GCE

Rewarding Learning

CCEA GCE Specification in

Biology

Version 2: 28 April 2017

For first teaching from September 2016
For first award of AS level in Summer 2017
For first award of A level in Summer 2018
Subject Code: 1010

Contents

Subject Code	1010
QAN AS Level	601/8486/3
QAN A Level	601/8487/5

This specification is available online at www.ccea.org.uk

1 Introduction

This specification sets out the content and assessment details for our Advanced Subsidiary (AS) and Advanced GCE courses in Biology. First teaching is from September 2016.

Students can take:

- the AS course as a final qualification; or
- the AS units plus the A2 units for a full GCE A level qualification.

We assess the AS units at a standard appropriate for students who have completed the first part of the full course. A2 units have an element of synoptic assessment (to assess students' understanding of the subject as a whole), as well as more emphasis on assessment objectives that reflect higher order thinking skills.

The full Advanced GCE award is based on students' marks from the AS (40 percent) and the A2 (60 percent). The guided learning hours for this specification, as for all GCEs, are:

- 180 hours for the Advanced Subsidiary level award; and
- 360 hours for the Advanced level award.

We will make the first AS awards for the specification in 2017 and the first A level awards in 2018. The specification builds on the broad objectives of the Northern Ireland Curriculum.

If there are any major changes to this specification, we will notify centres in writing. The online version of the specification will always be the most up to date; to view and download this please go to www.ccea.org.uk

1.1 Aims

This specification aims to encourage students to:

- develop their interest in and enthusiasm for biology, including developing an interest in further study and careers in the subject;
- develop and draw together different areas of knowledge, skills and understanding of different aspects of the subject;
- develop competence and confidence in a number of skills, including independent learning, creative thinking, practical, mathematical and problem-solving;
- carry out practical tasks and present their findings in different formats;
- develop an appreciation and understanding of scientific methods; and
- appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society.

1.2 Key features

The following are important features of this specification.

- It includes six assessment units. All six are externally assessed. Two of these involve an element of internal assessment.
- The topics in each unit are organised in a logical sequence, building on previous knowledge and understanding as appropriate.
- Key practical tasks and the mathematical skills required are clearly identified.
- Assessment at A2 includes more question types, more demanding evaluative tasks, extended writing, and synoptic assessment that encourages students to develop their understanding of the subject as a whole.
- A range of support is available, including specimen assessment materials, exemplar schemes of work and teacher guidance.

1.3 Prior attainment

Students do not need to have reached a particular level of attainment before beginning to study this specification. However, the AS specification builds on the knowledge, understanding and skills developed in GCSE Biology, GCSE Science Double Award and other equivalent courses. Knowledge, understanding and skills developed in GCSE Mathematics are also relevant. The A2 section of this GCE builds on the knowledge, understanding and skills developed at AS level.

1.4 Classification codes and subject combinations

Every specification has a national classification code that indicates its subject area. The classification code for this qualification is 1010.

Please note that if a student takes two qualifications with the same classification code, universities and colleges that they apply to may take the view that they have achieved only one of the two GCEs. The same may occur with any two GCE qualifications that have a significant overlap in content, even if the classification codes are different. Because of this, students who have any doubts about their subject combinations should check with the universities and colleges that they would like to attend before beginning their studies.

2 Specification at a Glance

The table below summarises the structure of the AS and A level courses:

Content	Assessment	Weightings
AS 1: Molecules and Cells	External written examination 1 hour 30 mins Students answer six to eight structured questions and write an essay.	37.5% of AS 15% of A level
AS 2: Organisms and Biodiversity	External written examination 1 hour 30 mins Students answer six to eight structured questions and write an essay.	37.5% of AS 15% of A level
AS 3: Practical Skills in AS Biology	External written examination assessing practical skills 1 hour and internal practical assessment (Teachers mark the assessment, and we moderate the results.)	25% of AS 10% of A level
A2 1: Physiology, Co-ordination and Control, and Ecosystems	External written examination 2 hours 15 mins Students answer six to nine structured questions and write an essay.	24% of A level
A2 2: Biochemistry, Genetics and Evolutionary Trends	External written examination 2 hours 15 mins Students answer six to nine structured questions and write an essay.	24% of A level
A2 3: Practical Skills in Biology	External written examination assessing practical skills 1 hour 15 mins and internal practical assessment (Teachers mark the assessment, and we moderate the results.)	12% of A level

3 Subject Content

We have divided this course into six units: three units at AS level and three units at A2. This section sets out the content and learning outcomes for each unit.

