

Scheme of Work

Cambridge International AS & A Level Biology 9700

For examination from 2022



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Introduction

This scheme of work has been designed to support you in your teaching and lesson planning. Making full use of this scheme of work will help you to improve both your teaching and your learners' potential. It is important to have a scheme of work in place in order for you to guarantee that the syllabus is covered fully. You can choose what approach to take and you know the nature of your institution and the levels of ability of your learners. What follows is just one possible approach you could take and you should always check the syllabus for the content of your course.

Suggestions for independent study (**I**) and formative assessment (**F**) are also included. Opportunities for differentiation are indicated as **Extension activities**; there is the potential for differentiation by resource, grouping, expected level of outcome, and degree of support by teacher, throughout the scheme of work. Timings for activities and feedback are left to the judgement of the teacher, according to the level of the learners and size of the class. Length of time allocated to a task is another possible area for differentiation.

Key concepts

The key concepts are highlighted as a separate item in the new syllabus. Reference to the key concepts is made throughout the scheme of work using the key shown below:

Key Concept 1 (KC1) – Cells as the units of life

A cell is the basic unit of life and all organisms are composed of one or more cells. There are two fundamental types of cell: prokaryotic and eukaryotic. Understanding how cells work provides an insight into the fundamental processes of all living organisms.

Key Concept 2 (KC2) – Biochemical processes

Cells are dynamic structures within which the chemistry of life takes place. Biochemistry and molecular biology help to explain how and why cells function as they do.

Key Concept 3 (KC3) – DNA, the molecule of heredity

Cells contain the molecule of heredity, DNA. DNA is essential for the continuity and evolution of life by allowing genetic information to be stored accurately, to be copied to daughter cells, to be passed from one generation to the next and for the controlled production of proteins. Rare errors in the accurate copying of DNA known as mutations result in genetic variation and are essential for evolution.

Key Concept 4 (KC4) – Natural selection

Natural selection acts on genetic variation and is the major mechanism in evolution, including speciation. Natural selection results in the accumulation of beneficial genetic mutations within populations and explains how populations can adapt to meet the demands of changing environments.

Key Concept 5 (KC5) – Organisms in their environment

All organisms interact with their biotic and abiotic environment. Studying these interactions allows biologists to understand better the effect of human activities on ecosystems, to develop more effective strategies to conserve biodiversity and to predict more accurately the future implications for humans of changes in the natural world.

Key Concept 6 (KC6) – Observation and experiment

The different fields of biology are intertwined and cannot be studied in isolation. Observation, enquiry, experimentation and fieldwork are fundamental to biology, allowing relevant evidence to be collected and considered as a basis on which to build new models and theories. Such models and theories are further tested by

experimentation and observation in a cyclical process of feedback and refinement, allowing the development of robust and evidence-based conceptual understandings.

Guided learning hours

Guided learning hours give an indication of the amount of contact time teachers need to have with learners to deliver a particular course. Our syllabuses are designed around 180 hours for Cambridge International AS Level, and 360 hours for Cambridge International A Level. The number of hours may vary depending on local practice and your learners' previous experience of the subject. The table below give some guidance about how many hours are recommended for each topic.

Topic	Suggested teaching time (hours / % of the course)	Suggested teaching order
1: Cell structure	It is recommended that this unit should take about 18 hours/ 5% of the course.	1.2.1, 1.2.2, 1.2.3, 1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 1.2.5, 1.2.6, 1.2.7, 1.2.4.
2: Biological molecules	It is recommended that this unit should take about 22 hours/ 6% of the course.	2.1.1, 2.1.2, 2.1.3, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.2.7, 2.2.8, 2.2.9, 2.2.10, 2.2.11, 2.2.3, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.3.5, 2.3.6, 2.4.1.
3: Enzymes	It is recommended that this unit should take about 22 hours/ 6% of the course.	3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.2.1, 3.2.2, 3.2.3, 3.2.4.
4: Cell membranes and transport	It is recommended that this unit should take about 22 hours/ 6% of the course.	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.2.6.
5: The mitotic cell cycle	It is recommended that this unit should take about 12 hours/ 3% of the course.	5.1.1, 5.1.2, 5.1.3, 5.1.5, 5.1.5, 5.1.6, 5.2.1, 5.2.2.
6: Nucleic acids and protein synthesis	It is recommended that this unit should take about 14 hours/ 4% of the course.	6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7.
7: Transport in plants	It is recommended that this unit should take about 18 hours/ 5% of the course.	7.1.1, 7.1.2, 7.1.3, 7.1.4, 7.2.1, 7.2.2, 7.2.3, 7.2.4, 7.2.5, 7.2.6, 7.2.7.
8: Transport in mammals	It is recommended that this unit should take about 14 hours/ 4% of the course.	8.1.1, 8.1.2, 8.1.3, 8.1.4, 8.1.5, 8.1.6, 8.1.7, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5, 8.2.6, 8.3.1, 8.3.2, 8.3.3, 8.3.4.
9: Gas exchange	It is recommended that this unit should take about 10 hours/ 3% of the course.	9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.1.5, 9.1.6, 9.1.7.

Topic	Suggested teaching time (hours / % of the course)	Suggested teaching order
10: Infectious diseases	It is recommended that this unit should take about 12 hours/ 3% of the course.	10.1.1, 10.1.2, 10.1.3, 10.1.4, 10.2.1, 10.2.2.
11: Immunity	It is recommended that this unit should take about 16 hours/ 4% of the course.	11.1.1, 11.1.2, 11.1.3, 11.1.4, 11.2.1, 11.2.2, 11.2.3, 11.2.4, 11.2.5, 11.2.6.
12: Energy and respiration	It is recommended that this unit should take about 20 hours/ 6% of the course.	12.1.1, 12.1.2, 12.1.3, 12.1.4, 12.1.5, 12.1.6, 12.1.7, 12.2.1, 12.2.2, 12.2.3, 12.2.4, 12.2.5, 12.2.6, 12.2.7, 12.2.8, 12.2.9, 12.2.10, 12.2.11, 12.2.12, 12.2.13, 12.2.14.
13: Photosynthesis	It is recommended that this unit should take about 22 hours/ 6% of the course.	13.1.1, 13.1.2, 13.1.3, 13.1.4, 13.1.5, 13.1.6, 13.1.7, 13.1.8, 13.1.9, 13.1.10, 13.1.11, 13.1.12, 13.2.1, 13.2.2, 13.2.3, 13.2.4.
14: Homeostasis	It is recommended that this unit should take about 24 hours/ 7% of the course.	14.1.1, 14.1.2, 14.1.3, 14.1.4, 14.1.5, 14.1.6, 14.1.7, 14.1.8, 14.1.9, 14.1.10, 14.1.11, 14.2.1, 14.2.2, 14.2.3, 14.2.4.
15: Control and coordination	It is recommended that this unit should take about 24 hours/ 7% of the course.	15.1.1, 15.1.2, 15.1.3, 15.1.4, 15.1.5, 15.1.6, 15.1.7, 15.1.8, 15.1.9, 15.1.10, 15.1.11, 15.1.12, 15.2.1, 15.2.2, 15.2.3.
16: Inheritance	It is recommended that this unit should take about 24 hours/ 7% of the course.	16.1.1, 16.1.2, 16.1.3, 16.1.4, 16.1.5, 16.1.6, 16.1.7, 16.2.1, 16.2.2, 16.2.3, 16.2.4, 16.2.5, 16.2.6, 16.2.7, 16.3.1, 16.3.2, 16.3.3, 16.3.4.
17: Selection and evolution	It is recommended that this unit should take about 20 hours/ 6% of the course.	17.1.1, 17.1.2, 17.1.3, 17.1.4, 17.2.1, 17.2.2, 17.2.3, 17.2.4, 17.2.5, 17.2.6, 17.2.7, 17.3.1, 17.3.2, 17.3.3, 17.3.4.
18: Classification, biodiversity and conservation	It is recommended that this unit should take about 24 hours/ 7% of the course.	18.1.1, 18.1.2, 18.1.3, 18.1.4, 18.1.5, 18.1.6, 18.2.1, 18.2.2, 18.2.3, 18.2.4, 18.2.5, 18.2.6, 18.3.1, 18.3.2, 18.3.3, 18.3.4, 18.3.5, 18.3.6.
19: Genetic technology	It is recommended that this unit should take about 22 hours/ 6% of the course.	19.1.1, 19.1.2, 19.1.3, 19.1.4, 19.1.5, 19.1.6, 19.1.7, 19.1.8, 19.1.9, 19.1.10, 19.1.11, 19.2.1, 19.2.2, 19.2.3, 19.2.4, 19.3.1, 19.3.2.

Resources

You can find the endorsed resources to support Cambridge International AS & A Level Biology on the Published resources tab of the syllabus page on our [public website](#)

Endorsed textbooks have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. All textbooks endorsed by Cambridge International for this syllabus are the ideal resource to be used alongside this scheme of work as they cover each learning objective. In addition to reading the syllabus, teachers should refer to the specimen assessment materials.

Test Maker is our new online service that makes it easy for teachers to create high-quality, customised test papers for their learners using Cambridge questions. Design a test for your whole class, or create individual tests for each learner. You can select questions depending on the level of difficulty and the assessment objectives they test. Test Maker is available from the School Support Hub www.cambridgeinternational.org/support.

School Support Hub

[School Support Hub](#) is a secure online resource bank and community forum for Cambridge teachers, where you can download specimen and past question papers, mark schemes and other teaching and learning resources. We also offer online and face-to-face training; details of forthcoming training opportunities are posted online. This scheme of work is available as PDF and an editable version in Microsoft Word format; both are available on the [School Support Hub](#). If you are unable to use Microsoft Word you can download Open Office free of charge from www.openoffice.org

Websites

This scheme of work includes website links providing direct access to internet resources. Cambridge Assessment International Education is not responsible for the accuracy or content of information contained in these sites. The inclusion of a link to an external website should not be understood to be an endorsement of that website or the site's owners (or their products/services).

The website pages referenced in this scheme of work were selected when the scheme of work was produced. Other aspects of the sites were not checked and only the particular resources are recommended.

How to get the most out of this scheme of work – integrating syllabus content, skills and teaching strategies

We have written this scheme of work for the Cambridge International AS & A Level Biology 9700 syllabus and it provides some ideas and suggestions of how to cover the content of the syllabus. We have designed the following features to help guide you through your course.

Learning outcomes help your learners by making it clear the knowledge they are trying to build. Pass these on to your learners by expressing them as 'We are learning to / about...'. Some longer outcomes have been rephrased. Refer to the syllabus for the full wording.

Suggested teaching activities give you lots of ideas about how you can present learners with new information without teacher talk or videos. Try more active methods which get your learners motivated and practising new skills.

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
1.1 The microscope in cell studies KC1 KC6	1.1 1 Make temporary preparations of cellular material suitable for viewing with a light microscope. 1.1 2 Draw cells from microscope slides and photomicrographs. 1.1 3 Calculate magnifications of images and actual sizes of specimens from drawings, photomicrographs and electron micrographs (scanning and transmission).	Provide learners with an unlabelled diagram of a light microscope. Host a quiz on the names of the key components , and discuss their features and functions. Host practical activities for learners to use a light microscope and develop drawings. These may include preparing a temporary, stained mount of plant tissue and stage micrometer to measure prepared slides of cells. Collect and display learners' measurements of cells on a board or screen. This will facilitate the discussion of size and appropriate sample sizes. Learners watch a video on the use of light and/ or electron microscopy: http://bigpictureeducation.com/video-light-microscopy and http://bigpictureeducation.com/video-electron-microscopy . Learners list things 'I knew' in green and things that 'are new' in red in order to reflect on their knowledge. (I) Learners design a 'step-by-step' guide, perhaps targeted at learners who have not yet studied the topic, to use an eyepiece graticule and stage micrometer . This is in the form of a flow diagram with statements separated by arrows, a short story, or an animation produced on a computer. (I) Learners prepare a series of flashcards that help them interchange measurements. For example, a numerical value in millimetres (e.g. 0.05 mm) written on one side of the card, is restated in micrometres on the other side (e.g. 5 µm). Useful resources to help structure this activity are: https://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/ www.biology.arizona.edu/cell_bio/tutorials/cells/cells2.html www.exo.net/~pauld/summer_institute/Nano%20Institute/Day1%20Scale/SM_Lesson2Student.pdf (I) Extension activity: Extend understanding by referring to unfamiliar applications. There are many examples of sophisticated light microscopy.
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support		

Formative assessment (F) is ongoing assessment which informs you about the progress of your learners. Don't forget to leave time to review what your learners have learnt: you could try question and answer, tests, quizzes, 'mind maps', or 'concept maps'. These kinds of activities can be found in the scheme of work.

Extension activities provide your more able learners with further challenge beyond the basic content of the course. Innovation and independent learning are the basis of these activities.

Independent study (I) gives your learners the opportunity to develop their own ideas and understanding with direct input from you.

Past papers, specimen papers and mark schemes are available for you to download at:
www.cambridgeinternational.org/support

Using these resources with your learners allows you to check their progress and give them confidence and understanding.

1 Cell structure

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
1.1 The microscope in cell studies KC1 KC6	1.1 1 Make temporary preparations of cellular material suitable for viewing with a light microscope. 1.1 2 Draw cells from microscope slides and photomicrographs. 1.1 3 Calculate magnifications of images and actual sizes of specimens from drawings, photomicrographs and electron micrographs (scanning and transmission). 1.1 4 Use an eyepiece graticule and stage micrometer scale to make measurements and use the appropriate units, millimetre (mm), micrometre (μm) and nanometre (nm). 1.1 5 Define resolution and magnification and explain the differences between these terms, with reference	<p>Provide learners with an unlabelled diagram of a light microscope. Host a class discussion to elicit some of the names of the key components, and discuss their features and functions. Learners reflect on their knowledge and make five recommendations for their future study on this topic. They write these on post-it notes, which they add to the class board. Learners consider the recommendations of others, and highlight common mistakes that learners make. (F)</p> <p>Host practical activities for learners to use a light microscope and develop their ability to produce scientific drawings. These may include preparing a temporary, stained mount of plant tissue, and using an eyepiece graticule and stage micrometer to measure prepared slides of cells. Collect and display class results for measuring cells on a board or screen. This will facilitate the discussion of themes such as variability of cell size and appropriate sample sizes.</p> <p>Learners watch a video on the use of light and/ or electron microscopy. Learners list things 'I knew' in green and things that 'are new' in red in order to reflect on their knowledge. (I)</p> <p>Learners design a 'step-by-step' guide, perhaps targeted at learners who have not yet studied the topic, to use an eyepiece graticule and stage micrometer. This is in the form of a flow diagram with statements separated by arrows, a short story, or an animation produced on a computer. (I)</p> <p>Learners prepare a series of flashcards that help them interchange measurements. For example, a numerical value in millimetres (e.g. 0.05 mm) written on one side of the card, is restated in micrometres on the other side (e.g. 5 μm). Useful resources to help structure this activity are: https://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/ www.biology.arizona.edu/cell_bio/tutorials/cells/cells2.html www.exo.net/~pauld/summer_institute/Nano%20Institute/Day1%20Scale/SM_Lesson2Student.pdf (I)</p> <p>Extension activity: Extend understanding by referring to unfamiliar applications. There are many sophisticated light microscope techniques (e.g. fluorescence microscopy, phase contrast, reflected light, dark field, bright field, confocal/multiphoton, Kohler illumination, and polarised light). Learners research examples, advantages and procedural details. Excellent resources to use are: http://zeiss-campus.magnet.fsu.edu/articles/basics/index.html www.olympus-lifescience.com/en/microscope-resource/</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	to light microscopy and electron microscopy.	
<p>1.2 Cells as the basic units of living organisms</p> <p>KC1</p> <p>KC6</p>	<p>1.2 1 Recognise organelles and other cell structures found in eukaryotic cells and outline their structures and functions.</p> <p>1.2 2 Describe and interpret photomicrographs, electron micrographs and drawings of typical plant and animal cells.</p> <p>1.2 3 Compare the structure of typical plant and animal cells.</p> <p>1.2.4 State that cells use ATP from respiration for energy-requiring processes.</p> <p>1.2.5 Outline key structural features of a prokaryotic cell as found in a typical bacterium.</p> <p>1.2.6 Compare the structure of a prokaryotic cell as found in a typical bacterium with the structures of typical eukaryotic cells in plants and animals.</p>	<p>Learners brainstorm in pairs a list of structures they know are present inside cells. After 2–3 minutes of discussion, the pairs join together into fours and then eights to discuss this further and come up with an agreed list of points. One or two learners from each group then draw and label the group's ideas on the class board. Review learners' prior knowledge by using resources such as: www.cellsalive.com/index.htm https://cellpics.cimr.cam.ac.uk/</p> <p>Extend thinking by asking learners to categorise organelles, to help distinguish their structures, for example: list three organelles lacking a boundary membrane, three that are surrounded by a single membrane, and three surrounded by two membranes (an envelope). (F)</p> <p>Learners work in groups to prepare Venn diagrams to compare prokaryotic and eukaryotic cells, related to their overall structure and the organelles found within them. Online resources such as https://www.livescience.com/65922-prokaryotic-vs-eukaryotic-cells.html may be helpful. The display must contain diagrams, photographs and text. Learners can prepare these on a large piece of paper or card with a range of materials. Then hold a 'marketplace activity' in which one member of each group stands by their poster and offers an explanation to other groups as they circulate around the room. (I)</p> <p>Learners make cells and organelles out of modelling clay to demonstrate how sections are made for viewing using microscopes. Cutting these at different angles will clearly illustrate how objects can look, depending on how the specimen was prepared (e.g. mitochondria often look sausage-shaped). They should extend their understanding by referring to the functions of the organelles, e.g. the role of mitochondria in producing ATP. Learners may use images of cells online to help them, including at websites such as: www.cellimagelibrary.org/, www.denniskunkel.com/ www.vcbio.science.ru.nl/en/virtuallessons/#fesemsimulatie</p> <p>Learners play a game of 'bingo' to consolidate the key terms from previous subtopics. Provide each learner with a grid of nine squares. Then provide 20 key terms related to cells on the board. Learners select nine words at random to fill in the grid. Then call out definitions of each of the 20 key terms – in random order. The first learner to tick off all their nine words calls 'bingo' and wins the contest. Simple definitions for the terms encountered in this topic can be found at: www.biologyreference.com/ (F)</p> <p>Extension activity: Learners prepare a series of five statements that can be classified as 'always true,' 'sometimes true' or 'never true.' Examples include 'All cells have a surface membrane' (always true),</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	1.2.7 State that all viruses are non-cellular structures with a nucleic acid core (either DNA or RNA) and a capsid made of protein, and that some viruses have an outer envelope made of phospholipids.	'Eukaryotic cells contain a nucleus' (sometimes true – not red blood cells), and 'Viruses and prokaryotic cells have membrane-bound organelles' (never true). (F)
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

