Course Induction Booklet 2026/27

BIOLOGY

Name:

Tutor Group:

Introduction

Biology A-level will give you the skills to make connections and associations with all living things around you. Biology literally means the study of life and if that's not important, what is? Being such a broad topic, you're bound to find a specific area of interest, plus it opens the door to a fantastic range of interesting careers.

Possible degree options
According to bestcourse4me.com, the top seven degree courses taken by students who have an A-level in Biology are:
• Biology
• Psychology
• Sport and exercise science
• Medicine
• Anatomy
• Physiology and Pathology Pharmacology
• Toxicology and Pharmacy Chemistry

Possible career options
Studying A-level Biology at university gives you all sorts of exciting career options, including:
• Doctor
• Clinical molecular geneticist
• Nature conservation officer
• Pharmacologist
• Research scientist
• Vet
• Secondary school teacher
• Marine biologist
• Dentist

Resources for Biology

- Recommended text book:

AQA A Level Biology (2nd edition)

Authors: Glenn Toole, Susan Toole
Publisher: Oxford University Press (including Nelson Thornes)
ISBN-13: 978-0-19-835177-1
Price: £42.00
Publication date: June 2015 - out now
Digital version - out now

2.2 AS

Assessments

Paper 1	Paper 2
What's assessed • Any content from topics 1–4, including relevant practical skills	**What's assessed** • Any content from topics 1–4, including relevant practical skills
Assessed • written exam: 1 hour 30 minutes • 75 marks • 50% of AS	**Assessed** • written exam: 1 hour 30 minutes • 75 marks • 50% of AS
Questions • 65 marks: short answer questions • 10 marks: comprehension question	**Questions** • 65 marks: short answer questions • 10 marks: extended response questions

2.3 A-level

Assessments

Paper 1	Paper 2	Paper 3
What's assessed • Any content from topics 1– 4, including relevant practical skills	**What's assessed** • Any content from topics 5–8, including relevant practical skills	**What's assessed** • Any content from topics 1–8, including relevant practical skills
Assessed • written exam: 2 hours • 91 marks • 35% of A-level	**Assessed** • written exam: 2 hours • 91 marks • 35% of A-level	**Assessed** • written exam: 2 hours • 78 marks • 30% of A-level
Questions • 76 marks: a mixture of short and long answer questions • 15 marks: extended response questions	**Questions** • 76 marks: a mixture of short and long answer questions • 15 marks: comprehension question	**Questions** • 38 marks: structured questions, including practical techniques • 15 marks: critical analysis of given experimental data • 25 marks: one essay from a choice of two titles

Learning Contract

Things your teacher will do:

- Prepare lessons fully
- Mark your work within 10 school days
- Be honest with you
- Meet when we agree
- Give you constructive feedback and targets for improvement with each assignment
- Deliver all the necessary parts of the syllabus
- Prepare for the exams with past papers, mark schemes and mocks
- Put on additional study support in out of school hours
- Treat you as an individual and the maturing young adult that you are
- Individual interviews with each students throughout the course of the year
- Give additional support and help with the course if needed and asked for

Things your teacher will <u>not</u> do:

- Do all your work for you
- Talk all lesson
- Take responsibility for your shortcomings
- Nursemaid or spoon-feed you
- Chase you up all the time, **you** are responsible for your learning

Things you, as the student, will do:

- Attend all lessons; we expect 100% attendance. If you cannot attend, you must bring a letter to your next lesson or email.
- Be punctual to all lessons; if you are 10 minutes late you will not be allowed in. If this is not possible due to emergency, contact your teacher ASAP
- Meet your TMG in all assessments.
- Bring your handbook, folder, notebook to all lessons
- Organise your work and revision notes after every lesson.
- Wear correct dress code at all times to all lessons
- Treat class members with respect, including teachers, at all times
- Meet all homework deadlines
- Read around the subject and take an active interest in it
- Behave like a maturing young adult at all times
- Access all electronic material you are guided to and complete all assignments

If this agreement is broken, consequences may include

1. Individual interview with teacher and/or KS5 coordinator
2. Letter or phone call home
3. Referral to the KS5 coordinator to be placed on the intervention programme.
4. Asked to leave the course by the Head teacher/KS5 coordinator

Signed: _____ (Student)

Signed: _____ (Teacher)

New assessment objectives (AOs)

All

These apply to both AS and A-level

		A-level	AS
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures	30-35%	35-40%
AO2	Apply knowledge and understanding of scientific ideas, processes, techniques and procedures: • in a theoretical context • in a practical context • when handling qualitative data • when handling quantitative data	40-45%	40-45%
AO3	Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to: • make judgements and reach conclusions • develop and refine practical design and procedures	25-30%	20-25%

AS and A-level topics

AS and A-level

1. Biological molecules
2. Cells
3. Organisms exchange substances with their environment
4. Genetic information, variation and relationships between organisms

A-level only

5. Energy transfers in and between organisms
6. Organisms respond to changes in their internal and external environments
7. Genetics, populations, evolution and ecosystems
8. The control of gene expression

Holy Family Catholic School Curriculum Overview Year 12 – Biology (A Level)

	Curriculum Content: Exam Board AQA	Suggested Reading or Extension Activities
Half Term 1 (Sept-Oct)	**3.1 Biological Molecules** This is a key topic which introduces the main biological molecules that students will need an understanding of for the whole course. This includes, Carbohydrates, Lipids, Proteins, Nucleic acids and Water. **Includes Required Practical 1** **3.2 Cells** This topic will look at the features in all cells and how we study them. It will also look into how cells arise from other cells including binary fission, mitosis and meiosis. **Includes Required Practical 2**	Pixl Independence: Biological Molecules and Cells The Spark of Life by Frances Ashcroft
Half Term 2 (Nov-Dec)	**3.2.3 Transport across Cell Membranes** This topic will look at the structure of the cell membrane along with the different processes of substances being transported across. **Includes Required Practical 3 and 4** **3.2.4 Cell Recognition and Immune system** This topic will study how cells can communicate with others to allow the recognition of 'self' and 'foreign' cells and how we respond to them in an immune response.	The Machinery of Life by David Goodsell Bad Science by Ben Goldacre
Half Term 3 (Jan-Feb)	**3.3.3 Exchanging Substances** This topic will study the different ways in which substances are exchanged between the internal and external environments of organisms. **3.4 DNA and Protein synthesis** This topic will look at the structure of DNA and chromosomes and the process of making proteins in the cell. **3.4.4 Genetic Diversity** This topic will look at how genetic diversity can be caused by gene mutations, chromosome mutation or random factors due to meiosis and fertilisation. This diversity is acted upon by natural selection, resulting in species becoming better adapted to their environment. **Includes Required Practical 6**	Pixl Independence: Exchange Genome by Matt Ridley The Double Helix by James Watson

Half Term 4 (Feb-Mar)	**3.3.4 Mass Transport in plants and animals** This topic will look at the different ways in which substances, which have been exchanged, are now transported around the organism. This is to ensure that diffusion gradients are maintained **Includes Required Practical 5** **3.4.5 Species and Biodiversity** This topic will look at what a species can be defined as and how they are classified and how we can measure biodiversity using species richness and an index of diversity.	Pixl Independence: Transport and Genetic Diversity The Selfish Gene by Richard Dawkins Do We Need Pandas? by Ken Thompson The Variety of Life Colin Tudge
Half Term 5 (Apr-May)	**Maths in Biology** This term we will study the maths requirement of the Biology specification including the three statistical tests; Chi squared, T test and Spearman's Rank. **Preparation for end of year exams.**	
Half Term 6 (Jun-Jul)	**3.5 Photosynthesis and Respiration** This is where the year 2 lessons begin with Photosynthesis. In this topic we will look at how life depends on continuous transfers of energy. In both processes we will study the production of ATP which is the molecule which provides energy to the organism.	The Life of a Leaf by Steven Vogel The Private Life of Plants by David Attenborough

Examples of Home Learning Tasks	Pixl Knowledge and Independence Completion of Lab book for required Practicals
Assessment Tasks, Methods & Frequency	Students will be given Formal assessments every half term in line with the assessment weeks in the school calendar. Questions will be synoptic of the topics they have been studying up to that point. Students will also be given 'Progress Tests' which will be used to check their understanding of the topic they have just completed. All assessments will use published AQA exam questions from previous years and specifications. Students lab books will be marked and assessed against the CPAC skills after every required practical.
Equipment that Students Need	Folders and dividers for each teacher and topic. Pen, pencil, ruler, rubber, scientific calculator, sharpener.

Parent / Carers can help their child by:	Make sure they have a quiet space to study with no distractions. Encourage them to not listen to music, use their phone when studying. Help with flashcard revision, quiz them and help check their answers. Encourage them to make a study timetable to organise their time.
Useful Websites	https://www.aqa.org.uk/subjects/science/as-and-a-level/biology-7401-7402 https://www.youtube.com/c/MissEstruch https://www.youtube.com/c/BiologyPracticalActivitiesandRevision https://www.physicsandmathstutor.com/biology-revision/a-level-aqa/

Extra-Curricular Activities & Career Opportunities	Sutton Trust Summer School Programmes Epping Forest/Kew Gardens fieldwork

Who Can I Contact?	Head of Science	Mr T. Thrasivoulou
	KS5 Science Co-ordinator	Mr A. Yohannes
	Teachers of Year 12 Biology	Mr Yohannes Mrs Wilbraham

Holy Family Catholic School Curriculum Overview Year 13 – Biology (A Level)