In each of the six units in GCE Biology, students are tested on each of the three assessment objectives. Candidates must:

- demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures **(AO1);**
- apply knowledge and understanding of scientific ideas, processes, techniques and procedures:
  - in a theoretical context;
  - in a practical context;
  - when handling qualitative data; and
  - when handling quantitative data **(AO2); and**
- analyse, interpret and evaluate scientific information, ideas and evidence to:
  - make judgements and reach conclusions; and
  - develop and refine practical design and procedures **(AO3)**.

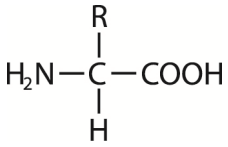
3.1 Unit AS 1: Molecules and Cells

This unit deals with molecules, enzymes, viruses, cells, cell physiology, continuity of cells, and tissues and organs. These are core topics in GCE Biology and underpin many of the other topics involved.

Assessment for this unit consists of a written examination that includes both short and extended questions. For more details, see Section 6.

Content	Learning Outcomes
1.1 Molecules	Students should be able to: 1.1.1 demonstrate knowledge and understanding of the importance of water as a solvent; and 1.1.2 outline the role of inorganic ions – potassium, calcium, magnesium, iron, hydrogencarbonate, nitrate and phosphate to include their role: • as components of biologically important compounds (calcium pectate, chlorophyll, haemoglobin, ATP, nucleic acids, phospholipids); and • in osmotic and buffering systems (details of the physical chemistry of buffering systems **not** required).

Content	Learning Outcomes
1.1 Molecules (cont.)	Students should be able to: 1.1.3 demonstrate knowledge and understanding of the occurrence, structure and function of carbohydrates: • monosaccharides (α- and β-glucose, fructose, $C_6H_{12}O_6$); • condensation reactions in the synthesis and hydrolysis reactions in the breakdown of disaccharides and polysaccharides; • the glycosidic bond; • maltose and sucrose as disaccharides; • cellulose – a structural polymer of β-glucose; • starch and glycogen as storage polymers of α-glucose; and • pentoses as components of nucleic acids (ribose and deoxyribose) and ATP (ribose); and 1.1.4 demonstrate knowledge and understanding of the occurrence, structure and function of lipids: • lipids as fats and oils; • triglycerides as condensation products of glycerol and fatty acids and the release of these on hydrolysis; • saturated and unsaturated fatty acids; and • the structure and properties of phospholipids as components of membranes.

Content	Learning Outcomes
1.1 Molecules (cont.)	Students should be able to: 1.1.5 demonstrate knowledge and understanding of the occurrence, structure and function of proteins: • the general structure of an amino acid molecule as:  • proteins as condensation products of amino acids and the release of these on hydrolysis; • primary structure: the amino acid sequence of a polypeptide involving peptide bonds; • secondary structure: α-helix and β-pleated sheet involving H-bonds; • tertiary structure: the folding of a polypeptide involving H-, ionic and disulfide bonds and hydrophobic interaction; • quaternary structure: more than one polypeptide making up a protein; • overall shape in relation to function in fibrous (collagen) and globular (enzyme) proteins; • conjugated proteins (glycoprotein and haemoglobin) containing prosthetic groups; and • prions as a disease-causing protein, due to changes in secondary structure giving a form rich in β-sheets: – infection can occur through eating prion-rich food; and – prion diseases are neurodegenerative disorders such as scrapie, Bovine Spongiform Encephalopathy (BSE) in animals and Creutzfeldt–Jakob Disease (CJD) in humans.

