GCSE
BIOLOGY
8461

Specification
For teaching from September 2016 onwards
For GCSE exams in 2018 onwards

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Are you using the latest version of this specification?

- You will always find the most up-to-date version of this specification on our website at aqa.org.uk/8461
- We will write to you if there are significant changes to the specification.

1 Introduction

1.1 Why choose AQA for GCSE Biology

Our philosophy: science for all

We believe that science has something to offer every student. That's why we have a suite of science qualifications for Key Stage 4 – to suit students of all abilities and all aspirations.

You'll see that our GCSE Biology, along with Chemistry and Physics, is a clear straightforward specification, with clear straightforward exams, so all your students can realise their potential.

Our specification has been developed with teachers

We've involved over a thousand teachers in developing our specification, exams and resources. So you can be confident that our GCSE Biology is relevant and interesting to teach and to learn. We've ensured that:

- the subject content is presented clearly, in a logical teaching order. We've also given teaching guidance and signposted opportunities for skills development throughout the specification
- the subject content and required practicals in our GCSE Combined Science: Trilogy are also in our GCSE Biology, Chemistry and Physics. So you have the flexibility to co-teach or to move your students between courses
- all our science qualifications provide opportunities for progression. Our GCSE Biology includes progression in the subject content and consistency in the exam questions, so that your students have the best preparation for A-level.

Our practicals have been trialled by teachers

There's no better way to learn about science than through purposeful practical activities as part of day to day teaching and learning. Our ten required practicals:

- are clearly laid out in the specification, so you know exactly what's required
- are deliberately open, so you can teach in the way that suits you and your students
- have already been trialled in schools.

You'll find even more support and guidance in our practical handbook, which includes recommendations and advice from teachers in the trial.

Straightforward exams, so students can give straightforward answers

We've improved our question papers. You'll find that our exams:

- use more straightforward language and fewer words so they're easier to understand
- have fewer contexts so students don't get confused
- have questions that increase in difficulty so students feel confident
- have been written with our GCSE Maths and A-level science teams, so students have consistency between content and questions.

Over 3,000 students have sat our specimen question papers and they agree that they're clearer and more straightforward than ever.

We don't profit from education – you do

We are an educational charity focused on the needs of teachers and students. This means that we spend our income on improving the quality of our specifications, exams, resources and support.

You can find out all about our Science qualifications at aqa.org.uk/science

1.2 Support and resources to help you teach

We've worked with experienced teachers to provide you with a range of resources that will help you confidently plan, teach and prepare for exams.

Teaching resources

Visit aqa.org.uk/8461 to see all our teaching resources. They include:

- additional practice papers to help students prepare for exams
- schemes of work, written by experienced teachers, including a scheme of work specifically for Foundation tier students
- a practical handbook, including recommendations and advice from teachers who've trialled our practicals
- AQA-approved textbooks reviewed by experienced senior examiners
- training courses to help you deliver AQA Biology qualifications
- subject expertise courses for all teachers, from newly-qualified teachers who are just getting started to experienced teachers looking for fresh inspiration.

Preparing for exams

Visit aqa.org.uk/8461 for everything you need to prepare for our exams, including:

- past papers, mark schemes and examiners' reports
- specimen papers and mark schemes for new courses
- Exampro: a searchable bank of past AQA exam questions
- exemplar student answers with examiner commentaries.

Analyse your students' results with Enhanced Results Analysis (ERA)

Find out which questions were the most challenging, how the results compare to previous years and where your students need to improve. ERA, our free online results analysis tool, will help you see where to focus your teaching. Register at aqa.org.uk/era

For information about results, including maintaining standards over time, grade boundaries and our post-results services, visit aqa.org.uk/results

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Wherever you are in your career, there's always something new to learn. As well as subject-specific training, we offer a range of courses to help boost your skills.

- Improve your teaching skills in areas including differentiation, teaching literacy and meeting Ofsted requirements.

- Prepare for a new role with our leadership and management courses.

You can attend a course at venues around the country, in your school or online – whatever suits your needs and availability. Find out more at coursesandevents.aqa.org.uk

Help and support available

Visit our website for information, guidance, support and resources at aqa.org.uk/8461

If you'd like us to share news and information about this qualification, sign up for emails and updates at aqa.org.uk/keepinformedscience

Alternatively, you can call or email our subject team direct.

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2 Specification at a glance

This qualification is linear. Linear means that students will sit all their exams at the end of the course.

2.1 Subject content

1. Cell biology (page 18)
2. Organisation (page 25)
3. Infection and response (page 33)
4. Bioenergetics (page 40)
5. Homeostasis and response (page 44)
6. Inheritance, variation and evolution (page 55)
7. Ecology (page 70)

2.2 Assessments

Paper 1
What's assessed Topics 1–4: Cell biology; Organisation; Infection and response; and Bioenergetics.
How it's assessed • Written exam: 1 hour 45 minutes • Foundation and Higher Tier • 100 marks • 50% of GCSE
Questions • Multiple choice, structured, closed short answer and open response.

Paper 2
What's assessed Topics 5–7: Homeostasis and response; Inheritance, variation and evolution; and Ecology.
How it's assessed • Written exam: 1 hour 45 minutes • Foundation and Higher Tier • 100 marks • 50% of GCSE
Questions • Multiple choice, structured, closed short answer and open response.

3 Working scientifically

Science is a set of ideas about the material world. We have included all the parts of what good science is at GCSE level: whether it be investigating, observing, experimenting or testing out ideas and thinking about them. The way scientific ideas flow through the specification will support you in building a deep understanding of science with your students. We know this will involve talking about, reading and writing about science plus the actual doing, as well as representing science in its many forms both mathematically and visually through models.

This specification encourages the development of knowledge and understanding in science through opportunities for working scientifically. Working scientifically is the sum of all the activities that scientists do. We feel it is so important that we have woven it throughout our specification and written papers.

Our schemes of work will take this further for you and signpost a range of ways to navigate through this qualification so your students are engaged and enthused. These free resources support the use of mathematics as a tool for thinking through the use of mathematical language in explanations, applications and evaluations.

The tables below show examples of the ways working scientifically could be assessed.

1 Development of scientific thinking

Students should be able to:	Examples of what students could be asked to do in an exam
WS 1.1 Understand how scientific methods and theories develop over time.	Give examples to show how scientific methods and theories have changed over time. Explain, with an example, why new data from experiments or observations led to changes in models or theories. Decide whether or not given data supports a particular theory.
WS 1.2 Use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts.	Recognise/draw/interpret diagrams. Translate from data to a representation with a model. Use models in explanations, or match features of a model to the data from experiments or observations that the model describes or explains. Make predictions or calculate quantities based on the model or show its limitations. Give examples of ways in which a model can be tested by observation or experiment.

Students should be able to:	Examples of what students could be asked to do in an exam
WS 1.3 Appreciate the power and limitations of science and consider any ethical issues which may arise.	Explain why data is needed to answer scientific questions, and why it may be uncertain, incomplete or not available. Outline a simple ethical argument about the rights and wrongs of a new technology.
WS 1.4 Explain everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments.	Describe and explain specified examples of the technological applications of science. Describe and evaluate, with the help of data, methods that can be used to tackle problems caused by human impacts on the environment.
WS 1.5 Evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences.	Give examples to show that there are hazards associated with science-based technologies which have to be considered alongside the benefits. Suggest reasons why the perception of risk is often very different from the measured risk (eg voluntary vs imposed risks, familiar vs unfamiliar risks, visible vs invisible hazards).
WS 1.6 Recognise the importance of peer review of results and of communicating results to a range of audiences.	Explain that the process of peer review helps to detect false claims and to establish a consensus about which claims should be regarded as valid. Explain that reports of scientific developments in the popular media are not subject to peer review and may be oversimplified, inaccurate or biased.

2 Experimental skills and strategies

Students should be able to:	Examples of what students could be asked to do in an exam
WS 2.1 Use scientific theories and explanations to develop hypotheses.	Suggest a hypothesis to explain given observations or data.

Students should be able to:	Examples of what students could be asked to do in an exam
WS 2.2 Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.	Describe a practical procedure for a specified purpose. Explain why a given practical procedure is well designed for its specified purpose. Explain the need to manipulate and control variables. Identify in a given context: • the independent variable as the one that is changed or selected by the investigator • the dependent variable that is measured for each change in the independent variable • control variables and be able to explain why they are kept the same. Apply understanding of apparatus and techniques to suggest a procedure for a specified purpose.
WS 2.3 Apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment.	Describe/suggest/select the technique, instrument, apparatus or material that should be used for a particular purpose, and explain why.
WS 2.4 Carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.	Identify the main hazards in specified practical contexts. Suggest methods of reducing the risk of harm in practical contexts.
WS 2.5 Recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative.	Suggest and describe an appropriate sampling technique in a given context.
WS 2.6 Make and record observations and measurements using a range of apparatus and methods.	Read measurements off a scale in a practical context and record appropriately.
WS 2.7 Evaluate methods and suggest possible improvements and further investigations.	Assess whether sufficient, precise measurements have been taken in an experiment. Evaluate methods with a view to determining whether or not they are valid.

3 Analysis and evaluation

Apply the cycle of collecting, presenting and analysing data, including:

Students should be able to:	Examples of what students could be asked to do in an exam
WS 3.1 Presenting observations and other data using appropriate methods.	Construct and interpret frequency tables and diagrams, bar charts and histograms. Plot two variables from experimental or other data.
WS 3.2 Translating data from one form to another.	Translate data between graphical and numeric form.
WS 3.3 Carrying out and represent mathematical and statistical analysis.	For example: • use an appropriate number of significant figures • find the arithmetic mean and range of a set of data • construct and interpret frequency tables and diagrams, bar charts and histograms • make order of magnitude calculations • change the subject of an equation • substitute numerical values into algebraic equations using appropriate units for physical quantities • determine the slope and intercept of a linear graph • draw and use the slope of a tangent to a curve as a measure of rate of change • understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.
WS 3.4 Representing distributions of results and make estimations of uncertainty.	Apply the idea that whenever a measurement is made, there is always some uncertainty about the result obtained. Use the range of a set of measurements about the mean as a measure of uncertainty.
WS 3.5 Interpreting observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.	Use data to make predictions. Recognise or describe patterns and trends in data presented in a variety of tabular, graphical and other forms. Draw conclusions from given observations.
WS 3.6 Presenting reasoned explanations including relating data to hypotheses.	Comment on the extent to which data is consistent with a given hypothesis. Identify which of two or more hypotheses provides a better explanation of data in a given context.

Students should be able to:	Examples of what students could be asked to do in an exam
WS 3.7 Being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.	Apply the following ideas to evaluate data to suggest improvements to procedures and techniques. • An accurate measurement is one that is close to the true value. • Measurements are precise if they cluster closely. • Measurements are repeatable when repetition, under the same conditions by the same investigator, gives similar results. • Measurements are reproducible if similar results are obtained by different investigators with different equipment. • Measurements are affected by random error due to results varying in unpredictable ways; these errors can be reduced by making more measurements and reporting a mean value. • Systematic error is due to measurement results differing from the true value by a consistent amount each time. • Any anomalous values should be examined to try to identify the cause and, if a product of a poor measurement, ignored.
WS 3.8 Communicating the scientific rationale for investigations, methods used, findings and reasoned conclusions through paper-based and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms.	Present coherent and logically structured responses, using the ideas in 2 Experimental skills and strategies and 3 Analysis and evaluation, applied to the required practicals, and other practical investigations given appropriate information.

4 Scientific vocabulary, quantities, units, symbols and nomenclature

Students should be able to:	Examples of what students could be asked to do in an exam
WS 4.1 Use scientific vocabulary, terminology and definitions. WS 4.2 Recognise the importance of scientific quantities and understand how they are determined. WS 4.3 Use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate. WS 4.4 Use prefixes and powers of ten for orders of magnitude (eg tera, giga, mega, kilo, centi, milli, micro and nano). WS 4.5 Interconvert units. WS 4.6 Use an appropriate number of significant figures in calculation.	The knowledge and skills in this section apply across the specification, including the required practicals.

4 Subject content

This specification is presented in a two column format. The left hand column contains the specification content that all students must cover, and that can be assessed in the written papers. The right hand column exemplifies some key opportunities for the following skills to be developed: WS refers to Working scientifically (page 11), MS refers to Mathematical requirements (page 91) and AT refers to Use of apparatus and techniques (page 93). These are not the only opportunities. Teachers are encouraged to introduce all of these skills where appropriate throughout the course.

Each topic begins with an overview. The overview puts the topic into a broader context and is intended to encourage an overarching approach to both the teaching and learning of each of the topic areas. It is not directly assessed. Any assessable content in this overview is replicated in the left hand column.

Most of the content is common with and co-teachable with GCSE Combined Science: Trilogy. Content that is only applicable to biology is indicated by (biology only) either next to the topic heading where it applies to the whole topic or immediately preceding each paragraph or bullet point as applicable. Content that is only applicable to higher tier is indicated by (HT only) either next to the topic heading where it applies to the whole topic or immediately preceding each paragraph or bullet point as applicable.

It is good practice to teach and develop all of the mathematical skills throughout the course. Some mathematical skills will only be assessed in certain subject areas. These are detailed in Mathematical requirements (page 91).

Science is a practical subject. Details of the assessment of required practicals can be found in Practical assessment (page 93).

Working scientifically (page 11) and Use of apparatus and techniques (page 93) skills will be assessed across all papers.

Fundamental biological concepts and principles

Students should have a basic understanding of the following biological principles and be able to apply them in either paper:

- The structure and functioning of cells and how they divide by mitosis and meiosis from sections Cell biology (page 18) and Meiosis (page 56).
- That variation occurs when gametes fuse at fertilisation from section Sexual and asexual reproduction (page 56).
- The two essential reactions for life on Earth: photosynthesis and respiration from sections Photosynthetic reaction (page 40) and Aerobic and anaerobic respiration (page 43).
- Metabolism is the sum of all the reactions happening in a cell or organism, in which molecules are made or broken down from section Metabolism (page 44).
- All molecules are recycled between the living world and the environment to sustain life from section How materials are cycled (page 74).

Students should be able to recall and use this knowledge in questions that link different areas of the specification to develop coherent arguments and explanations.

4.1 Cell biology

Cells are the basic unit of all forms of life. In this section we explore how structural differences between types of cells enables them to perform specific functions within the organism. These differences in cells are controlled by genes in the nucleus. For an organism to grow, cells must divide by mitosis producing two new identical cells. If cells are isolated at an early stage of growth before they have become too specialised, they can retain their ability to grow into a range of different types of cells. This phenomenon has led to the development of stem cell technology. This is a new branch of medicine that allows doctors to repair damaged organs by growing new tissue from stem cells.