	Curriculum Content Exam Board: AQA	Suggested Reading or Extension Activities
Half Term 1 (Sept-Oct)	**3.5.1 Photosynthesis** In this topic, we will review the content that was taught at the end of Year 12 and apply theory to past exam questions. **Includes Required Practical 7 and 8** **3.5.2 Respiration** In this topic, we will review the content that was taught at the end of Year 12 and apply theory to past exam questions. **Includes Required Practical 9** **3.5.3 Energy and Ecosystems** This topic will look at communities in Biology and how biological molecules that are made in photosynthesis are consumed by other organisms. We will also look at the transfer of biomass and its stored chemical energy in a community from one organism to another and the efficiency of this process.	Pixl Independence: Energy Transfers Darwin's Island by Steve Jones Life on Earth by David Attenborough
Half Term 2 (Nov-Dec)	**3.5.4 Nutrient cycles** This topic will look at how nutrients are recycled within natural ecosystems, specially in the nitrogen and phosphorus cycle and the role of microorganisms in these cycles. It will also look at the use of artificial and natural fertilisers in farming and the environmental impacts these can have on the ecosystem. **3.6.2 Nervous Communication** This topic will look at how organisms respond to different stimuli to produce an effect. It will study how nerve cells enable communication in animals and contrast it to hormones as a method of communication. **Includes Required Practical 10**	Pixl Independence: Responding to Change Life Unfolding by Jamie Davies
Half Term 3 (Jan-Feb)	**3.7.1 Inheritance** This topic will look at how the theory of evolution underpins modern biology. This results in different species sharing a common ancestry, as represented in phylogenetic classification. Common ancestry can explain the similarities between all living	Pixl Independence: Populations The Immortal Life of Henrietta Lacks by Rebecca Skloot

	organisms, such as common chemistry (e.g. all proteins made from the same 20 or so amino acids), physiological pathways (e.g. anaerobic respiration), cell structure, DNA as the genetic material and a 'universal' genetic code. The individuals of a species share the same genes but (usually) different combinations of alleles of these genes. An individual inherits alleles from their parent or parents **3.6.3 Skeletal Muscle and Homeostasis** This topic looks at the process involved in muscle contraction and the use of ATP in this process. We look at how the body controls the internal environment particularly in regards to blood glucose and water potential of blood **Required practical 11**	
Half Term 4 (Feb-Mar)	**3.7.2 Populations** In this topic, we will study how species exist in different populations and how this variation arises. We will also look at how natural selection occurs and how the change in allele frequency in a population indicates evolution. **Includes Required Practical 12** **3.8 The control of gene expression** This topic looks at the cells ability to control metabolic activities by regulating transcription and translation of their genome. We will look at other factors, both internal and external, that will control the expression of genes and thus the phenotypes of organisms. We will also look at the medical and technological applications of altering the epigenome, genomes and proteomes of an organism.	Pixl Independence: Gene Expression The Greatest Show on Earth by Richard Dawkins The Epigenetics Revolution by Nessa Carey
Half Term 5 (Apr-May)	**3.7.3 Populations in ecosystems** This topic looks at Populations of different species that live in communities. Competition occurs within and between these populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem. **3.8.2 DNA Technology** In this topic we study the use of DNA technology in the diagnosis and treatment of human diseases. We will also evaluate information relating to screening individuals for genetically determined conditions and drug responses	

Half Term 6 (Jun-Jul)	Revision and exam practice	

Examples of Home Learning Tasks	Pixl Knowledge and Independence Completion of Lab book for required Practicals
Assessment Tasks, Methods & Frequency	Students will be given Formal assessments every half term in line with the assessment weeks in the school calendar. Questions will be synoptic of the topics they have been studying up to that point. Students will also be given 'Progress Tests' which will be used to check their understanding of the topic they have just completed. All assessments will use published AQA exam questions from previous years and specifications. Students lab books will be marked and assessed against the CPAC skills after every required practical.
Equipment that Students Need	Folders and dividers for each teacher and topic. Pen, pencil, ruler, rubber, scientific calculator, sharpener.

Parent / Carers can help their child by:	Make sure they have a quiet space to study with no distractions. Encourage them to not listen to music, use their phone when studying. Help with flashcard revision, quiz them and help check their answers. Encourage them to make a study timetable to organise their time.
Useful Websites	https://www.aqa.org.uk/subjects/science/as-and-a-level/biology-7401-7402 https://www.youtube.com/c/MissEstruch https://www.youtube.com/c/BiologyPracticalActivitiesandRevision https://www.physicsandmathstutor.com/biology-revision/a-level-aqa/
Extra-Curricular Activities & Career Opportunities	Sutton Trust Summer School Programmes

Who Can I Contact?	Head of Science	Mr T. Thrasivoulou
	KS5 Science Co-ordinator	Mr A. Yohannes
	Teachers of Year 13 Biology	Mr Yohannes Mrs Wilbraham

Skills Needed for Biology

Mathematics (MS)

Overall, at least 10% of the marks in assessments for biology will require the use of mathematical skills.
These skills will be applied in the context of biology and will be at least the standard of higher tier GCSE mathematics.
The following tables illustrate where these mathematical skills may be developed during teaching or could be assessed. Those shown in bold type would only be tested in the full A-level course.

6.1 Arithmetic and numerical computation

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 0.1	Recognise and make use of appropriate units in calculations	Students may be tested on their ability to: • convert between units, eg mm3 to cm3 as part of volumetric calculations • work out the unit for a rate, eg breathing rate
MS 0.2	Recognise and use expressions in decimal and standard form	Students may be tested on their ability to: • use an appropriate number of decimal places in calculations, eg for a mean • carry out calculations using numbers in standard and ordinary form, eg use of magnification • understand standard form when applied to areas such as size of organelles • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form, eg $0.0050\ \text{mol dm}^{-3}$ is equivalent to $5.0 \times 10^{-3}\ \text{mol dm}^{-3}$

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 0.3	Use ratios, fractions and percentages	Students may be tested on their ability to: • calculate percentage yields • calculate surface area to volume ratio • use scales for measuring • represent phenotypic ratios (monohybrid and dihybrid crosses)
MS 0.4	Estimate results	Students may be tested on their ability to: • estimate results to sense check that the calculated values are appropriate
MS 0.5	**Use calculators to find and use power, exponential and logarithmic functions**	**Students may be tested on their ability to:** • **estimate the number of bacteria grown over a certain length of time**

6.2 Handling data

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 1.1	Use an appropriate number of significant figures	Students may be tested on their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures • understand that calculated results can only be reported to the limits of the least accurate measurement
MS 1.2	Find arithmetic means	Students may be tested on their ability to: • find the mean of a range of data, eg the mean number of stomata in the leaves of a plant
MS 1.3	Construct and interpret frequency tables and diagrams, bar charts and histograms	Students may be tested on their ability to: • represent a range of data in a table with clear headings, units and consistent decimal places • interpret data from a variety of tables, eg data relating to organ function • plot a range of data in an appropriate format, eg enzyme activity over time represented on a graph • interpret data for a variety of graphs, eg explain electrocardiogram traces
MS 1.4	Understand simple probability	Students may be tested on their ability to: • use the terms probability and chance appropriately • understand the probability associated with genetic inheritance
MS 1.5	Understand the principles of sampling as applied to scientific data	Students may be tested on their ability to: • analyse random data collected by an appropriate means, eg use Simpson's index of diversity to calculate the biodiversity of a habitat
MS 1.6	Understand the terms mean, median and mode	Students may be tested on their ability to: • calculate or compare the mean, median and mode of a set of data, eg height/mass/size of a group of organisms
MS 1.7	Use a scatter diagram to identify a correlation between two variables	Students may be tested on their ability to: • interpret a scattergram, eg the effect of lifestyle factors on health
MS 1.8	Make order of magnitude calculations	Students may be tested on their ability to: • use and manipulate the magnification formula $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$
MS 1.9	Select and use a statistical test	Students may be tested on their ability to select and use: • the chi-squared test to test the significance of the difference between observed and expected results • the Student's t-test • the correlation coefficient

MS 1.10	Understand measures of dispersion, including standard deviation and range	Students may be tested on their ability to: • calculate the standard deviation • understand why standard deviation might be a more useful measure of dispersion for a given set of data, eg where there is an outlying result
MS 1.11	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Students may be tested on their ability to: • calculate percentage error where there are uncertainties in measurement

6.3 Algebra

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 2.1	Understand and use the symbols: =, <, <<, >>, >, ∝, ~.	No exemplification required.
MS 2.2	Change the subject of an equation	Students may be tested on their ability to: • use and manipulate equations, eg magnification
MS 2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Students may be tested on their ability to: • use a given equation, eg Simpson's index of diversity $d = \frac{N(N-1)}{\Sigma n(n-1)}$
MS 2.4	Solve algebraic equations	Students may be tested on their ability to: • solve equations in a biological context, eg $cardiac\ output = stroke\ volume \times heart\ rate$
MS 2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Students may be tested on their ability to:** • **use a logarithmic scale in the context of microbiology, eg growth rate of a microorganism such as yeast**

6.4 Graphs

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 3.1	Translate information between graphical, numerical and algebraic forms	Students may be tested on their ability to: • understand that data may be presented in a number of formats and be able to use these data, eg dissociation curves
MS 3.2	Plot two variables from experimental or other data	Students may be tested on their ability to: • select an appropriate format for presenting data, bar charts, histograms, graphs and scattergrams
MS 3.3	Understand that $y = mx + c$ represents a linear relationship	Students may be tested on their ability to: • predict/sketch the shape of a graph with a linear relationship, eg the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme
MS 3.4	**Determine the intercept of a graph**	**Students may be tested on their ability to:** • **read off an intercept point from a graph, eg compensation point in plants**
MS 3.5	Calculate rate of change from a graph showing a linear relationship	Students may be tested on their ability to: • calculate a rate from a graph, eg rate of

MS 3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Students may be tested on their ability to: • use this method to measure the gradient of a point on a curve, eg amount of product formed plotted against time when the concentration of enzyme is fixed

6.5 Geometry and trigonometry

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 4.1	Calculate the circumferences, surface areas and volumes of regular shapes	Students may be tested on their ability to: • calculate the circumference and area of a circle • calculate the surface area and volume of rectangular prisms, of cylindrical prisms and of spheres • eg calculate the surface area or volume of a cell

AS Practical Assessment

Assessment of practical skills in this AS specification will be by written exams only
15% of the marks in the papers will relate to practical work.

Use of apparatus and techniques (AT)

All students taking an A-level Biology qualification are expected to have had opportunities to use the following apparatus and develop and demonstrate these techniques.

	Apparatus and techniques
AT a	use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)
AT b	use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer
AT c	use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions
AT d	use of light microscope at high power and low power, including use of a graticule
AT e	produce scientific drawing from observation with annotations
AT f	use qualitative reagents to identify biological molecules
AT g	separate biological compounds using thin layer/paper chromatography or electrophoresis
AT h	safely and ethically use organisms to measure: • plant or animal responses • physiological functions
AT i	use microbiological aseptic techniques, including the use of agar plates and broth
AT j	safely use instruments for dissection of an animal organ, or plant organ
AT k	use sampling techniques in fieldwork
AT l	use ICT such as computer modelling, or data logger to collect data, or use software to process data

7.2 AS required practical activities

The following practicals must be carried out by all students taking this course. Written papers will assess knowledge and understanding of these, and the skills exemplified within each practical.