Content	Learning Outcomes
1.1 Molecules (cont.)	Students should be able to: 1.1.6 demonstrate knowledge and understanding of the occurrence, structure and function of nucleic acids: • nucleic acids as condensation products of nucleotides and the release of these on hydrolysis; • nucleotides as condensation products of a pentose sugar, a nitrogenous base and inorganic phosphate; • helical structure of DNA in terms of two antiparallel chains with specific base pairings; and • comparison of DNA and RNA; 1.1.7 demonstrate knowledge and understanding of the replication of DNA: • replication as a semi-conservative process involving opening the helix (by DNA helicase) followed by the synthesis of complementary nucleic acid chains alongside each of the existing chains to form two identical helices; • the role of DNA polymerase; and • the Meselson–Stahl experiment; *1.1.8 carry out practical work to detect the presence of carbohydrate and proteins using biochemical tests:* • *iodine test;* • *Benedict's test;* • *glucose specific tests;* and • *Biuret test;* and *1.1.9 carry out practical work to identify amino acids using paper chromatography:* • *prepare, run and develop the chromatogram;* and • *calculate R_f values.*

Content	Learning Outcomes
1.2 Enzymes	Students should be able to: 1.2.1 demonstrate knowledge and understanding of the structure of enzymes as globular proteins, including: • the concept of the active site; • specificity; and • the role of cofactors and coenzymes; 1.2.2 demonstrate knowledge and understanding of the relationship between enzyme structure and function, including: • catalysts that lower the activation energy through the formation of enzyme–substrate complexes; • the lock and key hypothesis and induced-fit hypothesis; • the effect of temperature, pH, substrate and enzyme concentrations on activity; and • enzyme inhibitors (competitive and non-competitive); 1.2.3 demonstrate knowledge and understanding of the importance of enzymes as biomarkers of disease, including: • that some enzymes are only present or active during disease processes (for example white blood cells can release elastase during respiratory infections, hydrolysing the structural protein elastin within the lung leading to reduced lung function); and • that detecting the presence of these enzymes in clinical samples such as blood, urine and sputum can be used for diagnosis or monitoring of disease; and 1.2.4 demonstrate knowledge and understanding of applying inhibitors as therapeutic drugs, including the activity of enzymes that contribute to disease processes, which can be targeted with active site-directed inhibitors.

Content	Learning Outcomes
1.2 Enzymes (cont.)	Students should be able to: 1.2.5 demonstrate knowledge and understanding of applying immobilised enzymes in biotechnology: • methods of immobilisation (physically or chemically securing enzymes on or inside insoluble support materials such as fibres, gels or plastic beads); • immobilisation as a technique that enables cost-effective enzyme applications (though with reduced activity because some active sites are inaccessible) with benefits including: – increased enzyme stability; – facilitation of continuous flow processes; and – enzyme-free products; and • diagnostic reagent strips using enzymes or inhibitors as biosensors (for example glucose monitoring strips or pregnancy tests); and *1.2.6 carry out practical work:* • *investigating factors, such as temperature, pH, substrate concentration and enzyme concentration that affect enzyme activity;* • *illustrating enzyme immobilisation;* and • *using a colorimeter to follow the course of a starch–amylase catalysed reaction (or other appropriate reaction).*

Content	Learning Outcomes
1.3 Viruses	Students should be able to: 1.3.1 demonstrate knowledge and understanding of the structure of bacteriophages (phages) and the human immunodeficiency virus (HIV) to include: • phages containing DNA bounded by a protein coat; and • HIV containing RNA bounded by a protein coat and a lipid bilayer containing glycoprotein and, as a retrovirus, containing reverse transcriptase whereby RNA is used to synthesise viral DNA (details of transcription should **not** be dealt with until A2); 1.3.2 demonstrate knowledge and understanding that viruses replicate in host cells (thereby destroying them), including: • that phages invade bacteria, where they replicate, destroying the bacterial cells (details of the phage life cycle **not** required); and • that HIV invades a type of lymphocyte (helper T-cell) thereby weakening the immune system (details of the immune system should **not** be dealt with until A2); and
1.4 Cells	1.4.1 demonstrate knowledge and understanding of the ultrastructure of eukaryotic and prokaryotic cells: • prokaryotic cells (for example, bacteria) as those without nuclei, mitochondria or endoplasmic reticulum and possessing naked, circular DNA, small ribosomes, possibly plasmids, and a cell wall; and • eukaryotic cells as those with a membrane-bound nucleus, chromosomes (helical DNA with a histone protein coat), mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus, vesicles, lysosomes and microtubules.