Biological molecules

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
2.1 Testing for biological molecules KC2 KC6	2.1.1 Describe and carry out the Benedict's test for reducing sugars, the iodine test for starch, the emulsion test for lipids and the biuret test for proteins. 2.1.2 Describe and carry out a semi-quantitative Benedict's test on a reducing sugar solution by standardising the test and using the results (time to first colour change or comparison to colour standards) to estimate the concentration. 2.1.3 Describe and carry out a test to identify the presence of non-reducing sugars, using acid hydrolysis and Benedict's solution.	<p>Display a list of key terms that learners must know in the form of a 'word board.' These include the types of biological molecule and their key functions in organisms. As you call out a word, ask for a show of hands to see who has heard of it, then ask learners to keep their hand raised if they would like to link at least two of the words together. An example could be 'carbohydrates and lipids contain the elements carbon, hydrogen and oxygen.' (F)</p> <p>Learners carry out some of the biochemical tests for different types of molecule. These may include simple laboratory techniques to confirm the presence of reducing sugars, starch, lipids and proteins. Demonstrate how dialysis tubing can be filled with starch solution and placed in a boiling tube of iodine solution. Invert the boiling tube (with bung) a few times and learners watch the contents of the dialysis tubing change colour. Ask learners to explain their observations.</p> <p>Learners develop their practical skills further by preparing a range of dilutions of glucose by serial dilution and use the Benedict's, iodine or biuret tests to estimate the unknown concentration of a solution of a given biological molecule. This exercise helps learners to form an understanding of the process of preparing solutions by serial dilution, and distinguish between qualitative, quantitative and semi-quantitative tests.</p> <p>Learners review their knowledge by constructing a table to list the biological molecules, test reagent, negative result and positive result in separate columns. (I)</p> <p>Extension activity: Discuss the use of a colorimeter to improve the accuracy of the calibration curves used to estimate the glucose concentration of a solution of unknown concentration.</p>
2.2 Carbohydrates and lipids KC2	2.2.1 Describe and draw the ring forms of α -glucose and β -glucose. 2.2.2 Define the terms monomer, polymer, macromolecule, monosaccharide, disaccharide and polysaccharide.	<p>Learners should already know some terms related to carbohydrates including glucose, sucrose, starch and cellulose. Provide learners with a series of incomplete sentences to review this knowledge. Initiate a 'think, pair, share' activity and then ask them to construct an ending or beginning. (F)</p> <p>Help learners refresh their knowledge of light microscopy by hosting a brief multiple-choice quiz with questions taken from past Cambridge IGCSE (or equivalent) papers. Learners can 'vote' for their choice of answer by holding up their hand when you call out 'A,' 'B,' 'C' or 'D.' You could use this activity to formatively assess learners before they begin. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	2.2.3 State the role of covalent bonds in joining smaller molecules together to form polymers.	Provide each learner with a piece of poster paper and provide guidance to help them draw a molecule of α -glucose. Learners then put their diagrams down on the classroom floor in a long line. Provide learners with board markers to join them together by drawing glycosidic bonds. This helps learners appreciate the concept of polymerisation: the result will be a molecule of amylose spanning the room from one side to the other. Learners take photos of the activity for later review.
	2.2.4 State that glucose, fructose and maltose are reducing sugars and that sucrose is a non-reducing sugar.	Tell learners that they will each represent a molecule of glucose. They should each hold a ball (or balloon) in their right hand and then link hands (or arms) but only when they have thrown the ball away. This emphasises the loss of water when forming polymers. The 'water molecules' can then be collected, counted, and used to show why the process is called condensation. Extend thinking by describing the other reducing sugars as monomers that can form maltose and the non-reducing sugars.
	2.2.5 Describe the formation of a glycosidic bond by condensation, with reference to disaccharides, including sucrose, and polysaccharides.	This topic requires learners to interpret numerous structural equations. Learners can discover how to draw these structures and how they change during biochemical reactions. However, it is harder to put this into words. Encourage learners to describe a condensation reaction between two glucose residues (low demand) or how β -glucose residues are arranged in cellulose relative to one another (high demand), and how the arrangement of cellulose molecules contributes to the function of plant cell walls. A useful animation is at: www.biotopics.co.uk/as/lipidcondensation.html
	2.2.6 Describe the breakage of a glycosidic bond in polysaccharides and disaccharides by hydrolysis, with reference to the non-reducing sugar test.	Learners draw a table or Venn diagram to show which monosaccharides combine into disaccharides, and the type of monosaccharides and bonds in polysaccharides, as a useful summary. (F)
	2.2.7 Describe the molecular structure of the polysaccharides starch and glycogen and relate their structures to their functions in living organisms.	Learners write the shortest sentence possible using the following key terms: polysaccharide, polymer, sugar, glycosidic. This is a good way to focus learners on developing their higher-order thinking skills to make sense of the meaning of these terms, rather than simply recall them. (F)
	2.2.8 Describe the molecular structure of the polysaccharide cellulose and outline how the arrangement	Extension activity: Learners apply their knowledge by displaying unfamiliar monosaccharides such as cellobiose, or polysaccharides such as chitin, and showing that the same general rules apply to condensation and hydrolysis reactions.

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>of cellulose molecules contributes to the function of plant cell walls.</p> <p>2.2.9 State that triglycerides are non-polar hydrophobic molecules and describe the molecular structure of triglycerides with reference to fatty acids, glycerol and the formation of ester bonds.</p> <p>2.2.10. Relate the molecular structure of triglycerides to their functions in living organisms.</p> <p>2.2.11 Describe the molecular structure of phospholipids with reference to their hydrophilic (polar) phosphate heads and hydrophobic (non-polar) fatty acid tails.</p>	<p>Invite learners to the class whiteboard to attempt to draw the components of a triglyceride from memory, and then show how ester bonds form between the molecules using a pen of a different colour. Through class discussion, relate the molecular structure of triglycerides to their functions in living organisms. (F)</p> <p>Show learners a series of images of organisms for which lipids are of vital importance. Examples include locusts (lipids needed as an energy store for long-distance travel), aquatic mammals (lipids needed for buoyancy/ insulation), and aquatic birds (lipids needed for waterproofing). Discuss their adaptations to their environments; then introduce the idea that their lipid content is higher than most animals and ask why.</p> <p>Learners produce a leaflet to illustrate the importance of lipids in the diet. They generally have a negative press, so their work should aim to persuade the reader of the vital functions of this molecule in accessible language. (I)</p> <p>Give learners an answer, and ask 'What's the question?'. Select a range of single-word terms (e.g. triglyceride, glycerol, fatty acids, phosphate head) and simple sentences and provide these to learners. (F)</p> <p>Extension activity: Help learners explore the diversity of phospholipids and the reason for this diversity, such as addition of other water-soluble groups to the phosphate group.</p>
<p>2.3 Proteins</p> <p>KC2</p>	<p>2.3 1 Describe and draw the general structure of an amino acid and the formation and breakage of a peptide bond.</p> <p>2.3.2 Explain the meaning of the terms primary structure, secondary structure, tertiary structure and quaternary structure of proteins.</p>	<p>Learners have an oversimplified idea of what is meant by 'protein.' Explain that proteins achieve a very wide range of functions in organisms. On the class board, show a range of these, including (but not limited to): antibodies, hormones, enzymes, collagen (connective tissue) and keratin (hair), muscle proteins, retina photoreceptors and milk protein. Learners decide, in pairs, how to categorise these molecules. (F)</p> <p>Learners work in pairs to produce a model of insulin. Share the primary structure of the two polypeptides and where they are attached by disulphide bonds. Learners prepare 20 different paper shapes of various colours to represent the different amino acids. Provide a key to inform learners which pieces of paper represent which amino acid. (I)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>2.3.3 Describe the types of interaction that hold protein molecules in shape:</p> <ul style="list-style-type: none"> • hydrophobic interactions • hydrogen bonding • ionic bonding • covalent bonding, including disulfide bonds. 	<p>Learners work in groups to make a concept map, mind map or other form of graphic organiser for the types of bond found in each level of protein structure. This is useful preparation for interpreting the content of the next section of this subtopic. (F)</p> <p>Extension activity: Construct a table that compares the types of bond found in the tertiary structure of proteins – the atoms the bonds form between, and the relative strength of the bonds. Also construct a table to compare fibrous and globular proteins.</p> <p>Ask a carefully chosen series of questions to elicit higher-order thinking skills among learners. One option is to ask them to compare key terms, to reinforce their knowledge of key definitions. (F)</p>
	<p>2.3.4 State that globular proteins are generally soluble and have physiological roles and fibrous proteins are generally insoluble and have structural roles.</p> <p>2.3.5 Describe the structure of a molecule of haemoglobin as an example of a globular protein, including the formation of its quaternary structure.</p> <p>2.3.6 Relate the structure of haemoglobin to its function, including the importance of iron in the haem group.</p> <p>2.3.7 Describe the structure of a molecule of collagen as an example of a fibrous protein, and the arrangement of collagen molecules to form collagen fibres.</p>	<p>Learners work together in small groups to produce a poster to show the similarities and differences between haemoglobin and collagen. Encourage them to show how these proteins are representatives of globular and fibrous proteins respectively. You could extend this activity into the next lesson by holding a 'marketplace' activity: one member of each group stands by their poster and offers an explanation to other groups as they move around the room. Help learners provide feedback to each other in a respectful way. Encourage learners to focus on key Syllabus statements, including the importance of iron in the haem group in haemoglobin, and the arrangement of collagen molecules to form collagen fibres.</p> <p>Present a series of questions on the board. Give learners 5 minutes to write down all the key terms they feel are relevant in their answers. Then model how to incorporate relevant key words into clear, exam-style answers. (F)</p> <p>Prepare a short, written passage that summarises the content of this subtopic. Include between five and ten spelling mistakes and conceptual errors. Learners spot and circle as many mistakes as possible, and offer corrections. An example would be learners' common use of collagen polypeptides and collagen fibres as interchangeable terms. Three collagen polypeptides, which have a helix structure, together form a triple helix called a collagen fibre. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	2.3.8 Relate the structures of collagen molecules and collagen fibres to their function.	
2.4 Water KC2	2.4.1 Explain how hydrogen bonding occurs between water molecules and relate the properties of water to its roles in living organisms, limited to solvent action, high specific heat capacity and latent heat of vaporisation.	<p>Show learners a demonstration to illustrate the unique properties of water. Learners engage in a ‘think, pair, share’ activity to try to explain why water behaves in this way. Examples include:</p> <ul style="list-style-type: none"> • Carefully balance a pin on the surface of a large beaker of water to demonstrate the surface tension of the liquid. Add a drop of detergent to reduce the surface tension and observe the pin sink immediately. • Set up two clamped, inverted round-bottomed flasks and cover one with a wet cloth. The temperature inside this flask will fall relative to the other. This illustrates the high latent heat of vaporisation of water. <p>Extension activity: Learners write an essay on the biological importance of water. Provide a writing frame (plan of ideas) for less confident learners. A good source of summary information is at: https://www.profmcdarby.com (I)</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

3 Enzymes

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
3.1 Mode of action of enzymes KC2 KC6	3.1.1 State that enzymes are globular proteins that catalyse reactions inside cells (intracellular enzymes) or are secreted to catalyse reactions outside cells (extracellular enzymes). 3.1.2 Explain the mode of action of enzymes in terms of an active site, enzyme–substrate complex, lowering of activation energy and enzyme specificity, including the lock-and-key hypothesis and the induced-fit hypothesis.	<p>Learners should have learnt about enzymes as biological catalysts at Cambridge IGCSE (or equivalent). Write the names of several enzymes on the board, including amylase, protease, lipase, sucrase, maltase, and lactase. Point out that they usually end with the suffix ‘-ase’ and the first part of an enzyme’s name is derived from the substrate that they digest. Indicate that all the reactions catalysed by the enzymes listed have in common the addition of water in hydrolysis reactions. (F)</p> <p>Help learners to understand the role of enzymes using an analogy. Light a match and use this as an analogy for the purpose of an enzyme. Elicit from learners that a small input of energy (the act of striking the match) is required to start a reaction, but that once it begins, it progresses without any further input of energy.</p> <p>Learners work together to produce from memory a detailed graph showing the progress of an enzyme-catalysed reaction, complete with explanatory labels. Then display a graph on the board to help learners identify what they have missed and to learn from their mistakes.</p> <p>Hand out three very small pieces of modelling clay to each pair of learners. Challenge them to model the events that happen during the hydrolysis of a substrate. Learners describe and explain how their models illustrate the two modes of action and formatively assess their understanding. Learners may use animations of enzyme action available on the internet.</p> <p>Learners prepare a ‘flipbook’ to convert a series of diagrams into a ‘moving picture’ showing the modes of enzyme action, or use paper cut-out models to show how enzymes can break up substrates into smaller molecules or can build up larger molecules from smaller ones. (I)</p> <p>Extension activity: Learners carry out research into non-hydrolytic enzymes. Some synthesise macromolecules, some transfer a chemical group, and some rearrange atoms in a molecule. Encourage learners to draw sketches of how this happens.</p>
	3.1.3 Investigate the progress of enzyme-catalysed reactions by measuring rates of formation of products using catalase	<p>Learners suggest how enzyme activity can be measured. Discuss with learners what features the substrate and product must show for this to be possible. For example, the substrate or product must be detectable, either due to a colour change, a change in pH, and so on.</p> <p>Host practical activities for learners to investigate enzyme-catalysed reactions. These may include:</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>and rates of disappearance of substrate using amylase.</p> <p>3.1.4 Outline the use of a colorimeter for measuring the progress of enzyme-catalysed reactions that involve colour changes.</p>	<ul style="list-style-type: none"> Following the course of an enzyme-catalysed reaction using amylase. Learners plot a graph of the concentration of starch (x-axis) against absorbance (y-axis) to measure the reduction in the intensity of the blue-black colour. Learners measure the rate of reaction by measuring the rate of formation of a product, using catalase (from celery) and the breakdown of hydrogen peroxide. Using other means to track the progress of an enzyme-catalysed reaction. Another example is at: www.saps.org.uk/secondary/teaching-resources/293-student-sheet-24-microscale-investigations-with-catalase <p>Further information related to these practical activities are at: www.nuffieldfoundation.org/practical-biology/factors-affecting-enzyme-activity</p> <p>Prepare three or four past paper questions, ideally of a multiple-choice or short-answer nature, which learners complete and pass to you as they leave the room. This 'exit card' technique can provide an opportunity for formative assessment to inform you whether you need to reinforce the content in the next lesson. (F)</p>
<p>3.2 Factors that affect enzyme action</p> <p>KC2</p> <p>KC6</p>	<p>3.2.1 Investigate and explain the effects of the following factors on the rate of enzyme-catalysed reactions:</p> <ul style="list-style-type: none"> temperature pH (using buffer solutions) enzyme concentration substrate concentration inhibitor concentration. 	<p>Resource Plus</p> <p>Carry out the <i>Investigating the effect of temperature on an enzyme-catalysed reaction</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>Proteases such as trypsin catalyse the hydrolysis of the protein casein, which gives milk its white colour. Learners investigate the rate of decolourisation of milk due to the hydrolysis of casein, providing a way to investigate how a change in temperature affects the rate of the reaction. Learners plan a laboratory method, analyse the difference between quantitative and qualitative data, and interpret measurements of reaction rate.</p> <p>Practical tasks that address the syllabus outcomes include the following:</p> <ul style="list-style-type: none"> Investigating the effect of temperature on the activity of trypsin in a reaction that catalyses the breakdown of opaque casein into a translucent solution. Analysing the effect of substrate (hydrogen peroxide) concentration on the activity of catalase. Investigating the effect of enzyme concentration on the activity of rennin. Investigating the effect of pH on the activity of amylase by recording the disappearance of a substrate by testing for starch with iodine solution on a spotting tile. <p>Further information related to these practical activities is at: www.nuffieldfoundation.org/practical-biology/factors-affecting-enzyme-activity</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
		<p>This series of practical activities provides a large number of opportunities to help learners understand what is meant by the independent variable, dependent variable, and standardised variables in an investigation. Help learners appreciate this by ‘standardising’ statements in writing frames, such as ‘an investigation into the effect of X and Y, while keeping A, B and C the same.’</p> <p>A significant number of key terms are introduced in this topic. To help familiarise learners with them, learners work in pairs to describe key words/terms to each other, but without using other (listed) key words. For example, challenge learners to describe the effect of high temperatures on human enzyme activity without using the three key terms: denature, bonds, and active site. (F)</p> <p>Extension activity: Provide an opportunity for learners to suggest why certain factors affect enzyme activity, and examples of enzymes that have unusual optimum values (e.g. <i>Taq</i> DNA polymerase and human pepsin). An accessible research article is at: www.nature.com/news/1998/980917/full/news980917-7.html</p>
	<p>3.2.2 Explain that the maximum rate of reaction (V_{max}) is used to derive the Michaelis–Menten constant (K_m), which is used to compare the affinity of different enzymes for their substrates.</p> <p>3.2.3 Explain the effects of reversible inhibitors, both competitive and non-competitive, on enzyme activity.</p>	<p>Host a class discussion to explain the concept of enzyme affinity, and how this can be quantified by reference to the Michaelis–Menten constant (K_m). To extend their understanding, learners construct Venn diagrams to summarise the differences between inhibitors. To do this, learners draw a circle labelled ‘competitive inhibitors’ overlapping with another circle labelled ‘non-competitive inhibitors’. Properties that they have in common (e.g. both reduce the ability for an enzyme to bind to its substrate) can be listed in the overlapping area. Properties that are unique (e.g. effect on K_m) can be listed separately. (I)</p> <p>Learners can carry out practical activities that focus on enzyme inhibition. However, the results are usually quite unreliable. One exception is the effect of phosphate on phosphatase.</p> <p>Extension activity: Learners carry out research to list medicinal drugs that rely on enzyme inhibition.</p>
	<p>3.2.4 Investigate the difference in activity between an enzyme immobilised in alginate and the same enzyme free in solution, and state the advantages of using immobilised enzymes.</p>	<p>Resource Plus</p> <p>Carry out the <i>Immobilising enzymes</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>In this task, learners encapsulate the enzyme lactase in alginate beads and show that its ability to hydrolyse its substrate, lactose, is not affected by immobilisation. As part of the task, learners are challenged to suggest how the equipment is used to investigate the effect of changing an independent variable and are introduced to statistical tests and the idea of a hypothesis.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
		<p>Learners write the shortest paragraph possible using the following key terms: immobilised, affinity, continuous, yield. This is a good way to focus learners on developing their higher-order thinking skills to make sense of the meaning of these terms, rather than simply recall them. (F)</p> <p>Extension activity: Learners research the different types of immobilisation. These include cross-linkage, encapsulation and adsorption. What are their relative advantages and disadvantages?</p>