Required activity	Apparatus and technique reference
1. Investigation into the effect of a named variable on the rate of an enzyme-controlled reaction	a, b, c, f, l
2. Preparation of stained squashes of cells from plant root tips; set-up and use of an optical microscope to identify the stages of mitosis in these stained squashes and calculation of a mitotic index	d, e, f
3. Production of a dilution series of a solute to produce a calibration curve with which to identify the water potential of plant tissue	c, h, j, l
4. Investigation into the effect of a named variable on the permeability of cell-surface membranes	a, b, c, j, l
5. Dissection of animal or plant gas exchange system or mass transport system or of organ within such a system	e, h, j
6. Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth	c, i

7.3 Practical skills to be assessed in written papers

Overall, at least 15% of the marks for an AS Biology qualification will require the assessment of practical skills.

In order to be able to answer these questions, students need to have been taught, and to have acquired competence in, the appropriate areas of practical skills as indicated in the table of coverage below.

7.3.1 Independent thinking

	Practical skill
PS 1.1	Solve problems set in practical contexts
PS 1.2	Apply scientific knowledge to practical contexts

7.3.2 Use and application of scientific methods and practices

	Practical skill
PS 2.1	Comment on experimental design and evaluate scientific methods
PS 2.2	Present data in appropriate ways
PS 2.3	Evaluate results and draw conclusions with reference to measurement uncertainties and errors
PS 2.4	Identify variables including those that must be controlled

7.3.3 Numeracy and the application of mathematical concepts in a practical context

	Practical skill
PS 3.1	Plot and interpret graphs
PS 3.2	Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
PS 3.3	Consider margins of error, accuracy and precision of data

7.3.4 Instruments and equipment

	Practical skill
PS 4.1	Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

A Level Practical Assessment

- A-level grades will be based only on marks from written exams.
- **A separate endorsement** of practical skills will be taken alongside the A-level. This will be assessed by teachers and will be based on direct observation of students' competency in a range of skills that are not assessable in written exams.

AT and PS descriptors are the same as the AS biology.

8.2 A-level required practical activities

The following practicals must be carried out by all students taking this course. Written papers will assess knowledge and understanding of these, and the skills exemplified within each practical.

Required activity	Apparatus and technique reference
1. Investigation into the effect of a named variable on the rate of an enzyme-controlled reaction	a, b, c, f, l
2. Preparation of stained squashes of cells from plant root tips; set-up and use of an optical microscope to identify the stages of mitosis in these stained squashes and calculation of a mitotic index	d, e, f
3. Production of a dilution series of a solute to produce a calibration curve with which to identify the water potential of plant tissue	c, h, j, l
4. Investigation into the effect of a named variable on the permeability of cell-surface membranes	a, b, c, j, l
5. Dissection of animal or plant gas exchange or mass transport system or of organ within such a system	e, h, j
6. Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth	c, i
7. Use of chromatography to investigate the pigments isolated from leaves of different plants, eg leaves from shade-tolerant and shade-intolerant plants or leaves of different colours	b, c, g

8. Investigation into the effect of a named factor on the rate of dehydrogenase activity in extracts of chloroplasts	a, b, c
9. Investigation into the effect of a named variable on the rate of respiration of cultures of single-celled organisms	a, b, c, i
10. Investigation into the effect of an environmental variable on the movement of an animal using either a choice chamber or a maze	h
11. Production of a dilution series of a glucose solution and use of colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown 'urine' sample	b, c, f
12. Investigation into the effect of a named environmental factor on the distribution of a given species	a, b, h, k, l

How to be Competent in Practical work to ensure a 'PASS'

In order to achieve a pass, students will need to have met the following expectations. Students can demonstrate these competencies in any practical activity undertaken throughout the course of study.
Students may work in groups but must be able to demonstrate and record independent evidence of their competency. This must include evidence of independent application of investigative approaches and methods to practical work.

Competency	Practical mastery
1. Follows written procedures	Correctly follows instructions to carry out the experimental techniques or procedures.
2. Applies investigative approaches and methods when using instruments and equipment	Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.

Competency	Practical mastery
3. Safely uses a range of practical equipment and materials	Identifies hazards and assesses risks associated with these hazards when carrying out experimental techniques and procedures in the lab or field. Uses appropriate safety equipment and approaches to minimise risks with minimal prompting. Identifies safety issues and makes adjustments when necessary.
4. Makes and records observations	Makes accurate observations relevant to the experimental or investigative procedure. Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
5. Researches, references and reports	Uses appropriate software and/or tools to process data, carry out research and report findings. Sources of information are cited demonstrating that research has taken place, supporting planning and conclusions.

GLOSSARY: COMMAND WORDS

The following command words are taken from Ofqual's official list of command words and their meanings that are relevant to this subject. In addition, where necessary, we have included our own command words and their meanings to complement Ofqual's list.

Analyse: Separate information into components and identify their characteristics
Annotate: Add notation or labelling to a graph, diagram or other drawing
Apply: Put into effect in a recognised way
Argue: Present a reasoned case
Assess: Make an informed judgement
Calculate: Work out the value of something
Comment: Present an informed opinion
Compare: Identify similarities and/ or differences
Complete: Finish a task by adding to given information
Consider: Review and respond to given information
Contrast: Identify differences
Criticise: Access worth against explicit expectations
Debate: Present different perspectives on an issue
Deduce: Draw conclusions from information provided
Define: Specify meaning
Describe: Give an account of

Design: Set out how something will be done
Determine: Use given data or information to obtain an answer
Develop: Take forward or build upon given information
Discuss: Present key points
Distinguish: List the differences between different items
Draw: Produce a diagram
Estimate: Assign an approximate value
Evaluate: Judge from available evidence
Explain: Give reasons
Explore: Investigate without preconceptions about the outcome
Give: Produce an answer from recall or from given information
Identify: Name or otherwise characterise
Justify: Support a case with evidence
Label: Provide appropriate names on a diagram
List: List a number of features or points without further elaboration
Name: Identify using a recognised technical term
Outline: Set out main characteristics
Predict: Give a plausible outcome
Relate: Give a technical term or its equivalent
Show: Provide structured evidence to reach a conclusion
Sketch: Draw approximately
State: Express in clear terms
Suggest: Present a possible case

GLOSSARY: BIOLOGY SPECIFIC

Accuracy: A measurement result is considered accurate if it is judged to be close to the true value.

Calibration: Marking a scale on a measuring instrument. This involves establishing the relationship between indications of a measuring instrument and standard or reference quantity values, which must be applied. For example, placing a thermometer in melting ice to see whether it reads 0^{0}C, in order to check if it has been calibrated correctly.

Data: Information, either qualitative or quantitative, that has been collected.

Errors: See also uncertainties.

Measurement error: The difference between a measured value and the true value.

Anomalies: These are values in a set of results which are judged not to be part of the variation caused by random uncertainty.

Random error: These cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next. Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by making more measurements and calculating a new mean.

Systematic error: These cause readings to differ from the true value by a consistent amount each time a measurement is made. Sources of systematic error can include the environment, methods of observation or instruments used. Systematic errors cannot be dealt with by simple repeats. If

a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

Zero error: Any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, eg the needle on an ammeter failing to return to zero when no current flows. A zero error may result in a systematic uncertainty.

Evidence: Data which has been shown to be valid.

Fair test: A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis: A proposal intended to explain certain facts or observations.

Interval: The quantity between readings, e.g. a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

Precision: Precise measurements are ones in which there is very little spread about the mean value. Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction: A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Range: The maximum and minimum values of the independent or dependent variables; important in ensuring that any pattern is detected.

Repeatable: A measurement is repeatable if the original experimenter repeats the investigation using the same method and equipment and obtains the same results.

Reproducible: A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

Resolution: This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.

Sketch graph: A line graph, not necessarily on a grid, that shows the general shape of the relationship between two variables. It will not have any points plotted and although the axes should be labelled they may not be scaled.

True value: This is the value that would be obtained in an ideal measurement.

Uncertainty: The interval within which the true value can be expected to lie, with a given level of confidence or probability, eg “the temperature is 20 °C ± 2 °C, at a level of confidence of 95 %.

Validity: Suitability of the investigative procedure to answer the question being asked. For example, an investigation to find out if the rate of a chemical reaction depended upon the concentration of one of the reactants would not be a valid procedure if the temperature of the reactants was not controlled.

Valid conclusion: A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Variables: These are physical, chemical or biological quantities or characteristics.

Categorical variables: Categorical variables have values that are labels. E.g. names of plants or types of material.

Continuous variables: Continuous variables can have values (called a quantity) that can be given a magnitude either by counting (as in the case of the number of shrimp) or by measurement (e.g. light intensity, flow rate etc.).

Control variables: A control variable is one which may, in addition to the independent variable, affect the outcome of the investigation and therefore has to be kept constant or at least monitored.

Dependent variables: The dependent variable is the variable of which the value is measured for each and every change in the independent variable.

Independent variables: The independent variable is the variable for which values are changed or selected by the investigator

Useful Websites

ABPI the Association of the British Pharmaceutical Industry
http://www.abpischools.org.uk/page/

http://www.accessexcellence.org/

http://www.bbc.co.uk/schools/asguru/index.shtml

http://www.biochem4schools.org/

http://www.biologyguide.net/ [At present for spec A – being revised June 08]

http://www.biologymad.com/ [At present for spec A]

http://www.biozone.co.nz/links.html [being up-dated for new specs]

http://bubl.ac.uk/link/b/biologyeducation.htm
BUBL LINK - Catalogue of Internet Resources

http://www.cellsalive.com/

http://www.eduseek.com/topic.aspx?id=1997

http://www.fungi4schools.org/

http://www.healthline.com/

http://www.innerbody.com/htm/body.html

Institute of Biology www.iob.org

http://www.ketteringpumpkins.co.uk/

http://www.lungsonline.com/

http://www.mrothery.co.uk/ [At present for spec B]

http://multimedia.mcb.harvard.edu/media.html

http://physics.syr.edu/courses/mirror/biomorph/

http://www.revision-notes.co.uk/revision/848.html

http://www.revisiontime.com/aBio.htm

S Cool http://www.s-cool.co.uk/topic_index.asp?subject_id=3&d=0

http://www.sciencedaily.com/news/health_medicine/human_biology/

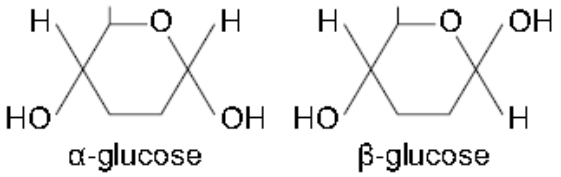
http://www.spolem.co.uk/alevel_home.htm

AS & A Level BIOLOGICAL MOLECULES

3.1.1 Monomers and polymers

Content	Opportunities for skills development
The variety of life, both past and present, is extensive, but the biochemical basis of life is similar for all living things. Monomers are the smaller units from which larger molecules are made. Polymers are molecules made from a large number of monomers joined together. Monosaccharides, amino acids and nucleotides are examples of monomers. A condensation reaction joins two molecules together with the formation of a chemical bond and involves the elimination of a molecule of water. A hydrolysis reaction breaks a chemical bond between two molecules and involves the use of a water molecule.	