Content	Learning Outcomes
1.4 Cells (cont.)	Students should be able to: 1.4.2 demonstrate knowledge and understanding of the structure and function of membranes, including: • membrane structure (fluid mosaic model): phospholipid bilayer, intrinsic and extrinsic protein, carbohydrate glycocalyx, glycoproteins and glycolipids, cholesterol (in animal cells); and • functions of membrane components: – proteins or glycoproteins as carriers; – hydrophilic channels; – enzymes; – receptors; – antigens; – recognition features; and – cholesterol in membrane stability.

Content	Learning Outcomes
1.4 Cells (cont.)	Students should be able to: 1.4.3 demonstrate knowledge and understanding of the structure and function of eukaryotic cell components: • membranes (fluid mosaic model) as structures surrounding cells and contributing to their internal structures to include their role defining the boundaries of organelles within the cytoplasm; • mitochondria (envelope, cristae and matrix); • chloroplasts (envelope, lamellae, thylakoids, grana, stroma, lipid droplets and starch grains); • rough endoplasmic reticulum (a membrane system with attached ribosomes); • ribosomes as sites of protein synthesis; • smooth endoplasmic reticulum; • Golgi apparatus; • lysosomes; • microtubules (centrioles and cell spindle) as components of the cytoskeleton enabling movement of structures within the cell; • plasmodesmata as plant cell to cell junctions; and • nuclear components: – chromosomes (DNA and histones as constituents, but without detail of their configuration); – nucleolus (the location of the DNA that codes for ribosomal RNA); – the nuclear envelope as a perforated double membrane; and – the outer membrane of the envelope is encrusted with ribosomes and is the site of origin of rough endoplasmic reticulum (RER).

Content	Learning Outcomes
1.4 Cells (cont.)	Students should be able to: 1.4.4 demonstrate knowledge and understanding of the different types of eukaryotic cell structure: • plant cells as protoplasts bordered by an extracellular cellulose cell wall and possessing chloroplasts and a large permanent vacuole bounded by a tonoplast membrane; • neighbouring cell walls adhered by a middle lamella (a sticky material composed of calcium pectate); • fungal cells as protoplasm (often multinucleate) bounded by an extracellular wall of chitin; and • animal cells as lacking chloroplasts and a cell wall and possessing centrioles; 1.4.5 demonstrate knowledge and understanding of using microscopy to examine cell structure, including: • light microscope; • electron microscope (transmission electron microscope (TEM) or scanning electron microscope (SEM), as appropriate); and • the difference between magnification and resolution; *1.4.6 carry out practical work to demonstrate knowledge and understanding of the use of homogenisation and centrifugation;* and *1.4.7 carry out practical work:* • *examining photomicrographs and electron micrographs;* • *recognising cell structures from photomicrographs and electron micrographs;* • *drawing individual cells or cell sections;* • *staining tissues to aid observation when using a microscope (for example using iodine or methylene blue);* • *calculating true size (in µm) and magnification, including using scale bars;* and • *using a graticule and stage micrometer to measure cell length.*

Content	Learning Outcomes
1.5 Cell physiology	Students should be able to: 1.5.1 demonstrate knowledge and understanding of the mechanisms by which substances move across membranes: • diffusion; • osmosis to include understanding of the terms: – solute potential (ψ_s), pressure potential (ψ_p) and water potential (ψ_{cell}); – lysis and crenation in animal cells; and – turgor, incipient plasmolysis and plasmolysis in plant cells; • facilitated diffusion involving the use of proteins in the membrane as channels or carriers; • active transport involving membrane carriers and energy expenditure; • endocytosis (phagocytosis, pinocytosis); and • exocytosis; 1.5.2 account for membrane permeability in terms of: • movement of fat-soluble substances (and water as it is sufficiently small) through the phospholipid bilayer; • movement of water-soluble substances through hydrophilic protein channels; and • the role of membrane carriers; and 1.5.3 calculate the water potential of a cell as the algebraic sum of the solute and pressure potentials of a cell.