4.1.1 Cell structure

4.1.1.1 Eukaryotes and prokaryotes

Content	Key opportunities for skills development
Plant and animal cells (eukaryotic cells) have a cell membrane, cytoplasm and genetic material enclosed in a nucleus.	
Bacterial cells (prokaryotic cells) are much smaller in comparison. They have cytoplasm and a cell membrane surrounded by a cell wall. The genetic material is not enclosed in a nucleus. It is a single DNA loop and there may be one or more small rings of DNA called plasmids.	
Students should be able to demonstrate an understanding of the scale and size of cells and be able to make order of magnitude calculations, including the use of standard form.	MS 1b, 2a, 2h WS 4.4 Use prefixes centi, milli, micro and nano.

4.1.1.2 Animal and plant cells

Content	Key opportunities for skills development
Students should be able to explain how the main sub-cellular structures, including the nucleus, cell membranes, mitochondria, chloroplasts in plant cells and plasmids in bacterial cells are related to their functions. Most animal cells have the following parts: • a nucleus • cytoplasm • a cell membrane • mitochondria • ribosomes. In addition to the parts found in animal cells, plant cells often have: • chloroplasts • a permanent vacuole filled with cell sap. Plant and algal cells also have a cell wall made of cellulose, which strengthens the cell.	WS 1.2 Recognise, draw and interpret images of cells.
Students should be able to use estimations and explain what they should be used to judge the relative size or area of sub-cellular structures.	MS 1d, 3a AT 7 Images of cells in videos, bioviewers, photographs and micrographs can be used as comparison for students own drawings.

Required practical activity 1: use a light microscope to observe, draw and label a selection of plant and animal cells. A magnification scale must be included.

AT skills covered by this practical activity: AT 1 and 7.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Practical assessment (page 95).

4.1.1.3 Cell specialisation

Content	Key opportunities for skills development
Students should be able to, when provided with appropriate information, explain how the structure of different types of cell relate to their function in a tissue, an organ or organ system, or the whole organism. Cells may be specialised to carry out a particular function: • sperm cells, nerve cells and muscle cells in animals • root hair cells, xylem and phloem cells in plants.	

4.1.1.4 Cell differentiation

Content	Key opportunities for skills development
Students should be able to explain the importance of cell differentiation. As an organism develops, cells differentiate to form different types of cells. • Most types of animal cell differentiate at an early stage. • Many types of plant cells retain the ability to differentiate throughout life. In mature animals, cell division is mainly restricted to repair and replacement. As a cell differentiates it acquires different sub-cellular structures to enable it to carry out a certain function. It has become a specialised cell.	

4.1.1.5 Microscopy

Content	Key opportunities for skills development
Students should be able to: • understand how microscopy techniques have developed over time • explain how electron microscopy has increased understanding of sub-cellular structures. Limited to the differences in magnification and resolution. An electron microscope has much higher magnification and resolving power than a light microscope. This means that it can be used to study cells in much finer detail. This has enabled biologists to see and understand many more sub-cellular structures.	WS 1.1

Content	Key opportunities for skills development
Students should be able to carry out calculations involving magnification, real size and image size using the formula: $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$ Students should be able to express answers in standard form if appropriate.	MS 1a, 1b, 2h, 3b WS 4.4 Use prefixes centi, milli, micro and nano.

4.1.1.6 Culturing microorganisms (biology only)

Content	Key opportunities for skills development
Bacteria multiply by simple cell division (binary fission) as often as once every 20 minutes if they have enough nutrients and a suitable temperature. Bacteria can be grown in a nutrient broth solution or as colonies on an agar gel plate. Uncontaminated cultures of microorganisms are required for investigating the action of disinfectants and antibiotics.	MS 1a, 1b, 1d, 2a, 2h Calculate the number of bacteria in a population after a certain time if given the mean division time. MS 5c Calculate cross-sectional areas of colonies or clear areas around colonies using πr^2.
Students should be able to describe how to prepare an uncontaminated culture using aseptic technique. They should be able to explain why: • Petri dishes and culture media must be sterilised before use • inoculating loops used to transfer microorganisms to the media must be sterilised by passing them through a flame • the lid of the Petri dish should be secured with adhesive tape and stored upside down • in school and college laboratories, cultures should be incubated at a maximum temperature of 25°C.	WS 2.2, 2.4
Students should be able to calculate cross-sectional areas of colonies or clear areas around colonies using πr^2.	MS 5c
Students should be able to calculate the number of bacteria in a population after a certain time if given the mean division time.	MS 1a, 2a, 2h
(HT only) Students should be able to express the answer in standard form.	MS 1b

Required practical activity 2: investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition.

AT skills covered by this practical activity: AT 1, 3, 4 and 8.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 96).

There are links with this practical to Antibiotics and painkillers (page 36).

4.1.2 Cell division

4.1.2.1 Chromosomes

Content	Key opportunities for skills development
The nucleus of a cell contains chromosomes made of DNA molecules. Each chromosome carries a large number of genes. In body cells the chromosomes are normally found in pairs.	WS 1.2 Use models and analogies to develop explanations of how cells divide.

4.1.2.2 Mitosis and the cell cycle

Content	Key opportunities for skills development
Cells divide in a series of stages called the cell cycle. Students should be able to describe the stages of the cell cycle, including mitosis. During the cell cycle the genetic material is doubled and then divided into two identical cells. Before a cell can divide it needs to grow and increase the number of sub-cellular structures such as ribosomes and mitochondria. The DNA replicates to form two copies of each chromosome. In mitosis one set of chromosomes is pulled to each end of the cell and the nucleus divides. Finally the cytoplasm and cell membranes divide to form two identical cells. Students need to understand the three overall stages of the cell cycle but do not need to know the different phases of the mitosis stage. Cell division by mitosis is important in the growth and development of multicellular organisms. Students should be able to recognise and describe situations in given contexts where mitosis is occurring.	

4.1.2.3 Stem cells

Content	Key opportunities for skills development
A stem cell is an undifferentiated cell of an organism which is capable of giving rise to many more cells of the same type, and from which certain other cells can arise from differentiation. Students should be able to describe the function of stem cells in embryos, in adult animals and in the meristems in plants. Stem cells from human embryos can be cloned and made to differentiate into most different types of human cells. Stem cells from adult bone marrow can form many types of cells including blood cells. Meristem tissue in plants can differentiate into any type of plant cell, throughout the life of the plant. Knowledge and understanding of stem cell techniques are not required. Treatment with stem cells may be able to help conditions such as diabetes and paralysis.	
In therapeutic cloning an embryo is produced with the same genes as the patient. Stem cells from the embryo are not rejected by the patient's body so they may be used for medical treatment. The use of stem cells has potential risks such as transfer of viral infection, and some people have ethical or religious objections. Stem cells from meristems in plants can be used to produce clones of plants quickly and economically. • Rare species can be cloned to protect from extinction. • Crop plants with special features such as disease resistance can be cloned to produce large numbers of identical plants for farmers.	WS 1.3 Evaluate the practical risks and benefits, as well as social and ethical issues, of the use of stem cells in medical research and treatments.

4.1.3 Transport in cells

4.1.3.1 Diffusion

Content	Key opportunities for skills development
Substances may move into and out of cells across the cell membranes via diffusion. Diffusion is the spreading out of the particles of any substance in solution, or particles of a gas, resulting in a net movement from an area of higher concentration to an area of lower concentration. Some of the substances transported in and out of cells by diffusion are oxygen and carbon dioxide in gas exchange, and of the waste product urea from cells into the blood plasma for excretion in the kidney. Students should be able to explain how different factors affect the rate of diffusion. Factors which affect the rate of diffusion are: • the difference in concentrations (concentration gradient) • the temperature • the surface area of the membrane. A single-celled organism has a relatively large surface area to volume ratio. This allows sufficient transport of molecules into and out of the cell to meet the needs of the organism.	WS 1.2 Recognise, draw and interpret diagrams that model diffusion. WS 1.5 Use of isotonic drinks and high energy drinks in sport.
Students should be able to calculate and compare surface area to volume ratios. Students should be able to explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area to volume ratio. Students should be able to explain how the small intestine and lungs in mammals, gills in fish, and the roots and leaves in plants, are adapted for exchanging materials. In multicellular organisms, surfaces and organ systems are specialised for exchanging materials. This is to allow sufficient molecules to be transported into and out of cells for the organism's needs. The effectiveness of an exchange surface is increased by: • having a large surface area • a membrane that is thin, to provide a short diffusion path • (in animals) having an efficient blood supply • (in animals, for gaseous exchange) being ventilated.	MS 1c, 5c

4.1.3.2 Osmosis

Content	Key opportunities for skills development
Water may move across cell membranes via osmosis. Osmosis is the diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.	WS 1.2 Recognise, draw and interpret diagrams that model osmosis.
Students should be able to: • use simple compound measures of rate of water uptake • use percentiles • calculate percentage gain and loss of mass of plant tissue.	MS 1a, 1c
Students should be able to plot, draw and interpret appropriate graphs.	MS 4a, 4b, 4c, 4d

Required practical activity 3: investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

AT skills covered by this practical activity: AT 1, 3 and 5.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Required practical activity 3 (page 96).

4.1.3.3 Active transport

Content	Key opportunities for skills development
Active transport moves substances from a more dilute solution to a more concentrated solution (against a concentration gradient). This requires energy from respiration. Active transport allows mineral ions to be absorbed into plant root hairs from very dilute solutions in the soil. Plants require ions for healthy growth. It also allows sugar molecules to be absorbed from lower concentrations in the gut into the blood which has a higher sugar concentration. Sugar molecules are used for cell respiration. Students should be able to: • describe how substances are transported into and out of cells by diffusion, osmosis and active transport • explain the differences between the three processes.	There are links with this content to Cell specialisation (page 20).

4.2 Organisation

In this section we will learn about the human digestive system which provides the body with nutrients and the respiratory system that provides it with oxygen and removes carbon dioxide. In

each case they provide dissolved materials that need to be moved quickly around the body in the blood by the circulatory system. Damage to any of these systems can be debilitating if not fatal. Although there has been huge progress in surgical techniques, especially with regard to coronary heart disease, many interventions would not be necessary if individuals reduced their risks through improved diet and lifestyle. We will also learn how the plant's transport system is dependent on environmental conditions to ensure that leaf cells are provided with the water and carbon dioxide that they need for photosynthesis.

4.2.1 Principles of organisation

Content	Key opportunities for skills development
Cells are the basic building blocks of all living organisms. A tissue is a group of cells with a similar structure and function. Organs are aggregations of tissues performing specific functions. Organs are organised into organ systems, which work together to form organisms.	MS 1c Students should be able to develop an understanding of size and scale in relation to cells, tissues, organs and systems.

4.2.2 Animal tissues, organs and organ systems

4.2.2.1 The human digestive system

Content	Key opportunities for skills development
This section assumes knowledge of the digestive system studied in Key Stage 3 science. The digestive system is an example of an organ system in which several organs work together to digest and absorb food. Students should be able to relate knowledge of enzymes to Metabolism (page 44). Students should be able to describe the nature of enzyme molecules and relate their activity to temperature and pH changes.	
Students should be able to carry out rate calculations for chemical reactions. Enzymes catalyse specific reactions in living organisms due to the shape of their active site.	MS 1a, 1c

Content	Key opportunities for skills development
Students should be able to use the 'lock and key theory' as a simplified model to explain enzyme action. Students should be able to recall the sites of production and the action of amylase, proteases and lipases. Students should be able to understand simple word equations but no chemical symbol equations are required. Digestive enzymes convert food into small soluble molecules that can be absorbed into the bloodstream. Carbohydrases break down carbohydrates to simple sugars. Amylase is a carbohydrase which breaks down starch. Proteases break down proteins to amino acids. Lipases break down lipids (fats) to glycerol and fatty acids. The products of digestion are used to build new carbohydrates, lipids and proteins. Some glucose is used in respiration. Bile is made in the liver and stored in the gall bladder. It is alkaline to neutralise hydrochloric acid from the stomach. It also emulsifies fat to form small droplets which increases the surface area. The alkaline conditions and large surface area increase the rate of fat breakdown by lipase.	WS 1.2 Students should be able to use other models to explain enzyme action.

Required practical activity 4: use qualitative reagents to test for a range of carbohydrates, lipids and proteins.

To include: Benedict's test for sugars; iodine test for starch; and Biuret reagent for protein.

AT skills covered by this practical activity: AT 2 and 8.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 97).

Required practical activity 5: investigate the effect of pH on the rate of reaction of amylase enzyme.

Students should use a continuous sampling technique to determine the time taken to completely digest a starch solution at a range of pH values. Iodine reagent is to be used to test for starch every 30 seconds. Temperature must be controlled by use of a water bath or electric heater.

AT skills covered by this practical activity: AT 1, 2, 5 and 8.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 97).

4.2.2.2 The heart and blood vessels

Content	Key opportunities for skills development
Students should know the structure and functioning of the human heart and lungs, including how lungs are adapted for gaseous exchange. The heart is an organ that pumps blood around the body in a double circulatory system. The right ventricle pumps blood to the lungs where gas exchange takes place. The left ventricle pumps blood around the rest of the body. Knowledge of the blood vessels associated with the heart is limited to the aorta, vena cava, pulmonary artery, pulmonary vein and coronary arteries. Knowledge of the names of the heart valves is not required. Knowledge of the lungs is restricted to the trachea, bronchi, alveoli and the capillary network surrounding the alveoli. The natural resting heart rate is controlled by a group of cells located in the right atrium that act as a pacemaker. Artificial pacemakers are electrical devices used to correct irregularities in the heart rate. The body contains three different types of blood vessel: • arteries • veins • capillaries. Students should be able to explain how the structure of these vessels relates to their functions.	
Students should be able to use simple compound measures such as rate and carry out rate calculations for blood flow.	MS 1a, 1c

4.2.2.3 Blood

Content	Key opportunities for skills development
Blood is a tissue consisting of plasma, in which the red blood cells, white blood cells and platelets are suspended. Students should know the functions of each of these blood components.	AT 7 Observing and drawing blood cells seen under a microscope. WS 1.5 Evaluate risks related to use of blood products.

Content	Key opportunities for skills development
Students should be able to recognise different types of blood cells in a photograph or diagram, and explain how they are adapted to their functions.	WS 3.5

4.2.2.4 Coronary heart disease: a non-communicable disease

Content	Key opportunities for skills development
Students should be able to evaluate the advantages and disadvantages of treating cardiovascular diseases by drugs, mechanical devices or transplant. In coronary heart disease layers of fatty material build up inside the coronary arteries, narrowing them. This reduces the flow of blood through the coronary arteries, resulting in a lack of oxygen for the heart muscle. Stents are used to keep the coronary arteries open. Statins are widely used to reduce blood cholesterol levels which slows down the rate of fatty material deposit. In some people heart valves may become faulty, preventing the valve from opening fully, or the heart valve might develop a leak. Students should understand the consequences of faulty valves. Faulty heart valves can be replaced using biological or mechanical valves. In the case of heart failure a donor heart, or heart and lungs can be transplanted. Artificial hearts are occasionally used to keep patients alive whilst waiting for a heart transplant, or to allow the heart to rest as an aid to recovery.	WS 1.4 WS 1.3 Evaluate methods of treatment bearing in mind the benefits and risks associated with the treatment.