3.1.2 Carbohydrates

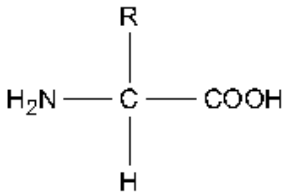
Content	Opportunities for skills development
Monosaccharides are the monomers from which larger carbohydrates are made. Glucose, galactose and fructose are common monosaccharides. A condensation reaction between two monosaccharides forms a glycosidic bond. Disaccharides are formed by the condensation of two monosaccharides: • maltose is a disaccharide formed by condensation of two glucose molecules • sucrose is a disaccharide formed by condensation of a glucose molecule and a fructose molecule • lactose is a disaccharide formed by condensation of a glucose molecule and a galactose molecule. Glucose has two isomers, α-glucose and β-glucose, with structures:  Polysaccharides are formed by the condensation of many glucose units. • Glycogen and starch are formed by the condensation of α-glucose. • Cellulose is formed by the condensation of β-glucose. The basic structure and functions of glycogen, starch and cellulose. The relationship of structure to function of these substances in animal cells and plant cells. Biochemical tests using Benedict's solution for reducing sugars and non-reducing sugars and iodine/potassium iodide for starch.	**AT f** Students could use, and interpret the results of, qualitative tests for reducing sugars, non-reducing sugars and starch. **AT g** Students could use chromatography, with known standard solutions, to separate a mixture of monosaccharides and identify their components. **AT c** Students could produce a dilution series of glucose solution and use colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown solution.

3.1.3 Lipids

Content	Opportunities for skills development
Triglycerides and phospholipids are two groups of lipid. Triglycerides are formed by the condensation of one molecule of glycerol and three molecules of fatty acid. A condensation reaction between glycerol and a fatty acid (RCOOH) forms an ester bond. The R-group of a fatty acid may be saturated or unsaturated. In phospholipids, one of the fatty acids of a triglyceride is substituted by a phosphate-containing group. The different properties of triglycerides and phospholipids related to their different structures. The emulsion test for lipids. **Students should be able to**: • recognise, from diagrams, saturated and unsaturated fatty acids • explain the different properties of triglycerides and phospholipids.	**AT f** Students could use, and interpret the results of, the emulsion test for lipids.

3.1.4 Proteins

3.1.4.1 General properties of proteins

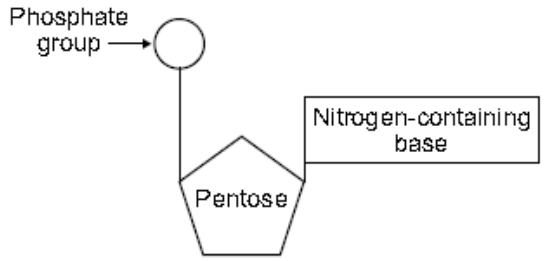
Content	Opportunities for skills development
Amino acids are the monomers from which proteins are made. The general structure of an amino acid as:  where NH2 represents an amine group, COOH represents a carboxyl group and R represents a carbon-containing side chain. The twenty amino acids that are common in all organisms differ only in their side group. A condensation reaction between two amino acids forms a peptide bond. • Dipeptides are formed by the condensation of two amino acids. • Polypeptides are formed by the condensation of many amino acids. A functional protein may contain one or more polypeptides.	**AT f** Students could use, and interpret the results of, a biuret test for proteins. **AT g** Students could use chromatography with known standard solutions, to separate a mixture of amino acids and identify their components.
The role of hydrogen bonds, ionic bonds and disulfide bridges in the structure of proteins. Proteins have a variety of functions within all living organisms. The relationship between primary, secondary, tertiary and quaternary structure, and protein function. The biuret test for proteins. **Students should be able to** relate the structure of proteins to properties of proteins named throughout the specification.	

3.1.4.2 Many proteins are enzymes

Content	Opportunities for skills development
Each enzyme lowers the activation energy of the reaction it catalyses. The induced-fit model of enzyme action. The properties of an enzyme relate to the tertiary structure of its active site and its ability to combine with complementary substrate(s) to form an enzyme-substrate complex. • The specificity of enzymes • The effects of the following factors on the rate of enzyme-controlled reactions – enzyme concentration, substrate concentration, concentration of competitive and of non-competitive inhibitors, pH and temperature. **Students should be able to:** • appreciate how models of enzyme action have changed over time • appreciate that enzymes catalyse a wide range of intracellular and extracellular reactions that determine structures and functions from cellular to whole-organism level.	**MS 0.5** Students could be given the hydrogen ion concentration of a solution in order to calculate its pH, using the formula: $pH = -log_{10}[H^+]$
Required practical 1: Investigation into the effect of a named variable on the rate of an enzyme-controlled reaction.	**PS 2.4** Students could identify the variables that must be controlled in their investigation into rate of reaction. **PS 3.3** Students could calculate the uncertainty of their measurements of the rate of reaction. **MS 3.2** Students could select an appropriate format for the graphical presentation of the results of their investigation into the rate of enzyme-controlled reactions. **MS 3.6** Students could use a tangent to find the initial rate of an enzyme-controlled reaction.

3.1.5 Nucleic acids are important information-carrying molecules

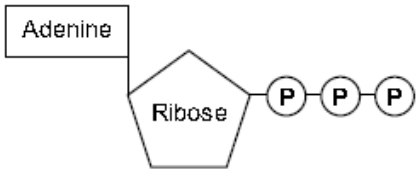
3.1.5.1 Structure of DNA and RNA

Content	Opportunities for skills development
Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are important information-carrying molecules. In all living cells, DNA holds genetic information and RNA transfers genetic information from DNA to the ribosomes. Ribosomes are formed from RNA and proteins. Both DNA and RNA are polymers of nucleotides. Each nucleotide is formed from a pentose, a nitrogen-containing organic base and a phosphate group:  • The components of a DNA nucleotide are deoxyribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or thymine. • The components of an RNA nucleotide are ribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or uracil. • A condensation reaction between two nucleotides forms a phosphodiester bond. A DNA molecule is a double helix with two polynucleotide chains held together by hydrogen bonds between specific complementary base pairs. An RNA molecule is a relatively short polynucleotide chain. **Students should be able to** appreciate that the relative simplicity of DNA led many scientists to doubt that it carried the genetic code.	**MS 0.3** Students could use incomplete information about the frequency of bases on DNA strands to find the frequency of other bases.

3.1.5.2 DNA replication

Content	Opportunities for skills development
The semi-conservative replication of DNA ensures genetic continuity between generations of cells. The process of semi-conservative replication of DNA in terms of: • unwinding of the double helix • breakage of hydrogen bonds between complementary bases in the polynucleotide strands • the role of DNA helicase in unwinding DNA and breaking its hydrogen bonds • attraction of new DNA nucleotides to exposed bases on template strands and base pairing • the role of DNA polymerase in the condensation reaction that joins adjacent nucleotides. **Students should be able to** evaluate the work of scientists in validating the Watson–Crick model of DNA replication.	

3.1.6 ATP

Content	Opportunities for skills development
A single molecule of adenosine triphosphate (ATP) is a nucleotide derivative and is formed from a molecule of ribose, a molecule of adenine and three phosphate groups.  Hydrolysis of ATP to adenosine diphosphate (ADP) and an inorganic phosphate group (Pi) is catalysed by the enzyme ATP hydrolase. • The hydrolysis of ATP can be coupled to energy-requiring reactions within cells. • The inorganic phosphate released during the hydrolysis of ATP can be used to phosphorylate other compounds, often making them more reactive. ATP is resynthesised by the condensation of ADP and Pi. This reaction is catalysed by the enzyme ATP synthase during photosynthesis, or during respiration.	

3.1.7 Water

Content	Opportunities for skills development
Water is a major component of cells. It has several properties that are important in biology. In particular, water: • is a metabolite in many metabolic reactions, including condensation and hydrolysis reactions • is an important solvent in which metabolic reactions occur • has a relatively high heat capacity, buffering changes in temperature • has a relatively large latent heat of vaporisation, providing a cooling effect with little loss of water through evaporation • has strong cohesion between water molecules; this supports columns of water in the tube-like transport cells of plants and produces surface tension where water meets air.	

3.1.8 Inorganic ions

Content	Opportunities for skills development
Inorganic ions occur in solution in the cytoplasm and body fluids of organisms, some in high concentrations and others in very low concentrations. Each type of ion has a specific role, depending on its properties. **Students should be able to** recognise the role of ions in the following topics: hydrogen ions and pH; iron ions as a component of haemoglobin; sodium ions in the co-transport of glucose and amino acids; and phosphate ions as components of DNA and of ATP.	

CELLS

3.2.1 Cell structure

The cell theory is a unifying concept in biology.

3.2.1.1 Structure of eukaryotic cells

Content	Opportunities for skills development
The structure of eukaryotic cells, restricted to the structure and function of: • cell-surface membrane • nucleus (containing chromosomes, consisting of protein-bound, linear DNA, and one or more nucleoli) • mitochondria • chloroplasts (in plants and algae) • Golgi apparatus and Golgi vesicles • lysosomes (a type of Golgi vesicle that releases lysozymes) • ribosomes • rough endoplasmic reticulum and smooth endoplasmic reticulum • cell wall (in plants, algae and fungi) • cell vacuole (in plants). In complex multicellular organisms, eukaryotic cells become specialised for specific functions. Specialised cells are organised into tissues, tissues into organs and organs into systems.	
Students should be able to apply their knowledge of these features in explaining adaptations of eukaryotic cells.	

3.2.1.2 Structure of prokaryotic cells and of viruses

Content	Opportunities for skills development
Prokaryotic cells are much smaller than eukaryotic cells. They also differ from eukaryotic cells in having: • cytoplasm that lacks membrane-bound organelles • smaller ribosomes • no nucleus; instead they have a single circular DNA molecule that is free in the cytoplasm and is not associated with proteins • a cell wall that contains murein, a glycoprotein. In addition, many prokaryotic cells have: • one or more plasmids • a capsule surrounding the cell • one or more flagella. Details of these structural differences are **not** required. Viruses are acellular and non-living. The structure of virus particles to include genetic material, capsid and attachment protein.	

