amount of food eaten, amount of exercise taken

20.2 We cannot be sure about any of these, so be prepared to accept reasoned arguments!

a Probably genes alone.
b Probably genes alone—although there are some species of plants whose flower colour varies depending on the pH of the soil in which they are growing.
c Both genes and environment—for example, leaves growing in shady places may be larger and thinner than leaves on the same plant growing in a sunny place.
d Both genes and environment—for example, roots may grow deeper if the soil is dry than if it is wet.

DNA, chromosomes and genes

This covers syllabus sections 17(*b*) (*c*), (*p*) and (*q*).

Note that the syllabus does not require any knowledge of the structure of DNA molecules, nor anything about the bases. This information has been added as a marginal note as some students will have heard about them, especially as the Human Genome Project has had quite a high profile in the world's media.

Alleles

This covers part of syllabus section 17(*e*).

It is very important that the words 'gene' and 'allele' are used correctly. If they are introduced clearly right from the start then students have no difficulty at all with these two terms.

The sickle cell version of haemoglobin is used as an example here, and will be used again later in this chapter, as an example of mutation.

Genotype and phenotype

This covers syllabus section 17(*f*).

Answers to questions

20.3 a The allele for red flowers is dominant, because in a plant with both alleles the flowers are red.
b R for the red allele and r for the white. Obviously, any pair of letters is acceptable, but they must be the upper and lower case for the same letter, and be easily distinguishable from one another.
c RR red, Rr red, rr white.

Heterozygous and homozygous genotypes

This covers part of syllabus section 17(*i*).

Answers to questions

20.4 They are red.

Inheriting genes, genes in gametes, gametes and fertilization, F_1 and F_2 generations

This covers syllabus sections 17(*d*), part of (*e*), (*i*) and (*j*),

The syllabus expects students to understand that a gene is length of DNA, and also that it is a unit of inheritance. This latter definition is introduced here as a convenient way of thinking about genes when studying their inheritance.

The way in which the genetic diagrams are presented here follows the standard convention. Note that the 'genetic diagram' is the whole explanation, not just the Punnett square showing the offspring genotypes. Encourage students to draw a circle around the gamete genotypes—again, this is a widely used and very helpful biological convention.

It is also very important to make sure that they understand that the diagram shows them *probabilities* of each genotype being produced. A very common error is to think that it shows *how many* offspring will be produced!

Do ensure that your students know the true definition of the terms F_1 generation and F_2 generation. These should not be used for any crosses other than those described in the text.

Answers to questions

20.5 B and b.

20.6 a Allele A, for tall plants, is dominant, because heterozygous plants are tall.
b aa.
c They are all a. Each gamete receives only one copy of the gene.

20.7a

phenotypes of parents	striped	striped
genotypes of parents	Bb	Bb
genotypes of gametes	B or b	B or b

Gentic cross

phenotypes of parents	Striped	Striped
genotypes of parents	Bb	Bb
genotypes of gametes	B or b	B or b

male gametes

female gametes	B	b
B	BB Striped	Bb Striped
b	BB Striped	Bb Plain

expected genotypes of offspring	1 BB : 2 Bb : 1 bb
expected phenotypes of offsping	3 Striped : 1 Plain

We would, therefore, expect the offspring to be produced in the ratio of 3 striped : 1 plain.

b There would be approximately 75 striped fish and 25 plain fish.

20.8 a The allele for short hair is probably dominant. (Some of the better students may realize that we cannot be sure about this – it is possible that the long hair allele is dominant, that the long-haired cat is heterozygous and the short-haired one heterozygous, and just by chance all of the kittens have short hair, even though we would expect half of them to have long hair.)

b For example, **H** for short hair and **h** for long hair.

c

phenotypes of parents	long haired	short haired
genotypes of parents	hh	HH
genotypes of gametes	all h	all H

Gentic cross

phenotypes of parents	Short hair	Long hair
genotypes of parents	HH	hh
genotypes of gametes	H	h
genotypes of offspring	Hh	
phenotypes of offspring	Short hair	

20.9a

phenotypes of parents	brown eyes	brown eyes
genotypes of parents	Bb	Bb
genotypes of gametes	B or b	B or b

Gentic cross

phenotypes of parents	brown eyes	brown eyes
genotypes of parents	Bb	Bb
genotypes of gametes	(B) or (b)	(B) or (b)

male gametes

female gametes	(B)	(b)
(B)	BB Brown	Bb Brown
(b)	BB Brown	Bb Brown eyes

b

phenotypes of parents	brown eyes	brown eyes
genotypes of parents	Bb	Bb
genotypes of gametes	B or b	B or b

Gentic cross

phenotypes of parents	Brown eyes	Blue eyes
genotypes of parents	Bb	bb
genotypes of gametes	(B) or (b)	(b)

male gametes

female gametes	(B)	(b)
(b)	BB Brown	Bb Blue eyes

expected genotypes of offspring 1 BB : 1 bb
expected phenotypes of offsping 3 Brown eyes : 1 Blue eyes

We would therefore expect half of their children to have brown eyes, and half to have blue eyes. However, this is only a probability, and it is perfectly possible that the 'blue-eyed' chance has come up more often than we would expect.