4.2.2.5 Health issues

Content	Key opportunities for skills development
Students should be able to describe the relationship between health and disease and the interactions between different types of disease. Health is the state of physical and mental well-being. Diseases, both communicable Communicable diseases (page 34) and non-communicable, are major causes of ill health. Other factors including diet, stress and life situations may have a profound effect on both physical and mental health. Different types of disease may interact. • Defects in the immune system mean that an individual is more likely to suffer from infectious diseases. • Viruses living in cells can be the trigger for cancers. • Immune reactions initially caused by a pathogen can trigger allergies such as skin rashes and asthma. • Severe physical ill health can lead to depression and other mental illness.	
Students should be able to translate disease incidence information between graphical and numerical forms, construct and interpret frequency tables and diagrams, bar charts and histograms, and use a scatter diagram to identify a correlation between two variables.	MS 2c, 2g, 4a
Students should understand the principles of sampling as applied to scientific data, including epidemiological data.	MS 2d

4.2.2.6 The effect of lifestyle on some non-communicable diseases

Content	Key opportunities for skills development
Students should be able to: • discuss the human and financial cost of these non-communicable diseases to an individual, a local community, a nation or globally • explain the effect of lifestyle factors including diet, alcohol and smoking on the incidence of non-communicable diseases at local, national and global levels.	WS 1.4

Content	Key opportunities for skills development
Risk factors are linked to an increased rate of a disease. They can be: • aspects of a person's lifestyle • substances in the person's body or environment. A causal mechanism has been proven for some risk factors, but not in others. • The effects of diet, smoking and exercise on cardiovascular disease. • Obesity as a risk factor for Type 2 diabetes. • The effect of alcohol on the liver and brain function. • The effect of smoking on lung disease and lung cancer. • The effects of smoking and alcohol on unborn babies. • Carcinogens, including ionising radiation, as risk factors in cancer. Many diseases are caused by the interaction of a number of factors.	WS 1.5 Interpret data about risk factors for specified diseases.
Students should be able to understand the principles of sampling as applied to scientific data in terms of risk factors.	MS 2d
Students should be able to translate information between graphical and numerical forms; and extract and interpret information from charts, graphs and tables in terms of risk factors.	MS 2c, 4a
Students should be able to use a scatter diagram to identify a correlation between two variables in terms of risk factors.	MS 2g

4.2.2.7 Cancer

Content	Key opportunities for skills development
Students should be able to describe cancer as the result of changes in cells that lead to uncontrolled growth and division. Benign tumours are growths of abnormal cells which are contained in one area, usually within a membrane. They do not invade other parts of the body. Malignant tumour cells are cancers. They invade neighbouring tissues and spread to different parts of the body in the blood where they form secondary tumours. Scientists have identified lifestyle risk factors for various types of cancer. There are also genetic risk factors for some cancers.	

4.2.3 Plant tissues, organs and systems

4.2.3.1 Plant tissues

Content	Key opportunities for skills development
Students should be able to explain how the structures of plant tissues are related to their functions. Plant tissues include: • epidermal tissues • palisade mesophyll • spongy mesophyll • xylem and phloem • meristem tissue found at the growing tips of shoots and roots. The leaf is a plant organ. Knowledge limited to epidermis, palisade and spongy mesophyll, xylem and phloem, and guard cells surrounding stomata.	AT 7 Observation and drawing of a transverse section of leaf.

4.2.3.2 Plant organ system

Content	Key opportunities for skills development
Students should be able to explain how the structure of root hair cells, xylem and phloem are adapted to their functions. Students should be able to explain the effect of changing temperature, humidity, air movement and light intensity on the rate of transpiration.	AT 3, 4, 5 Measure the rate of transpiration by the uptake of water. AT 6, 7 Investigate the distribution of stomata and guard cells. MS 2a, 2d, 5c Process data from investigations involving stomata and transpiration rates to find arithmetic means, understand the principles of sampling and calculate surface areas and volumes.
Students should be able to understand and use simple compound measures such as the rate of transpiration.	MS 1a, 1c

Content	Key opportunities for skills development
Students should be able to: • translate information between graphical and numerical form • plot and draw appropriate graphs, selecting appropriate scales for axes • extract and interpret information from graphs, charts and tables.	MS 2c, 4a, 4c
The roots, stem and leaves form a plant organ system for transport of substances around the plant. Students should be able to describe the process of transpiration and translocation, including the structure and function of the stomata. Root hair cells are adapted for the efficient uptake of water by osmosis, and mineral ions by active transport. Xylem tissue transports water and mineral ions from the roots to the stems and leaves. It is composed of hollow tubes strengthened by lignin adapted for the transport of water in the transpiration stream. The role of stomata and guard cells are to control gas exchange and water loss. Phloem tissue transports dissolved sugars from the leaves to the rest of the plant for immediate use or storage. The movement of food molecules through phloem tissue is called translocation. Phloem is composed of tubes of elongated cells. Cell sap can move from one phloem cell to the next through pores in the end walls. Detailed structure of phloem tissue or the mechanism of transport is not required.	

4.3 Infection and response

Pathogens are microorganisms such as viruses and bacteria that cause infectious diseases in animals and plants. They depend on their host to provide the conditions and nutrients that they need to grow and reproduce. They frequently produce toxins that damage tissues and make us feel ill. This section will explore how we can avoid diseases by reducing contact with them, as well as how the body uses barriers against pathogens. Once inside the body our immune system is triggered which is usually strong enough to destroy the pathogen and prevent disease. When at risk from unusual or dangerous diseases our body's natural system can be enhanced by the use of vaccination. Since the 1940s a range of antibiotics have been developed which have proved successful against a number of lethal diseases caused by bacteria. Unfortunately many groups of bacteria have now become resistant to these antibiotics. The race is now on to develop a new set of antibiotics.

4.3.1 Communicable diseases

4.3.1.1 Communicable (infectious) diseases

Content	Key opportunities for skills development
Students should be able to explain how diseases caused by viruses, bacteria, protists and fungi are spread in animals and plants. Students should be able to explain how the spread of diseases can be reduced or prevented. Pathogens are microorganisms that cause infectious disease. Pathogens may be viruses, bacteria, protists or fungi. They may infect plants or animals and can be spread by direct contact, by water or by air. Bacteria and viruses may reproduce rapidly inside the body. Bacteria may produce poisons (toxins) that damage tissues and make us feel ill. Viruses live and reproduce inside cells, causing cell damage.	WS 1.4

4.3.1.2 Viral diseases

Content	Key opportunities for skills development
Measles is a viral disease showing symptoms of fever and a red skin rash. Measles is a serious illness that can be fatal if complications arise. For this reason most young children are vaccinated against measles. The measles virus is spread by inhalation of droplets from sneezes and coughs. HIV initially causes a flu-like illness. Unless successfully controlled with antiretroviral drugs the virus attacks the body's immune cells. Late stage HIV infection, or AIDS, occurs when the body's immune system becomes so badly damaged it can no longer deal with other infections or cancers. HIV is spread by sexual contact or exchange of body fluids such as blood which occurs when drug users share needles. Tobacco mosaic virus (TMV) is a widespread plant pathogen affecting many species of plants including tomatoes. It gives a distinctive 'mosaic' pattern of discolouration on the leaves which affects the growth of the plant due to lack of photosynthesis.	

4.3.1.3 Bacterial diseases

Content	Key opportunities for skills development
Salmonella food poisoning is spread by bacteria ingested in food, or on food prepared in unhygienic conditions. In the UK, poultry are vaccinated against *Salmonella* to control the spread. Fever, abdominal cramps, vomiting and diarrhoea are caused by the bacteria and the toxins they secrete. Gonorrhoea is a sexually transmitted disease (STD) with symptoms of a thick yellow or green discharge from the vagina or penis and pain on urinating. It is caused by a bacterium and was easily treated with the antibiotic penicillin until many resistant strains appeared. Gonorrhoea is spread by sexual contact. The spread can be controlled by treatment with antibiotics or the use of a barrier method of contraception such as a condom.	

4.3.1.4 Fungal diseases

Content	Key opportunities for skills development
Rose black spot is a fungal disease where purple or black spots develop on leaves, which often turn yellow and drop early. It affects the growth of the plant as photosynthesis is reduced. It is spread in the environment by water or wind. Rose black spot can be treated by using fungicides and/or removing and destroying the affected leaves.	

4.3.1.5 Protist diseases

Content	Key opportunities for skills development
The pathogens that cause malaria are protists. The malarial protist has a life cycle that includes the mosquito. Malaria causes recurrent episodes of fever and can be fatal. The spread of malaria is controlled by preventing the vectors, mosquitos, from breeding and by using mosquito nets to avoid being bitten.	

4.3.1.6 Human defence systems

Content	Key opportunities for skills development
Students should be able to describe the non-specific defence systems of the human body against pathogens, including the: • skin • nose • trachea and bronchi • stomach. Students should be able to explain the role of the immune system in the defence against disease. If a pathogen enters the body the immune system tries to destroy the pathogen. White blood cells help to defend against pathogens by: • phagocytosis • antibody production • antitoxin production.	

4.3.1.7 Vaccination

Content	Key opportunities for skills development
Students should be able to explain how vaccination will prevent illness in an individual, and how the spread of pathogens can be reduced by immunising a large proportion of the population. Vaccination involves introducing small quantities of dead or inactive forms of a pathogen into the body to stimulate the white blood cells to produce antibodies. If the same pathogen re-enters the body the white blood cells respond quickly to produce the correct antibodies, preventing infection. Students do not need to know details of vaccination schedules and side effects associated with specific vaccines.	WS 1.4 Evaluate the global use of vaccination in the prevention of disease.

4.3.1.8 Antibiotics and painkillers

Content	Key opportunities for skills development
Students should be able to explain the use of antibiotics and other medicines in treating disease. Antibiotics, such as penicillin, are medicines that help to cure bacterial disease by killing infective bacteria inside the body. It is important that specific bacteria should be treated by specific antibiotics.	WS 1.4

Content	Key opportunities for skills development
The use of antibiotics has greatly reduced deaths from infectious bacterial diseases. However, the emergence of strains resistant to antibiotics is of great concern.	There are links with this content to Culturing microorganisms (biology only) (page 21). There are links with this content to Resistant bacteria (page 69).
Antibiotics cannot kill viral pathogens. Painkillers and other medicines are used to treat the symptoms of disease but do not kill pathogens. It is difficult to develop drugs that kill viruses without also damaging the body's tissues.	

4.3.1.9 Discovery and development of drugs

Content	Key opportunities for skills development
Students should be able to describe the process of discovery and development of potential new medicines, including preclinical and clinical testing. Traditionally drugs were extracted from plants and microorganisms. • The heart drug digitalis originates from foxgloves. • The painkiller aspirin originates from willow. • Penicillin was discovered by Alexander Fleming from the *Penicillium* mould. Most new drugs are synthesised by chemists in the pharmaceutical industry. However, the starting point may still be a chemical extracted from a plant.	
New medical drugs have to be tested and trialled before being used to check that they are safe and effective. New drugs are extensively tested for toxicity, efficacy and dose. Preclinical testing is done in a laboratory using cells, tissues and live animals. Clinical trials use healthy volunteers and patients. • Very low doses of the drug are given at the start of the clinical trial. • If the drug is found to be safe, further clinical trials are carried out to find the optimum dose for the drug. • In double blind trials, some patients are given a placebo.	WS 1.6 Understand that the results of testing and trials are published only after scrutiny by peer review.

4.3.2 Monoclonal antibodies (biology only) (HT only)

4.3.2.1 Producing monoclonal antibodies

Content	Key opportunities for skills development
Students should be able to describe how monoclonal antibodies are produced. Monoclonal antibodies are produced from a single clone of cells. The antibodies are specific to one binding site on one protein antigen and so are able to target a specific chemical or specific cells in the body. They are produced by stimulating mouse lymphocytes to make a particular antibody. The lymphocytes are combined with a particular kind of tumour cell to make a cell called a hybridoma cell. The hybridoma cell can both divide and make the antibody. Single hybridoma cells are cloned to produce many identical cells that all produce the same antibody. A large amount of the antibody can be collected and purified.	

4.3.2.2 Uses of monoclonal antibodies

Content	Key opportunities for skills development
Students should be able to describe some of the ways in which monoclonal antibodies can be used. Some examples include: • For diagnosis such as in pregnancy tests. • In laboratories to measure the levels of hormones and other chemicals in blood, or to detect pathogens. • In research to locate or identify specific molecules in a cell or tissue by binding to them with a fluorescent dye. • To treat some diseases: for cancer the monoclonal antibody can be bound to a radioactive substance, a toxic drug or a chemical which stops cells growing and dividing. It delivers the substance to the cancer cells without harming other cells in the body. Students are not expected to recall any specific tests or treatments but given appropriate information they should be able to explain how they work.	WS 1.3 Appreciate the power of monoclonal antibodies and consider any ethical issues.
Monoclonal antibodies create more side effects than expected. They are not yet as widely used as everyone hoped when they were first developed.	WS 1.5 Evaluate the advantages and disadvantages of monoclonal antibodies.

4.3.3 Plant disease (biology only)

4.3.3.1 Detection and identification of plant diseases

Content	Key opportunities for skills development
(HT only) Plant diseases can be detected by: • stunted growth • spots on leaves • areas of decay (rot) • growths • malformed stems or leaves • discolouration • the presence of pests. (HT only) Identification can be made by: • reference to a gardening manual or website • taking infected plants to a laboratory to identify the pathogen • using testing kits that contain monoclonal antibodies.	WS 1.4 The everyday application of scientific knowledge to detect and identify plant disease.
Plants can be infected by a range of viral, bacterial and fungal pathogens as well as by insects. Knowledge of plant diseases is restricted to tobacco mosaic virus as a viral disease, black spot as a fungal disease and aphids as insects. Plants can be damaged by a range of ion deficiency conditions: • stunted growth caused by nitrate deficiency • chlorosis caused by magnesium deficiency. Knowledge of ions is limited to nitrate ions needed for protein synthesis and therefore growth, and magnesium ions needed to make chlorophyll.	WS 1.4 The understanding of ion deficiencies allows horticulturists to provide optimum conditions for plants.

4.3.3.2 Plant defence responses

Content	Key opportunities for skills development
Students should be able to describe physical and chemical plant defence responses. Physical defence responses to resist invasion of microorganisms. • Cellulose cell walls. • Tough waxy cuticle on leaves. • Layers of dead cells around stems (bark on trees) which fall off. Chemical plant defence responses. • Antibacterial chemicals. • Poisons to deter herbivores. Mechanical adaptations. • Thorns and hairs deter animals. • Leaves which droop or curl when touched. • Mimicry to trick animals.	There are links with this content to Adaptations (page 73).