3.2.1.3 Methods of studying cells

Content	Opportunities for skills development
The principles and limitations of optical microscopes, transmission electron microscopes and scanning electron microscopes. Measuring the size of an object viewed with an optical microscope. The difference between magnification and resolution. Use of the formula: $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$ Principles of cell fractionation and ultracentrifugation as used to separate cell components. **Students should be able to** appreciate that there was a considerable period of time during which the scientific community distinguished between artefacts and cell organelles.	**AT d, e and f** Students could use iodine in potassium iodide solution to identify starch grains in plant cells. **MS 1.8**

3.2.2 All cells arise from other cells

Content	Opportunities for skills development
Within multicellular organisms, not all cells retain the ability to divide. Eukaryotic cells that do retain the ability to divide show a cell cycle. • DNA replication occurs during the interphase of the cell cycle. • Mitosis is the part of the cell cycle in which a eukaryotic cell divides to produce two daughter cells, each with the identical copies of DNA produced by the parent cell during DNA replication. The behaviour of chromosomes during interphase, prophase, metaphase, anaphase and telophase of mitosis. The role of spindle fibres attached to centromeres in the separation of chromatids. Division of the cytoplasm (cytokinesis) usually occurs, producing two new cells. Meiosis is covered in section 3.4.3 **Students should be able to:** • recognise the stages of the cell cycle: interphase, prophase, metaphase, anaphase and telophase (including cytokinesis) • explain the appearance of cells in each stage of mitosis.	

Mitosis is a controlled process. Uncontrolled cell division can lead to the formation of tumours and of cancers. Many cancer treatments are directed at controlling the rate of cell division.

Binary fission in prokaryotic cells involves:

- replication of the circular DNA and of plasmids
- division of the cytoplasm to produce two daughter cells, each with a single copy of the circular DNA and a variable number of copies of plasmids.

Being non-living, viruses do not undergo cell division. Following injection of their nucleic acid, the infected host cell replicates the virus particles.

Required practical 2: Preparation of stained squashes of cells from plant root tips; set-up and use of an optical microscope to identify the stages of mitosis in these stained squashes and calculation of a mitotic index. Students should measure the apparent size of cells in the root tip and calculate their actual size using the formula: $Actual\ size = \frac{size\ of\ image}{magnification}$	**AT d and e** **MS 0.3** Calculation of a mitotic index. **MS 1.8**

3.2.3 Transport across cell membranes

Content	Opportunities for skills development
The basic structure of all cell membranes, including cell-surface membranes and the membranes around the cell organelles of eukaryotes, is the same. The arrangement and any movement of phospholipids, proteins, glycoproteins and glycolipids in the fluid-mosaic model of membrane structure. Cholesterol may also be present in cell membranes where it restricts the movement of other molecules making up the membrane. Movement across membranes occurs by: • simple diffusion (involving limitations imposed by the nature of the phospholipid bilayer) • facilitated diffusion (involving the roles of carrier proteins and channel proteins) • osmosis (explained in terms of water potential) • active transport (involving the role of carrier proteins and the importance of the hydrolysis of ATP) • co-transport (illustrated by the absorption of sodium ions and glucose by cells lining the mammalian ileum). Cells may be adapted for rapid transport across their internal or external membranes by an increase in surface area of, or by an increase in the number of protein channels and carrier molecules in, their membranes.	

Students should be able to: • explain the adaptations of specialised cells in relation to the rate of transport across their internal and external membranes • explain how surface area, number of channel or carrier proteins and differences in gradients of concentration or water potential affect the rate of movement across cell membranes.	
Required practical 3: Production of a dilution series of a solute to produce a calibration curve with which to identify the water potential of plant tissue. **Required practical 4:** Investigation into the effect of a named variable on the permeability of cell-surface membranes.	**MS 3.2** Students could plot the data from their investigations in an appropriate format. **MS 3.4** Students could determine the water potential of plant tissues using the intercept of a graph of, eg, water potential of solution against gain/loss of mass.

3.2.4 Cell recognition and the immune system

Content	Opportunities for skills development
Each type of cell has specific molecules on its surface that identify it. These molecules include proteins and enable the immune system to identify: • pathogens • cells from other organisms of the same species • abnormal body cells • toxins. Definition of antigen. The effect of antigen variability on disease and disease prevention. Phagocytosis of pathogens. The subsequent destruction of ingested pathogens by lysozymes. The response of T lymphocytes to a foreign antigen (the cellular response). • The role of antigen-presenting cells in the cellular response. • The role of helper T cells (TH cells) in stimulating cytotoxic T cells (TC cells), B cells and phagocytes. The role of other T cells is **not** required.	

The response of B lymphocytes to a foreign antigen, clonal selection and the release of monoclonal antibodies (the humoral response). • Definition of antibody. • Antibody structure. • The formation of an antigen-antibody complex, leading to the destruction of the antigen, limited to agglutination and phagocytosis of bacterial cells. • The roles of plasma cells and of memory cells in producing primary and secondary immune responses. The use of vaccines to provide protection for individuals and populations against disease. The concept of herd immunity. The differences between active and passive immunity.	

Content	Opportunities for skills development
Structure of the human immunodeficiency virus (HIV) and its replication in helper T cells. How HIV causes the symptoms of AIDS. Why antibiotics are ineffective against viruses. The use of monoclonal antibodies in: • targeting medication to specific cell types by attaching a therapeutic drug to an antibody • medical diagnosis. Details of the production of monoclonal antibodies is **not** required. Ethical issues associated with the use of vaccines and monoclonal antibodies. The use of antibodies in the ELISA test. **Students should be able to:** • discuss ethical issues associated with the use of vaccines and monoclonal antibodies • evaluate methodology, evidence and data relating to the use of vaccines and monoclonal antibodies.	

Organisms exchange substances with their environment

3.3.1 Surface area to volume ratio

Content	Opportunities for skills development
The relationship between the size of an organism or structure and its surface area to volume ratio. Changes to body shape and the development of systems in larger organisms as adaptations that facilitate exchange as this ratio reduces. **Students should be able to** appreciate the relationship between surface area to volume ratio and metabolic rate.	**PS 1.1** Students could use agar blocks containing indicator to determine the effect of surface area to volume ratio and concentration gradient on the diffusion of an acid or alkali. **MS 4.1** Students could be given the dimensions of cells with different shapes from which to calculate the surface area to volume ratios of these cells.

3.3.2 Gas exchange

Content	Opportunities for skills development
Adaptations of gas exchange surfaces, shown by gas exchange: • across the body surface of a single-celled organism • in the tracheal system of an insect (tracheae, tracheoles and spiracles) • across the gills of fish (gill lamellae and filaments including the counter-current principle) • by the leaves of dicotyledonous plants (mesophyll and stomata). Structural and functional compromises between the opposing needs for efficient gas exchange and the limitation of water loss shown by terrestrial insects and xerophytic plants. The gross structure of the human gas exchange system limited to the alveoli, bronchioles, bronchi, trachea and lungs. The essential features of the alveolar epithelium as a surface over which gas exchange takes place.	**AT j** Students could dissect mammalian lungs, the gas exchange system of a bony fish or of an insect. **AT d** Students could use an optical microscope to: • examine prepared mounts of gas exchange surfaces of a mammal, fish and insect, or temporary mounts of gills • examine vertical sections through a dicotyledonous leaf. **AT b** Students could use three-way

Ventilation and the exchange of gases in the lungs. The mechanism of breathing to include the role of the diaphragm and the antagonistic interaction between the external and internal intercostal muscles in bringing about pressure changes in the thoracic cavity. **Students should be able to:** • interpret information relating to the effects of lung disease on gas exchange and/or ventilation • interpret data relating to the effects of pollution and smoking on the incidence of lung disease • analyse and interpret data associated with specific risk factors and the incidence of lung disease • evaluate the way in which experimental data led to statutory restrictions on the sources of risk factors • recognise correlations and causal relationships.	[illegible] taps, manometers and simple respirometers to measure volumes of air involved in gas exchange. **MS 2.2** Students could be given values of pulmonary ventilation rate (PVR) and one other measure, requiring them to change the subject of the equation: $PVR = tidal\ volume \times breathing\ rate$

3.3.3 Digestion and absorption

Content	Opportunities for skills development
During digestion, large biological molecules are hydrolysed to smaller molecules that can be absorbed across cell membranes. Digestion in mammals of: • carbohydrates by amylases and membrane-bound disaccharidases • lipids by lipase, including the action of bile salts • proteins by endopeptidases, exopeptidases and membrane-bound dipeptidases. Mechanisms for the absorption of the products of digestion by cells lining the ileum of mammals, to include: • co-transport mechanisms for the absorption of amino acids and of monosaccharides • the role of micelles in the absorption of lipids.	**PS 1.1** Students could: • design and carry out investigations into the effect of a pH or bile salts on the rate of reaction catalysed by a digestive enzyme • use Visking tubing models to investigate the absorption of the products of digestion.

3.3.4.1 Mass transport in animals

Content	Opportunities for skills development
The haemoglobins are a group of chemically similar molecules found in many different organisms. Haemoglobin is a protein with a quaternary structure. The role of haemoglobin and red blood cells in the transport of oxygen. The loading, transport and unloading of oxygen in relation to the oxyhaemoglobin dissociation curve. The cooperative nature of oxygen binding to show that the change in shape of haemoglobin caused by binding of the first oxygens makes the binding of further oxygens easier. The effects of carbon dioxide concentration on the dissociation of oxyhaemoglobin (the Bohr effect). Many animals are adapted to their environment by possessing different types of haemoglobin with different oxygen transport properties. The general pattern of blood circulation in a mammal. Names are required only of the coronary arteries and of the blood vessels entering and leaving the heart, lungs and kidneys. The gross structure of the human heart. Pressure and volume changes and associated valve movements during the cardiac cycle that maintain a unidirectional flow of blood.	**AT h** Students could design and carry out an investigation into the effect of a named variable on human pulse rate or on the heart rate of an invertebrate, such as *Daphnia*. **MS 2.2** Students could be given values of cardiac output (CO) and one other measure, requiring them to change the subject of the equation: $CO = stroke\ volume \times heart\ rate$
The structure of arteries, arterioles and veins in relation to their function. The structure of capillaries and the importance of capillary beds as exchange surfaces. The formation of tissue fluid and its return to the circulatory system. **Students should be able to:** • analyse and interpret data relating to pressure and volume changes during the cardiac cycle • analyse and interpret data associated with specific risk factors and the incidence of cardiovascular disease • evaluate conflicting evidence associated with risk factors affecting cardiovascular disease • recognise correlations and causal relationships.	
Required practical 5: Dissection of animal or plant gas exchange system or mass transport system or of organ within such a system.	**AT j**

3.3.4.2 Mass transport in plants

Content	Opportunities for skills development
Xylem as the tissue that transports water in the stem and leaves of plants. The cohesion-tension theory of water transport in the xylem. Phloem as the tissue that transports organic substances in plants. The mass flow hypothesis for the mechanism of translocation in plants. The use of tracers and ringing experiments to investigate transport in plants. **Students should be able to:** • recognise correlations and causal relationships • interpret evidence from tracer and ringing experiments and to evaluate the evidence for and against the mass flow hypothesis.	**AT b** Students could set up and use a potometer to investigate the effect of a named environmental variable on the rate of transpiration.