Past and specimen papers

Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

4: Cell membranes and transport

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>4.1 Fluid mosaic membranes</p> <p>KC1</p> <p>KC2</p> <p>KC5</p> <p>KC6</p>	<p>4.1.1 Describe the fluid mosaic model of membrane structure with reference to the hydrophobic and hydrophilic interactions that account for the formation of the phospholipid bilayer and the arrangement of proteins.</p> <p>4.1.2 Describe the arrangement of cholesterol, glycolipids and glycoproteins in cell surface membranes.</p> <p>4.1.3 Describe the roles of phospholipids, cholesterol, glycolipids, proteins and glycoproteins in cell surface membranes, with reference to stability, fluidity, permeability, transport (carrier proteins and channel proteins), cell signalling (cell surface receptors) and cell recognition (cell surface antigens – see 11.1.2).</p> <p>4.1.4 Outline the main stages in the process of cell signalling leading to specific responses.</p>	<p>Resource Plus</p> <p>Carry out the <i>Investigating the effect of temperature on the permeability of plant cell membranes</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>Learners indirectly determine the integrity of cell membranes by measuring the loss of a coloured pigment from tissue at different temperatures. This investigation also offers an opportunity to revise the use of the colorimeter, which can provide quantitative data for further analysis, as well as exercises that distinguish between key experimental terms such as validity, reliability, accuracy, random error and systematic error.</p> <p>Describe how the cell surface membrane has been likened to ‘protein icebergs floating in a sea of phospholipids.’ An animation that may help is: www.wisc-online.com/learn/natural-science/life-science/ap1101/construction-of-the-cell-membrane</p> <p>Learners model the arrangement of molecules in a fluid mosaic membrane. This helps them understand the idea that the different components are free to move. Provide a range of simple items, or cut-outs, and keep the models for reference in subsequent lessons as a visual aid. Ensure that learners have included all types of molecule, and ask them to use their model to explain the functions of phospholipids, cholesterol, glycolipids, proteins and glycoproteins. (I)</p> <p>Learners use modelling clay to build models to show the events that occur during cell signalling. Two strips of paper can be used to represent the phospholipid bilayer. Use clay to represent ligands (small balls), receptor membrane proteins (shaped like a two-pronged fork) and intracellular enzymes (connected to the cytoplasmic region of the membrane receptors). (I)</p> <p>Each learner writes a question about fluid mosaic membranes from the lesson on a coloured paper strip and the answer on differently-coloured paper strip. In groups of 6–8, hand out the strips so that each learner gets a question and an answer. One learner reads out their question, and the learner with the right answer then reads it out, followed by their question. (F)</p> <p>Extension activity: In the modelling activity, challenge learners to evaluate their model and identify ways in which it is not an accurate representation of the cell surface membrane.</p>
<p>4.2 Movement into and out of cells</p>	<p>4.2.1 Describe and explain the processes of simple diffusion, facilitated diffusion,</p>	<p>Write the six methods of transport on the board: diffusion, facilitated diffusion, osmosis, active transport, exocytosis and endocytosis. Initiate a ‘think, pair, share’ activity between pairs of learners to consider all associated key terms they can think of that relate to them. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
KC1 KC2 KC6	<p>osmosis, active transport, endocytosis and exocytosis</p> <p>4.2.2 Investigate simple diffusion and osmosis using plant tissue and non-living materials, including dialysis (Visking) tubing and agar.</p> <p>4.2.3 Illustrate the principle that surface area to volume ratios decrease with increasing size by calculating surface areas and volumes of simple 3-D shapes.</p> <p>4.2.4 Investigate the effect of changing surface area to volume ratio on diffusion using agar blocks of different sizes.</p> <p>4.2.5 Investigate the effects of immersing plant tissues in solutions of different water potentials, using the results to estimate the water potential of the tissues.</p> <p>4.2.6 Explain the movement of water between cells and solutions in terms of water potential and explain the different effects of the movement of water on plant cells and animal cells.</p>	<p>Resource Plus</p> <p>Carry out the <i>Investigating the effect of changing surface area-to-volume ratio on diffusion</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>In this task, learners use agar jelly containing the indicator cresol red to investigate how varying the surface area to volume ratio of a cell affects the diffusion of a small molecule. There are opportunities to practise mathematical and graphing skills, and to evaluate the method, with a particular emphasis on the types of error (random or systematic).</p> <p>Learners carry out practical activities to investigate and explain the movement into and out of cells in terms of water potential. These include:</p> <ul style="list-style-type: none"> Learners estimate the water potential of potato tuber cells by placing pieces of potato tuber into solutions with different water potentials. They find the percentage change in mass for a range of solutions of known concentration and plot a graph. The concentration at which the potato cells neither gain nor lose water can be read from the graph. Useful information is at: www.saps.org.uk/secondary/teaching-resources/286-measuring-the-water-potential-of-a-potato-cell Learners estimate the water potential equivalent to that of onion epidermal cells. They determine the point at which half of a population of onion cells look normal and half are plasmolysed to identify the point of incipient plasmolysis. Useful information is at: www.kscience.co.uk/animations/plasmolysis.htm Challenge learners to explain the different effects of the movement of water on plant cells and animal cells. <p>To model exocytosis, learners fill a balloon with strips of paper on which revision questions have been written. The balloon, representing a vesicle, is blown up and tied. For exocytosis, the learners show how the balloon is passed from the Golgi body (perhaps represented by the individual who prepared the balloon) to the end of a line of learners to reach an individual at the end, who represents the plasma membrane. One or more learners role play the bilayer and burst the balloon ‘behind their backs’ to show the fusion of the vesicle and exocytosis of the contents. Challenge learners to suggest how a similar role play could be used to illustrate endocytosis.</p> <p>Share animations and interactive platforms with learners that illustrate the various types of movement into and out of cells. A good example is https://phet.colorado.edu/en/simulation/legacy/membrane-channels</p> <p>Ask questions of learners ‘in reverse.’ Give them a series of answers and challenge them to suggest a question for each. This engages learners in higher-order thinking skills. To add an extra degree of challenge, learners decide on the most appropriate command term (taken from the syllabus) for each of their responses. For example, provide the term ‘by active transport, using ATP from the mitochondria’ to</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
		<p>learners, for which they identify a question (e.g. 'How does a cell absorb substances against the concentration gradient') and the most appropriate command word ('Explain'). (F)</p> <p>Extension activity: Learners explain a number of 'real-world' applications of the importance of osmosis, including the basis of isotonic energy drinks and bathing solutions used during transport of organs for transplant.</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

5 The mitotic cell cycle

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>5.1 Replication and division of nuclei and cells</p> <p>KC1</p> <p>KC3</p>	<p>5.1.1 Describe the structure of a chromosome.</p> <p>5.1.2 Explain the importance of mitosis in the production of genetically identical daughter cells during:</p> <ul style="list-style-type: none"> • growth of multicellular organisms • replacement of damaged or dead cells • repair of tissues by cell replacement • asexual reproduction. <p>5.1.3 Outline the mitotic cell cycle.</p> <p>5.1.4 Outline the role of telomeres in preventing the loss of genes from the ends of chromosomes during DNA replication.</p> <p>5.1.5 Outline the role of stem cells in cell replacement and tissue repair by mitosis.</p> <p>5.1.6 Explain how uncontrolled cell division can result in the formation of a tumour.</p>	<p>Learners work in groups of three or four to decide on three ideas they know about cell division. Then ask them to share their facts in groups and to compile a master list, with the most important at the top. Ask for ideas as a class, and find out which other groups agreed. To make this activity more effective and inclusive, do not choose learners on the basis of 'hands up.' Instead, choose learners at random. Use this opportunity to explain to learners the importance of mitosis in the production of genetically identical daughter cells during growth, replacement and repair (including the role of stem cells) and asexual reproduction (F)</p> <p>Learners explore the structure of chromosomes using a karyotype. Learners work together to group the chromosomes in pairs, and then identify the structures called sister chromatids, centromeres and telomeres. Learners could fix the karyograms that they produce into their study notes, to provide a useful reference point during subsequent lessons.</p> <p>Show a range of simplified and actual electron micrographs of chromosomes and their ultrastructure. Recommended animations which are good for consolidating learners' understanding of packaging DNA include: www.hhmi.org/biointeractive/dna-packaging www.dnalc.org/resources/3d/07-how-dna-is-packaged-basic.html</p> <p>Learners sequence a set of diagrams into a flow chart showing changes that occur to result in a tumour (must include an abnormal mass from which two arrows emerge to a benign growth and a cancerous (malignant) growth. (I)</p> <p>Tell learners that they must work in pairs or groups of three to identify the 'odd one out' in a series of three key words. Display a series of key words in triplets on the board or provide on paper, and ask learners to discuss which one is less related to the other two terms. They must justify their decisions. Examples include: 'chromatid, chromosome, centromere?' (here, centromere would be the odd one out as it does not consist of a strand of DNA identical to the others). (F)</p> <p>Extension activity: To link this topic with cell signalling (Topic 4), challenge learners to research the control of the cell cycle, including checkpoint protein kinases and the process of phosphorylation.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>5.2 Chromosome behaviour in mitosis</p> <p>KC1</p> <p>KC3</p>	<p>5.2.1 Describe the behaviour of chromosomes in plant and animal cells during the mitotic cell cycle and the associated behaviour of the nuclear envelope, the cell surface membrane and the spindle (names of the main stages of mitosis are expected: prophase, metaphase, anaphase and telophase).</p> <p>5.2.2 Interpret photomicrographs, diagrams and microscope slides of cells in different stages of the mitotic cell cycle and identify the main stages of mitosis.</p>	<p>Resource Plus</p> <p>Carry out the <i>Investigating mitosis by preparing a root tip squash</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>In this task, learners prepare a root tip squash for viewing with a light microscope, in order to identify cells in different stages of mitosis. As part of this task, learners carry out activities requiring knowledge of eyepiece graticules and stage micrometers and of drawing scientifically. There are also opportunities to evaluate a range of investigation plans.</p> <p>Prepare seven images of cells undergoing different stages of mitosis, printed on A3 paper (ideally laminated). Ask seven volunteers to hold up one of the seven images each, so that the whole class can see. Ask the rest of the class to rearrange the volunteers in the correct order to show the process of mitosis from start to finish – and asking the first and final members to then form a circle, to emphasise that it is a cycle. Then give each member of the ‘audience’ a card that contains a description of an event during mitosis. Learners stand by the learner holding the appropriate A3 sheet. Animations can be used to reinforce this knowledge: www.cellsalive.com/cell_cycle_js.htm and www.biology.arizona.edu/cell_bio/tutorials/cell_cycle/mitosis_movie.html</p> <p>Prepare a written text that summarises the concepts that learners have studied in this subtopic. Include some conceptual errors such as ‘anaphase is the longest stage of mitosis’ and ‘spindle fibres attach to the telomeres during prophase.’ Learners spot and circle as many mistakes as possible, and offer corrections. (F)</p> <p>Extension activity: Challenge learners to calculate the mitotic index of a plant tissue and ask them to consider how the measurement of the mitotic index can be used as a means of investigating the effect of a named variable on plant tissue growth.</p>
<p>Past and specimen papers</p>		
<p>Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)</p>		

6 Nucleic acids and protein synthesis

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
6.1 Structure of nucleic acids and replication of DNA KC2 KC3	6.1.1 Describe the structure of nucleotides, including the phosphorylated nucleotide ATP. 6.1.2 State that the bases adenine and guanine are purines with a double ring structure, and that the bases cytosine, thymine and uracil are pyrimidines with a single ring. 6.1.3 Describe the structure of a DNA molecule as a double helix. 6.1.5 Describe the structure of an RNA molecule, using the example of messenger RNA.	<p>In Topic 1 Cell structure learners studied the regions of cells in which DNA is found in eukaryotes and in prokaryotes. The synthesis of macromolecules is described in Topic 2 Biological molecules, and DNA synthesis in the S phase of the cell cycle is explored in Topic 5 The mitotic cell cycle. Prepare a short quiz, using Paper 1 multiple-choice questions, to review and refresh knowledge. (F)</p> <p>Provide paper or card cut-outs of DNA nucleotides for learners to join together. Learners note that A will pair with T, C will pair with G, and that the A + T pair is the same size as the C + G pair. Help learners to see that purine + purine and pyrimidine + pyrimidine combinations are not possible, and that the two polynucleotide strands must run in antiparallel directions, in order to allow the bases to face each other. Use this opportunity to extend learners' thinking by helping them draw the structure of a nucleotide, including the phosphorylated nucleotide ATP, and the structure of an RNA molecule.</p> <p>Learners write the shortest sentence possible using a range of provided key terms related to this topic. This focuses learners on developing their higher-order thinking skills and understand the meaning of the terms. Examples are 'base,' 'hydrogen' and 'polymer.' To provide extra help to less confident learners, reduce the number of words that they are expected to use. (F)</p> <p>Extension activity: Learners prepare a short story that summarises the history of the discovery of the structure of DNA, including the work of Levene, Chargaff and others.</p>
	6.1.4 Describe the semi-conservative replication of DNA during the S phase of the cell cycle, including: <ul style="list-style-type: none"> • the roles of DNA polymerase and DNA ligase • the differences between leading strand and lagging strand replication as a consequence of 	<p>Provide cut-out shapes and ask learners to model DNA replication. Next, learners cut out the nucleotides in the other row (which are not joined together). Learners show how these join with the other strand. This time, ask learners to 'be DNA polymerase' and show how these can be joined together and how hydrogen bonds form between the now-adjacent base pairs. You could use animations as a summary of this activity: www.wiley.com/college/pratt/0471393878/student/animations/dna_replication/index.html</p> <p>Provide learners with the first and last 'scene' of a cartoon strip of six scenes and simple flashcards with the name of the enzyme and the function on the other side. Ask them to design the other scenes to tell the story of DNA replication, using different cartoon characters to represent the enzymes. (I)</p> <p>Extension activity: to link this topic with Topic 5, learners research the action of various chemotherapy drugs, which prevent DNA replication and slow down cell division.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	DNA polymerase adding nucleotides only in a 5' to 3' direction.	
6.2 Protein synthesis KC2 KC3	6.2.1 State that a polypeptide is coded for by a gene and that a gene is a sequence of nucleotides that forms part of a DNA molecule. 6.2.2 Describe the principle of the universal genetic code in which different triplets of DNA bases either code for specific amino acids or for start and stop signals. 6.2.3 Describe how the information in DNA is used during transcription and translation to construct polypeptides, including the roles of: RNA polymerase, messenger RNA, codons, transfer RNA, anticodons, ribosomes. 6.2.4 State that the strand of a DNA molecule that is used in transcription is called the transcribed or template strand and that the other strand is called the non-transcribed strand. 6.2.5 Explain that, in eukaryotes, the RNA	<p>Show the primary structure of a simple protein, such as insulin, on the board to remind learners that proteins are made of amino acids arranged in a precise sequence (you may wish to remind learners of the models they constructed in Topic 2). Hold an open-ended discussion to challenge learners to suggest how the sequence of bases in DNA dictates the sequence of amino acids in a polypeptide. You may wish to show an animation such as www.youtube.com/watch?v=J3HVV2k2No to help explain this concept.</p> <p>Organise a role-play activity where a volunteer group of learners 'acts out' the process of protein synthesis in front of the rest of the class. For example, some learners hold balloons (onto which the names of the different amino acids are written) to represent amino acids, each with a piece of string attached. Some learners act as the relevant tRNA molecules, each holding a piece of paper listing a different anticodon. Learners summarise this process as an annotated flow chart. Challenge learners to suggest how the removal of introns from the primary transcript to form mRNA could be incorporated into the role-play.</p> <p>Learners construct an analogy for protein synthesis. For example, it is like photocopying some instructions (mRNA) from a page in an encyclopaedia (a gene on a chromosome) in a library (the nucleus) to build a model in the school's science department (ribosome). Review their suggestions to identify misconceptions. Challenge learners to suggest how the removal of introns from the primary transcript to form mRNA could be incorporated into the analogy. (I)</p> <p>Formalise learners' knowledge of the genetic code (universal, non-overlapping, degenerate, sequential), by introducing the mRNA genetic dictionary / mRNA codon table. Use highly visual representations of the genetic code in the form of a 'codon wheel,' e.g. www.yourgenome.org/facts/what-does-dna-do. Give learners a card that has a codon on one side and an anticodon on the other, and challenge learners chosen at random to call out their amino acid.</p> <p>To review the wide range of key terms in this lesson, provide each learner with a piece of paper (divided to look like a domino) with a key term in one half and an unrelated definition in the other. Examples of suitable key terms include 'anticodon,' 'intron,' 'universal,' and so on. Learners circulate around the room to find the person who has the domino with the definition of their key word, and also the person who has the key word for their definition. (F)</p> <p>Prepare a missing-word exercise (writing frame), with a list of the missing words, which learners work in pairs to complete. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>molecule formed following transcription (primary transcript) is modified by the removal of non-coding sequences (introns) and the joining together of coding sequences (exons) to form mRNA.</p>	<p>Extension activity: Learners extend their knowledge of the universal genetic code by carrying out research into the topic of codon usage bias in nature. What are the benefits of using certain codons over others to encode particular amino acids?</p>
	<p>6.2.6 State that a gene mutation is a change in the sequence of base pairs in a DNA molecule that may result in an altered polypeptide.</p> <p>6.2.7 Explain that a gene mutation is a result of substitution or deletion or insertion of nucleotides in DNA and outline how each of these types of mutation may affect the polypeptide produced.</p>	<p>Learners engage with a case study to analyse the sequence of DNA from the Hb^A (normal) allele of the beta-globin gene, and then the mutant Hb^S allele. Host a discussion to describe the difference between these molecules, and suggest how this may have happened.</p> <p>Learners construct a sentence involving a series of three-letter words. An example is: 'YOU CAN EAT THE NUT.' Demonstrate how a single substitution may still leave a sentence that makes sense. However, a single deletion or addition of a base does not. Learners construct flow diagrams to illustrate the effects of the three different types of mutation on protein structure and function.</p> <p>Extension activity: Learners do some research and evaluate the definition of gene that is commonly used at this level: 'A gene is a length of DNA that codes for a polypeptide.'</p>
Past and specimen papers		
<p>Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)</p>		