4.4 Bioenergetics

In this section we will explore how plants harness the Sun's energy in photosynthesis in order to make food. This process liberates oxygen which has built up over millions of years in the Earth's atmosphere. Both animals and plants use this oxygen to oxidise food in a process called aerobic respiration which transfers the energy that the organism needs to perform its functions. Conversely, anaerobic respiration does not require oxygen to transfer energy. During vigorous exercise the human body is unable to supply the cells with sufficient oxygen and it switches to anaerobic respiration. This process will supply energy but also causes the build-up of lactic acid in muscles which causes fatigue.

4.4.1 Photosynthesis

4.4.1.1 Photosynthetic reaction

Content	Key opportunities for skills development
Photosynthesis is represented by the equation: carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen Students should recognise the chemical symbols: CO_2, H_2O, O_2 and $C_6H_{12}O_6$.	
Students should be able to describe photosynthesis as an endothermic reaction in which energy is transferred from the environment to the chloroplasts by light.	There are links with this content to Plant tissues (page 32), the leaf.

4.4.1.2 Rate of photosynthesis

Content	Key opportunities for skills development
Students should be able to explain the effects of temperature, light intensity, carbon dioxide concentration, and the amount of chlorophyll on the rate of photosynthesis.	
Students should be able to: • measure and calculate rates of photosynthesis • extract and interpret graphs of photosynthesis rate involving one limiting factor • plot and draw appropriate graphs selecting appropriate scale for axes • translate information between graphical and numeric form.	MS 3d Solve simple algebraic equations. MS 1a, 1c, 2c, 4a, 4c
(HT only) These factors interact and any one of them may be the factor that limits photosynthesis. (HT only) Students should be able to explain graphs of photosynthesis rate involving two or three factors and decide which is the limiting factor.	
(HT only) Students should understand and use inverse proportion – the inverse square law and light intensity in the context of photosynthesis. (HT only) Limiting factors are important in the economics of enhancing the conditions in greenhouses to gain the maximum rate of photosynthesis while still maintaining profit.	MS 3a, 3d (HT only) WS 1.4 Use data to relate limiting factors to the cost effectiveness of adding heat, light or carbon dioxide to greenhouses.

Required practical activity 6: investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

AT skills covered by this practical activity: AT 1, 2, 3, 4 and 5.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 98).

4.4.1.3 Uses of glucose from photosynthesis

Content	Key opportunities for skills development
The glucose produced in photosynthesis may be: • used for respiration • converted into insoluble starch for storage • used to produce fat or oil for storage • used to produce cellulose, which strengthens the cell wall • used to produce amino acids for protein synthesis. To produce proteins, plants also use nitrate ions that are absorbed from the soil.	AT 8 Tests to identify starch, glucose and proteins using simple qualitative reagents.

4.4.2 Respiration

4.4.2.1 Aerobic and anaerobic respiration

Content	Key opportunities for skills development
Students should be able to describe cellular respiration as an exothermic reaction which is continuously occurring in living cells. The energy transferred supplies all the energy needed for living processes. Respiration in cells can take place aerobically (using oxygen) or anaerobically (without oxygen), to transfer energy. Students should be able to compare the processes of aerobic and anaerobic respiration with regard to the need for oxygen, the differing products and the relative amounts of energy transferred. Organisms need energy for: • chemical reactions to build larger molecules • movement • keeping warm. Aerobic respiration is represented by the equation: glucose + oxygen → carbon dioxide + water Students should recognise the chemical symbols: $C_6H_{12}O_6$, O_2, CO_2 and H_2O. Anaerobic respiration in muscles is represented by the equation: glucose → lactic acid As the oxidation of glucose is incomplete in anaerobic respiration much less energy is transferred than in aerobic respiration. Anaerobic respiration in plant and yeast cells is represented by the equation: glucose → ethanol + carbon dioxide Anaerobic respiration in yeast cells is called fermentation and has economic importance in the manufacture of bread and alcoholic drinks.	

4.4.2.2 Response to exercise

Content	Key opportunities for skills development
During exercise the human body reacts to the increased demand for energy. The heart rate, breathing rate and breath volume increase during exercise to supply the muscles with more oxygenated blood. If insufficient oxygen is supplied anaerobic respiration takes place in muscles. The incomplete oxidation of glucose causes a build up of lactic acid and creates an oxygen debt. During long periods of vigorous activity muscles become fatigued and stop contracting efficiently.	AT 1, 3, 4 Investigations into the effect of exercise on the body.
(HT only) Blood flowing through the muscles transports the lactic acid to the liver where it is converted back into glucose. Oxygen debt is the amount of extra oxygen the body needs after exercise to react with the accumulated lactic acid and remove it from the cells.	

4.4.2.3 Metabolism

Content	Key opportunities for skills development
Students should be able to explain the importance of sugars, amino acids, fatty acids and glycerol in the synthesis and breakdown of carbohydrates, proteins and lipids. Metabolism is the sum of all the reactions in a cell or the body. The energy transferred by respiration in cells is used by the organism for the continual enzyme controlled processes of metabolism that synthesise new molecules. Metabolism includes: • conversion of glucose to starch, glycogen and cellulose • the formation of lipid molecules from a molecule of glycerol and three molecules of fatty acids • the use of glucose and nitrate ions to form amino acids which in turn are used to synthesise proteins • respiration • breakdown of excess proteins to form urea for excretion. All of these aspects are covered in more detail in the relevant specification section but are linked together here.	

4.5 Homeostasis and response

Cells in the body can only survive within narrow physical and chemical limits. They require a constant temperature and pH as well as a constant supply of dissolved food and water. In order to

do this the body requires control systems that constantly monitor and adjust the composition of the blood and tissues. These control systems include receptors which sense changes and effectors that bring about changes. In this section we will explore the structure and function of the nervous system and how it can bring about fast responses. We will also explore the hormonal system which usually brings about much slower changes. Hormonal coordination is particularly important in reproduction since it controls the menstrual cycle. An understanding of the role of hormones in reproduction has allowed scientists to develop not only contraceptive drugs but also drugs which can increase fertility.

4.5.1 Homeostasis

Content	Key opportunities for skills development
Students should be able to explain that homeostasis is the regulation of the internal conditions of a cell or organism to maintain optimum conditions for function in response to internal and external changes. Homeostasis maintains optimal conditions for enzyme action and all cell functions. In the human body, these include control of: • blood glucose concentration • body temperature • water levels. These automatic control systems may involve nervous responses or chemical responses. All control systems include: • cells called receptors, which detect stimuli (changes in the environment) • coordination centres (such as the brain, spinal cord and pancreas) that receive and process information from receptors • effectors, muscles or glands, which bring about responses which restore optimum levels.	

4.5.2 The human nervous system

4.5.2.1 Structure and function

Content	Key opportunities for skills development
Students should be able to explain how the structure of the nervous system is adapted to its functions. The nervous system enables humans to react to their surroundings and to coordinate their behaviour. Information from receptors passes along cells (neurones) as electrical impulses to the central nervous system (CNS). The CNS is the brain and spinal cord. The CNS coordinates the response of effectors which may be muscles contracting or glands secreting hormones. stimulus → receptor → coordinator → effector → response Students should be able to explain how the various structures in a reflex arc – including the sensory neurone, synapse, relay neurone and motor neurone – relate to their function. Students should understand why reflex actions are important. Reflex actions are automatic and rapid; they do not involve the conscious part of the brain.	
Students should be able to extract and interpret data from graphs, charts and tables, about the functioning of the nervous system.	MS 2c
Students should be able to translate information about reaction times between numerical and graphical forms.	MS 4a

Required practical activity 7: plan and carry out an investigation into the effect of a factor on human reaction time.

AT skills covered by this practical activity: AT 1, 3 and 4.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 98).

4.5.2.2 The brain (biology only)

Content	Key opportunities for skills development
The brain controls complex behaviour. It is made of billions of interconnected neurones and has different regions that carry out different functions. Students should be able to identify the cerebral cortex, cerebellum and medulla on a diagram of the brain, and describe their functions.	

Content	Key opportunities for skills development
(HT only) Students should be able to explain some of the difficulties of investigating brain function and treating brain damage and disease. (HT only) Neuroscientists have been able to map the regions of the brain to particular functions by studying patients with brain damage, electrically stimulating different parts of the brain and using MRI scanning techniques. The complexity and delicacy of the brain makes investigating and treating brain disorders very difficult.	(HT only) WS 1.5 Evaluate the benefits and risks of procedures carried out on the brain and nervous system.

4.5.2.3 The eye (biology only)

Content	Key opportunities for skills development
Students should be able to relate the structures of the eye to their functions. This includes: • accommodation to focus on near or distant objects • adaptation to dim light. The eye is a sense organ containing receptors sensitive to light intensity and colour.	

Content	Key opportunities for skills development
Students should be able to identify the following structures on a diagram of the eye and explain how their structure is related to their function: • retina • optic nerve • sclera • cornea • iris • ciliary muscles • suspensory ligaments. Accommodation is the process of changing the shape of the lens to focus on near or distant objects. To focus on a near object: • the ciliary muscles contract • the suspensory ligaments loosen • the lens is then thicker and refracts light rays strongly. To focus on a distant object: • the ciliary muscles relax • the suspensory ligaments are pulled tight • the lens is then pulled thin and only slightly refracts light rays. Two common defects of the eyes are myopia (short sightedness) and hyperopia (long sightedness) in which rays of light do not focus on the retina. • Generally these defects are treated with spectacle lenses which refract the light rays so that they do focus on the retina. • New technologies now include hard and soft contact lenses, laser surgery to change the shape of the cornea and a replacement lens in the eye.	WS 1.2
Students should be able to interpret ray diagrams, showing these two common defects of the eye and demonstrate how spectacle lenses correct them.	WS 1.2, 1.4

4.5.2.4 Control of body temperature (biology only)

Content	Key opportunities for skills development
Body temperature is monitored and controlled by the thermoregulatory centre in the brain. The thermoregulatory centre contains receptors sensitive to the temperature of the blood. The skin contains temperature receptors and sends nervous impulses to the thermoregulatory centre. If the body temperature is too high, blood vessels dilate (vasodilation) and sweat is produced from the sweat glands. Both these mechanisms cause a transfer of energy from the skin to the environment. If the body temperature is too low, blood vessels constrict (vasoconstriction), sweating stops and skeletal muscles contract (shiver).	
(HT only) Students should be able to explain how these mechanisms lower or raise body temperature in a given context.	

4.5.3 Hormonal coordination in humans

4.5.3.1 Human endocrine system

Content	Key opportunities for skills development
Students should be able to describe the principles of hormonal coordination and control by the human endocrine system. The endocrine system is composed of glands which secrete chemicals called hormones directly into the bloodstream. The blood carries the hormone to a target organ where it produces an effect. Compared to the nervous system the effects are slower but act for longer. The pituitary gland in the brain is a 'master gland' which secretes several hormones into the blood in response to body conditions. These hormones in turn act on other glands to stimulate other hormones to be released to bring about effects. Students should be able to identify the position of the following on a diagram of the human body: • pituitary gland • pancreas • thyroid • adrenal gland • ovary • testes.	

4.5.3.2 Control of blood glucose concentration

Content	Key opportunities for skills development
Blood glucose concentration is monitored and controlled by the pancreas. If the blood glucose concentration is too high, the pancreas produces the hormone insulin that causes glucose to move from the blood into the cells. In liver and muscle cells excess glucose is converted to glycogen for storage. Students should be able to explain how insulin controls blood glucose (sugar) levels in the body. Type 1 diabetes is a disorder in which the pancreas fails to produce sufficient insulin. It is characterised by uncontrolled high blood glucose levels and is normally treated with insulin injections. In Type 2 diabetes the body cells no longer respond to insulin produced by the pancreas. A carbohydrate controlled diet and an exercise regime are common treatments. Obesity is a risk factor for Type 2 diabetes. Students should be able to compare Type 1 and Type 2 diabetes and explain how they can be treated.	WS 1.3 Evaluate information around the relationship between obesity and diabetes, and make recommendations taking into account social and ethical issues.
Students should be able to extract information and interpret data from graphs that show the effect of insulin in blood glucose levels in both people with diabetes and people without diabetes.	MS 2c
(HT only) If the blood glucose concentration is too low, the pancreas produces the hormone glucagon that causes glycogen to be converted into glucose and released into the blood. (HT only) Students should be able to explain how glucagon interacts with insulin in a negative feedback cycle to control blood glucose (sugar) levels in the body.	

4.5.3.3 Maintaining water and nitrogen balance in the body (biology only)

Content	Key opportunities for skills development
Students should be able to explain the effect on cells of osmotic changes in body fluids. Water leaves the body via the lungs during exhalation. Water, ions and urea are lost from the skin in sweat. There is no control over water, ion or urea loss by the lungs or skin. Excess water, ions and urea are removed via the kidneys in the urine. If body cells lose or gain too much water by osmosis they do not function efficiently.	
(HT only) The digestion of proteins from the diet results in excess amino acids which need to be excreted safely. In the liver these amino acids are deaminated to form ammonia. Ammonia is toxic and so it is immediately converted to urea for safe excretion.	
Students should be able to describe the function of kidneys in maintaining the water balance of the body. The kidneys produce urine by filtration of the blood and selective reabsorption of useful substances such as glucose, some ions and water. Knowledge of other parts of the urinary system, the structure of the kidney and the structure of a nephron is not required.	
Students should be able to translate tables and bar charts of glucose, ions and urea before and after filtration.	MS 4a
(HT only) Students should be able to describe the effect of ADH on the permeability of the kidney tubules. (HT only) The water level in the body is controlled by the hormone ADH which acts on the kidney tubules. ADH is released by the pituitary gland when the blood is too concentrated and it causes more water to be reabsorbed back into the blood from the kidney tubules. This is controlled by negative feedback.	

Content	Key opportunities for skills development
People who suffer from kidney failure may be treated by organ transplant or by using kidney dialysis. Students should know the basic principles of dialysis.	WS 1.4 Students should be able to describe how kidney dialysis works. WS 1.5 Evaluate the advantages and disadvantages of treating organ failure by mechanical device or transplant.