Genetic information, variation and relationships between organisms

3.4.1 DNA, genes and chromosomes

Content	Opportunities for skills development
In prokaryotic cells, DNA molecules are short, circular and not associated with proteins. In the nucleus of eukaryotic cells, DNA molecules are very long, linear and associated with proteins, called histones. Together a DNA molecule and its associated proteins form a chromosome. The mitochondria and chloroplasts of eukaryotic cells also contain DNA which, like the DNA of prokaryotes, is short, circular and not associated with protein. A gene is a base sequence of DNA that codes for: • the amino acid sequence of a polypeptide • a functional RNA (including ribosomal RNA and tRNAs). A gene occupies a fixed position, called a locus, on a particular DNA molecule. A sequence of three DNA bases, called a triplet, codes for a specific amino acid. The genetic code is universal, non-overlapping and degenerate.	
In eukaryotes, much of the nuclear DNA does not code for polypeptides. There are, for example, non-coding multiple repeats of base sequences between genes. Even within a gene only some sequences, called exons, code for amino acid sequences. Within the gene, these exons are separated by one or more non-coding sequences, called introns.	

3.4.2 DNA and protein synthesis

Content	Opportunities for skills development
The concept of the genome as the complete set of genes in a cell and of the proteome as the full range of proteins that a cell is able to produce. The structure of molecules of messenger RNA (mRNA) and of transfer RNA (tRNA). Transcription as the production of mRNA from DNA. The role of RNA polymerase in joining mRNA nucleotides. • In prokaryotes, transcription results directly in the production of mRNA from DNA. • In eukaryotes, transcription results in the production of pre-mRNA; this is then spliced to form mRNA. Translation as the production of polypeptides from the sequence of codons carried by mRNA. The roles of ribosomes, tRNA and ATP. **Students should be able to:** • relate the base sequence of nucleic acids to the amino acid sequence of polypeptides, when provided with suitable data about the genetic code	
• interpret data from experimental work investigating the role of nucleic acids. Students will **not** be required to recall in written papers specific codons and the amino acids for which they code.	

3.4.3 Genetic diversity can arise as a result of mutation or during meiosis

Content	Opportunities for skills development
Gene mutations involve a change in the base sequence of chromosomes. They can arise spontaneously during DNA replication and include base deletion and base substitution. Due to the degenerate nature of the genetic code, not all base substitutions cause a change in the sequence of encoded amino acids. Mutagenic agents can increase the rate of gene mutation. Mutations in the number of chromosomes can arise spontaneously by chromosome non-disjunction during meiosis. Meiosis produces daughter cells that are genetically different from each other. The process of meiosis only in sufficient detail to show how: • two nuclear divisions result usually in the formation of four haploid daughter cells from a single diploid parent cell • genetically different daughter cells result from the independent segregation of homologous chromosomes • crossing over between homologous chromosomes results in further genetic variation among daughter cells. **Students should be able to:** • complete diagrams showing the chromosome content of cells after the first and second meiotic division, when given the chromosome content of the parent cell • explain the different outcome of mitosis and meiosis • recognise where meiosis occurs when given information about an unfamiliar life cycle • explain how random fertilisation of haploid gametes further increases genetic variation within a species.	**AT d** Students could examine meiosis in prepared slides of suitable plant or animal tissue. **MS 0.5** Students could: • use the expression 2^n to calculate the possible number of different combinations of chromosomes following meiosis, without crossing over • derive a formula from this to calculate the possible number of different combinations of chromosomes following random fertilisation of two gametes, where n is the number of homologous chromosomes pairs.

3.4.4 Genetic diversity and adaptation

Content	Opportunities for skills development
Genetic diversity as the number of different alleles of genes in a population. Genetic diversity is a factor enabling natural selection to occur. The principles of natural selection in the evolution of populations. • Random mutation can result in new alleles of a gene. • Many mutations are harmful but, in certain environments, the new allele of a gene might benefit its possessor, leading to increased reproductive success. • The advantageous allele is inherited by members of the next generation. • As a result, over many generations, the new allele increases in frequency in the population. Directional selection, exemplified by antibiotic resistance in bacteria, and stabilising selection, exemplified by human birth weights. Natural selection results in species that are better adapted to their environment. These adaptations may be anatomical, physiological or behavioural.	**MS 2.5** Students could use a logarithmic scale when dealing with data relating to large numbers of bacteria in a culture.
Students should be able to: • use unfamiliar information to explain how selection produces changes within a population of a species • interpret data relating to the effect of selection in producing change within populations • show understanding that adaptation and selection are major factors in evolution and contribute to the diversity of living organisms.	
Required practical 6: Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth.	**AT i**

3.4.5 Species and taxonomy

Content	Opportunities for skills development
Two organisms belong to the same species if they are able to produce fertile offspring. Courtship behaviour as a necessary precursor to successful mating. The role of courtship in species recognition. A phylogenetic classification system attempts to arrange species into groups based on their evolutionary origins and relationships. It uses a hierarchy in which smaller groups are placed within larger groups, with no overlap between groups. Each group is called a taxon (plural taxa). One hierarchy comprises the taxa: domain, kingdom, phylum, class, order, family, genus and species. Each species is universally identified by a binomial consisting of the name of its genus and species, eg, *Homo sapiens*. Recall of different taxonomic systems, such as the three domain or five kingdom systems, will **not** be required. **Students should be able to** appreciate that advances in immunology and genome sequencing help to clarify evolutionary relationships between organisms.	

3.4.6 Biodiversity within a community

Content	Opportunities for skills development
Biodiversity can relate to a range of habitats, from a small local habitat to the Earth. Species richness is a measure of the number of different species in a community. An index of diversity describes the relationship between the number of species in a community and the number of individuals in each species. Calculation of an index of diversity (d) from the formula $d = \frac{N(N-1)}{\Sigma n(n-1)}$ where N = total number of organisms of all species and n = total number of organisms of each species. Farming techniques reduce biodiversity. The balance between conservation and farming.	**MS 2.3** Students could be given data from which to calculate an index of diversity and interpret the significance of the calculated value of the index.

3.4.7 Investigating diversity

Content	Opportunities for skills development
Genetic diversity within, or between species, can be made by comparing: • the frequency of measurable or observable characteristics • the base sequence of DNA • the base sequence of mRNA • the amino acid sequence of the proteins encoded by DNA and mRNA. **Students should be able to:** • interpret data relating to similarities and differences in the base sequences of DNA and in the amino acid sequences of proteins to suggest relationships between different organisms within a species and between species • appreciate that gene technology has caused a change in the methods of investigating genetic diversity; inferring DNA differences from measurable or observable characteristics has been replaced by direct investigation of DNA sequences. Knowledge of gene technologies will **not** be tested. Quantitative investigations of variation within a species involve:	**AT k** Students could: • design appropriate methods to ensure random sampling • carry out random sampling within a single population • use random samples to investigate the effect of position on the growth of leaves. **MS 1.2** Students could use standard scientific calculators to calculate the mean values of data they have collected or have been given.
• appreciate that gene technology has caused a change in the methods of investigating genetic diversity; inferring DNA differences from measurable or observable characteristics has been replaced by direct investigation of DNA sequences. Knowledge of gene technologies will **not** be tested. Quantitative investigations of variation within a species involve: • collecting data from random samples • calculating a mean value of the collected data and the standard deviation of that mean • interpreting mean values and their standard deviations. Students will **not** be required to calculate standard deviations in written papers.	**MS 1.2** Students could use standard scientific calculators to calculate the mean values of data they have collected or have been given. **MS 1.10** Students could calculate, and interpret the values of, the standard deviations of their mean values.

A Level ONLY

Energy transfer in and between organisms

3.5.1 Photosynthesis (A-level only)

Content	Opportunities for skills development
The light-dependent reaction in such detail as to show that: • chlorophyll absorbs light, leading to photoionisation of chlorophyll • some of the energy from electrons released during photoionisation is conserved in the production of ATP and reduced NADP • the production of ATP involves electron transfer associated with the transfer of electrons down the electron transfer chain and passage of protons across chloroplast membranes and is catalysed by ATP synthase embedded in these membranes (chemiosomotic theory) • photolysis of water produces protons, electrons and oxygen. The light-independent reaction uses reduced NADP from the light-dependent reaction to form a simple sugar. The hydrolysis of ATP, also from the light-dependent reaction, provides the additional energy for this reaction. The light-independent reaction in such detail as to show that: • carbon dioxide reacts with ribulose bisphosphate (RuBP) to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme rubisco • ATP and reduced NADP from the light-dependent reaction are used to reduce GP to triose phosphate	**AT a** Students could devise and carry out experiments to investigate the effect of named environmental variables on the rate of photosynthesis using aquatic plants, algae or immobilised algal beads.
• some of the triose phosphate is used to regenerate RuBP in the Calvin cycle • some of the triose phosphate is converted to useful organic substances. **Students should be able to:** • identify environmental factors that limit the rate of photosynthesis • evaluate data relating to common agricultural practices used to overcome the effect of these limiting factors.	
Required practical 7: Use of chromatography to investigate the pigments isolated from leaves of different plants, eg, leaves from shade-tolerant and shade-intolerant plants or leaves of different colours. **Required practical 8:** Investigation into the effect of a named factor on the rate of dehydrogenase activity in extracts of chloroplasts.	**AT g and b**