20.10 a The genetic diagram will show that the gametes from one parent all contain a copy of the dominant allele, while the gametes from the other parent all contain a copy of the recessive allele. Therefore, all the offspring will have one of each.

b The genetic diagram should look like that for Q20.9a.

Codominance, human blood groups

This covers syllabus section 17(*k*).

The syllabus requires students to study codominance through the example of human blood groups, but a simpler example is used to introduce this new concept.

Note that the Institute of Biology recommends that the term ‘incomplete dominance’ is no longer used, and that all cases where both alleles have an effect on the phenotype of a heterozygote are known as ‘codominance’.

Answers to questions

20.11 a The expected offspring ratios will be 1 roan : 1 white.
b All red.
c 1 red : 2 roan ; 1 white.

20.12 Students will probably need to draw a genetic diagram to answer this question. This will show that it is not possible for any of the offspring to have the genotype AB, because each one will inherit an l^o allele from their mother.

20.13 a For any of the children to have blood group O, the father must have an l^o allele. Therefore, his genotype is $l^A l^o$. Similarly, the mother must also have an l^o allele. As one of the children has blood group B, it must have inherited an l^B allele from its mother, so her genotype is $l^B l^o$, meaning that her blood group is B.
b The chances are completely unaffected by what genotypes or phenotypes any of the previous children had. Each time an egg is fertilized, there are equal chances that a sperm of either genotype will fuse with an egg of either genotype. So the chance is one in four, or 25 per cent.

Sex determination in humans

This covers syllabus section 17(*l*).

Mutations

This covers syllabus sections 17(*g*) and (*h*).

Mutation is introduced as being a mistake in the DNA copying process, and responsible for the initial formation of different alleles of a gene.

Answers to questions

20.4 a Haemoglobin, which is contained inside red blood cells, transports oxygen from the lungs to respiring cells all over the body.

b When a person does strenuous exercise, their muscle cells respire rapidly, using up oxygen and causing the oxygen concentration in the body to drop. This causes the red blood cells containing faulty haemoglobin to become sickle-shaped and get stuck in capillaries. This is painful and dangerous, and it stops oxygen being delivered to body cells. They can no longer respire, so cannot release energy.

c A heterozygous person has a mixture of normal haemoglobin and sickle haemoglobin in their red blood cells. There is usually enough normal haemoglobin present to stop the process described in *b* from happening.

Selection and evolution

This covers syllabus sections 17(*m*), (*n*) and (*o*).

Students normally have no problem with the concepts described here. The major possible source of error is that they imagine that an individual organism somehow makes itself 'fitter', perhaps by a purposeful mutation, so care has to be taken to avoid this view from developing.

The potentially very large topics of natural selection and evolution are not given a heavy weighting in the syllabus, so both are dealt with quite simply here. Antibiotic resistance in bacteria is a topical issue of international importance, and is explored in Q20.15. Do ensure that students do not use the term 'immunity' instead of 'resistance'.

Answers to questions

20.15 a All the bacteria without the genes which make them resistant to the antibiotic will be killed. The only ones surviving will be those with the gene for resistance. They will continue to breed, passing on this gene to their offspring.

b The more often an antibiotic is used, the more likely it is that populations of bacteria will be exposed to it, and the more likely it is that some of these populations will become resistant. This can mean that we can no longer find antibiotics that will kill bacteria that are causing serious illnesses.

Genetic engineering

This covers syllabus sections 17(*r*), (*s*), (*t*) and (*u*).

The details of genetic engineering are extremely difficult for students at this level to understand, and it is suggested that you keep coverage of this topic simple. There is no need for an understanding of the details of procedures for transferring genes from one organism to another.

New examples of genetic engineering are occurring all the time, and it is recommended that students keep an eye on the media, as well as the Internet, to find current examples and the debate surrounding them.

There has been public outcry in many parts of the world against some types of genetic engineering, and it is important that students think for themselves, using their own knowledge, rather than being carried along unthinkingly by biased media reports. There is no doubt that some genetic engineering projects are potentially of great benefit to people, but in other cases it is difficult to see who will benefit other than large international companies. An open mind and balanced arguments should be encouraged.

No answers can be provided for Questions 20.16 and 20.17.