4.5.3.4 Hormones in human reproduction

Content	Key opportunities for skills development
Students should be able to describe the roles of hormones in human reproduction, including the menstrual cycle. During puberty reproductive hormones cause secondary sex characteristics to develop. Oestrogen is the main female reproductive hormone produced in the ovary. At puberty eggs begin to mature and one is released approximately every 28 days. This is called ovulation. Testosterone is the main male reproductive hormone produced by the testes and it stimulates sperm production. Several hormones are involved in the menstrual cycle of a woman. • Follicle stimulating hormone (FSH) causes maturation of an egg in the ovary. • Luteinising hormone (LH) stimulates the release of the egg. • Oestrogen and progesterone are involved in maintaining the uterus lining.	
(HT only) Students should be able to explain the interactions of FSH, oestrogen, LH and progesterone, in the control of the menstrual cycle.	
(HT only) Students should be able to extract and interpret data from graphs showing hormone levels during the menstrual cycle.	MS 2c

4.5.3.5 Contraception

Content	Key opportunities for skills development
Students should be able to evaluate the different hormonal and non-hormonal methods of contraception. Fertility can be controlled by a variety of hormonal and non-hormonal methods of contraception. These include: • oral contraceptives that contain hormones to inhibit FSH production so that no eggs mature • injection, implant or skin patch of slow release progesterone to inhibit the maturation and release of eggs for a number of months or years • barrier methods such as condoms and diaphragms which prevent the sperm reaching an egg • intrauterine devices which prevent the implantation of an embryo or release a hormone • spermicidal agents which kill or disable sperm • abstaining from intercourse when an egg may be in the oviduct • surgical methods of male and female sterilisation.	WS 1.3 Show why issues around contraception cannot be answered by science alone. WS 1.4 Explain everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments.

4.5.3.6 The use of hormones to treat infertility (HT only)

Content	Key opportunities for skills development
Students should be able to explain the use of hormones in modern reproductive technologies to treat infertility. This includes giving FSH and LH in a 'fertility drug' to a woman. She may then become pregnant in the normal way. In Vitro Fertilisation (IVF) treatment. • IVF involves giving a mother FSH and LH to stimulate the maturation of several eggs. • The eggs are collected from the mother and fertilised by sperm from the father in the laboratory. • The fertilised eggs develop into embryos. • At the stage when they are tiny balls of cells, one or two embryos are inserted into the mother's uterus (womb).	WS 1.1 Developments of microscopy techniques have enabled IVF treatments to develop. WS 1.3 Understand social and ethical issues associated with IVF treatments.
Although fertility treatment gives a woman the chance to have a baby of her own: • it is very emotionally and physically stressful • the success rates are not high • it can lead to multiple births which are a risk to both the babies and the mother.	WS 1.4 Evaluate from the perspective of patients and doctors the methods of treating infertility.

4.5.3.7 Negative feedback (HT only)

Content	Key opportunities for skills development
Students should be able to explain the roles of thyroxine and adrenaline in the body. Adrenaline is produced by the adrenal glands in times of fear or stress. It increases the heart rate and boosts the delivery of oxygen and glucose to the brain and muscles, preparing the body for 'flight or fight'. Thyroxine from the thyroid gland stimulates the basal metabolic rate. It plays an important role in growth and development.	
Thyroxine levels are controlled by negative feedback.	WS 1.2, MS 2c Interpret and explain simple diagrams of negative feedback control.

4.5.4 Plant hormones (biology only)

4.5.4.1 Control and coordination

Content	Key opportunities for skills development
Plants produce hormones to coordinate and control growth and responses to light (phototropism) and gravity (gravitropism or geotropism). Unequal distributions of auxin cause unequal growth rates in plant roots and shoots.	
(HT only) Gibberellins are important in initiating seed germination. (HT only) Ethene controls cell division and ripening of fruits. (HT only) The mechanisms of how gibberellins and ethene work are not required.	

Required practical activity 8: investigate the effect of light or gravity on the growth of newly germinated seedlings.

Record results as both length measurements and as careful, labelled biological drawings to show the effects.

AT skills covered by this practical activity: AT 1, 3, 4 and 7.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 99).

4.5.4.2 Use of plant hormones (HT only)

Content	Key opportunities for skills development
Students should be able to describe the effects of some plant hormones and the different ways people use them to control plant growth. Plant growth hormones are used in agriculture and horticulture. Auxins are used: • as weed killers • as rooting powders • for promoting growth in tissue culture. Ethene is used in the food industry to control ripening of fruit during storage and transport. Gibberellins can be used to: • end seed dormancy • promote flowering • increase fruit size.	WS 1.3, 1.4 Understand how the everyday use of hormones as weedkillers has an effect on biodiversity.

4.6 Inheritance, variation and evolution

In this section we will discover how the number of chromosomes are halved during meiosis and then combined with new genes from the sexual partner to produce unique offspring. Gene mutations occur continuously and on rare occasions can affect the functioning of the animal or plant. These mutations may be damaging and lead to a number of genetic disorders or death. Very rarely a new mutation can be beneficial and consequently, lead to increased fitness in the individual. Variation generated by mutations and sexual reproduction is the basis for natural selection; this is how species evolve. An understanding of these processes has allowed scientists to intervene through selective breeding to produce livestock with favoured characteristics. Once new varieties of plants or animals have been produced it is possible to clone individuals to produce larger numbers of identical individuals all carrying the favourable characteristic. Scientists have now discovered how to take genes from one species and introduce them in to the genome of another by a process called genetic engineering. In spite of the huge potential benefits that this technology can offer, genetic modification still remains highly controversial.

4.6.1 Reproduction

4.6.1.1 Sexual and asexual reproduction

Content	Key opportunities for skills development
Students should understand that meiosis leads to non-identical cells being formed while mitosis leads to identical cells being formed. Sexual reproduction involves the joining (fusion) of male and female gametes: • sperm and egg cells in animals • pollen and egg cells in flowering plants. In sexual reproduction there is mixing of genetic information which leads to variety in the offspring. The formation of gametes involves meiosis. Asexual reproduction involves only one parent and no fusion of gametes. There is no mixing of genetic information. This leads to genetically identical offspring (clones). Only mitosis is involved.	There are links with this content to Mitosis and the cell cycle (page 22).

4.6.1.2 Meiosis

Content	Key opportunities for skills development
Students should be able to explain how meiosis halves the number of chromosomes in gametes and fertilisation restores the full number of chromosomes. Cells in reproductive organs divide by meiosis to form gametes. When a cell divides to form gametes: • copies of the genetic information are made • the cell divides twice to form four gametes, each with a single set of chromosomes • all gametes are genetically different from each other. Gametes join at fertilisation to restore the normal number of chromosomes. The new cell divides by mitosis. The number of cells increases. As the embryo develops cells differentiate. Knowledge of the stages of meiosis is not required.	WS 1.2 Modelling behaviour of chromosomes during meiosis.

4.6.1.3 Advantages and disadvantages of sexual and asexual reproduction (biology only)

Content	Key opportunities for skills development
Advantages of sexual reproduction: • produces variation in the offspring • if the environment changes variation gives a survival advantage by natural selection • natural selection can be speeded up by humans in selective breeding to increase food production. Advantages of asexual reproduction: • only one parent needed • more time and energy efficient as do not need to find a mate • faster than sexual reproduction • many identical offspring can be produced when conditions are favourable.	There are links with this content to Animal and plant cells (page 19) and Cloning (biology only) (page 65).
Some organisms reproduce by both methods depending on the circumstances. • Malarial parasites reproduce asexually in the human host, but sexually in the mosquito. • Many fungi reproduce asexually by spores but also reproduce sexually to give variation. • Many plants produce seeds sexually, but also reproduce asexually by runners such as strawberry plants, or bulb division such as daffodils. Knowledge of reproduction in organisms is restricted to those mentioned. Students are expected to be able to explain the advantages and disadvantages of asexual and sexual reproduction for any organism if given appropriate information.	WS 1.1 Historical developments of our understanding of the causes and preventiaon of malaria.

4.6.1.4 DNA and the genome

Content	Key opportunities for skills development
Students should be able to describe the structure of DNA and define genome. The genetic material in the nucleus of a cell is composed of a chemical called DNA. DNA is a polymer made up of two strands forming a double helix. The DNA is contained in structures called chromosomes. A gene is a small section of DNA on a chromosome. Each gene codes for a particular sequence of amino acids, to make a specific protein. The genome of an organism is the entire genetic material of that organism. The whole human genome has now been studied and this will have great importance for medicine in the future.	
Students should be able to discuss the importance of understanding the human genome. This is limited to the: • search for genes linked to different types of disease • understanding and treatment of inherited disorders • use in tracing human migration patterns from the past.	WS 1.1, 1.4

4.6.1.5 DNA structure (biology only)

Content	Key opportunities for skills development
Students should be able to describe DNA as a polymer made from four different nucleotides. Each nucleotide consists of a common sugar and phosphate group with one of four different bases attached to the sugar. DNA contains four bases, A, C, G and T. A sequence of three bases is the code for a particular amino acid. The order of bases controls the order in which amino acids are assembled to produce a particular protein.	
The long strands of DNA consist of alternating sugar and phosphate sections. Attached to each sugar is one of the four bases. The DNA polymer is made up of repeating nucleotide units.	WS 1.2 Interpret a diagram of DNA structure but will not be required to reproduce it.

Content	Key opportunities for skills development
(HT only) Students should be able to: • recall a simple description of protein synthesis • explain simply how the structure of DNA affects the protein made • describe how genetic variants may influence phenotype: a) in coding DNA by altering the activity of a protein: and b) in non-coding DNA by altering how genes are expressed. (HT only) In the complementary strands a C is always linked to a G on the opposite strand and a T to an A. (HT only) Students are not expected to know or understand the structure of mRNA, tRNA, or the detailed structure of amino acids or proteins. (HT only) Students should be able to explain how a change in DNA structure may result in a change in the protein synthesised by a gene. (HT only) Proteins are synthesised on ribosomes, according to a template. Carrier molecules bring specific amino acids to add to the growing protein chain in the correct order. (HT only) When the protein chain is complete it folds up to form a unique shape. This unique shape enables the proteins to do their job as enzymes, hormones or forming structures in the body such as collagen.	
(HT only) Mutations occur continuously. Most do not alter the protein, or only alter it slightly so that its appearance or function is not changed. (HT only) A few mutations code for an altered protein with a different shape. An enzyme may no longer fit the substrate binding site or a structural protein may lose its strength. (HT only) Not all parts of DNA code for proteins. Non-coding parts of DNA can switch genes on and off, so variations in these areas of DNA may affect how genes are expressed.	WS 1.2 Modelling insertions and deletions in chromososmes to illustrate mutations.

4.6.1.6 Genetic inheritance

Content	Key opportunities for skills development
Students should be able to explain the terms: • gamete • chromosome • gene • allele • dominant • recessive • homozygous • heterozygous • genotype • phenotype. Some characteristics are controlled by a single gene, such as: fur colour in mice; and red-green colour blindness in humans. Each gene may have different forms called alleles. The alleles present, or genotype, operate at a molecular level to develop characteristics that can be expressed as a phenotype. A dominant allele is always expressed, even if only one copy is present. A recessive allele is only expressed if two copies are present (therefore no dominant allele present). If the two alleles present are the same the organism is homozygous for that trait, but if the alleles are different they are heterozygous. Most characteristics are a result of multiple genes interacting, rather than a single gene.	
Students should be able to understand the concept of probability in predicting the results of a single gene cross, but recall that most phenotype features are the result of multiple genes rather than single gene inheritance.	MS 2e
Students should be able to use direct proportion and simple ratios to express the outcome of a genetic cross.	MS 1c, 3a
Students should be able to complete a Punnett square diagram and extract and interpret information from genetic crosses and family trees.	MS 2c, 4a
(HT only) Students should be able to construct a genetic cross by Punnett square diagram and use it to make predictions using the theory of probability.	MS 2e, WS 1.2

4.6.1.7 Inherited disorders

Content	Key opportunities for skills development
Some disorders are inherited. These disorders are caused by the inheritance of certain alleles. • Polydactyly (having extra fingers or toes) is caused by a dominant allele. • Cystic fibrosis (a disorder of cell membranes) is caused by a recessive allele. Students should make informed judgements about the economic, social and ethical issues concerning embryo screening, given appropriate information.	WS 1.3 Appreciate that embryo screening and gene therapy may alleviate suffering but consider the ethical issues which arise.

4.6.1.8 Sex determination

Content	Key opportunities for skills development
Ordinary human body cells contain 23 pairs of chromosomes. 22 pairs control characteristics only, but one of the pairs carries the genes that determine sex. • In females the sex chromosomes are the same (XX). • In males the chromosomes are different (XY).	
Students should to be able to carry out a genetic cross to show sex inheritance. Students should understand and use direct proportion and simple ratios in genetic crosses.	MS 1c, 3a

4.6.2 Variation and evolution

4.6.2.1 Variation

Content	Key opportunities for skills development
Students should be able to describe simply how the genome and its interaction with the environment influence the development of the phenotype of an organism. Differences in the characteristics of individuals in a population is called variation and may be due to differences in: • the genes they have inherited (genetic causes) • the conditions in which they have developed (environmental causes) • a combination of genes and the environment.	

Content	Key opportunities for skills development
Students should be able to: • state that there is usually extensive genetic variation within a population of a species • recall that all variants arise from mutations and that: most have no effect on the phenotype; some influence phenotype; very few determine phenotype. Mutations occur continuously. Very rarely a mutation will lead to a new phenotype. If the new phenotype is suited to an environmental change it can lead to a relatively rapid change in the species.	There are links with this content to Speciation (biology only) (page 67).

4.6.2.2 Evolution

Content	Key opportunities for skills development
Students should be able to describe evolution as a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of a new species. The theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago. Students should be able to explain how evolution occurs through natural selection of variants that give rise to phenotypes best suited to their environment. If two populations of one species become so different in phenotype that they can no longer interbreed to produce fertile offspring they have formed two new species.	WS 1.2 Use the theory of evolution by natural selection in an explanation.

4.6.2.3 Selective breeding

Content	Key opportunities for skills development
Students should be able to explain the impact of selective breeding of food plants and domesticated animals. Selective breeding (artificial selection) is the process by which humans breed plants and animals for particular genetic characteristics. Humans have been doing this for thousands of years since they first bred food crops from wild plants and domesticated animals. Selective breeding involves choosing parents with the desired characteristic from a mixed population. They are bred together. From the offspring those with the desired characteristic are bred together. This continues over many generations until all the offspring show the desired characteristic. The characteristic can be chosen for usefulness or appearance: • Disease resistance in food crops. • Animals which produce more meat or milk. • Domestic dogs with a gentle nature. • Large or unusual flowers. Selective breeding can lead to 'inbreeding' where some breeds are particularly prone to disease or inherited defects.	WS 1.3, 1.4 Explain the benefits and risks of selective breeding given appropriate information and consider related ethical issues.

4.6.2.4 Genetic engineering

Content	Key opportunities for skills development
Students should be able to describe genetic engineering as a process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic. Plant crops have been genetically engineered to be resistant to diseases or to produce bigger better fruits.	
Bacterial cells have been genetically engineered to produce useful substances such as human insulin to treat diabetes.	There are links with this content to Role of biotechnology (page 81).