7 Transport in plants

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
7.1 Structure of transport tissues KC5 KC6	7.1.1 Draw plan diagrams of transverse sections of stems, roots and leaves of herbaceous dicotyledonous plants from microscope slides and photomicrographs. 7.1.2 Describe the distribution of xylem and phloem in transverse sections of stems, roots and leaves of herbaceous dicotyledonous plants. 7.1.3 Draw and label xylem vessel elements, phloem sieve tube elements and companion cells from microscope slides, photomicrographs and electron micrographs. 7.1.4 Relate the structure of xylem vessel elements, phloem sieve tube elements and companion cells to their functions.	<p>To revise the structure and function of a light microscope, ask individual learners to state the function of a part, and then select another learner to describe its function. (F)</p> <p>Learners identify different plant tissues and draw plan diagrams of transverse sections of the stems, roots and leaves, complete with magnification values, to produce a table comparing the two. An alternative to making primary observations using a microscope is to distribute prints of light micrographs for learners to analyse. Share success criteria by showing 'outline maps' of areas at school, and elicit that fine details of the school spaces (cells in this analogy), are not required in order to recognise them. (I)</p> <p>Show learners four or five exemplar answers to one Paper 3 exam question that include diagrams. Learners rank the diagrams in order of quality and then explain the order they select. The intention is to help learners understand mark schemes and success criteria.</p> <p>Prepare three or four past paper questions, ideally of multiple-choice or short-answer questions, which learners complete and pass to you as they leave the room. This 'exit card' technique enables you to judge whether you need to reinforce the content of this lesson in the next lesson. (F)</p> <p>Extension activity: Learners make and examine their own freshly prepared sections of plant material. There are some safety implications, due to the use of sharp objects, so you should demonstrate the technique first.</p>
7.2 Transport mechanisms KC5	7.2.1 State that some mineral ions and organic compounds can be transported within plants dissolved in water.	<div data-bbox="824 1254 1034 1318" style="background-color: #e91e63; color: white; padding: 2px;">Resource Plus</div> <div data-bbox="824 1318 2056 1382" style="border: 1px solid black; padding: 2px;">Carry out the <i>Investigating the effect of carbon dioxide concentration on stomatal density</i> experiment referring to the Teaching Pack for lesson plans and resources.</div>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
KC6	<p>7.2.2 Describe the transport of water from the soil to the xylem through the:</p> <ul style="list-style-type: none"> • apoplast pathway, including reference to lignin and cellulose • symplast pathway, including reference to the endodermis, Casparian strip and suberi. <p>7.2.3 Explain that transpiration involves the evaporation of water from the internal surfaces of leaves followed by diffusion of water vapour to the atmosphere.</p> <p>7.2.4 Explain how hydrogen bonding of water molecules is involved with movement of water in the xylem by cohesion-tension in transpiration pull and by adhesion to cellulose in cell walls.</p> <p>7.2.5 Make annotated drawings of transverse sections of leaves from xerophytic plants to explain how they are adapted to reduce water loss by transpiration.</p>	<p>In this task, learners will use microscopy to find the stomatal density of plant leaves grown in high, atmospheric and low carbon dioxide concentrations. As part of this task, they develop their practice using a light microscope and carry out activities requiring knowledge of eyepiece graticules and stage micrometers as well as evaluating the conclusions of investigations using statistical tests.</p> <p>Bring contextual relevance to the study of transport in plants. Learners research how gold mining is now partly dependent on analysing the contents of leaves such as eucalyptus. After allowing 2–3 minutes for them to undertake internet research, ask a number of questions, including ‘How did the gold particles get there?’ Develop the discussion by showing the short clip of David Attenborough, high up next to a tree, discussing how water can be brought upwards: www.youtube.com/watch?v=Qwb6mVeMpW8</p> <p>Provide a series of cut-out statements that describe how water moves up a plant. Learners arrange the statements in order. Learners describe the mechanism in a stepwise fashion, starting at the top of the plant and working to the bottom. A useful animation that shows the movement of water in the xylem vessels of plants is at: www.saps.org.uk/animations/plant_biology/index.html?video=1 Emphasise how hydrogen bonding of water molecules is involved in this process. (I)</p> <p>Learners undertake a practical activity to explore how to set up a potometer to measure the rate of transpiration from a young branch. This can be constructed using a long piece of capillary tubing that has a short length of rubber tubing attached at one end. The whole apparatus can be supported vertically. Learners actually measure the rate water is taken up by a shoot and make the assumption that all the water that is taken up is lost by the leaves. Learners carry out an investigation into the effect of a factor on the rate of transpiration of a plant, such as humidity, temperature or carbon dioxide concentration. A useful website is: www.nuffieldfoundation.org/practical-biology/measuring-rate-water-uptake-plant-shoot-using-potometer.</p> <p>Help learners to produce annotated drawings of transverse sections of leaves from xerophytic plants to explain how they are adapted to reduce water loss by transpiration. Demonstrate on the class whiteboard how this is done, and encourage learners to follow your guidance. Provide learners with clear success criteria, and give an opportunity for self- or peer-assessment.</p> <p>Ask a carefully-chosen series of hinge questions (a point in a lesson when you check whether or not learners have grasped a key concept and are ready to move on to study another) to elicit higher-order thinking skills among learners. One option is to ask them to compare key terms, to reinforce their knowledge of key definitions, including: lignin/ cellulose (low demand), apoplast/symplast (intermediate demand) and cohesion/tension (high demand). (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
		<p>Extension activity: Learners study a graph showing how the rate of transpiration varies during a 24-hour day and interpret the plot using a word list (include, for example, stomata, photosynthesis, gas exchange, etc.). Encourage learners to consider how, and why, their graph would be different for a xerophytic plant.</p>
	<p>7.2.6 State that assimilates dissolved in water, such as sucrose and amino acids, move from sources to sinks in phloem sieve tubes.</p> <p>7.2.7 Explain how companion cells transfer assimilates to phloem sieve tubes, with reference to proton pumps and cotransporter proteins.</p> <p>7.2.8 Explain mass flow in phloem sieve tubes down a hydrostatic pressure gradient from source to sink.</p>	<p>Show an image of trees that have been subject to ‘ring barking.’ Ask learners for suggestions as to why these trees die and identify the location of the phloem vessels. Through a class discussion, encourage ideas from learners in order to arrive at a consensus to explain what is happening. (F)</p> <p>Learners prepare a numbered list to show the sequence of events that occur in the phloem sieve elements / companion cells. They should compare their work with an on-screen animation, for example: www.saps.org.uk/animations/plant_biology/index.html?video=1 http://highered.mheducation.com/sites/9834092339/student_view0/chapter38/animation_-_phloem_loading.html</p> <p>Write on the board: ‘Why is _____ an example of _____?’ Learners use this shell to pose questions about the role of the phloem. An example is ‘Why is the phloem an example of a tissue?’ (F)</p> <p>Extension activity: Learners suggest how aphid stylets and radioactive markers are used to determine the movement of assimilates through phloem vessels.</p>
<p>Past and specimen papers</p>		
<p>Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)</p>		

8 Transport in mammals

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>8.1 The circulatory system</p> <p>KC5</p> <p>KC6</p>	<p>8.1.1 State that the mammalian circulatory system is a closed double circulation consisting of a heart, blood and blood vessels including arteries, arterioles, capillaries, venules and veins.</p> <p>8.1.2 Describe the functions of the main blood vessels of the pulmonary and systemic circulations, limited to pulmonary artery, pulmonary vein, aorta and vena cava.</p> <p>8.1.3 Recognise arteries, veins and capillaries from microscope slides, photomicrographs and electron micrographs and make plan diagrams showing the structure of arteries and veins in transverse section (TS) and longitudinal section (LS).</p> <p>8.1.4 Explain how the structure of muscular arteries, elastic arteries, veins and capillaries are each related to their functions.</p>	<p>Learners work in pairs to brainstorm a list of terms they know about the circulatory system from their studies at Cambridge IGCSE (or equivalent), including what is meant by pulmonary and systemic circulations. After 2–3 minutes of discussion, the pairs join together into groups of four and then groups of eight to discuss this further and come up with an agreed list of points. One or two learners from each group then write the group’s ideas on the class board to form a ‘mind map.’ Useful videos, including memorable songs, can be found on YouTube, for example: www.youtube.com/watch?v=LqhvmUEdOYY&index=10&list=PL806169ECA3C97794 (F)</p> <p>Provide modelling clay of many colours. Learners build an artery, a vein and a capillary, paying attention to ensure that the relative widths of the three vessels are correct. The layers of tissue in the artery and vein must be made with different colours, but must be consistent between the two blood vessels. To extend the activity, provide butter knives to the learners and ask them to cut their models in half in a transverse section, to display the structures in the wall and the relative lumen diameters. Also prepare a longitudinal section to demonstrate how this would appear different, and use websites such as www.histology.leeds.ac.uk/circulatory/arteries.php to source images for learners to add further details. (I)</p> <p>Draw a table or Venn diagram to compare arteries, veins and capillaries. Learners could show the three circles of a Venn diagram as the transverse sections of these three blood vessels (not to scale), and they could label diagrams in the same activity, to make an interesting poster. They should emphasise in their work how the structure of muscular arteries, elastic arteries, veins and capillaries are each related to their functions. (F)</p> <p>Prepare a crossword containing clues for words related to the content of the lesson. Include the names of the layers of the tissues in the walls of arteries and veins. Learners undertake the activity in pairs and with a competition format, with the pair that finishes the crossword first as the winning team. (F)</p> <p>Extension activity: Learners research and contrast the mammalian circulatory system with organisms organised differently, e.g. insect, fish and amphibians.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>8.1.5 Recognise and draw red blood cells, monocytes, neutrophils and lymphocytes from microscope slides, photomicrographs and electron micrographs.</p> <p>8.1.6 State that water is the main component of blood and tissue fluid and relate the properties of water to its role in transport in mammals, limited to solvent action and high specific heat capacity.</p> <p>8.1.7 State the functions of tissue fluid and describe the formation of tissue fluid in a capillary network.</p>	<p>Hold a quick round of ‘true or false’ questions to review learners’ knowledge of water and blood, for example: ‘Water is the main component of blood’ (true) and ‘Red blood cells have no contents’ (false). (F)</p> <p>Learners use a microscope to examine a smear of mammalian blood and make observations of different types of blood cell. Summarise the appearance and functions of white blood cells (note that only monocytes, neutrophils and lymphocytes are required).</p> <p>Learners benefit from a visual representation of the link between blood and tissue fluid. They could work in small groups to prepare a poster with a range of materials, perhaps based on a diagram of a capillary bed. Host a ‘marketplace’ to extend this activity into the next lesson. One member of each group stands by their poster and gives an explanation to other groups as they move around the room. (F)</p> <p>Extension activity: Use Bloom’s taxonomy to construct five or six questions of a range of high-order thinking skills on this subject to ask learners on the subject of blood. Arrange these into envelopes, placed on the pyramid. This emphasises their challenging nature and must ask for suggestions, evaluations and justifications.</p>
<p>8.2 Transport of oxygen and carbon dioxide</p> <p>KC5</p>	<p>8.2.1 Describe the role of red blood cells in transporting oxygen and carbon dioxide with reference to the roles of:</p> <ul style="list-style-type: none"> • haemoglobin • carbonic anhydrase • the formation of haemoglobinic acid • the formation of carbaminohaemoglobin. <p>8.2.2 Describe the chloride shift and explain the importance of the chloride shift.</p>	<p>Provide context at the beginning of this topic to help learners appreciate its importance. For example, show a video clip of mountaineers using oxygen cylinders. Use this information to revise the reasons why cells need oxygen, and why carbon dioxide must be removed from tissues. Develop understanding by asking further questions, such as ‘What is the purpose of a red blood cell?’ (F)</p> <p>Learners draw a large chalk diagram of the oxygen dissociation curve on the school playground, or they may each draw their own diagram. When you call out a specific scenario, learners should ‘jump’ to either the left or the right side of the curve. Scenarios include ‘What happens if fetal haemoglobin replaces adult?’ and ‘What happens if the pH of the blood decreases?’ Use this exercise to identify and, by repeating scenarios, correct misconceptions. (F)</p> <p>Learners produce a time-lapse video using, for example, a mobile phone that shows how a model of haemoglobin (built with modelling clay) undergoes conformational changes as it circulates around the body. To extend the activity, place the model on top of an image of an individual doing intense physical activity, and use this to explain how haemoglobin tends to release some of its oxygen when carbon dioxide concentration is high – the Bohr effect. This activity makes the mechanism of oxygen transport by haemoglobin much more memorable. (I)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>8.2.3 Describe the role of plasma in the transport of carbon dioxide.</p> <p>8.2.4 Describe and explain the oxygen dissociation curve of adult haemoglobin.</p> <p>8.2.5 Explain the importance of the oxygen dissociation curve at partial pressures of oxygen in the lungs and in respiring tissues.</p> <p>8.2.6 Describe the Bohr shift and explain the importance of the Bohr shift.</p>	<p>Learners produce a series of flash cards that have a key term from these topics on one side, and the definition on the other. They challenge their peers to provide the term or the definition when one side of the card is displayed on the desk. Good examples would be the Bohr effect and the chloride shift. (F)</p> <p>Extension activity: Construct an oxygen dissociation curve for a variety of organisms other than humans.</p>
<p>8.3 The heart</p> <p>KC6</p>	<p>8.3.1 Describe the external and internal structure of the mammalian heart.</p> <p>8.3.2 Explain the differences in the thickness of the walls of the:</p> <ul style="list-style-type: none"> • atria and ventricles • left ventricle and right ventricle. <p>8.3.3 Describe the cardiac cycle, with reference to the relationship between blood pressure changes during systole and diastole and the opening and closing of valves.</p>	<p>Review learners' prior knowledge of the structure and function of the heart by asking them to construct a dichotomous key to differentiate between the different chambers/valves of the heart. For example, the first branch could read 'chamber' or 'vessel.' The second branches leading from these could read 'carry oxygenated blood' or 'carry deoxygenated blood,' and so on. (F)</p> <p>Being mindful of cultural sensitivities, host a dissection for learners to explore the anatomical features of the heart. Arrange the heart with the blood vessels facing away from them (towards the head of the animal) and to find the coronary vessels, which travel diagonally from top right to bottom left across the ventricles. They trace the pathway as it leaves the chambers by putting a finger into a chamber and finding out which vessel(s) this leads into. Drawings, or possibly photographs, could be taken when key structures are exposed. Challenge learners to draw valves and connected tendons, and measure thicknesses of the walls of the chambers.</p> <p>Resource Plus</p> <div style="border: 1px solid black; padding: 5px;"> <p>Carry out the <i>Heart dissection</i> experiment (in Resource Plus for Cambridge IGCSE/O Level Biology 0610/5090) referring to the Teaching Pack for lesson plans and resources.</p> </div> <p>Learners construct a graph on the wall or floor of the classroom that shows the pressure and volume changes on one side of the heart. Hand out sections of the graph to learners, who discuss what is happening in their small section. Hold a discussion in which learners contribute ideas and produce a fully</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	8.3.4 Explain the roles of the sinoatrial node, the atrioventricular node and the Purkyne tissue in the cardiac cycle (knowledge of nervous and hormonal control is not expected).	<p>annotated version of the graph by joining the sections together. To reinforce their learning, show an animation to help learners visualise the circulation of blood and the electrical control of the heartbeat: www.nhlbi.nih.gov/health-topics/how-heart-works</p> <p>Extension activity: Learners research common congenital diseases of the heart, such as atrial septal defect, tetralogy of Fallot and aortic stenosis. They could use websites containing images of diseased adult hearts such as: https://webpath.med.utah.edu/CVHTML/CVIDX.html</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

9 Gas exchange

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>9.1 The gas exchange system</p> <p>KC1</p>	<p>9.1.1 Describe the structure of the human gas exchange system.</p> <p>9.1.2 Describe the distribution in the gas exchange system of cartilage, ciliated epithelium, goblet cells, squamous epithelium of alveoli, smooth muscle and capillaries.</p> <p>9.1.3 Recognise cartilage, ciliated epithelium, goblet cells, squamous epithelium of alveoli, smooth muscle and capillaries in microscope slides, photomicrographs and electron micrographs.</p> <p>9.1.4 Recognise trachea, bronchi, bronchioles and alveoli in microscope slides, photomicrographs and electron micrographs and make plan diagrams of transverse sections of the walls of the trachea and bronchus.</p> <p>9.1.5 Describe the functions of ciliated epithelial cells, goblet cells and mucous glands in maintaining the</p>	<p>Learners should have some knowledge of the gas exchange system from Cambridge IGCSE (or equivalent). To assess this, demonstrate a model of the lungs, thorax and airways by suspending a balloon (lung) inside a plastic bottle (thorax) that has been cut in half and sealed at the bottom with a stretched balloon (diaphragm). A straw (trachea), sealed with modelling clay, emerges from the bottle neck. Pulling down on the diaphragm will inflate the lung. Learners describe and explain the events that you demonstrate using this model. An alternative opening to this topic is to use a spirometer to show learners how lung capacity can be measured: www.nuffieldfoundation.org/practical-biology/using-spirometer-investigate-human-lung-function (F)</p> <p>Learners observe prepared slides (or print-outs of photomicrographs and electron micrographs) of transverse and longitudinal sections of the wall of the trachea, bronchi, bronchioles and alveoli. Learners draw tissue maps and compare the features. Help learners to recognise ciliated epithelium, goblet cells, squamous epithelium of alveoli, smooth muscle and capillaries.</p> <p>Sources of histology sections: www.meddean.luc.edu/lumen/MedEd/Histo/frames/Histo15.html www.anatomyatlases.org/MicroscopicAnatomy/Section11/Section11.shtml (I)</p> <p>Learners describe the pathway of an oxygen molecule through the human gas exchange system, from the trachea and into the red blood cells where it binds to haemoglobin. Animations can help to provide further guidance, e.g. www.johnwiley.net.au/highered/interactions/media/Respiration/content/Respiration/resp1a/frameset.htm (I)</p> <p>Display a challenging, 3–4-mark question on the whiteboard. Allow learners 2–3 minutes to work in pairs to record as many key terms they feel are necessary to answer it. Show how to incorporate the relevant key words into a clear, exam-style answer.</p> <p>Host a lively class debate to motivate learners with higher-order thinking. The focus should be a controversial statement, rather than a question. For example, ask learners to evaluate a statement such as ‘The gas exchange system is more vital to humans than the circulatory system.’ (F)</p> <p>Draw a very large diagram of the gas exchange system on the whiteboard. However, ensure that between five and ten mistakes have been intentionally included. These include spelling mistakes, but also conceptual errors. For example, show cilia in the alveoli, and cartilage rings around the bronchioles. The ‘think, pair, share’ technique can provide a useful introduction to help learners form an opinion. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>health of the gas exchange system.</p> <p>9.1.6 Describe the functions in the gas exchange system of cartilage, smooth muscle, elastic fibres and squamous epithelium.</p> <p>9.1.7 Describe gas exchange between air in the alveoli and blood in the capillaries.</p>	<p>Extension activity: Learners extend their knowledge of the gas exchange system by researching the effects of tobacco smoke. With careful planning, provide an opportunity to ‘flip the classroom’ in advance of this lesson, to encourage learners to arrive already prepared. Examples of sources include: https://ash.org.uk/fact-sheets/</p>
<p>Past and specimen papers</p>		
<p>Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)</p>		