3.5.2 Respiration (A-level only)

Content	Opportunities for skills development
Respiration produces ATP. Glycolysis is the first stage of anaerobic and aerobic respiration. It occurs in the cytoplasm and is an anaerobic process. Glycolysis involves the following stages: • phosphorylation of glucose to glucose phosphate, using ATP • production of triose phosphate • oxidation of triose phosphate to pyruvate with a net gain of ATP and reduced NAD. If respiration is only anaerobic, pyruvate can be converted to ethanol or lactate using reduced NAD. The oxidised NAD produced in this way can be used in further glycolysis. If respiration is aerobic, pyruvate from glycolysis enters the mitochondrial matrix by active transport. Aerobic respiration in such detail as to show that: • pyruvate is oxidised to acetate, producing reduced NAD in the process • acetate combines with coenzyme A in the link reaction to produce acetylcoenzyme A	**AT b** Students could use a redox indicator to investigate dehydrogenase activity.
• acetylcoenzyme A reacts with a four-carbon molecule, releasing coenzyme A and producing a six-carbon molecule that enters the Krebs cycle • in a series of oxidation-reduction reactions, the Krebs cycle generates reduced coenzymes and ATP by substrate-level phosphorylation, and carbon dioxide is lost • synthesis of ATP by oxidative phosphorylation is associated with the transfer of electrons down the electron transfer chain and passage of protons across inner mitochondrial membranes and is catalysed by ATP synthase embedded in these membranes (chemiosomotic theory) • other respiratory substrates include the breakdown products of lipids and amino acids, which enter the Krebs cycle.	
Required practical 9: Investigation into the effect of a named variable on the rate of respiration of cultures of single-celled organisms.	**AT b and i**

3.5.3 Energy and ecosystems (A-level only)

Content	Opportunities for skills development
In any ecosystem, plants synthesise organic compounds from atmospheric, or aquatic, carbon dioxide. Most of the sugars synthesised by plants are used by the plant as respiratory substrates. The rest are used to make other groups of biological molecules. These biological molecules form the biomass of the plants. Biomass can be measured in terms of mass of carbon or dry mass of tissue per given area per given time. The chemical energy store in dry biomass can be estimated using calorimetry. Gross primary production (GPP) is the chemical energy store in plant biomass, in a given area or volume, in a given time. Net primary production (NPP) is the chemical energy store in plant biomass after respiratory losses to the environment have been taken into account, ie $NPP = GPP - R$ where GPP represents gross productivity and R represents respiratory losses to the environment.	**MS 0.1** Students could be given data from which to calculate gross primary productivity and to derive the appropriate units. **AT a** Students could carry out investigations to find the dry mass of plant samples or the energy released by samples of plant biomass. **MS 2.4** Students could be given data from which to calculate: • the net productivity of producers or consumers from given data • the efficiency of energy transfers within ecosystems. **MS 0.3** Students could be given data from which to calculate percentage yields.
This net primary production is available for plant growth and reproduction. It is also available to other trophic levels in the ecosystem, such as herbivores and decomposers. The net production of consumers (N), such as animals, can be calculated as: $N = I - (F + R)$ where I represents the chemical energy store in ingested food, F represents the chemical energy lost to the environment in faeces and urine and R represents the respiratory losses to the environment. **Students should be able to** appreciate the ways in which productivity is affected by farming practices designed to increase the efficiency of energy transfer by: • simplifying food webs to reduce energy losses to non-human food chains • reducing respiratory losses within a human food chain.	

3.5.4 Nutrient cycles (A-level only)

Content	Opportunities for skills development
Nutrients are recycled within natural ecosystems, exemplified by the nitrogen cycle and the phosphorus cycle. Microorganisms play a vital role in recycling chemical elements such as phosphorus and nitrogen. • The role of saprobionts in decomposition. • The role of mycorrhizae in facilitating the uptake of water and inorganic ions by plants. • The role of bacteria in the nitrogen cycle in sufficient detail to illustrate the processes of saprobiotic nutrition, ammonification, nitrification, nitrogen fixation and denitrification. (The names of individual species of bacteria are **not** required). The use of natural and artificial fertilisers to replace the nitrates and phosphates lost by harvesting plants and removing livestock. The environmental issues arising from the use of fertilisers including leaching and eutrophication.	**PS 1.1** Students could devise investigations into the effect of named minerals on plant growth.

Organisms respond to changes in their internal and external environments

3.6.1.1 Survival and response (A-level only)

Content	Opportunities for skills development
Organisms increase their chance of survival by responding to changes in their environment. In flowering plants, specific growth factors move from growing regions to other tissues, where they regulate growth in response to directional stimuli. The effect of different concentrations of indoleacetic acid (IAA) on cell elongation in the roots and shoots of flowering plants as an explanation of gravitropism and phototropism in flowering plants. Taxes and kineses as simple responses that can maintain a mobile organism in a favourable environment. The protective effect of a simple reflex, exemplified by a three-neurone simple reflex. Details of spinal cord and dorsal and ventral roots are **not** required.	**AT h** Students could design and carry out investigations into the effects of indoleacetic acid on root growth in seedlings.
Required practical 10: Investigation into the effect of an environmental variable on the movement of an animal using either a choice chamber or a maze.	**AT h**

3.6.1.2 Receptors (A-level only)

Content	Opportunities for skills development
The Pacinian corpuscle should be used as an example of a receptor to illustrate that: • receptors respond only to specific stimuli • stimulation of a receptor leads to the establishment of a generator potential. The basic structure of a Pacinian corpuscle. Deformation of stretch-mediated sodium ion channels in a Pacinian corpuscle leads to the establishment of a generator potential. The human retina in sufficient detail to show how differences in sensitivity to light, sensitivity to colour and visual acuity are explained by differences in the optical pigments of rods and cones and the connections rods and cones make in the optic nerve.	**AT h** Students could design and carry out investigations into: • the sensitivity of temperature receptors in human skin • habituation of touch receptors in human skin • resolution of touch receptors in human skin.

3.6.1.3 Control of heart rate (A-level only)

Content	Opportunities for skills development
Myogenic stimulation of the heart and transmission of a subsequent wave of electrical activity. The roles of the sinoatrial node (SAN), atrioventricular node (AVN) and Purkyne tissue in the bundle of His. The roles and locations of chemoreceptors and pressure receptors and the roles of the autonomic nervous system and effectors in controlling heart rate.	**AT h** Students could design and carry out an investigation into the effect of a named variable on human pulse rate. **MS 2.2** Students could use values of heart rate (R) and stroke volume (V) to calculate cardiac output (CO), using the formula $CO = R \times V$

3.6.2.1 Nerve impulses (A-level only)

Content	Opportunities for skills development
The structure of a myelinated motor neurone. The establishment of a resting potential in terms of differential membrane permeability, electrochemical gradients and the movement of sodium ions and potassium ions. Changes in membrane permeability lead to depolarisation and the generation of an action potential. The all-or-nothing principle. The passage of an action potential along non-myelinated and myelinated axons, resulting in nerve impulses. The nature and importance of the refractory period in producing discrete impulses and in limiting the frequency of impulse transmission. Factors affecting the speed of conductance: myelination and saltatory conduction; axon diameter; temperature.	**MS 0.2** Students could use appropriate units when calculating the maximum frequency of impulse conduction given the refractory period of a neurone.

3.6.2.2 Synaptic transmission (A-level only)

Content	Opportunities for skills development
The detailed structure of a synapse and of a neuromuscular junction. The sequence of events involved in transmission across a cholinergic synapse in sufficient detail to explain: • unidirectionality • temporal and spatial summation • inhibition by inhibitory synapses. A comparison of transmission across a cholinergic synapse and across a neuromuscular junction. **Students should be able to** use information provided to predict and explain the effects of specific drugs on a synapse. (Recall of the names and mode of action of individual drugs will **not** be required.)	

3.6.3 Skeletal muscles are stimulated to contract by nerves and act as effectors (A-level only)

Content	Opportunities for skills development
Muscles act in antagonistic pairs against an incompressible skeleton. Gross and microscopic structure of skeletal muscle. The ultrastructure of a myofibril. The roles of actin, myosin, calcium ions and ATP in myofibril contraction. The roles of calcium ions and tropomyosin in the cycle of actinomyosin bridge formation. (The role of troponin is **not** required.) The roles of ATP and phosphocreatine in muscle contraction. The structure, location and general properties of slow and fast skeletal muscle fibres.	**AT d** Students could examine prepared slides of skeletal muscle using an optical microscope. **AT h** Students could investigate the effect of repeated muscular contraction on the rate of muscle fatigue in human vounteers.

3.6.4.1 Principles of homeostasis and negative feedback (A-level only)

Content	Opportunities for skills development
Homeostasis in mammals involves physiological control systems that maintain the internal environment within restricted limits. The importance of maintaining a stable core temperature and stable blood pH in relation to enzyme activity. The importance of maintaining a stable blood glucose concentration in terms of availability of respiratory substrate and of the water potential of blood. Negative feedback restores systems to their original level. The possession of separate mechanisms involving negative feedback controls departures in different directions from the original state, giving a greater degree of control. **Students should be able to** interpret information relating to examples of negative and positive feedback.	

3.6.4.2 Control of blood glucose concentration (A-level only)

Content	Opportunities for skills development
The factors that influence blood glucose concentration. The role of the liver in glycogenesis, glycogenolysis and gluconeogenesis. The action of insulin by: • attaching to receptors on the surfaces of target cells • controlling the uptake of glucose by regulating the inclusion of channel proteins in the surface membranes of target cells • activating enzymes involved in the conversion of glucose to glycogen. The action of glucagon by: • attaching to receptors on the surfaces of target cells • activating enzymes involved in the conversion of glycogen to glucose • activating enzymes involved in the conversion of glycerol and amino acids into glucose. The role of adrenaline by: • attaching to receptors on the surfaces of target cells • activating enzymes involved in the conversion of glycogen to glucose. The second messenger model of adrenaline and glucagon action, involving adenyl cyclate, cyclic AMP (cAMP) and protein kinase. The causes of types I and II diabetes and their control by insulin and/or manipulation of the diet. **Students should be able to** evaluate the positions of health advisers and the food industry in relation to the increased incidence of type II diabetes.	
Required practical 11: Production of a dilution series of a glucose solution and use of colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown 'urine' sample.	**AT b and c**

3.6.4.3 Control of blood water potential (A-level only)

Content	Opportunities for skills development
Osmoregulation as control of the water potential of the blood. The roles of the hypothalamus, posterior pituitary and antidiuretic hormone (ADH) in osmoregulation. The structure of the nephron and its role in: • the formation of glomerular filtrate • reabsorption of glucose and water by the proximal convoluted tubule • maintaining a gradient of sodium ions in the medulla by the loop of Henle • reabsorption of water by the distal convoluted tubule and collecting ducts.	

Genetics, populations, evolution and ecosystems

3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
The genotype is the genetic constitution of an organism. The phenotype is the expression of this genetic constitution and its interaction with the environment. There may be many alleles of a single gene. Alleles may be dominant, recessive or codominant. In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous. The use of fully labelled genetic diagrams to interpret, or predict, the results of: • monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles • crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis. Use of the chi-squared (X^2) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.	**AT h** Students could investigate genetic ratios using crosses of *Drosophila* or Fast Plant® **MS 0.3** Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses. **MS 1.4** Students could show understanding of the probability associated with inheritance. **MS 1.9** Students could use the X^2 test to investigate the significance of differences between expected and observed phenotypic ratios.