Content	Key opportunities for skills development
Students should be able to explain the potential benefits and risks of genetic engineering in agriculture and in medicine and that some people have objections. In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' and transferred to cells of other organisms. Crops that have had their genes modified in this way are called genetically modified (GM) crops. GM crops include ones that are resistant to insect attack or to herbicides. GM crops generally show increased yields. Concerns about GM crops include the effect on populations of wild flowers and insects. Some people feel the effects of eating GM crops on human health have not been fully explored. Modern medical research is exploring the possibility of genetic modification to overcome some inherited disorders.	WS 1.3, 1.4
(HT only) Students should be able to describe the main steps in the process of genetic engineering. (HT only) In genetic engineering: • enzymes are used to isolate the required gene; this gene is inserted into a vector, usually a bacterial plasmid or a virus • the vector is used to insert the gene into the required cells • genes are transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics.	(HT only) WS 1.4 Interpret information about genetic engineering techniques and to make informed judgements about issues concerning cloning and genetic engineering, including GM crops.

4.6.2.5 Cloning (biology only)

Content	Key opportunities for skills development
Tissue culture: using small groups of cells from part of a plant to grow identical new plants. This is important for preserving rare plant species or commercially in nurseries. Cuttings: an older, but simple, method used by gardeners to produce many identical new plants from a parent plant. Embryo transplants: splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers. Adult cell cloning: • The nucleus is removed from an unfertilised egg cell. • The nucleus from an adult body cell, such as a skin cell, is inserted into the egg cell. • An electric shock stimulates the egg cell to divide to form an embryo. • These embryo cells contain the same genetic information as the adult skin cell. • When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.	WS 1.3, 1.4 Explain the potential benefits and risks of cloning in agriculture and in medicine and that some people have ethical objections. There are links with this content to Advantages and disadvantages of sexual and asexual reproduction (biology only) (page 57) and Selective breeding (page 63).

4.6.3 The development of understanding of genetics and evolution

4.6.3.1 Theory of evolution (biology only)

Content	Key opportunities for skills development
Charles Darwin, as a result of observations on a round the world expedition, backed by years of experimentation and discussion and linked to developing knowledge of geology and fossils, proposed the theory of evolution by natural selection. • Individual organisms within a particular species show a wide range of variation for a characteristic. • Individuals with characteristics most suited to the environment are more likely to survive to breed successfully. • The characteristics that have enabled these individuals to survive are then passed on to the next generation. Darwin published his ideas in *On the Origin of Species* (1859). There was much controversy surrounding these revolutionary new ideas. The theory of evolution by natural selection was only gradually accepted because: • the theory challenged the idea that God made all the animals and plants that live on Earth • there was insufficient evidence at the time the theory was published to convince many scientists • the mechanism of inheritance and variation was not known until 50 years after the theory was published. Other theories, including that of Jean-Baptiste Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur. A study of creationism is not required.	WS 1.1, 1.3 Students should appreciate that the theory of evolution by natural selection developed over time and from information gathered by many scientists.

4.6.3.2 Speciation (biology only)

Content	Key opportunities for skills development
Students should be able to: • describe the work of Darwin and Wallace in the development of the theory of evolution by natural selection • explain the impact of these ideas on biology. Alfred Russel Wallace independently proposed the theory of evolution by natural selection. He published joint writings with Darwin in 1858 which prompted Darwin to publish *On the Origin of Species* (1859) the following year. Wallace worked worldwide gathering evidence for evolutionary theory. He is best known for his work on warning colouration in animals and his theory of speciation. Alfred Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation. Students should be able to describe the steps which give rise to new species.	There are links with this content to Evolution (page 62). WS 1.1 The theory of speciation has developed over time.

4.6.3.3 The understanding of genetics (biology only)

Content	Key opportunities for skills development
Students should be able to: • describe the development of our understanding of genetics including the work of Mendel • understand why the importance of Mendel's discovery was not recognised until after his death. In the mid-19th Century Gregor Mendel carried out breeding experiments on plants. One of his observations was that the inheritance of each characteristic is determined by 'units' that are passed on to descendants unchanged. In the late 19th Century behaviour of chromosomes during cell division was observed.	WS 1.1 Our current understanding of genetics has developed over time.
In the early 20th Century it was observed that chromosomes and Mendel's 'units' behaved in similar ways. This led to the idea that the 'units', now called genes, were located on chromosomes. In the mid-20th Century the structure of DNA was determined and the mechanism of gene function worked out. This scientific work by many scientists led to the gene theory being developed.	There are links with this content to Genetic inheritance (page 60). WS 1.1

4.6.3.4 Evidence for evolution

Content	Key opportunities for skills development
Students should be able to describe the evidence for evolution including fossils and antibiotic resistance in bacteria. The theory of evolution by natural selection is now widely accepted. Evidence for Darwin's theory is now available as it has been shown that characteristics are passed on to offspring in genes. There is further evidence in the fossil record and the knowledge of how resistance to antibiotics evolves in bacteria.	WS 1.3 Data is now available to support the theory of evolution.

4.6.3.5 Fossils

Content	Key opportunities for skills development
Fossils are the 'remains' of organisms from millions of years ago, which are found in rocks. Fossils may be formed: • from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent • when parts of the organism are replaced by minerals as they decay • as preserved traces of organisms, such as footprints, burrows and rootlet traces.	MS 2c, 4a Extract and interpret information from charts, graphs and tables.
Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity. This is why scientists cannot be certain about how life began on Earth.	WS 1.3 Appreciate why the fossil record is incomplete.
We can learn from fossils how much or how little different organisms have changed as life developed on Earth.	WS 1.1 Understand how scientific methods and theories develop over time.
Students should be able to extract and interpret information from charts, graphs and tables such as evolutionary trees.	MS 2c, 4a

4.6.3.6 Extinction

Content	Key opportunities for skills development
Extinctions occur when there are no remaining individuals of a species still alive. Students should be able to describe factors which may contribute to the extinction of a species.	

4.6.3.7 Resistant bacteria

Content	Key opportunities for skills development
Bacteria can evolve rapidly because they reproduce at a fast rate. Mutations of bacterial pathogens produce new strains. Some strains might be resistant to antibiotics, and so are not killed. They survive and reproduce, so the population of the resistant strain rises. The resistant strain will then spread because people are not immune to it and there is no effective treatment.	
MRSA is resistant to antibiotics. To reduce the rate of development of antibiotic resistant strains: • doctors should not prescribe antibiotics inappropriately, such as treating non-serious or viral infections • patients should complete their course of antibiotics so all bacteria are killed and none survive to mutate and form resistant strains • the agricultural use of antibiotics should be restricted. The development of new antibiotics is costly and slow. It is unlikely to keep up with the emergence of new resistant strains.	There are links with this content to Antibiotics and painkillers (page 36).

4.6.4 Classification of living organisms

Content	Key opportunities for skills development
Traditionally living things have been classified into groups depending on their structure and characteristics in a system developed by Carl Linnaeus. Linnaeus classified living things into kingdom, phylum, class, order, family, genus and species. Organisms are named by the binomial system of genus and species.	

Content	Key opportunities for skills development
Students should be able to use information given to show understanding of the Linnaean system. Students should be able to describe the impact of developments in biology on classification systems. As evidence of internal structures became more developed due to improvements in microscopes, and the understanding of biochemical processes progressed, new models of classification were proposed. Due to evidence available from chemical analysis there is now a 'three-domain system' developed by Carl Woese. In this system organisms are divided into: • Archaea (primitive bacteria usually living in extreme environments) • Bacteria (true bacteria) • Eukaryota (which includes protists, fungi, plants and animals).	WS 1.1 Understand how scientific methods and theories develop over time.
Evolutionary trees are a method used by scientists to show how they believe organisms are related. They use current classification data for living organisms and fossil data for extinct organisms.	WS 1.2 Interpret evolutionary trees.

4.7 Ecology

The Sun is a source of energy that passes through ecosystems. Materials including carbon and water are continually recycled by the living world, being released through respiration of animals, plants and decomposing microorganisms and taken up by plants in photosynthesis. All species live in ecosystems composed of complex communities of animals and plants dependent on each other and that are adapted to particular conditions, both abiotic and biotic. These ecosystems provide essential services that support human life and continued development. In order to continue to benefit from these services humans need to engage with the environment in a sustainable way. In this section we will explore how humans are threatening biodiversity as well as the natural systems that support it. We will also consider some actions we need to take to ensure our future health, prosperity and well-being.

4.7.1 Adaptations, interdependence and competition

4.7.1.1 Communities

Content	Key opportunities for skills development
Students should be able to describe: • different levels of organisation in an ecosystem from individual organisms to the whole ecosystem • the importance of interdependence and competition in a community. Students should be able to, when provided with appropriate information: • suggest the factors for which organisms are competing in a given habitat • suggest how organisms are adapted to the conditions in which they live. An ecosystem is the interaction of a community of living organisms (biotic) with the non-living (abiotic) parts of their environment. To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there. Plants in a community or habitat often compete with each other for light and space, and for water and mineral ions from the soil. Animals often compete with each other for food, mates and territory. Within a community each species depends on other species for food, shelter, pollination, seed dispersal etc. If one species is removed it can affect the whole community. This is called interdependence. A stable community is one where all the species and environmental factors are in balance so that population sizes remain fairly constant.	WS 2.6 Recording first-hand observations of organisms.
Students should be able to extract and interpret information from charts, graphs and tables relating to the interaction of organisms within a community.	MS 2c, 4a Extract and interpret information from charts, graphs and tables.

4.7.1.2 Abiotic factors

Content	Key opportunities for skills development
Students should be able to explain how a change in an abiotic factor would affect a given community given appropriate data or context. Abiotic (non-living) factors which can affect a community are: • light intensity • temperature • moisture levels • soil pH and mineral content • wind intensity and direction • carbon dioxide levels for plants • oxygen levels for aquatic animals.	WS 1.2
Students should be able to extract and interpret information from charts, graphs and tables relating to the effect of abiotic factors on organisms within a community.	MS 2c, 4a Extract and interpret information from charts, graphs and tables.

4.7.1.3 Biotic factors

Content	Key opportunities for skills development
Students should be able to explain how a change in a biotic factor might affect a given community given appropriate data or context. Biotic (living) factors which can affect a community are: • availability of food • new predators arriving • new pathogens • one species outcompeting another so the numbers are no longer sufficient to breed.	WS 1.2
Students should be able to extract and interpret information from charts, graphs and tables relating to the effect of biotic factors on organisms within a community.	MS 2c, 4a Extract and interpret information from charts, graphs and tables.

4.7.1.4 Adaptations

Content	Key opportunities for skills development
Students should be able to explain how organisms are adapted to live in their natural environment, given appropriate information. Organisms have features (adaptations) that enable them to survive in the conditions in which they normally live. These adaptations may be structural, behavioural or functional.	
Some organisms live in environments that are very extreme, such as at high temperature, pressure, or salt concentration. These organisms are called extremophiles. Bacteria living in deep sea vents are extremophiles.	

4.7.2 Organisation of an ecosystem

4.7.2.1 Levels of organisation

Content	Key opportunities for skills development
Students should understand that photosynthetic organisms are the producers of biomass for life on Earth. Feeding relationships within a community can be represented by food chains. All food chains begin with a producer which synthesises molecules. This is usually a green plant or alga which makes glucose by photosynthesis. A range of experimental methods using transects and quadrats are used by ecologists to determine the distribution and abundance of species in an ecosystem.	
In relation to abundance of organisms students should be able to: • understand the terms mean, mode and median • calculate arithmetic means • plot and draw appropriate graphs selecting appropriate scales for the axes.	MS 2b, 2f, 4a, 4c
Producers are eaten by primary consumers, which in turn may be eaten by secondary consumers and then tertiary consumers.	
Consumers that kill and eat other animals are predators, and those eaten are prey. In a stable community the numbers of predators and prey rise and fall in cycles.	WS 1.2 Interpret graphs used to model predator-prey cycles.
Students should be able to interpret graphs used to model these cycles.	MS 4a

Required practical activity 9: measure the population size of a common species in a habitat. Use sampling techniques to investigate the effect of a factor on the distribution of this species.

AT skills covered by this practical activity: AT 1, 3, 4, 6 and 8.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 99).

4.7.2.2 How materials are cycled

Content	Key opportunities for skills development
Students should: • recall that many different materials cycle through the abiotic and biotic components of an ecosystem • explain the importance of the carbon and water cycles to living organisms. All materials in the living world are recycled to provide the building blocks for future organisms. The carbon cycle returns carbon from organisms to the atmosphere as carbon dioxide to be used by plants in photosynthesis. The water cycle provides fresh water for plants and animals on land before draining into the seas. Water is continuously evaporated and precipitated. Students are not expected to study the nitrogen cycle. Students should be able to explain the role of microorganisms in cycling materials through an ecosystem by returning carbon to the atmosphere as carbon dioxide and mineral ions to the soil.	WS 1.2 Interpret and explain the processes in diagrams of the carbon cycle, the water cycle. There are links with the water cycle to GCSE Chemistry The Earth's early atmosphere. WS 1.2

4.7.2.3 Decomposition (biology only)

Content	Key opportunities for skills development
Students should be able to explain how temperature, water and availability of oxygen affect the rate of decay of biological material.	
Students should be able to: • calculate rate changes in the decay of biological material • translate information between numerical and graphical form • plot and draw appropriate graphs selecting appropriate scales for the axes.	MS 1c, 4a, 4c
Gardeners and farmers try to provide optimum conditions for rapid decay of waste biological material. The compost produced is used as a natural fertiliser for growing garden plants or crops. Anaerobic decay produces methane gas. Biogas generators can be used to produce methane gas as a fuel.	

Required practical activity 10: investigate the effect of temperature on the rate of decay of fresh milk by measuring pH change.

AT skills covered by this practical activity: AT 1, 3, 4 and 5.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 100).

4.7.2.4 Impact of environmental change (biology only) (HT only)

Content	Key opportunities for skills development
Students should be able to evaluate the impact of environmental changes on the distribution of species in an ecosystem given appropriate information. Environmental changes affect the distribution of species in an ecosystem. These changes include: • temperature • availability of water • composition of atmospheric gases. The changes may be seasonal, geographic or caused by human interaction.	WS 1.4 There are links with this content to Biodiversity and the effect of human interaction on ecosystems (page 75).

4.7.3 Biodiversity and the effect of human interaction on ecosystems

4.7.3.1 Biodiversity

Content	Key opportunities for skills development
Biodiversity is the variety of all the different species of organisms on earth, or within an ecosystem. A great biodiversity ensures the stability of ecosystems by reducing the dependence of one species on another for food, shelter and the maintenance of the physical environment. The future of the human species on Earth relies on us maintaining a good level of biodiversity. Many human activities are reducing biodiversity and only recently have measures been taken to try to stop this reduction.	WS 1.4 Explain how waste, deforestation and global warming have an impact on biodiversity.