10: Infectious diseases

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>10.1 Infectious diseases</p> <p>KC1</p> <p>KC5</p>	<p>10.1.1 State that infectious diseases are caused by pathogens and are transmissible.</p> <p>10.1.2 State the name and type of pathogen that causes each of the following diseases:</p> <ul style="list-style-type: none"> • cholera • malaria • tuberculosis (TB) • HIV/AIDS <p>10.1.3 Explain how cholera, malaria, TB and HIV are transmitted.</p> <p>10.1.4 Discuss the biological, social and economic factors that need to be considered in the prevention and control of cholera, malaria, TB and HIV (details of the life cycle of the malarial parasite are not expected).</p>	<p>List a number of infectious and non-infectious diseases on the whiteboard. Learners discuss the definition of infectious disease. Learners write the shortest summary paragraph possible using the key terms that emerge from this discussion. This is a good way to focus learners on developing their higher-order thinking skills to make sense of the meaning of these terms, rather than simply recall them. (F)</p> <p>Learners prepare short information sheets to list how the transmission cycle for each disease can be broken, with an emphasis on the mode of infection. For example, learners might show how drinking water supplies are contaminated with sewage, then consumed, or how malarial parasites make their way from a host, via a mosquito, to another. Their work can later be photocopied and made into a booklet for future reference. (I)</p> <p>Learners design a dichotomous key to help identify which pathogen is which in a series of steps. They may need to revisit their work from Topic 1 <i>Cell Structure</i> to help with the names of organelles. (I)</p> <p>Learners play a game called ‘name that pathogen’. List a number of diseases on the board and ask learners to pick the right disease for the facts being read. As the basis of a competition, the fewer clues required to guess the pathogen, the more points the learner achieves. Clues include the methods of transmission, global distribution, clinical features, and so on.</p> <p>Learners write the shortest summary paragraph possible using the following key terms: infectious, pathogen, transmissible, and so on. This is a good way to develop their higher-order thinking skills to understand these terms, rather than simply recall them. (F)</p> <p>Extension activity: Identify ways in which the diseases listed in the syllabus could be linked. For example, tell learners why there is often a correlation in disease pattern, e.g. a greater risk of being infected with TB in people with HIV/AIDS.</p>
<p>10.2 Antibiotics</p> <p>KC1</p> <p>KC2</p>	<p>10.2.1 Outline how penicillin acts on bacteria and why antibiotics do not affect viruses.</p> <p>10.2.2 Discuss the consequences of antibiotic</p>	<p>Learners prepare for this lesson in advance by ‘flipping the classroom’. Provide a series of questions from Paper 1 for them to research using textbooks and the internet. The intention of these questions is to trigger interest and enrich the dialogue at the start of this lesson. (I)</p> <p>Learners produce a series of flash cards that have a key term related to antibiotics on one side, and a definition or explanation regarding how that term relates to the mechanism of penicillin action, for example,</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	resistance and the steps that can be taken to reduce its impact.	<p>'peptidoglycan' on one side of the card and 'cross links between these molecules do not form in the cell wall of growing cells' on the other side. (I)</p> <p>Learners prepare a brief document, listing how bacterial antibiotic resistance is reduced. Points to consider in reducing impact include: dosage; length of treatment; use of narrow-spectrum antibiotics; identify correctly the causative organism; hygiene and aseptic conditions in areas such as hospitals; measures to reduce the impact of antibiotic therapy with farm animals. (I)</p> <p>Extension activity: Learners suggest how some bacteria have resistance to antibiotics. For example, they may have enzymes such as beta-lactamase that hydrolyse the toxin.</p> <p>Each learner writes a question about something from the topic of antibiotics on a coloured paper strip and the answer on another paper strip of a different colour. In groups of 8–10, hand out the strips so that each learner gets a question and an answer. One learner reads out their question, and the learner with the right answer then reads it out, followed by their question. (F)</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

11 Immunity

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
11.1 The immune system KC1 KC5	11.1.1 Describe the mode of action of phagocytes (macrophages and neutrophils). 11.1.2 Explain what is meant by an antigen (see 4.1.3) and state the difference between self-antigens and non-self antigens. 11.1.3 Describe the sequence of events that occurs during a primary immune response with reference to the roles of: <ul style="list-style-type: none"> • macrophages • B-lymphocytes, including plasma cells • T-lymphocytes, limited to T-helper cells and T-killer cells. 11.1.4 Explain the role of memory cells in the secondary immune response and in long-term immunity.	To review relevant prior learning, host a brief quiz using Paper 1 questions from Topic 1 Cell structure, Topic 2 Biological molecules, and Topic 10 Infectious diseases in the coursebook. (F) Learners can find the process of phagocytosis challenging to imagine. Help them by asking them to prepare a 'flipbook', to show how phagocytosis occurs. Learners require a small notepad, in which they complete or add small sketches on each page, each of which differs only slightly from the one before. By rapidly flicking through the pages, a moving image will illustrate the process. Learners review their flipbooks by comparing the contents with a published animation, e.g. http://highered.mheducation.com/sites/0072507470/student_view0/chapter3/animation_phagocytosis.html (I) Learners in pairs brainstorm and list all the terms that they know are associated with the immune system. Terms such as 'white blood cell,' 'antibody' and 'infection' will be some expected terms. Pairs of learners then join with another pair and combine their lists of terms in rank order based on the strength of learners' understanding of the terms. The first word on the list is the term learners feel most confident about. Other terms are added in order of understanding so the least understood term is last. Learners submit their top three words to the class board, possibly in the form of a word cloud (using www.menti.com/). Give a series of laminated cards to pairs of learners that show the key events of an immune response. Include some cards that show electron micrographs of different blood cell types (sourced from websites such as https://webpath.med.utah.edu/HISTHTML/EM/EM.html#1). Learners work together to determine the order of events, and the cells involved, in an immune response. Learners explain their choices and compare different learners' judgements. Extend this so that learners play a part in a story of an infection and the primary immune response in a class role play. Extension activity: Research autoimmune disorders such as myasthenia gravis, psoriasis and multiple sclerosis. Here, self-antigens are mistakenly recognised by phagocytes and other leucocytes as non-self.
11.2 Antibodies and vaccination KC2	11.2.1 Relate the molecular structure of antibodies to their functions.	Learners discuss the role of vaccinations. As a visual prompt, display the programme of vaccinations recommended in your country or region. Contrast this with the vaccination programme for a country with very different risks to health.

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>11.2.2 Outline the hybridoma method for the production of monoclonal antibodies.</p> <p>11.2.3 Outline the principles of using monoclonal antibodies in the diagnosis of disease and in the treatment of disease.</p> <p>11.2.4 Describe the differences between active immunity and passive immunity and between natural immunity and artificial immunity.</p> <p>11.2.5 Explain that vaccines contain antigens that stimulate immune responses to provide long-term immunity.</p> <p>11.2.6 Explain how vaccination programmes can help to control the spread of infectious diseases.</p>	<p>Illustrate the importance of complementary molecule binding by asking learners to work in pairs to model antibody action. One member of each pair makes a range of shapes using modelling clay, representing antigens. The other member of the pair makes antibodies that will bind to these antigens. (I)</p> <p>Give learners statements that describe the stages of the process to make monoclonal antibodies and ask them to arrange them into a logical order. Learners undertake independent research into current developments in the use of monoclonal antibodies in medicine. Learners prepare a poster or presentation to summarise the use of a specific antibody for this purpose. (I)</p> <p>Learners suggest meanings for the term immunity and write out a common definition. Help them construct a table to compare natural active, artificial active, natural passive and artificial passive immunity. The comparisons must consider the exposure to antigen, presence or absence of an immune response, clonal selection, secretion of antibody molecules by plasma cells and immunological memory.</p> <p>Learners read online sources related to monoclonal antibodies, such as www.mayoclinic.org/diseases-conditions/cancer/in-depth/monoclonal-antibody/art-20047808. They think of appropriate analogies to describe the action of these molecules. One example is as a magnet: show how passing a magnet over the top of a range of magnetic items will result in only some binding.</p> <p>Learners consider the effective features of a global vaccination programme.</p> <p>Extension activity: You could set further reading on vaccination programmes using websites such as www.who.int</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

12 Energy and respiration

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
12.1 Energy KC1 KC2	<p>12.1.1 Outline the need for energy in living organisms, as illustrated by active transport, movement and anabolic reactions, such as DNA replication and protein synthesis.</p> <p>12.1.2 Describe the features of ATP that make it suitable as the universal energy currency.</p> <p>12.1.3 State that ATP is synthesised by:</p> <ul style="list-style-type: none"> • transfer of phosphate in substrate-linked reactions • chemiosmosis in membranes of mitochondria and chloroplasts 	<p>Learners know from Topics 1, 2 and 6 that all living things need a source of cellular energy, obtained from mitochondria in the form of ATP, to supply their activities. Provide an activity to refresh their knowledge of this information using Paper 1 questions to host a discussion. Extend thinking by describing how ATP is a suitable molecule as the universal energy currency. (F)</p> <p>On the board, draw a banknote or a coin with the words 'One ATP' displayed on it. Discuss with learners how it is possible to think of this molecule as 'currency' and how 'spending' ATP allows cells to use the energy they store. Reinforce the idea that this 'currency' can be 'spent' on a wide range of purchases, and challenge learners to list as many biological uses of energy as they can. Examples include: cytokinesis, muscle contraction, flagellum motion, endocytosis, maintenance of body temperature, active transport and electrical discharge. After providing an example to set the scene, ask a learner for an example. Then ask another. Continue this until all members of the class have been asked for an idea.</p> <p>Learners convert the discussions of this lesson into a series of short, bullet-point statements. Introduce key terms, such as phosphorylation and chemiosmosis, that learners will encounter in subsequent lessons. (F)</p>
	<p>12.1.4 Explain the relative energy values of carbohydrates, lipids and proteins as respiratory substrates.</p> <p>12.1.5 State that the respiratory quotient (RQ) is the ratio of the number of molecules of carbon dioxide produced to the number of molecules of oxygen taken in, as a result of respiration.</p>	<p>Learners undertake a 'think, pair, share' discussion to revisit their knowledge of the relative value of different components of a balanced diet in providing energy. Help learners identify fatty acids / triglycerides as the most energy-rich molecule per unit mass, due to the number of hydrogen atoms being much higher. (F)</p> <p>Learners carry out a practical activity in which they use a simple respirometer to calculate the respiratory quotient (RQ) of germinating seeds, or the effect of temperature on the rate of respiration of a small invertebrate. Simple designs, using a single syringe and capillary tubing are more sensitive to temperature and require minimal handling. Websites that provide guidance include: https://pbiol.rsb.org.uk/energy/gas-balance-in-respiration-and-photosynthesis/measuring-respiratory-quotient https://pbiol.rsb.org.uk/energy/gas-balance-in-respiration-and-photosynthesis/measuring-the-rate-of-metabolism. To extend thinking, challenge learners to calculate RQ values of a range of different respiratory substrates from equations for respiration.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>12.1.6 Calculate RQ values of different respiratory substrates from equations for respiration.</p> <p>12.1.7 Describe and carry out investigations, using simple respirometers, to determine the RQ of germinating seeds or small invertebrates (e.g. blow fly larvae).</p>	<p>Learners write down three ideas they learnt in this lesson. Then ask them to share their facts in groups and to compile a master list of facts, with the most important at the top. Ask for ideas to be shared and find out which other groups agreed. To make this activity more effective and inclusive, do not choose learners on the basis of 'hands up.' Instead, choose learners at random. (F)</p> <p>Extension activity: Learners explain how alternative experiments, without the use of respirometers, can be conducted to give more accurate readings for values of the respiratory quotient.</p>
<p>12.2 Respiration</p> <p>KC1</p> <p>KC2</p> <p>KC6</p>	<p>12.2.1 State where each of the four stages in aerobic respiration occurs in eukaryotic cells.</p> <p>12.2.2 Outline glycolysis as phosphorylation of glucose and the subsequent splitting of fructose 1,6-bisphosphate (6C) into two triose phosphate molecules (3C), which are then further oxidised to pyruvate (3C), with the production of ATP and reduced NAD.</p> <p>12.2.3 Explain that, when oxygen is available, pyruvate enters mitochondria to take part in the link reaction.</p> <p>12.2.4 Describe the link reaction, including the role of coenzyme A in the transfer of acetyl (2C) groups .</p> <p>12.2.5 Outline the Krebs cycle.</p>	<p>Remind learners of the molecular structure of glucose from Topic 2 by showing a model of this molecule. Elicit discussion to explain that the atoms can be separated, and this underlies the process of respiration. (F)</p> <p>Help learners to understand that dividing a complex biological mechanism into smaller stages can help to understand it. After describing the mechanisms, learners close their books and attempt to sketch or record as bullet points the key facts on a blank piece of paper. Next, allow learners to look at their notes and correct and classify their own errors to reflect on their performance.</p> <p>Animations and interactive graphics: www.science.smith.edu/departments/Biology/Bio231/etc.html, www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html, http://higher.ed.mheducation.com/sites/9834092339/student_view0/chapter7/how_glycolysis_works.html, www.wiley.com/legacy/college/boyer/0470003790/animations/tca/tca.htm, http://vcell.ndsu.nodak.edu/animations/flythrough/mitochondria_03.htm www.johnkyrk.com (F)</p> <p>Learners work in pairs to draw and label a diagram of a mitochondrion on a piece of poster paper. Review misconceptions as you walk around the room, and then produce a diagram on the board for learners to use to make their corrections. Extend the activity by asking learners to write the name of each of the four stages of aerobic respiration in the correct locations on the mitochondrion. You can use resources to illustrate the events of aerobic respiration.</p> <p>Set up a Krebs cycle 'circus' for learners to move between stations at which they collect or drop off coins or photocopies of molecular structures that represent the different intermediates.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>12.2.6 Explain that reactions in the Krebs cycle involve decarboxylation and dehydrogenation and the reduction of the coenzymes NAD and FAD.</p> <p>12.2.7 Describe the role of NAD and FAD in transferring hydrogen to carriers in the inner mitochondrial membrane.</p> <p>12.2.8 Explain what happens during oxidative phosphorylation.</p> <p>12.2.9 Describe the relationship between the structure and function of mitochondria using diagrams and electron micrographs.</p>	<p>Learners design two or three multiple-choice questions on the subject of aerobic respiration. Before the next lesson, select the best 10 and provide these to the class as a formative exercise. This will motivate learners to make high-quality questions. (F)</p> <p>Extension activity: Learners interpret how respiratory inhibitors can be used to study aerobic respiration, and to draw conclusions from graphs. Further information can be sourced online, e.g. www.biologymad.com/master.html?http://www.biologymad.com/PhotosynResp/PhotosynResp.htm</p>
	<p>12.2.10 Outline respiration in anaerobic conditions in mammals (lactate fermentation) and in yeast cells (ethanol fermentation).</p> <p>12.2.11 Explain why the energy yield from respiration in aerobic conditions is much greater than the energy yield from respiration in anaerobic conditions.</p> <p>12.2.12 Explain how rice is adapted to grow with its roots</p>	<p>Learners brainstorm and list what they know about anaerobic respiration. After a few minutes, pairs join together into groups of four and then groups of eight to discuss this further and come up with an agreed list of points. One or two learners from each group then write the group's ideas on the class board to form a 'mind map.' (F)</p> <p>Learners carry out a practical activity to investigate effect of glucose concentration on the respiration rate of yeast using a redox indicator. Indicators such as 2,6-dichlorophenolindophenol (DCPIP) and methylene blue are often used to detect oxidation and reduction reactions. Both these substances change from blue to colourless when they accept electrons or hydrogen (i.e. are reduced). With this knowledge, small groups can be set the task of planning an appropriate investigation to carry out.</p> <p>Resource Plus</p> <p>Carry out the <i>Investigating the rate of aerobic respiration in yeast</i> experiment referring to the Teaching Pack for lesson plans and resources.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>submerged in water, limited to the development of aerenchyma in roots, ethanol fermentation in roots and faster growth of stems.</p> <p>12.2.13 Describe and carry out investigations using redox indicators, including DCPIP and methylene blue, to determine the effects of temperature and substrate concentration on the rate of respiration of yeast.</p> <p>12.2.14 Describe and carry out investigations using simple respirometers to determine the effect of temperature on the rate of respiration.</p>	<p>In this task, learners use a redox indicator to measure the rate of aerobic respiration in yeast at different temperatures. As part of this task, learners consider how best to plan an investigation and present obtained results.</p> <p>Learners prepare Venn diagrams or tables to visually compare the mechanisms and features of aerobic and anaerobic respiration. An example of a similarity is that glycolysis occurs in both; a difference is that the Krebs cycle occurs only in aerobic respiration. Learners compare their work with those of others to identify any points of comparison that they did not identify. (I)</p> <p>Remind learners of xerophytes and adaptation to survival in arid conditions, Topic 7 <i>Transport in plants</i> and prompt learners to undertake independent research focusing on the adaptations of rice to grow in paddies (fields that are intentionally flooded). Learners make poster presentations that can be displayed for group feedback using post-it notes. (I)</p> <p>Prepare a crossword containing all the terms used in this lesson, with clear clues. When completed, this will be an excellent sheet of definitions. Learners keep their copies to refer to throughout the topics of aerobic and anaerobic respiration. (I)</p> <p>Learners design an investigation, with a focus on how to collect valid, reliable and accurate data, to find the longest time rice plants are able to withstand being submerged. Discuss an example plan with learners and how it differs from theirs, before providing an opportunity for learners to assess their own work. (F)</p> <p>Extension activity: Learners investigate what happens to the lactate produced during anaerobic respiration in animals. Ask more confident learners to host a brief description, in the form of a 5-minute 'master class,' to extend the knowledge of the rest of the class.</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