3.7.2 Populations (A-level only)

Content	Opportunities for skills development
Species exist as one or more populations. A population as a group of organisms of the same species occupying a particular space at a particular time that can potentially interbreed. The concepts of gene pool and allele frequency. The Hardy–Weinberg principle provides a mathematical model, which predicts that allele frequencies will not change from generation to generation. The conditions under which the principle applies. The frequency of alleles, genotypes and phenotypes in a population can be calculated using the Hardy–Weinberg equation: $p^2 + 2pq + q^2 = 1$ where p is the frequency of one (usually the dominant) allele and q is the frequency of the other (usually recessive) allele of the gene.	**AT k** Students could collect data about the frequency of observable phenotypes within a single population. **MS 2.4** Students could calculate allele, genotype and phenotype frequencies from appropriate data using the Hardy–Weinberg equation.

3.7.3 Evolution may lead to speciation (A-level only)

Content	Opportunities for skills development
Individuals within a population of a species may show a wide range of variation in phenotype. This is due to genetic and environmental factors. The primary source of genetic variation is mutation. Meiosis and the random fertilisation of gametes during sexual reproduction produce further genetic variation. Predation, disease and competition for the means of survival result in differential survival and reproduction, ie natural selection. Those organisms with phenotypes providing selective advantages are likely to produce more offspring and pass on their favourable alleles to the next generation. The effect of this differential reproductive success on the allele frequencies within a gene pool. The effects of stabilising, directional and disruptive selection. Evolution as a change in the allele frequencies in a population. Reproductive separation of two populations can result in the accumulation of difference in their gene pools. New species arise when these genetic differences lead to an inability of members of the populations to interbreed and produce fertile offspring. In this way, new species arise from existing species.	**MS 1.5** Students could apply their knowledge of sampling to the concept of genetic drift. **PS 1.2** Students could devise an investigation to mimic the effects of random sampling on allele frequencies in a population. **AT l** Students could use computer programs to model the effects of natural selection and of genetic drift.

Allopatric and sympatric speciation.The importance of genetic drift in causing changes in allele frequency in small populations.

Students should be able to:

- explain why individuals within a population of a species may show a wide range of variation in phenotype
- explain why genetic drift is important only in small populations
- explain how natural selection and isolation may result in change in the allele and phenotype frequency and lead to the formation of a new species
- explain how evolutionary change over a long period of time has resulted in a great diversity of species.

3.7.4 Populations in ecosystems (A-level only)

Content	Opportunities for skills development
Populations of different species form a community. A community and the non-living components of its environment together form an ecosystem. Ecosystems can range in size from the very small to the very large. Within a habitat, a species occupies a niche governed by adaptation to both abiotic and biotic conditions. An ecosystem supports a certain size of population of a species, called the carrying capacity. This population size can vary as a result of: • the effect of abiotic factors • interactions between organisms: interspecific and intraspecific competition and predation. The size of a population can be estimated using: • randomly placed quadrats, or quadrats along a belt transect, for slow-moving or non-motile organisms • the mark-release-recapture method for motile organisms. The assumptions made when using the mark-release-recapture method. Ecosystems are dynamic systems.	**AT k** Students could: • investigate the distribution of organisms in a named habitat using randomly placed frame quadrats, or a belt transect • use both percentage cover and frequency as measures of abundance of a sessile species. **AT h** Students could use the mark-release-recapture method to investigate the abundance of a motile species. **AT i**

Primary succession, from colonisation by pioneer species to climax community. At each stage in succession, certain species may be recognised which change the environment so that it becomes more suitable for other species with different adaptations. The new species may change the environment in such a way that it becomes less suitable for the previous species. Changes that organisms produce in their abiotic environment can result in a less hostile environment and change biodiversity. Conservation of habitats frequently involves management of succession. **Students should be able to:** • show understanding of the need to manage the conflict between human needs and conservation in order to maintain the sustainability of natural resources • evaluate evidence and data concerning issues relating to the conservation of species and habitats and consider conflicting evidence • use given data to calculate the size of a population estimated using the mark-release-recapture method.	Students could use turbidity measurements to investigate the growth rate of a broth culture of microorganisms. **MS 2.5** Students could use a logarithmic scale in representing the growth of a population of microorganisms.
Required practical 12: Investigation into the effect of a named environmental factor on the distribution of a given species.	**AT a and k**

Control of Gene Expression

3.8.1 Alteration of the sequence of bases in DNA can alter the structure of proteins (A-level only)

Content	Opportunities for skills development
Gene mutations might arise during DNA replication. They include addition, deletion, substitution, inversion, duplication and translocation of bases. Gene mutations occur spontaneously. The mutation rate is increased by mutagenic agents. Mutations can result in a different amino acid sequence in the encoded polypeptide. • Some gene mutations change only one triplet code. Due to the degenerate nature of the genetic code, not all such mutations result in a change to the encoded amino acid. • Some gene mutations change the nature of all base triplets downstream from the mutation, ie result in a frame shift. **Students should be able to** relate the nature of a gene mutation to its effect on the encoded polypeptide.	

3.8.2.1 Most of a cell's DNA is not translated (A-level only)

Content	Opportunities for skills development
Totipotent cells are cells that can mature into any type of body cell. During development, totipotent cells translate only part of their DNA, resulting in cell specialisation. Totipotent cells occur only for a limited time in mammalian embryos. Pluripotent, multipotent and unipotent cells are found in mature mammals. They can divide to form a limited number of different cell types. • Pluripotent stem cells can divide in unlimited numbers and can be used in treating human disorders. • Unipotent cells, exemplified by cardiomycetes. • Induced pluripotent stem cells (iPS cells) can be produced from unipotent cells using appropriate protein transcription factors. **Students should be able to** evaluate the use of stem cells in treating human disorders.	**AT i** Students could produce tissue cultures of explants of cauliflower (*Brassica oleracea*).

3.8.2.2 Regulation of transcription and translation (A-level only)

Content	Opportunities for skills development
In eukaryotes, transcription of target genes can be stimulated or inhibited when specific transcriptional factors move from the cytoplasm into the nucleus. The role of the steroid hormone, oestrogen, in initiating transcription. Epigenetic control of gene expression in eukaryotes. Epigenetics involves heritable changes in gene function, without changes to the base sequence of DNA. These changes are caused by changes in the environment that inhibit transcription by: • increased methylation of the DNA or • decreased acetylation of associated histones. The relevance of epigenetics on the development and treatment of disease, especially cancer. In eukaryotes and some prokaryotes, translation of the mRNA produced from target genes can be inhibited by RNA interference (RNAi). **Students should be able to**: • interpret data provided from investigations into gene expression • evaluate appropriate data for the relative influences of genetic and environmental factors on phenotype.	

3.8.2.3 Gene expression and cancer (A-level only)

Content	Opportunities for skills development
The main characteristics of benign and malignant tumours. The role of the following in the development of tumours: • tumour suppressor genes and oncogenes • abnormal methylation of tumour suppressor genes and oncogenes • increased oestrogen concentrations in the development of some breast cancers. **Students should be able to:** • evaluate evidence showing correlations between genetic and environmental factors and various forms of cancer • interpret information relating to the way in which an understanding of the roles of oncogenes and tumour suppressor genes could be used in the prevention, treatment and cure of cancer.	

3.8.3 Using genome projects (A-level only)

Content	Opportunities for skills development
Sequencing projects have read the genomes of a wide range of organisms, including humans. Determining the genome of simpler organisms allows the sequences of the proteins that derive from the genetic code (the proteome) of the organism to be determined. This may have many applications, including the identification of potential antigens for use in vaccine production. In more complex organisms, the presence of non-coding DNA and of regulatory genes means that knowledge of the genome cannot easily be translated into the proteome. Sequencing methods are continuously updated and have become automated.	

3.8.4.1 Recombinant DNA technology (A-level only)

Content	Opportunities for skills development
Recombinant DNA technology involves the transfer of fragments of DNA from one organism, or species, to another. Since the genetic code is universal, as are transcription and translation mechanisms, the transferred DNA can be translated within cells of the recipient (transgenic) organism. Fragments of DNA can be produced by several methods, including: • conversion of mRNA to complementary DNA (cDNA), using reverse transcriptase • using restriction enzymes to cut a fragment containing the desired gene from DNA • creating the gene in a 'gene machine'. Fragments of DNA can be amplified by *in vitro* and *in vivo* techniques. The principles of the polymerase chain reaction (PCR) as an *in vitro* method to amplify DNA fragments. The culture of transformed host cells as an *in vivo* method to amplify DNA fragments. • The addition of promoter and terminator regions to the fragments of DNA.	**AT g** Students could investigate the specificity of restriction enzymes using extracted DNA and electrophoresis.
• The use of restriction endonucleases and ligases to insert fragments of DNA into vectors. Transformation of host cells using these vectors. • The use of marker genes to detect genetically modified (GM) cells or organisms. (Students will **not** be required to recall specific marker genes in a written paper.) **Students should be able to:** • interpret information relating to the use of recombinant DNA technology • evaluate the ethical, financial and social issues associated with the use and ownership of recombinant DNA technology in agriculture, in industry and in medicine • balance the humanitarian aspects of recombinant DNA technology with the opposition from environmentalists and anti-globalisation activists • relate recombinant DNA technology to gene therapy.	

3.8.4.2 Differences in DNA between individuals of the same species can be exploited for identification and diagnosis of heritable conditions (A-level only)

Content	Opportunities for skills development
The use of labelled DNA probes and DNA hybridisation to locate specific alleles of genes. The use of labelled DNA probes that can be used to screen patients for heritable conditions, drug responses or health risks. The use of this information in genetic counselling and personalised medicine. **Students should be able to** evaluate information relating to screening individuals for genetically determined conditions and drug responses.	

3.8.4.3 Genetic fingerprinting (A-level only)

Content	Opportunities for skills development
An organism's genome contains many variable number tandem repeats (VNTRs). The probability of two individuals having the same VNTRs is very low. The technique of genetic fingerprinting in analysing DNA fragments that have been cloned by PCR, and its use in determining genetic relationships and in determining the genetic variability within a population. The use of genetic fingerprinting in the fields of forensic science, medical diagnosis, animal and plant breeding. **Students should be able to:** • explain the biological principles that underpin genetic fingerprinting techniques • interpret data showing the results of gel electrophoresis to separate DNA fragments • explain why scientists might use genetic fingerprinting in the fields of forensic science, medical diagnosis, animal and plant breeding.	**AT g** Students could use gel electrophoresis to produce 'fingerprints' of food dyes.