4.7.3.2 Waste management

Content	Key opportunities for skills development
Rapid growth in the human population and an increase in the standard of living mean that increasingly more resources are used and more waste is produced. Unless waste and chemical materials are properly handled, more pollution will be caused. Pollution can occur: • in water, from sewage, fertiliser or toxic chemicals • in air, from smoke and acidic gases • on land, from landfill and from toxic chemicals. Pollution kills plants and animals which can reduce biodiversity.	There are links with this content to GCSE Chemistry 4.9.3.1 Atmospheric pollutants from fuels.

4.7.3.3 Land use

Content	Key opportunities for skills development
Humans reduce the amount of land available for other animals and plants by building, quarrying, farming and dumping waste.	
The destruction of peat bogs, and other areas of peat to produce garden compost, reduces the area of this habitat and thus the variety of different plant, animal and microorganism species that live there (biodiversity). The decay or burning of the peat releases carbon dioxide into the atmosphere.	WS 1.4, 1.5 Understand the conflict between the need for cheap available compost to increase food production and the need to conserve peat bogs and peatlands as habitats for biodiversity and to reduce carbon dioxide emissions. There are links within this section to Global warming (page 77). There are links within this section to Factors affecting food security (page 80).

4.7.3.4 Deforestation

Content	Key opportunities for skills development
Large-scale deforestation in tropical areas has occurred to: • provide land for cattle and rice fields • grow crops for biofuels	WS 1.4 Evaluate the environmental implications of deforestation.

4.7.3.5 Global warming

Content	Key opportunities for skills development
Students should be able to describe some of the biological consequences of global warming. Levels of carbon dioxide and methane in the atmosphere are increasing, and contribute to 'global warming'.	WS 1.6 Understand that the scientific consensus about global warming and climate change is based on systematic reviews of thousands of peer reviewed publications. WS 1.3 Explain why evidence is uncertain or incomplete in a complex context.

4.7.3.6 Maintaining biodiversity

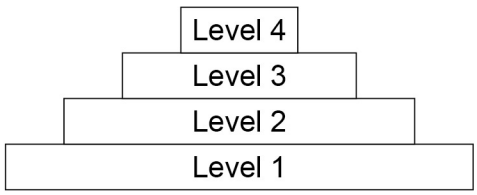
Content	Key opportunities for skills development
Students should be able to describe both positive and negative human interactions in an ecosystem and explain their impact on biodiversity. Scientists and concerned citizens have put in place programmes to reduce the negative effects of humans on ecosystems and biodiversity. These include: • breeding programmes for endangered species • protection and regeneration of rare habitats • reintroduction of field margins and hedgerows in agricultural areas where farmers grow only one type of crop • reduction of deforestation and carbon dioxide emissions by some governments • recycling resources rather than dumping waste in landfill.	WS 1.4, 1.5 Evaluate given information about methods that can be used to tackle problems caused by human impacts on the environment. Explain and evaluate the conflicting pressures on maintaining biodiversity given appropriate information.

4.7.4 Trophic levels in an ecosystem (biology only)

4.7.4.1 Trophic levels

Content	Key opportunities for skills development
Students should be able to describe the differences between the trophic levels of organisms within an ecosystem. Trophic levels can be represented by numbers, starting at level 1 with plants and algae. Further trophic levels are numbered subsequently according to how far the organism is along the food chain. Level 1: Plants and algae make their own food and are called producers. Level 2: Herbivores eat plants/algae and are called primary consumers. Level 3: Carnivores that eat herbivores are called secondary consumers. Level 4: Carnivores that eat other carnivores are called tertiary consumers. Apex predators are carnivores with no predators. Decomposers break down dead plant and animal matter by secreting enzymes into the environment. Small soluble food molecules then diffuse into the microorganism.	

4.7.4.2 Pyramids of biomass

Content	Key opportunities for skills development
Pyramids of biomass can be constructed to represent the relative amount of biomass in each level of a food chain. Trophic level 1 is at the bottom of the pyramid.  	WS 1.2
Students should be able to construct accurate pyramids of biomass from appropriate data.	MS 2c

4.7.4.3 Transfer of biomass

Content	Key opportunities for skills development
Students should be able to: • describe pyramids of biomass • explain how biomass is lost between the different trophic levels. Producers are mostly plants and algae which transfer about 1% of the incident energy from light for photosynthesis.	
Only approximately 10% of the biomass from each trophic level is transferred to the level above it. Losses of biomass are due to: • not all the ingested material is absorbed, some is egested as faeces • some absorbed material is lost as waste, such as carbon dioxide and water in respiration and water and urea in urine. Large amounts of glucose are used in respiration.	MS 1c Calculate the efficiency of biomass transfer between trophic levels.
Students should be able to calculate the efficiency of biomass transfers between trophic levels by percentages or fractions of mass. Students should be able to explain how this affects the number of organisms at each trophic level.	MS 1c

4.7.5 Food production (biology only)

4.7.5.1 Factors affecting food security

Content	Key opportunities for skills development
Students should be able to describe some of the biological factors affecting levels of food security. Food security is having enough food to feed a population. Biological factors which are threatening food security include: • the increasing birth rate has threatened food security in some countries • changing diets in developed countries means scarce food resources are transported around the world • new pests and pathogens that affect farming • environmental changes that affect food production, such as widespread famine occurring in some countries if rains fail • the cost of agricultural inputs • conflicts that have arisen in some parts of the world which affect the availability of water or food. Sustainable methods must be found to feed all people on Earth.	WS 1.4 Interpret population and food production statistics to evaluate food security.

4.7.5.2 Farming techniques

Content	Key opportunities for skills development
The efficiency of food production can be improved by restricting energy transfer from food animals to the environment. This can be done by limiting their movement and by controlling the temperature of their surroundings. Some animals are fed high protein foods to increase growth.	WS 1.3 Understand that some people have ethical objections to some modern intensive farming methods. WS 1.4 Evaluate the advantages and disadvantages of modern farming techniques.

4.7.5.3 Sustainable fisheries

Content	Key opportunities for skills development
Fish stocks in the oceans are declining. It is important to maintain fish stocks at a level where breeding continues or certain species may disappear altogether in some areas. Control of net size and the introduction of fishing quotas play important roles in conservation of fish stocks at a sustainable level.	WS 1.4 Understand how application of different fishing techniques promotes recovery of fish stocks.

4.7.5.4 Role of biotechnology

Content	Key opportunities for skills development
Students should be able to describe and explain some possible biotechnical and agricultural solutions, including genetic modification, to the demands of the growing human population. Modern biotechnology techniques enable large quantities of microorganisms to be cultured for food. The fungus *Fusarium* is useful for producing mycoprotein, a protein-rich food suitable for vegetarians. The fungus is grown on glucose syrup, in aerobic conditions, and the biomass is harvested and purified. A genetically modified bacterium produces human insulin. When harvested and purified this is used to treat people with diabetes. GM crops could provide more food or food with an improved nutritional value such as golden rice.	There are links with this content to Genetic engineering (page 63).

4.8 Key ideas

The complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas in biology.

These key ideas are of universal application, and we have embedded them throughout the subject content. They underpin many aspects of the science assessment.

These ideas include:

- life processes depend on molecules whose structure is related to their function
- the fundamental units of living organisms are cells, which may be part of highly adapted structures including tissues, organs and organ systems, enabling living processes to be performed effectively
- living organisms may form populations of single species, communities of many species and ecosystems, interacting with each other, with the environment and with humans in many different ways
- living organisms are interdependent and show adaptations to their environment

- life on Earth is dependent on photosynthesis in which green plants and algae trap light from the Sun to fix carbon dioxide and combine it with hydrogen from water to make organic compounds and oxygen
- organic compounds are used as fuels in cellular respiration to allow the other chemical reactions necessary for life
- the chemicals in ecosystems are continually cycling through the natural world
- the characteristics of a living organism are influenced by its genome and its interaction with the environment
- evolution occurs by a process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees.

5 Scheme of assessment

Find past papers and mark schemes, and specimen papers for new courses, on our website at aqa.org.uk/pastpapers

This specification is designed to be taken over two years.

This is a linear qualification. In order to achieve the award, students must complete all assessments at the end of the course and in the same series.

GCSE exams and certification for this specification are available for the first time in May/June 2018 and then every May/June for the life of the specification.

All materials are available in English only.

Our GCSE exams in Biology include questions that allow students to demonstrate:

- their knowledge and understanding of the content developed in one section or topic, including the associated mathematical and practical skills or
- their ability to apply mathematical and practical skills to areas of content they are not normally developed in or
- their ability to draw together different areas of knowledge and understanding within one answer.

A range of question types will be used, including multiple choice, short answer and those that require extended responses. Extended response questions will be of sufficient length to allow students to demonstrate their ability to construct and develop a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. Extended responses may be prose, extended calculations, or a combination of both, as appropriate to the question.

5.1 Aims and learning outcomes

Biology should be taught in progressively greater depth over the course of Key Stage 3 and Key Stage 4. GCSE outcomes may reflect or build upon subject content which is typically taught at Key Stage 3. There is no expectation that teaching of such content should be repeated during the GCSE course where it has already been covered at an earlier stage.

GCSE study in biology provides the foundations for understanding the material world. Scientific understanding is changing our lives and is vital to the world's future prosperity, and all students should be taught essential aspects of the knowledge, methods, processes and uses of science. They should be helped to appreciate how the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas relating to the sciences which are both inter-linked, and are of universal application. These key ideas include:

- the use of conceptual models and theories to make sense of the observed diversity of natural phenomena
- the assumption that every effect has one or more cause
- that change is driven by differences between different objects and systems when they interact
- that many such interactions occur over a distance without direct contact
- that science progresses through a cycle of hypothesis, practical experimentation, observation, theory development and review
- that quantitative analysis is a central element both of many theories and of scientific methods of inquiry.

These key ideas are relevant in different ways and with different emphases in biology, chemistry and physics. Examples of their relevance to biology are given below.

The GCSE specification in biology should enable students to:

- develop scientific knowledge and conceptual understanding of biology
- develop understanding of the nature, processes and methods of biology through different types of scientific enquiries that help them to answer scientific questions about the world around them
- develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments
- develop their ability to evaluate claims based on biology through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

Biology should be studied in ways that help students to develop curiosity about the natural world, insight into how science works, and appreciation of its relevance to their everyday lives. The scope and nature of such study should be broad, coherent, practical and satisfying, and thereby encourage students to be inspired, motivated and challenged by the subject and its achievements.

5.2 Assessment objectives

Assessment objectives (AOs) are set by Ofqual and are the same across all GCSE Biology specifications and all exam boards.

The exams will measure how students have achieved the following assessment objectives.

- AO1: Demonstrate knowledge and understanding of: scientific ideas; scientific techniques and procedures.
- AO2: Apply knowledge and understanding of: scientific ideas; scientific enquiry, techniques and procedures.
- AO3: Analyse information and ideas to: interpret and evaluate; make judgements and draw conclusions; develop and improve experimental procedures.

5.2.1 Assessment objective weightings for GCSE Biology

Assessment objectives (AOs)	Component weightings (approx %)		Overall weighting (approx %)
	Paper 1	Paper 2	
AO1	37–43	37–43	40
AO2	37–43	37–43	40
AO3	17–23	17–23	20
Overall weighting of components	50	50	100

5.3 Assessment weightings

The marks awarded on the papers will be scaled to meet the weighting of the components. Students' final marks will be calculated by adding together the scaled marks for each component. Grade boundaries will be set using this total scaled mark. The scaling and total scaled marks are shown in the table below.

Component	Maximum raw mark	Scaling factor	Maximum scaled mark
Paper 1	100	x1	100
Paper 2	100	x1	100
		Total scaled mark:	200

6 General administration

You can find information about all aspects of administration, as well as all the forms you need, at aqa.org.uk/examsadmin

6.1 Entries and codes

You only need to make one entry for each qualification – this will cover all the question papers, non-exam assessment and certification.

Every specification is given a national discount (classification) code by the Department for Education (DfE), which indicates its subject area.

If a student takes two specifications with the same discount code:

- further and higher education providers are likely to take the view that they have only achieved one of the two qualifications
- only one of them will be counted for the purpose of the *School and College Performance tables* – the DfE's rules on 'early entry' will determine which one.

Please check this before your students start their course.

Qualification title	Tier	AQA entry code	DfE discount code
AQA GCSE in Biology	Foundation	8461F	TBC
	Higher	8461H	TBC

This specification complies with:

- Ofqual *General conditions of recognition* that apply to all regulated qualifications
- Ofqual GCSE qualification level conditions that apply to all GCSEs
- Ofqual GCSE subject level conditions that apply to all GCSEs in this subject
- all other relevant regulatory documents.

The Ofqual qualification accreditation number (QAN) is 601/8752/9.

6.2 Overlaps with other qualifications

There are no overlaps with any other AQA qualifications at this level.

6.3 Awarding grades and reporting results

The qualification will be graded on a nine-point scale: 1–9 – where 9 is the best grade.

A student taking Foundation Tier assessments will be awarded a grade within the range of 1 to 5. Students who fail to reach the minimum standard for grade 1 will be recorded as U (unclassified) and will not receive a qualification certificate.

A student taking Higher Tier assessments will be awarded a grade within the range of 4 to 9. A student sitting the Higher Tier who just fails to achieve grade 4 will be awarded an allowed grade 3. Students who fail to reach the minimum standard for the allowed grade 3 will be recorded as U (unclassified) and will not receive a qualification certificate.

6.4 Re-sits and shelf life

Students can re-sit the qualification as many times as they wish, within the shelf life of the qualification.

6.5 Previous learning and prerequisites

There are no previous learning requirements. Any requirements for entry to a course based on this specification are at the discretion of schools and colleges.

6.6 Access to assessment: diversity and inclusion

General qualifications are designed to prepare students for a wide range of occupations and further study. Therefore our qualifications must assess a wide range of competences.

The subject criteria have been assessed to see if any of the skills or knowledge required present any possible difficulty to any students, whatever their ethnic background, religion, sex, age, disability or sexuality. If any difficulties were encountered, the criteria were reviewed again to make sure that tests of specific competences were only included if they were important to the subject.

As members of the Joint Council for Qualifications (JCQ) we participate in the production of the JCQ document *Access Arrangements and Reasonable Adjustments: General and Vocational qualifications*. We follow these guidelines when assessing the needs of individual students who may require an access arrangement or reasonable adjustment. This document is published on the JCQ website at jcq.org.uk

6.6.1 Students with disabilities and special needs

We can make arrangements for disabled students and students with special needs to help them access the assessments, as long as the competences being tested are not changed. Access arrangements must be agreed **before** the assessment. For example, a Braille paper would be a reasonable adjustment for a Braille reader but not for a student who does not read Braille.

We are required by the Equality Act 2010 to make reasonable adjustments to remove or lessen any disadvantage that affects a disabled student.

If you have students who need access arrangements or reasonable adjustments, you can apply using the Access arrangements online service at aqa.org.uk/eaqa

6.6.2 Special consideration

We can give special consideration to students who have been disadvantaged at the time of the assessment through no fault of their own – for example a temporary illness, injury or serious problem such as the death of a relative. We can only do this **after** the assessment.