13 Photosynthesis

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>13.1 Photosynthesis as an energy transfer process</p> <p>KC1</p> <p>KC2</p> <p>KC6</p>	<p>13.1.1 Describe the relationship between the structure of chloroplasts, as shown in diagrams and electron micrographs, and their function.</p> <p>13.1.2 Explain that energy transferred as ATP and reduced NADP from the light-dependent stage is used during the light-independent stage (Calvin cycle) of photosynthesis to produce complex organic molecules.</p> <p>13.1.3 State that within a chloroplast, the thylakoids, which occur in stacks called grana, are the site of the light-dependent stage and the stroma is the site of the light-independent stage.</p> <p>13.1.4 Describe the role of chloroplast pigments in light absorption in thylakoids.</p> <p>13.1.5 Interpret absorption spectra of chloroplast pigments and action spectra for photosynthesis.</p> <p>13.1.6 Describe and use chromatography to separate</p>	<p>Emphasise the importance of photosynthesis in context using a relevant video clip such as: www.nasa.gov/content/goddard/seeing-photosynthesis-from-space-nasa-scientists-use-satellites-to-measure-plant-health/. This shows how fluorescence released by chlorophyll can be detected by satellites in space in order to produce maps of world vegetation and its health. Discuss what is meant by 'photosynthesis' and review prior learning. (F)</p> <p>Establishing a good understanding of the key terms that learners will need for this topic is important. Ask a series of questions on the anatomy of the leaf, that require one-word answers, so that learners can visualise mesophyll tissue and mesophyll cells containing chloroplasts, and the absorption of different wavelengths of light by pigments found in plants.</p> <p>Show electron micrographs of chloroplasts (e.g. www.vcbio.science.ru.nl/en/fesem/applets/chloroplast/). Move around the class and ask each learner to identify a blank label on the diagram, and/or identify cells that have a large number of these organelles. (F)</p> <p>Learners undertake a practical activity using paper chromatography to separate mixtures of photosynthetic pigments according to their solubility. More-soluble compounds move further along the chromatogram than less-soluble ones. Learners make measurements and calculate R_f values. They compare these with published values to make identifications. Guidance regarding this practical is at: www.saps.org.uk/secondary/teaching-resources/181-student-sheet-10-thin-layer-chromatography-for-photosynthetic-pigments. Extend by providing learners an opportunity to analyse the absorption spectra of chloroplast pigments that they have identified, and how this compares with the action spectra for photosynthesis.</p> <p>Learners carry out a practical investigation into the Hill reaction: they investigate the effect of changing the colour of light (wavelength) on the rate of the light-dependent reaction of isolated chloroplasts, using DCPIP as an indicator. Learners suggest how they could investigate the effect of a given variable on the light-independent stage of photosynthesis. Guidance regarding this practical is at: https://pbiol.rsb.org.uk/energy/photosynthesis/investigating-the-light-dependent-reaction-in-photosynthesis</p> <p>Prepare a timeline showing the sites and events of each step of the light-dependent and light-independent stages of photosynthesis. During the activity, provide learners with an opportunity to seek support from more confident learners who you identify as the activity progresses. Some good overview</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>and identify chloroplast pigments.</p> <p>13.1.7 State that cyclic photophosphorylation and non-cyclic photophosphorylation occur during the light-dependent stage of photosynthesis.</p> <p>13.1.8 Explain that in cyclic photophosphorylation:</p> <ul style="list-style-type: none"> • only photosystem I (PSI) is involved • photoactivation of chlorophyll occurs • ATP is synthesised. <p>13.1.9 Explain what happens in non-cyclic photophosphorylation.</p> <p>13.1.10 Explain what happens during photophosphorylation.</p> <p>13.1.11 Outline what happens in the three main stages of the Calvin cycle.</p> <p>13.1.12 State that Calvin cycle intermediates are used to produce other molecules, limited to GP to produce some amino acids and TP to produce carbohydrates, lipids and amino acids.</p>	<p>animations, to prepare for or conclude learners' independent work, are: www.sumanasinc.com/webcontent/animations/content/harvestinglight.html</p> <p>Display or draw a large diagram of the thylakoid membrane showing the various components of the mechanism of the light-dependent stage of photosynthesis, but which is covered by between five and ten numbered 'jigsaw' pieces. Ask learners to choose which pieces to remove, which gradually reveals the image, and to identify parts of the mechanism. Learners label and annotate an unlabelled version of the diagram as you summarise the role of the molecular components. This helps to break up the amount of information you provide learners with into a series of smaller explanations.</p> <p>Learners compare and contrast the Krebs cycle and the Calvin cycle. They present their work in a very visual way for display. For example, encourage them to draw up a table on a piece of poster paper to compare the processes. Subsequently hold a 'marketplace' activity in which one member of each group stands by their poster and offers an explanation to other groups as they circulate around the room. (I)</p> <p>Extension activity: How was the light-independent stage first determined? Set learners the task of carrying out online research into the work of Calvin and the lollipop flask containing <i>Chlorella</i> algae. Extend thinking by explaining to learners that Calvin cycle intermediates are used to produce other molecules, limited to GP to produce some amino acids and TP to produce carbohydrates, lipids and amino acids.</p> <p>A significant number of key terms, are introduced in this topic. To help familiarise learners with these terms, learners work in pairs to describe key words to each other, but without using other (listed) key words. For example, challenge learners to describe what happens in the light-independent reaction without using the three key terms: <i>ATP</i>, <i>rubisco</i>, and <i>glucose</i>. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
13.2 Investigation of limiting factors	13.2.1 State that light intensity, carbon dioxide concentration and temperature are examples of limiting factors of photosynthesis.	Learners consider in small groups how the rate of photosynthesis can be measured. Many will recall some methods from their Cambridge IGCSE (or equivalent) studies. Options include those described in: www.saps.org.uk/secondary/teaching-resources/157-measuring-the-rate-of-photosynthesis
KC5	13.2.2 Explain the effects of changes in light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis.	Arrange learners into a line of four or five and ask them to pass small items (e.g. coins) from one end to the other, except for one learner who you ask to wait at least for a few seconds before passing the item on. Draw on this analogy to explain how limiting factors restrict the further increase in the rate of photosynthesis. Explain that knowledge of these factors is important in controlling the growing conditions of commercial crops, especially in protected environments.
KC6	13.2.3 Describe and carry out investigations using redox indicators, including DCPIP and methylene blue, and a suspension of chloroplasts to determine the effects of light intensity and light wavelength on the rate of photosynthesis.	<p>Resource Plus</p> <p>Carry out the <i>Investigating photosynthesis</i> experiment (in Resource Plus for Cambridge IGCSE/O Level Biology 0610/5090) referring to the Teaching Pack for lesson plans and resources. Challenge learners to consider how the experiment can explain the effects of changes in light intensity and adding advanced material.</p>
	13.2.4 Describe and carry out investigations using whole plants, including aquatic plants, to determine the effects of light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis.	<p>Learners undertake a practical investigation into the effect of light intensity, temperature or carbon dioxide concentration on the rate of photosynthesis. Information is provided at: www.saps.org.uk/secondary/teaching-resources/190-using-pondweed-to-experiment-with-photosynthesis. For example, learners observe the effect of changing light intensity on the rate of photosynthesis of an aquatic plant. An activity that uses unicellular algae such as <i>Chlorella</i> immobilised in alginate beads to investigate photosynthesis is at: www.saps.org.uk/secondary/teaching-resources/235-student-sheet-23-photosynthesis-using-algae-wrapped-in-jelly-balls</p> <p>Use a technique called ‘rainbow grouping’ to help learners share their practical experiences. Give learners a number or colour. Learners with the same number or colour then join up, making groups of representatives of each original group. In their new group, learners take turns to describe and explain the data they collected, and evaluate sources of error in the investigation.</p>
Past and specimen papers		
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14 Homeostasis

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
14.1 Homeostasis in mammals KC2 KC5	14.1.1 Explain what is meant by homeostasis and the importance of homeostasis in mammals. 14.1.2 Explain the principles of homeostasis in terms of internal and external stimuli, receptors, coordination systems, effectors and negative feedback. 14.1.3 State that urea is produced in the liver from the deamination of excess amino acids. 14.1.4 Describe the structure of the human kidney. 14.1.5 Identify, in diagrams, photomicrographs and electron micrographs, the parts of a nephron and its associated blood vessels and structures. 14.1.6 Describe and explain the formation of urine in the nephron. 14.1.7 Relate the detailed structure of the Bowman's capsule and proximal convoluted tubule to their	<p>To prepare learners for the topic of homeostasis, hold a quiz to refresh and review learners' understanding of key terms related to glucose in respiration (Topic 12), and transport across membranes, cell signalling and osmosis (Topic 4). (F)</p> <p>Host a discussion with learners to identify the physiological factors that are maintained at a set point (e.g. temperature, blood glucose concentration, blood pH / carbon dioxide concentration, water balance / water potential, metabolic wastes) and explain the importance of maintaining the balance. Use this opportunity to revise the source of excretory substances, e.g. urea is produced in the liver from the deamination of excess amino acids.</p> <p>Learners identify analogies to describe the role of homeostasis in the body. Examples include a cooking oven with a thermostat, a thermostatically controlled water bath, central heating systems, and air-conditioned rooms. During the subsequent discussion, discuss homeostasis and link the analogies to key terms. Write these on the board such as stimulus (internal and external), receptor, coordination centre, effector and response. Learners record a summary of the discussion in the form of a flow diagram, including these key terms.</p> <p>Show a short animation of the movement of substances that occur in a nephron. An example is found at www.sumanasinc.com/webcontent/animations/content/kidney.html. Pause the animation at regular intervals for learners to discuss, in small groups, and give a summary sentence that describes the events.</p> <p>Learners convert a diagram of a nephron into a sketch of a graph to show the change in the contents of a nephron. To make this more challenging, provide learners with only 60 seconds to do this, or to add labels to their work to illustrate the roles of the hypothalamus, posterior pituitary gland, antidiuretic hormone (ADH), aquaporins and collecting ducts in osmoregulation. (I)</p> <p>Learners draw diagrams of transverse and longitudinal sections of kidney tissue, including detail showing the tubules in different planes, labelling glomerulus, renal convoluted tubule (proximal and distal), Bowman's capsule, loop of Henle and collecting duct. You could provide histology images, such as: https://webpath.med.utah.edu/RENAHTML/RENALIDX.html and www.histology.leeds.ac.uk/urinary/kidney.php, (I)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>functions in the formation of urine.</p> <p>14.1.8 Describe the roles of the hypothalamus, posterior pituitary gland, antidiuretic hormone (ADH), aquaporins and collecting ducts in osmoregulation.</p>	<p>A key skill is being able to recognise structures in electron micrographs. Good sources of kidney sections include https://wellcomecollection.org/works/h2parxes and https://wellcomecollection.org/works/ask2jkuq Other images can be found at https://www.dartmouth.edu/~emlab/gallery/</p> <p>Learners prepare a table to show the visible features that can be used to distinguish different parts of the nephron, including their functions. Place an emphasis on listing structures that adapt cells in these regions to their functions, e.g. microvilli and mitochondria in the epithelial cells lining the proximal convoluted tubule. (F)</p> <p>Extension activity: Learners suggest the symptoms of <i>diabetes insipidus</i>, a condition that is due to an inability to secrete ADH, and Goodpastures syndrome, in which the body's immune system attacks the basement membrane.</p>
	<p>14.1.9 Describe the principles of cell signalling using the example of the control of blood glucose concentration by glucagon.</p> <p>14.1.10 Explain how negative feedback control mechanisms regulate blood glucose concentration, with reference to the effects of insulin on muscle cells and liver cells and the effect of glucagon on liver cells.</p> <p>14.1.11 Explain the principles of operation of test strips and biosensors for measuring the concentration of glucose in blood and urine, with reference to glucose oxidase and peroxidase enzymes.</p>	<p>Print and write on cards the sequence of events that occurs in control of blood glucose concentration. Shuffle the cards and ask the learners to arrange them in the correct sequence. The cards include the secretion and effects of insulin and glucagon. You could use animations to summarise this, such as: http://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120109/bio48.swf::Action%20of%20Epinephrine%20on%20a%20Liver%20Cell (I)</p> <p>Learners construct Venn diagrams to compare the features of insulin and glucagon. They should include the origin, mode of action, targets and functions of these hormones. (F)</p> <p>Arrange learners into two teams. Host a debate in which learners from each team prepare a convincing argument to state why either one of the two methods of monitoring blood glucose concentration (glucose dipsticks and glucose biosensors) are preferable over the other.</p> <p>Show some extended-answer responses to the same past paper question by three different learners, which achieve a range of marks. Learners decide why marks were awarded and how they could be improved. (F)</p> <p>Extension activity: Learners prepare a glossary to include all of the words that begin with the letter 'G' in this topic (e.g. glucose, glycogen, glycogenolysis, glycogenesis and gluconeogenesis).</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
14.2 Homeostasis in plants KC2 KC5	14.2.1 Explain that stomata respond to changes in environmental conditions by opening and closing and that regulation of stomatal aperture balances the need for carbon dioxide uptake by diffusion with the need to minimise water loss by transpiration. 14.2.2 Explain that stomata have daily rhythms of opening and closing. 14.2.3 Describe the structure and function of guard cells and explain the mechanism by which they open and close stomata. 14.2.4 Describe the role of abscisic acid in the closure of stomata during times of water stress, including the role of calcium ions as a second messenger.	Refresh learners' knowledge of key terms related to plant transport, which they encountered in Topic 7. Learners describe 'a day in the life of a leaf'. Ask learners to consider what happens to the stomata on the underside of a leaf over 24 hours, beginning at midnight. Choose a learner to begin and then move to another to continue. Keep doing this until the description has reached the next midnight. Review this activity by hosting a brief quiz consisting of a series of multiple-choice questions taken from Paper 1. (F) Learners observe the opening and closing of stomata from freshly-obtained leaves from a well-watered plant that has been kept in the light. As soon as the epidermis is immersed in a solution of 15% urea and observed through a microscope, the stomata can be seen to close as the guard cells become plasmolysed. If the epidermis is immersed in a solution of dilute magnesium sulfate, then they will deplasmolyse and the stomata will open again. Learners use separate cards (around 10–12) to write out definitions and features of the terms stimulus, receptor, effector, control centre, response that are linked to homeostasis in plants. Learners swap with a partner, who can write down the relevant term that is being described. (I) Learners produce a 'concept map' to illustrate their learning during the lesson in a very visual way. Provide a series of words to help structure their work. (F) Extension activity: Learners arrange a glossary of terms introduced in this lesson into a logical order. For example, to describe the mechanism of closure of stomata, ABA comes first, and osmosis comes last. Ensure that reference is made to the role of calcium ions as a second messenger. This could be the basis of a competition, with the winning learners being first to finish.
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