Your exams officer should apply online for special consideration at aqa.org.uk/eaqa

For more information and advice about access arrangements, reasonable adjustments and special consideration please see aqa.org.uk/access or email accessarrangementsqueries@aqa.org.uk

6.7 Working with AQA for the first time

If your school or college has not previously offered any AQA specification, you need to register as an AQA centre to offer our specifications to your students. Find out how at aqa.org.uk/becomeacentre

6.8 Private candidates

A private candidate is someone who enters for exams through an AQA-approved school or college but is not enrolled as a student there.

If you are a private candidate you may be self-taught, home-schooled or have private tuition, with a tutor or distance learning organisation. You must be based in the UK.

All GCSE science students need to complete practical experiments as part of their learning. A minimum of eight experiments are required for single science qualifications and 16 for double science qualifications. This equips students with essential practical knowledge and experiences, enables them to put theory into practice and helps them develop skills for higher education.

Private candidates wishing to study GCSE sciences need to find a school or college who will let them carry out the required practicals. Schools or colleges accepting private candidates must make provision for them to carry out all of the required practical activities as specified in Practical assessment (page 93). This is likely to incur a cost. We recommend you contact your local schools and colleges to organise this as early as possible.

Students won't be assessed whilst conducting their practical work, but the written exam will include questions on it. Therefore, candidates lacking hands on experience will be at an immediate disadvantage.

If you have any queries as a private candidate, you can:

- speak to the Exams officer at the school or college where you intend to take your exams
- visit our website at aqa.org.uk/exams-administration
- email: privatecandidates@aqa.org.uk

7 Mathematical requirements

Students will be required to demonstrate the following mathematics skills in GCSE Biology assessments.

Questions will target maths skills at a level of demand appropriate to each subject. In Foundation Tier papers questions assessing maths requirements will not be lower than that expected at Key Stage 3 (as outlined in *Mathematics Programmes of Study: Key Stage 3*, by the DfE, document reference DFE-00179-2013). In Higher Tier papers questions assessing maths requirements will not be lower than that of questions and tasks in assessments for the Foundation Tier in a GCSE Qualification in Mathematics.

1	Arithmetic and numerical computation
a	Recognise and use expressions in decimal form
b	Recognise and use expressions in standard form
c	Use ratios, fractions and percentages
d	Make estimates of the results of simple calculations

2	Handling data
a	Use an appropriate number of significant figures
b	Find arithmetic means
c	Construct and interpret frequency tables and diagrams, bar charts and histograms
d	Understand the principles of sampling as applied to scientific data
e	Understand simple probability
f	Understand the terms mean, mode and median
g	Use a scatter diagram to identify a correlation between two variables
h	Make order of magnitude calculations

3	Algebra
a	Understand and use the symbols: =, <, <<, >>, >, $\propto$, ~
d	Solve simple algebraic equations

4	Graphs
a	Translate information between graphical and numeric form
b	Understand that $y = mx + c$ represents a linear relationship
c	Plot two variables from experimental or other data
d	Determine the slope and intercept of a linear graph

5	Geometry and trigonometry
c	Calculate areas of triangles and rectangles, surface areas and volumes of cubes

Mathematical skills references are taken from the DfE subject criteria. Where there is a break in a sequence, the 'missing' references are criteria **not** applicable to GCSE Biology and have been deliberately omitted from this list.

8 Practical assessment

Practical work is at the heart of biology, so we have placed it at the heart of this specification.

There are three interconnected, but separate reasons for doing practical work in schools. They are:

1. To support and consolidate scientific concepts (knowledge and understanding).

   This is done by applying and developing what is known and understood of abstract ideas and models. Through practical work we are able to make sense of new information and observations, and provide insights into the development of scientific thinking.

2. To develop investigative skills. These transferable skills include:

   - devising and investigating testable questions
   - identifying and controlling variables
   - analysing, interpreting and evaluating data.

3. To build and master practical skills such as:

   - using specialist equipment to take measurements
   - handling and manipulating equipment with confidence and fluency
   - recognising hazards and planning how to minimise risk.

By focusing on the reasons for carrying out a particular practical, teachers will help their students understand the subject better, to develop the skills of a scientist and to master the manipulative skills required for further study or jobs in STEM subjects.

Questions in the written exams will draw on the knowledge and understanding students have gained by carrying out the practical activities listed below. These questions will count for at least 15% of the overall marks for the qualification. Many of our questions will also focus on investigative skills and how well students can apply what they know to practical situations often in novel contexts.

The practical handbook will help teachers plan purposeful practical work that develops both practical and investigative skills and encourages the thinking behind the doing so that they can reach their potential.

Teachers are encouraged to further develop students' abilities by providing other opportunities for practical work throughout the course. Opportunities are signposted in the right hand column of the content section of this specification for further skills development.

Our biology scheme of work will provide ideas and suggestions for good practical activities that are manageable with large classes.

8.1 Use of apparatus and techniques

All students are expected to have carried out the required practical activities in Required practical activities (page 94).

The following list includes opportunities for choice and use of appropriate laboratory apparatus for a variety of experimental problem-solving and/or enquiry-based activities.

Safety is an overriding requirement for all practical work. Schools and colleges are responsible for ensuring that appropriate safety procedures are followed whenever their students undertake practical work, and should undertake full risk assessments.

Use and production of appropriate scientific diagrams to set up and record apparatus and procedures used in practical work is common to all science subjects and should be included wherever appropriate.

AT 1–7 are common with combined science. AT 8 is biology only.

	Apparatus and techniques
AT 1	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).
AT 2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater (links to A-level AT a).
AT 3	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes.
AT 4	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment (links to A-level AT h).
AT 5	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator.
AT 6	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field (links to A-level AT k).
AT 7	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings (links to A-level AT d and e).
AT 8 (Biology only)	Use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem-solving contexts including continuous sampling in an investigation (links to A-level AT f).

8.2 Required practical activities

The following practical activities must be carried out by all students taking GCSE Biology.

Following any revision by the Secretary of State of the apparatus or techniques specified, we will review and revise the required practical activities as appropriate.

Schools and colleges will be informed of any changes in a timely manner and the amended specification will be published, highlighting the changes accordingly.

Teachers are encouraged to vary their approach to these practical activities. Some are more suitable for highly structured approaches that develop key techniques while others allow opportunities for students to develop investigative approaches.

This list is not designed to limit the practical activities carried out by students. A rich practical experience will include more than the ten required practical activities. The explicit teaching of practical skills will build students' competence. Many teachers will also use practical approaches to introduce content knowledge in the course of their normal teaching.

Schools and colleges are required to provide a practical science statement to AQA, that is true and accurate written statement, which confirms that it has taken reasonable steps to secure that each student has:

- completed the required practical activities detailed in this specification
- made a contemporaneous record of such work undertaken during the activities and the knowledge, skills and understanding derived from those activities.

We will provide a form for the head of centre to sign. You must submit the form to us by the date published at aqa.org.uk/science. We will contact schools and colleges directly with the deadline date and timely reminders if the form is not received. Failure to send this form counts as malpractice/maladministration, and may result in formal action or warning for the school or college

Practicals 1, 3, 4, 5, 6, 7, and 9 are common with GCSE Combined Science: Trilogy and GCSE Combined Science: Synergy. Practicals 2, 8 and 10 are GCSE Biology only.

8.2.1 Required practical activity 1

Use a light microscope to observe, draw and label a selection of plant and animal cells.

A magnification scale must be included.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record length and area.

AT 7 – use a microscope to make observations of biological specimens and produce labelled scientific drawings.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

MS 1d, 3a – use estimations to judge the relative size or area of sub-cellular structures.

8.2.2 Required practical activity 2 (biology only)

Investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record length and area.

AT 3 – use appropriate apparatus and techniques to observe and measure the process of bacterial growth.

AT 4 – safe and ethical use of bacteria to measure physiological function and response to antibiotics and antiseptics in the environment.

AT 8 – the use of appropriate techniques and qualitative reagents in problem-solving contexts to find the best antibiotic to use or the best concentration of antiseptic to use.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – develop hypotheses about the effectiveness of the antibiotics or antiseptics to be used.

WS 2.2 – plan experiments to make observations, test hypotheses and explore phenomena.

WS 2.4 – have due regard for accuracy of measurements, and health and safety when using bacterial cultures.

MS 5c – calculate cross-sectional areas of bacterial cultures and clear agar jelly using πr^2.

8.2.3 Required practical activity 3

Investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record mass and time.

AT 3 – use appropriate apparatus and techniques to observe and measure the process of osmosis.

AT 5 – measure the rate of osmosis by water uptake.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use the theory of osmosis to create hypotheses on plant tissue.

WS 2.2 – plan experiments to test hypotheses.

WS 2.4 – have due regard for accuracy of measurements and health and safety.

WS 2.6 – make and record observations and measurements of mass.

WS 2.7 – evaluate the method and suggest possible improvements and further investigations.

WS 3.1 – present observations and other data in graphical form.

WS 3.2 – translate mass data into graphical form.

MS 1a, 1c – use simple compound measures of rate of water uptake.

MS 1c – use percentiles and calculate percentage gain and loss of mass of plant tissue.

MS 2b – find mean mass of plant tissue.

MS 4a, 4b, 4c, 4d – plot, draw and interpret appropriate graphs.

8.2.4 Required practical activity 4

Use qualitative reagents to test for a range of carbohydrates, lipids and proteins.

To include: Benedict's test for sugars; iodine test for starch; and Biuret reagent for protein.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 2 – safe use of a Bunsen burner and a boiling water bath.

AT 8 – use of qualitative reagents to identify biological molecules.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, and health and safety considerations.

8.2.5 Required practical activity 5

Investigate the effect of pH on the rate of reaction of amylase enzyme.

Students should use a continuous sampling technique to determine the time taken to completely digest a starch solution at a range of pH values. Iodine reagent is to be used to test for starch every 30 seconds. Temperature must be controlled by use of a water bath or electric heater.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record the volumes of liquids, time and pH.

AT 2 – safe use of a water bath or electric heater.

AT 5 – measure the rate of reaction by the colour change of iodine indicator.

AT 8 – use of qualitative iodine reagent to identify starch by continuous sampling.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations and hypothesis on how pH affects amylase activity.

WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements, and health and safety.

WS 2.5 – describe the appropriate sampling technique to ensure samples are representative.

WS 2.6 – make and record observations and measurements of time.

WS 3.1 – present a graph of amylase activity against pH.

WS 3.2 – translate numeric data into graphical form.

MS 1a, 1c – carry out rate calculations for chemical reactions.

8.2.6 Required practical activity 6

Investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record the rate of production of oxygen gas produced; and to measure and control the temperature of water in a large beaker that acts as a 'heat shield'.

AT 2 – use a thermometer to measure and control temperature of water bath.

AT 3 – use appropriate apparatus and techniques to observe and measure the process of oxygen gas production.

AT 4 – safe and ethical use and disposal of living pondweed to measure physiological functions and responses to light.

AT 5 – measuring rate of reaction by oxygen gas production.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories and explanations to develop hypotheses on how light intensity affects the rate of photosynthesis.

WS 2.2 – plan experiments to test hypotheses.

WS 2.5 – recognise that multiple samples will be needed at each light intensity.

WS 2.6 – make and record observations of gas production.

WS 3.1 – present a graph of light intensity against rate of photosynthesis.

WS 3.2 – translate numeric data into graphical form.

MS 1a, 1c – measure and understand the rate of photosynthesis reactions.

MS 4a, 4c – plot and draw appropriate graphs of rate of photosynthesis against light intensity selecting appropriate scale for axes.

MS 3a, 3d (HT) – understand and use inverse proportion: the inverse square law and light intensity in the context of photosynthesis.

8.2.7 Required practical activity 7

Plan and carry out an investigation into the effect of a factor on human reaction time.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record time.

AT 3 – selecting appropriate apparatus and techniques to measure the process of reaction time.

AT 4 – safe and ethical use of humans to measure physiological function of reaction time and responses to a chosen factor.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

MS 4a – translate information between numerical and graphical forms.

8.2.8 Required practical activity 8 (biology only)

Investigate the effect of light or gravity on the growth of newly germinated seedlings.

Record results both as length measurements and as accurate, labelled biological drawings to show the effects.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record length and time.

AT 3 – selecting appropriate apparatus and techniques to measure the growth of shoots or roots.

AT 4 – safe and ethical use of plants to measure physiological function of growth in response to light or gravity.

AT 7 – observations of biological specimens to produce labelled scientific drawings.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.2 – plan experiments to make observations to explore the phenomena of plant responses.

WS 2.3 – apply knowledge of a range of techniques, apparatus and materials appropriate to the experiment.

WS 2.6 – make and record observations and measurements using length and biological drawings.

WS 2.7 – suggest improvements and further investigations.

WS 3.1 – present observations as tables, graphs or drawings.

8.2.9 Required practical activity 9

Measure the population size of a common species in a habitat.

Use sampling techniques to investigate the effect of a factor on the distribution of this species.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record length and area.

AT 3 – use transect lines and quadrats to measure distribution of a species.

AT 4 – safe and ethical use of organisms and response to a factor in the environment.

AT 6 – application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field.

AT 8 – use of appropriate techniques in more complex contexts including continuous sampling in an investigation.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – develop hypotheses regarding distribution of a species as a consequence of a factor.

WS 2.2 – plan experiments to test hypotheses on distribution.

WS 2.3 – apply a range of techniques, including the use of transects and quadrats, and the measurement of an abiotic factor.

MS 1d, 3a – estimates of population size based on sampling.

MS 2b – calculate arithmetic means.

MS 2d – understand principles of sampling.

MS 2f – understand the terms mean, mode and median as applied to ecological data.

MS 4c – plot and draw appropriate graphs selecting appropriate scales for the axes.

8.2.10 Required practical activity 10 (biology only)

Investigate the effect of temperature on the rate of decay of fresh milk by measuring pH change.

Apparatus and techniques

In doing this practical students should cover these parts of the Apparatus and Techniques requirements.

AT 1 – use appropriate apparatus to record temperature and pH.

AT 3 – the use of appropriate apparatus to measure anaerobic decay.

AT 4 – safe use of microorganisms.

AT 5 – measurement of rate of decay by pH change.

Key opportunities for skills development

In doing this practical there are key opportunities for students to develop the following skills.

WS 2.1 – use scientific theories to make a hypothesis about the effect of temperature on rate of decay.

WS 2.4 – carry out experiments with due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

WS 2.6 – make and record observations and measurements.

WS 2.7 – evaluate method and identify possible improvements.

MS 1c – calculate rate changes in the decay of biological material.

MS 4a – translate information between numerical and graphical form.

MS 4c – plot and draw appropriate graphs selecting appropriate scales for the axes.

Get help and support

Visit our website for information, guidance, support and resources at aqa.org.uk/8461

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