15 Control and coordination

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>15.1 Control and coordination in mammals</p> <p>KC2 – Biochemical processes</p> <p>KC5 – Organisms in their environment</p>	<p>15.1.1 Describe the features of the endocrine system with reference to the hormones ADH, glucagon and insulin.</p> <p>15.1.2 Compare the features of the nervous system and the endocrine system.</p> <p>15.1.3 Describe the structure and function of a sensory neurone and a motor neurone and state that intermediate neurones connect sensory neurones and motor neurones.</p> <p>15.1.4 Outline the role of sensory receptor cells in detecting stimuli and stimulating the transmission of impulses in sensory neurones.</p> <p>15.1.5 Describe the sequence of events that results in an action potential in a sensory neurone, using a chemoreceptor cell in a human taste bud as an example.</p> <p>15.1.6 Describe and explain changes to the membrane potential of neurones.</p>	<p>Help learners to compare the features of the nervous system and the endocrine system by constructing a table to show similarities and differences.</p> <p>Refresh learners' knowledge of membrane proteins involved in transport (Topic 4). Ask a series of questions that require learners to recall key terms. (F)</p> <p>Learners investigate reflexes by comparing their reaction times when responding to sight, touch and sound. They can then analyse their data, using the <i>t</i>-test to assess the statistical significance of the differences, and evaluate their method. Help learners link their observations with the mechanism involving different types of neurone and how sensory receptor cells detect stimuli and stimulate the transmission of impulses in sensory neurones. (I)</p> <p>Display diagrams or animations to show the outside and the inside of a neurone to explain the events associated with depolarisation. Learners prepare axes on graph paper and sketch the changes to potential as each stage is discussed. Learners annotate the graph, explaining what is occurring at different time points: resting potential, rising and falling phases of action potential, and refractory period. An excellent interactive demonstration of nervous impulses is at: https://phet.colorado.edu/en/simulation/neuron</p> <p>Animations to further support this activity include: www.sumanasinc.com/webcontent/animations/neurobiology.html and http://highered.mheducation.com/sites/0072943696/student_view0/chapter8/animation_voltage-gated_channels_and_the_action_potential_quiz_1.html</p> <p>Arrange learners into a long line and ask them to model how action potentials are propagated along neurones. Ask a learner at one end to 'send an impulse' by asking them to raise an arm and then lower it very quickly. The movement of the arm represents depolarisation. The learner next to them should then do the same, and so on, until the 'impulse' reaches the end of the line. Ask learners to suggest how a synapse can be represented by this model.</p> <p>Challenge learners to convert between an image of a diagram (for example, photomicrographs of a longitudinal section of a nerve) and an image of a graph (for example, the journey of an impulse along the axon) or text. This helps them to apply their knowledge. (F)</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>15.1.7 Describe and explain the rapid transmission of an impulse in a myelinated neurone with reference to saltatory conduction.</p> <p>15.1.8 Explain the importance of the refractory period in determining the frequency of impulses.</p> <p>15.1.9 Describe the structure of a cholinergic synapse and explain how it functions, including the role of calcium ions.</p>	<p>Arrange learners into groups of four or five. Learners research the mechanism by which an impulse is transmitted across a synapse, using a range of sources. Give learners different numbers or colours and 'rainbow group' them to place all of those with the same number or colour together. Learners in their new groups then discuss their thoughts. Learners rearrange a set of diagrams to arrive at the correct sequence of events in synaptic transmission. Compare with an animation: www.sumanasinc.com/webcontent/animations/content/synaptictransmission.html (I)</p> <p>Encourage learners to understand the key stages in the transmission of a nervous impulse by asking them what would happen if key components were missing – for example, calcium ions, sodium pumps, and so on. This prompts higher-order thinking as they are required to do more than simply recall the function of these particles. (F)</p> <p>Extension activity: Learners explain the difference between conduction in unmyelinated and myelinated neurones, and research disorders in which myelin is lost (e.g. multiple sclerosis). Images are at: www.bu.edu/histology/m/t_electr.htm www.conncad.com/gallery/spines_boutons_synapses.html</p>
	<p>15.1.10 Describe the roles of neuromuscular junctions, transverse system tubules and sarcoplasmic reticulum in stimulating contraction in striated muscle.</p> <p>15.1.11 Describe the ultrastructure of striated muscle with reference to sarcomere structure using electron micrographs and diagrams.</p> <p>15.1.12 Explain the sliding filament model of muscular contraction including the roles of troponin, tropomyosin, calcium ions and ATP.</p>	<p>Show electron micrographs to learners so that they see that striated muscle is voluntary. In skeletal muscle, the multinucleate cells are also known as muscle fibres and contain a bundle of myofibrils. An example is: www.bu.edu/histology/p/21601ooa.htm</p> <p>Provide learners with a range of simple items such as string, elastic bands, toothpicks, cotton buds, and so on. Challenge them to produce a moving product to illustrate the sliding filament model. For example, the toothpicks and cotton buds could be used to represent actin and myosin. Learners should take photographs and videos of their models for future reference. (I)</p> <p>Learners sort cards containing details of the sequence of events occurring following depolarisation at the synaptic terminal of the motor neurone end with calcium ion release by the sarcoplasmic reticulum. Learners use the final, ordered cards to produce a written account, or a flow chart diagram, summarising the sequence of events occurring from the arrival of an action potential at the synaptic terminal of the motor neurone to the contraction of the sarcomere. (I)</p> <p>Extension activity: Learners investigate the terms 'slow-' and 'fast-twitch' muscle fibres.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
15.2 Control and coordination in plants KC2 KC5	15.2.1 Describe the rapid response of the Venus fly trap to stimulation of hairs on the lobes of modified leaves and explain how the closure of the trap is achieved. 15.2.2 Explain the role of auxin in elongation growth by stimulating proton pumping to acidify cell walls. 15.2.3 Describe the role of gibberellin in the germination of barley (see 16.3.4).	Show time-lapse videos of plants that have observable responses to stimuli: https://plantsinmotion.bio.indiana.edu/plantmotion/movements/nastic/nastic.html . Learners compile a list of similarities between communication in flowering plants and in mammals by comparing chemical communication in plants and animals. Present comparisons as a table or use a table to plan and then write out comparisons using examples. Host a whole-class activity in which one learner makes a statement about the role of gibberellin in the germination of barley and is followed by the next. The first learner states the first event occurring in the mechanism, and then chooses the next member of the group to continue the 'story'. Prepare a crossword containing clues for words related to the content of recent lessons on control and coordination. Learners undertake the activity in pairs. Learners highlight the key terms that they had most difficulty in remembering by underlining them or using coloured markers for future reference. (F)
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

16 Inheritance

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
16.1 Passage of information from parents to offspring KC1 KC3	16.1.1 Explain the meanings of the terms haploid (n) and diploid (2n). 16.1.2 Explain what is meant by homologous pairs of chromosomes. 16.1.3 Explain the need for a reduction division during meiosis in the production of gametes. 16.1.4 Describe the behaviour of chromosomes in plant and animal cells during meiosis and the associated behaviour of the nuclear envelope, the cell surface membrane and the spindle. 16.1.5 Interpret photomicrographs and diagrams of cells in different stages of meiosis and identify the main stages of meiosis. 16.1.6 Explain that crossing over and random orientation (independent assortment) of pairs of homologous chromosomes and sister chromatids during meiosis	<p>Introduce the topic of meiosis by reinforcing learners' knowledge of mitosis from Topic 5. Display a range of multiple-choice questions from Paper 1 as stimuli on the board. Using these, host a class discussion related to the purpose of mitosis, the sub-stages and the importance of its control. Lead a discussion to help learners understand the need for a reduction division during meiosis in the production of gametes. (F)</p> <p>Learners choose two different organisms, e.g. fruit fly (n=4) and humans. Using 2ⁿ, learners work out how many different types of gamete can be formed with two homologous pairs assorting randomly and independently at metaphase I of meiosis. (I)</p> <p>Learners undertake a practical activity to examine the stages of meiosis in the locust testis or prepared slides of an immature anther. Staining cells allows them to see the chromosomes, and observe the stages of meiosis. Learners produce annotated diagrams to outline the formation of pollen grains and embryo sacs. They use a calibrated eyepiece graticule to measure the drawings, and add a scale bar to the drawing. (I)</p> <p>Learners model the process using pipe cleaner or string models of different colours, with sticky labels for alleles. It is useful to have three homologous pairs of chromosomes, of three different sizes or colours. Mobile phones or digital cameras can be used to capture these events. Learners show the behaviour of two homologous pairs of chromosomes in meiosis I and II, including ways to represent random segregation of pairs of alleles and even crossing over (scissors will be required).</p> <p>Animations of meiosis are very useful, as they will show how in meiosis II the spindle forms 90 degrees to the position of the spindle in meiosis I, and how different-coloured homologous chromosomes are able to swap material during crossing over. Sources include: www.sumanasinc.com/webcontent/animations/content/meiosis.html, www.johnkyrk.com/meiosis.html, www.wiley.com/college/test/0471787159/biology_basics/animations/meiosis.swf vcell.ndsu.edu/animations/meiosis/index.htm.</p> <p>Animations of crossing over are also useful. Sources include: www.dnafb.org/11/animation.html</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>produces genetically different gametes.</p> <p>16.1.7 Explain that the random fusion of gametes at fertilisation produces genetically different individuals.</p>	<p>Independent assortment: www.sumanasinc.com/webcontent/animations/content/independentassortment.html</p> <p>Extension activity: Learners determine the causes of chromosomal disorders such as Down's syndrome. Research how two homologous chromosomes could be inherited from one parent.</p>
<p>16.2 The roles of genes in determining the phenotype</p> <p>KC3</p>	<p>16.2.1 Explain the terms gene, locus, allele, dominant, recessive, codominant, linkage, test cross, F1, F2, phenotype, genotype, homozygous and heterozygous.</p> <p>16.2.2 Interpret and construct genetic diagrams, including Punnett squares, to explain and predict the results of monohybrid crosses and dihybrid crosses that involve dominance, codominance, multiple alleles and sex linkage.</p> <p>16.2.3 Interpret and construct genetic diagrams, including Punnett squares, to explain and predict the results of dihybrid crosses that involve autosomal linkage and epistasis.</p> <p>16.2.4 Interpret and construct genetic diagrams, including Punnett squares, to explain</p>	<p>Do an activity to help learners identify what they already know about monohybrid crosses. Ask learners to identify any ideas or key terms that they were previously not aware of. (F)</p> <p>Learners use coloured beads or sweets to represent different alleles, and then randomly select pairs of these items to create diploid genotypes illustrating the results of different genetic crosses. This helps learners appreciate that alleles are discrete (separate) entities that do not combine.</p> <p>Learners research and present a short presentation about a disease or trait that interests them. Provide an opportunity to 'flip' the classroom: ask learners to pre-read the relevant section of their textbook, with further internet research, and be expected to offer mini-summaries of the concepts in a subsequent lesson. (I)</p> <p>To practise using the chi-squared analysis, provide learners with tangible examples of characteristics that are not related to genetics. This worksheet directs learners to count the number of different coloured sweets in a bag and to calculate the chi-squared statistic to see if the deviation from equal numbers of each colour is attributable to chance: www.biologycorner.com/worksheets/chi_square_candy.html. Alternative examples include analysing the observed/expected number of lessons of a particular subject that a learner has during a term, or the observed/expected number of stripes or dots visible on the school tie that the learners are wearing.</p> <p>Draw or display a large diagram of a Punnett square (ideally, showing an example of dihybrid cross or epistasis), but which has been covered by 12–15 small numbered 'jigsaw' pieces (this can be done virtually with computer software, or by affixing A3 sheets to the whiteboard). Ask learners to choose which pieces to remove, thus gradually revealing the image, and to identify what type of inheritance is shown, and the proportion of individuals with the various genotypes and phenotypes.</p> <p>Write a passage that summarises the wide range of concepts that learners have encountered in this subtopic, in which between five and ten mistakes have been intentionally included. These include spelling mistakes, but also conceptual errors, e.g. 'There is a 0.25 probability of the offspring of a cross</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>and predict the results of test crosses.</p> <p>16.2.5 Use the chi-squared test to test the significance of differences between observed and expected results.</p> <p>16.2.6 Explain the relationship between genes, proteins and phenotype with respect to the <i>TYR</i> gene, <i>HBB</i> gene, <i>F8</i> gene and <i>HTT</i> gene.</p>	<p>between a male of blood group AB and a female of blood group O of a child being born with blood group A.' (F)</p> <p>Learners make a guide for a younger learner to explain the relationship between genes, proteins and phenotype. Ask different learners to research the different genes listed in the syllabus and provide a short presentation for the benefit of the rest of the class.</p>
<p>16.3 Gene control</p> <p>KC2</p> <p>KC3</p> <p>KC5</p>	<p>16.2.7 Explain the role of gibberellin in stem elongation including the role of the dominant allele, <i>Le</i>, and the recessive allele, <i>le</i>.</p> <p>16.3.1 Describe the differences between structural genes and regulatory genes and the differences between repressible enzymes and inducible enzymes.</p> <p>16.3.2 Explain genetic control of protein production in a prokaryote using the <i>lac</i> operon.</p> <p>16.3.3 State that transcription factors are proteins that bind to DNA and are involved in the control of gene expression in eukaryotes by decreasing or</p>	<p>Write key terms on the board that learners will recall from their work on transcription (Topic 6). As you call out a word, ask learners to raise their hand to see who can remember it, and then ask learners to keep their hand raised if they would like to provide some information related to it. Ask learners questions such as 'What do you think of that response?' and 'Is there anything further to add?' to develop a discussion. (F)</p> <p>Learners take part in a role-play activity to show how the different DNA sequences and proteins interact during bacterial control of lactose metabolism. Learners should place pieces of paper, representing genes, along a piece of string or rope which has been placed on the floor. The repressor could be represented by one learner who holds a sign stating 'stop' to prevent RNA polymerase from transcribing the three structural genes. Give suggestions for items that represent lactose. Ask learners to suggest how this could be used to illustrate the response of bacteria when they encounter lactose.</p> <p>After this activity, help learners draw up a table to distinguish between structural and regulatory genes, and repressible and inducible enzymes. Review learners' experience by comparing their actions with an online interactive demonstration, e.g.: https://phet.colorado.edu/en/simulation/legacy/gene-machine-lac-operon</p> <p>Place a long piece of string on the floor that spans the entire classroom. Provide each learner with a piece of paper and ask them to determine a list of events that occur when seed germination is initiated. Learners work together to write their agreed steps on the pieces of paper and attach these to the string. Discuss the decisions that the learners have made. Allow learners to take photographs of this 'timeline' using their mobile phones for future reference.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>increasing the rate of transcription.</p> <p>16.3.4 Explain how gibberellin activates genes by causing the breakdown of DELLA protein repressors, which normally inhibit factors that promote transcription.</p>	<p>Provide a writing frame to help learners write an account of the sequences of events in the control of transcription by the <i>lac</i> operon and by gibberellins. This must have a series of model sentences but with key words removed. Learners complete the sentences using their experiences during the lesson and wider research. (F)</p> <p>Extension activity: Learners carry out further research to consider occasions in which a gene is 'switched on' or 'off' in response to stimuli. Examples include developmental genes including those that determine gender, stem cell characteristics and growth.</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

17 Selection and evolution

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
17.1 Variation KC3	17.1.1 Explain, with examples, that phenotypic variation is due to genetic factors or environmental factors or a combination of genetic and environmental factors. 17.1.2 Explain what is meant by discontinuous variation and continuous variation. 17.1.3 Explain the genetic basis of discontinuous variation and continuous variation. 17.1.4 Use the <i>t</i> -test to compare the means of two different samples.	<p>Learners list as many features as they can that we can use to recognise each other. Examples may include hair and eye colour, height, weight, age, sex, and so on. Ask learners to also list features that cannot be seen – such as ABO blood group and tidal volume. Identify which are examples of continuous variation, and which are examples of discontinuous variation. Elicit the idea that genetic and environmental factors tend to be unequal in their contribution to traits that illustrate discontinuous variation and continuous variation.</p> <p>Developing on the previous activity, learners collect data from classmates. Learners then use the <i>t</i>-test to compare means of, for example, height or hair length between males and females, for example. A useful website to support analysis using the <i>t</i>-test is: www.theseashore.org.uk/theseashore/Stats%20for%20twits/T%20Test.html</p> <p>Prepare learners for the next lesson (on natural and artificial selection) by providing a series of questions for them to research in advance using internet sources. Questions may include ‘What is the importance of variation between members of a species?’ and ‘What are the benefits of producing sexually rather than asexually?’ (I)</p>
17.2 Natural and artificial selection KC3 KC4 KC5	17.2.1 Explain that natural selection occurs because populations have the capacity to produce many offspring that compete for resources; in the ‘struggle for existence’, individuals that are best adapted are most likely to survive to reproduce and pass on their alleles to the next generation. 17.2.2 Explain how environmental factors can act as stabilising, disruptive and	<p>It is very important that learners are confident in using some of the key terms they encountered in Topics 6 and 16, including allele, frequency, dominant, recessive, homozygous, heterozygous, mutation, and so on. Ask learners individually to choose a term and offer a definition for it. (F)</p> <p>Use active learning to demonstrate a model that represents the natural selection of the Hb^S allele. Place around 20–30 beads or sweets of two different colours in a non-transparent bag to represent the alleles Hb^A and Hb^S. There should be an equal number of both. Ask a learner to take two sweets at random. If an Hb^A and an Hb^S are taken, count this twice. This models the advantage experienced by heterozygous individuals. If two Hb^S alleles are drawn out, place these out of sight. This models the disadvantage experienced by recessive homozygous individuals. Discuss how this models natural selection and point out the most common phenotype in the sweets that remain on the table. Learners record numbers of each genotype in each generation and construct graphs to show the effect of selection over time.</p> <p>Work through the interactive activity on natural selection with learners: https://phet.colorado.edu/en/simulation/legacy/natural-selection</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
	<p>directional forces of natural selection.</p> <p>17.2.3 Explain how selection, the founder effect and genetic drift, including the bottleneck effect, may affect allele frequencies in populations.</p> <p>17.2.4 Outline how bacteria become resistant to antibiotics as an example of natural selection.</p> <p>17.2.5 Use the Hardy–Weinberg principle to calculate allele and genotype frequencies in populations and state the conditions when this principle can be applied.</p> <p>17.2.6 Describe the principles of selective breeding (artificial selection).</p> <p>17.2.7 Outline the following examples of selective breeding:</p> <ul style="list-style-type: none"> • the introduction of disease resistance to varieties of wheat and rice • inbreeding and hybridisation to produce vigorous, uniform varieties of maize • improving the milk yield of dairy cattle. 	<p>Learners record a step-by-step guide to explain how natural selection occurs. This could consist of a series of diagrams, a flow chart with statements separated by arrows or a short story. Examples of case studies include: warfarin resistance in rats; melanism in peppered moths; cyanogenic clover; antibiotic resistance in bacteria; resistance in insects to insecticides. Alternatively, link with areas of significant research and provide suggested websites. For example, Peter and Rosemary Grant’s research into finches of the Galapagos islands: www.biointeractive.org/classroom-resources/origin-species-beak-finch the adaptive radiation of Anolis lizards on Caribbean Islands: www.biointeractive.org/classroom-resources/lizard-evolution-virtual-lab (I)</p> <p>To support learning of the material in this unit, share an automated Hardy-Weinberg calculator with learners, e.g. www.perinatology.com/calculators/Hardy-Weinberg.htm. Learners may use this to check their answers after manually calculating values. Tutorials and quizzes on the Hardy–Weinberg equilibrium: http://higherred.mheducation.com/sites/dl/free/0767424263/322933/fuentes_4_1.html www.wwnorton.com/college/biology/discoverbio3/core/content/ch17/animations.asp</p> <p>Learners prepare Venn diagrams that compare the processes of natural and artificial selection. They could prepare these on a large piece of paper or card with a range of materials, and subsequently show them in a ‘marketplace’ activity. This involves one member of each group standing by their poster and offering an explanation to other learners as they move around the room. Challenge learners to include in their descriptions references to inbreeding depression, outbreeding and hybrid vigour. Ask learners to include plenty of examples in their work. Examples of natural selection are described above. Examples of artificial selection: www.irri.org/disease-and-pest-resistant-rice www.thoughtco.com/wheat-domestication-the-history-170669 https://learn.genetics.utah.edu/content/evolution/corn/ http://www.holsteinusa.com/holstein_breed/breedhistory.html (I)</p> <p>Challenge learners to write a ‘how to’ guide to help their peers in the following year group to answer questions using the Hardy–Weinberg equations. They should describe the problems they encountered and mistakes they initially made during this lesson. Their work must be written in a casual, friendly tone. (F)</p> <p>Extension activity: Learners suggest why the Hardy–Weinberg equations cannot be used if there are multiple alleles, or if there is a codominant relationship between the alleles, and how selection, the founder effect and genetic drift, including the bottleneck effect, invalidate the equations.</p>

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
17.3 Evolution KC3 KC4 KC5	<p>17.3.1 Outline the theory of evolution as a process leading to the formation of new species from pre-existing species over time, as a result of changes to gene pools from generation to generation.</p> <p>17.3.2 Discuss how DNA sequence data can show evolutionary relationships between species.</p> <p>17.3.3 Explain how speciation may occur as a result of genetic isolation by:</p> <ul style="list-style-type: none"> • geographical separation (allopatric speciation) • ecological and behavioural separation (sympatric speciation). 	<p>Show the <i>Tree of Life</i>, which is a short animated video showing how the process of evolution is thought to have occurred: www.youtube.com/watch?v=H6lrUUDboZo. Inspired by this, learners work in pairs to construct a one-sentence definition for the term 'evolution'. They submit their work in the form of sticky notes to the board, or on a shared electronic document or word cloud (Multimeter). Highlight key terms that are common to many learners' submissions (expected: 'change,' 'selection' and 'extinction'); and examples (some learners may write 'Darwin's finches', 'peppered moth', and 'antibiotic resistance').</p> <p>Learners suggest the traditional types of evidence used to investigate relatedness between different organisms (e.g. comparative morphology and anatomy, fossils, classification and embryology). Provide learners with the DNA sequences of a section of a gene common to four or five different species (e.g. cytochrome-c oxidase). Challenge learners to suggest how this can be used to show evolutionary relationships between the species.</p> <p>Other resources on evolution: https://evolution.berkeley.edu/evolibrary/resourcelibrary.php</p> <p>Provide learners with a number of past paper questions related to evolution, and they work in pairs to construct the questions. Discuss the suggestions learners have submitted. (F)</p>
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

18 Classification, biodiversity and conservation

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
18.1 Classification KC4	<p>18.1.1 Discuss the meaning of the term species, limited to the biological species concept, morphological species concept and ecological species concept.</p> <p>18.1.2 Describe the classification of organisms into three domains: Archaea, Bacteria and Eukarya.</p> <p>18.1.3 State that Archaea and Bacteria are prokaryotes and that there are differences between them, limited to differences in membrane lipids, ribosomal RNA and composition of cell walls.</p> <p>18.1.4 Describe the classification of organisms in the Eukarya domain into the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species.</p> <p>18.1.5 Outline the characteristic features of the kingdoms Protocista, Fungi, Plantae and Animalia.</p> <p>18.1.6 Outline how viruses are classified, limited to the type of nucleic acid (RNA or DNA) and</p>	<p>Display a 'tree of life' showing the three domains and present the information about them in an incomplete table which learners individually complete with ticks/crosses. Learners decide on a memorable mnemonic to help remember the hierarchical order of taxons.</p> <p>Extend by prompting learners to use the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species to classify a variety of organisms. Explore the different types of species concept to deepen learners' understanding.</p> <p>Using internet research, learners prepare a poster explaining why the five-domain classification system was replaced by the three-domain system in the 1970s. Emphasise the evidence from molecular biology. Each poster must include a blank table with three columns (ready to accept examples of each of the three domains). After learners complete their work, discuss why viruses are not included in the three-domain classification. (I)</p> <p>Learners identify examples of species that have been reclassified in the light of molecular evidence. This article describes the news that the African elephant, previously thought of as one species, <i>Loxodonta africana</i>, is in fact two: www.nationalgeographic.com/news/2010/12/101222-african-elephants-two-species-new-science/. You may wish to extend the discussion by considering the concept of convergent evolution, including the vertebrate and cephalopod eyes, e.g. www.zo.utexas.edu/courses/THOC/Convergence.html. Learners produce a factsheet for future reference. (I)</p> <p>Learners summarise the characteristic features of the kingdoms Protocista, Fungi, Plantae and Animalia. For example, they may produce a series of cards showing photomicrographs and photographs of various species with their characteristics on the reverse side. Further information and useful images: www.linnean.org/learning/teaching www.nationalgeographic.com/ www.kew.org/</p> <p>Provide learners with a sheet listing all of the key terms and brief definitions. Ask them to link together 5–10 pairs of terms to write a set of summary notes on this topic. (F)</p> <p>Recap the key terms associated with classification. For example, learners complete a crossword containing clues for various taxa, or identify the 'odd one out' in a series of words. For example, the odd one out in the series 'vertebrate, mollusc and plant' is the plant, because it is a kingdom. (F)</p>

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	whether this is single stranded or double stranded.	Extension activity: Learners invent an imaginary organism and produce a list of characteristics that allows another member of the class to correctly classify it.
18.2 Biodiversity KC5 KC6	18.2.1 Define the terms ecosystem and niche. 18.2.2 Explain that biodiversity can be assessed at different levels, including: <ul style="list-style-type: none"> • the number and range of different ecosystems and habitats • the number of species and their relative abundance • the genetic variation within each species. 18.2.3 Explain the importance of random sampling in determining the biodiversity of an area. 18.2.4 Describe and use suitable methods to assess the distribution and abundance of organisms in an area, limited to frame quadrats, line transects, belt transects and mark-release-recapture using the Lincoln index. 18.2.5 Use Spearman's rank correlation and Pearson's linear correlation to analyse the relationships between two variables, including how biotic and abiotic factors affect the	<p>Before the lesson, ask learners to find definitions of the term biodiversity. They write them on sticky notes, which they attach to the board at the beginning of the lesson. Learners read the work of others and identify any common themes in these definitions. Provide a summary to emphasise which key terms feature.</p> <p>Model the process of random sampling by holding up one page from a large newspaper that contains words of different-sized fonts, images and blank areas. Explain that this simulates a field or area of forest, which has no more than 26 species living there, each species represented by a letter of the alphabet. Make the analogy clear by showing a series of images of a region of coastline, grassland or forest from their local area, or satellite images from e.g. Google Maps.</p> <p>Learners discuss a method to determine how many different species and how many individuals of each species there are. Discuss a suitable strategy, highlighting: the importance of having to sample; taking a number of samples (the sample may be unrepresentative, e.g. a photograph represents a bare rock, so no individuals would be found); choosing the correct size/area of each sample; random sampling (biased sampling – any measurements can only apply to the sample, not to the whole area). (I)</p> <p>Learners prepare a series of flashcards that help them understand the key differences between the terms ecosystem, habitat, and niche. (I)</p> <p>There are significant opportunities for primary practical work during the study of this topic. For example, learners could use quadrats to investigate species abundance or distribution in a grassy area (e.g. a playing field, a lawn or a meadow), a rocky shore, or a sand dune. However, if these are not available, learners investigate different types of moss or lichen on a rock or on a tree trunk, using miniature quadrats. They record results as species frequency, species density, percentage cover, or use an abundance scale (e.g. ACFOR). Random sampling can be used, or a systematic sampling method with quadrats to sample organisms along a transect line, perhaps by collecting data to calculate Simpson's index of diversity.</p> <p>Model the use of the Lincoln index using a container of beans or beads. Remove a small handful to be marked for the first sample, add them back to the container, shake them up, remove a second sample for the 'recapture' (closed eyes) and record results, obtaining the estimate using the formula.</p>

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	<p>distribution and abundance of species.</p> <p>18.2.6 Use Simpson's index of diversity (D) to calculate the biodiversity of an area, and state the significance of different values of D.</p>	<p>Using model data, demonstrate how to use Spearman's rank correlation and Pearson's linear correlation to analyse the relationships between two variables. You may wish to help learners to become familiar with these statistical tests by using data that is familiar to them at first, for example, the correlation between age and height (Pearson's), or between the year and the population of your country (Spearman's rank). Help learners to then use these tests to investigate how biotic and abiotic factors affect the distribution and abundance of species.</p>
<p>18.3 Conservation</p> <p>KC5</p>	<p>18.3.1 Explain why populations and species can become extinct.</p> <p>18.3.2 Outline reasons for the need to maintain biodiversity.</p> <p>18.3.3 Outline the roles of zoos, botanic gardens, conserved areas (including national parks and marine parks), 'frozen zoos' and seed banks, in the conservation of endangered species.</p> <p>18.3.4 Describe methods of assisted reproduction used in the conservation of endangered mammals, limited to IVF, embryo transfer and surrogacy.</p> <p>18.3.5 Explain reasons for controlling invasive alien species.</p> <p>18.3.6 Outline the role in conservation of the International Union for the</p>	<p>Project a world map onto the board. Learners put sticky notes onto the relevant countries or regions that host key threats to biodiversity. Encourage learners to identify the patterns that emerge, e.g. regions of the planet that are around the equator (coral reefs and rainforest) and have a high human population density. Extend the discussion by discussing reasons for the need to maintain biodiversity.</p> <p>Learners can be overwhelmed by the number and names of species that are threatened. As support, ask learners to consider the range of threats that affect a particular example. For instance, coral reefs in the Caribbean are threatened by globally increasing ocean temperatures, tourism, and so on. Use this, or a similar example, to explain reasons for controlling invasive alien species (here, predation by invasive lionfish).</p> <p>Learners write a definition of the term 'endangered', researching a named example and including the species name and the reasons for it being endangered. You may extend this activity by considering listed species on: www.worldwildlife.org/species/directory?direction=desc&sort=extinction_status and www.iucnredlist.org/</p> <p>Provide an opportunity for each learner to research one species that is considered endangered. Either host a visit to a national park, nature reserve, zoo or botanic garden to enable learners to see the work that is being done locally, or ask learners to carry out research using websites for the International Union for the Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) www.iucnredlist.org and www.cites.org/. Each learner prepares a one-page summary that lists key features of the species and why it is endangered. Provide a 'scaffold' to help them, containing subtitles and missing words, to maintain consistency. Bind learners' work into a booklet so that the whole class has a copy for future reference</p> <p>Learners carry out research, and summarise their findings in the form of a blog, podcast or website, into San Diego Frozen Zoo Global and the Millennium Seed Bank at Kew Gardens in the UK: www.sandiegozooglobal.org www.kew.org/science-conservation/save-seed-prosper/millennium-seed-bank/index.htm.</p>

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	Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	Extension activity: Learners reflect on whether single-celled organisms (including bacteria) could be endangered, and how these could be identified and protected.
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support (F)		

19 Genetic technology

Syllabus ref. and Key Concepts (KC)	Learning outcomes	Suggested teaching activities
<p>19.1 Principles of genetic technology</p> <p>KC2</p> <p>KC3</p> <p>KC6</p>	<p>19.1.1 Define the term recombinant DNA.</p> <p>19.1.2 Explain that genetic engineering is the deliberate manipulation of genetic material to modify specific characteristics of an organism and that this may involve transferring a gene into an organism so that the gene is expressed.</p> <p>19.1.3 Explain that genes to be transferred into an organism may be:</p> <ul style="list-style-type: none"> • extracted from the DNA of a donor organism • synthesised from the mRNA of a donor organism • synthesised chemically from nucleotides. <p>19.1.4 Explain the roles of restriction endonucleases, DNA ligase, plasmids, DNA polymerase and reverse transcriptase in the transfer of a gene into an organism.</p> <p>19.1.5 Explain why a promoter may have to be</p>	<p>Resource Plus</p> <p>Carry out the <i>Investigating how gel electrophoresis is used to separate DNA fragments of different lengths.</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>In this task, learners follow instructions to carry out gel electrophoresis to identify the genotype of different people for a specific gene. As part of this task, learners undertake a circus of activities associated with gel electrophoresis and analyse a gel to draw conclusions. Additional animations can further support this activity, such as: https://learn.genetics.utah.edu/content/labs/gel/ www.medicine.mcgill.ca/physio/vlab/Other_exps/endo/electrophoresis.htm, www.sumanasinc.com/webcontent/animations/content/pcr.html</p> <p>Learners match a series of key terms to definitions (taken from Topic 6) that concern the structure of DNA and RNA. Words will include specific, complementary and hybridisation. (F)</p> <p>Learners work in pairs to undertake an activity focusing on the analysis of the stages of genetic engineering. Provide each learner with an image showing one of the steps undertaken in the process of genetic engineering. Also provide each learner with a piece of blank paper. Each learner takes it in turn to describe the image to their partner using only spoken words (they cannot sketch or use hand signals). Their partner is expected to reproduce the diagram during the description and then both learners discuss what it shows. (I)</p> <p>The process of genetic engineering is often explained by using analogy (e.g. the genetic engineer's 'toolkit'). It can be of great help to learners to think that the process consists of 'tools'. Examples include restriction enzymes being represented as scissors, and glue acting as DNA ligase. Animations that use analogies: www.dnafb.org/ http://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120078/bio37.swf::Restriction%20Endonucleases http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch03/3-26.html (I)</p> <p>Learners compare and contrast cellular DNA replication during the cell cycle with the process of PCR. Provide a list of characteristics of each process to each learner. Learners consider the similarities and the differences between them by cutting out the statements, mixing them up and then sticking the</p>

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	<p>transferred into an organism as well as the desired gene.</p> <p>19.1.6 Explain how gene expression may be confirmed by the use of marker genes coding for fluorescent products.</p> <p>19.1.7 Explain that gene editing is a form of genetic engineering involving the insertion, deletion or replacement of DNA at specific sites in the genome.</p> <p>19.1.8 Describe and explain the steps involved in the polymerase chain reaction (PCR) to clone and amplify DNA, including the role of <i>Taq</i> polymerase.</p> <p>19.1.9 Describe and explain how gel electrophoresis is used to separate DNA fragments of different lengths.</p> <p>19.1.10 Outline how microarrays are used in the analysis of genomes and in detecting mRNA in studies of gene expression.</p> <p>19.1.11 Outline the benefits of using databases that provide information about</p>	<p>characteristics on a large sheet of paper to re-create the table. To assess understanding, learners prepare a piece of paper that has 'DNA replication' on one side, and 'PCR' on the other. They hold up the correct side to show you when you call out a statement. (I)</p> <p>Provide opportunities for learners to undertake calculations related to the process of PCR. The three stages of PCR are repeated n times, giving $2n$ copies of the original DNA. Learners calculate the number of molecules of DNA produced from one double-stranded starting molecule, after a given number of cycles. This would be an excellent opportunity to use mini-whiteboards with learners so that you can immediately see who is able to calculate the figures accurately, and who needs further support. (F)</p> <p>Support learners as they explore a database associated with bioinformatics, such as Ensembl (genome), GenBank (DNA sequence), UniProt (protein sequence), PDB (protein structure) and COSMIC (somatic mutations in cancer). Provide an opportunity for learners to compare the primary sequence of a protein common to a wide range of organisms (e.g. ribonuclease, cytochrome c-oxidase, or others). Learners compare the number and sequence of amino acids and comment on the similarities and differences. This is an opportunity to revisit the nature of some amino acids (which ones can form disulfide bonds), which they encountered in Topic 2, and to suggest the evolutionary relationships between them. The following is a useful source of lesson ideas: www.bioinformaticaindeklas.nl/en/</p> <p>Learners explore the new technique of CRISPR/CAS9-dependent gene editing by carrying out research to write a newspaper article for a general (non-scientific) audience. The challenge is for them to describe and explain the procedure in simple terms, but with sufficient detail and scientifically accurate. Encourage learners to show their work to their family or friends who may not study biology. (I)</p> <p>Learners make a model microarray using items of rubbish (e.g. empty food packets, cardboard, paper, etc.). They then take it in turns to explain to you how this gene technology works with reference to sources they have found in their textbook or online.</p> <p>Many of the procedures listed in the syllabus in this chapter require learners to recall the series of steps that are undertaken when carrying them out in the laboratory. Support learners to produce a clear summary set of notes on this topic, perhaps by asking them to complete a series of missing-word boxes in a flow diagram, or arranging a series of numbered statements into the correct order. (F)</p> <p>Extension activity: Provide learners with a brief historical perspective on the use of antibiotic resistance markers to enable screening and explain why these are becoming less favoured.</p>

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	nucleotide sequences of genes and genomes, and amino acid sequences of proteins and protein structures.	
19.2 Genetic technology applied to medicine KC3 KC2	19.2.1 Explain the advantages of using recombinant human proteins to treat disease, using the examples insulin, factor VIII and adenosine deaminase. 19.2.2 Outline the advantages of genetic screening, using the examples of breast cancer (<i>BRCA1</i> and <i>BRCA2</i>), Huntington's disease and cystic fibrosis. 19.2.3 Outline how genetic diseases can be treated with gene therapy, using the examples severe combined immunodeficiency (SCID) and inherited eye diseases. 19.2.4 Discuss the social and ethical considerations of using genetic screening and gene therapy in medicine.	<p>Show learners the sequence of DNA from a normal allele of a given gene, and then a mutant allele. Using their knowledge of key terms they encountered in Topics 6 and 16, learners engage in a 'think, pair, share' activity to describe the difference, and refresh their knowledge of how mutations happen and why they lead to a change in phenotype. Provide a writing frame to help learners set out the steps that occur to change the function of a protein when a mutation happens. The frame should have a series of model sentences with key words removed. Extend the discussion to consider the advantages of using recombinant human proteins to treat these diseases. (F)</p> <p>Learners work in pairs or small groups to design and produce a poster on the treatments offered by gene therapy, for use in a public awareness campaign. (I)</p> <p>Discuss the social and ethical considerations of using genetic screening and gene therapy. Include in the discussion genetic screening for conditions for which treatment does and does not exist. Remind learners to keep the language they use simple, but based on accurate scientific explanations.</p> <p>Learners write their ideas under four headings on pieces of paper 'Genetic screening – social consideration'; 'Genetic screening – ethical consideration'; 'Gene therapy - social consideration'; 'Gene therapy - ethical consideration'. Learners justify their statements to a small group and, if agreed, add it to a poster. Display the posters for learners to consider and make notes. (I)</p> <p>Learners write the shortest sentence possible using a range of key terms that feature in the topic of genetic technology applied to medicine. This is a good way to focus learners on developing their higher-order thinking skills to make sense of the meaning of these terms, rather than simply recall them. (F)</p>
19.3 Genetically modified organisms in agriculture KC3	19.3.1 Explain that genetic engineering may help to solve the global demand for food by improving the quality and productivity of farmed	Learners work in pairs to research how many, if any, local crops in their country and in other neighbouring countries are genetically modified organisms (GMOs). After 2–3 minutes of discussion, the pairs join together into groups of four and then groups of eight to discuss this further and come up with an agreed list of examples and associated information. One or two learners from each group then draw and label the group's ideas on the class board to form a summary list. Through a class discussion, develop an

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	<p>animals and crop plants, using the examples of GM salmon, herbicide resistance in soybean and insect resistance in cotton.</p> <p>19.3.2 Discuss the ethical and social implications of using genetically modified organisms (GMOs) in food production.</p>	<p>understanding that some countries grow more GMOs in food production than others. Discuss the reasons for this.</p> <p>In groups, learners use resources to produce an annotated flow diagram to summarise how one crop or livestock from the list specified in the syllabus was produced. Make copies of learners' work and share with the rest of the class. (F)</p> <p>Extension activity: Learners carry out calculations to compare, in ratios and percentages, the sizes of the areas on which GMOs and non-GMOs are grown or farmed. Extend the activity by considering the ethical and social implications of using genetically modified organisms (GMOs) in food production.</p>
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