Content	Learning Outcomes
1.5 Cell physiology (cont.)	Students should be able to: *1.5.4 carry out practical work to include:* • *measuring the average water potential of cells in a plant tissue:* – *using a weighing method for a potato or other suitable tissue;* – *calculating the percentage change in mass;* and – *determining the average water potential from a graph of percentage change in mass against solute potential of immersing solution;* • *measuring the average solute potential of cells at incipient plasmolysis by:* – *using onion epidermis or other suitable tissue;* – *calculating percentage plasmolysis;* and – *determining the average solute potential from a graph of percentage plasmolysis against solute potential of the immersing solution (at 50% plasmolysis the average pressure potential is zero);* and
1.6 Continuity of cells	1.6.1 demonstrate knowledge and understanding of the cell cycle: • the main events during G_1, S and G_2 of interphase; • that the two gap phases are more than time delays as they give time for the cell to monitor the internal and external environment to ensure all is ready for the S and M phases (in many cases, including unfavourable conditions, cells can delay progress through G_1 and go into G_0 [resting state], which they can remain in for days, weeks or years); • nuclear division (mitosis) following the replication of DNA during the S phase; • cytokinesis in animal and plant cells; and • the link between loss of control points in the cell cycle and cancer.

Content	Learning Outcomes
1.6 Continuity of cells (cont.)	Students should be able to: 1.6.2 demonstrate knowledge and understanding that chromosome structure includes DNA and histones in the nucleus of eukaryotic cells; 1.6.3 demonstrate knowledge and understanding of the process of mitosis: • its significance in maintaining genetic constancy; and • the events of prophase, metaphase, anaphase and telophase and the appearance and behaviour of chromosomes; 1.6.4 demonstrate knowledge and understanding of the relationship of anticancer drugs to the cell cycle: • mitotic poisons that inhibit microtubule formation, for example vincristine; and • antimetabolities as S-phase inhibitors preventing DNA synthesis, for example 5'Fluorouracil; 1.6.5 demonstrate knowledge and understanding of the chromosome number of a cell and its significance in haploidy (where cells have one set of non-homologous chromosomes) and diploidy (where cells have two sets of homologous chromosomes): • the chromosome number of a cell as shown in a photomicrograph; and • chromosomes and homologous pairs as shown in a human karyotype; and 1.6.6 demonstrate knowledge and understanding of the process of meiosis and understand its significance in producing haploid cells and genetic variation: • the events of prophase I (excluding the names of the prophase stages), metaphase I, anaphase I, telophase I, prophase II, metaphase II, anaphase II, and telophase II including the appearance and behaviour of chromosomes; and • recombination of genes resulting from chiasma formation (crossing-over) during prophase I as a source of genetic variation.

Content	Learning Outcomes
1.6 Continuity of cells (cont.)	Students should be able to: 1.6.7 demonstrate knowledge and understanding of the independent assortment of chromosomes resulting from the random alignment of homologous pairs on the spindle as a source of genetic variation; 1.6.8 *carry out practical work:* • *preparing and staining root tip squashes;* • *recognising chromosomes at different stages of cell division;* • *identifying the stages of mitosis;* and • *examining prepared slides or photographs of the processes of mitosis and meiosis and identifying the structures visible and the different stages;* and
1.7 Tissues and organs	1.7.1 demonstrate knowledge and understanding that cells in tissues and organs are specialised: • a tissue as an amalgamation of cells that all perform the same function; and • an organ as a body part composed of several tissues grouped together to perform an overall function.

Content	Learning Outcomes
1.7 Tissues and organs (cont.)	Students should be able to: 1.7.2 demonstrate knowledge and understanding of the structure and function of the ileum (a mammalian organ): • the tissue layers as the mucosa, muscularis mucosa, submucosa, muscularis externa and serosa; • the role of the mucosa: – columnar epithelium (with microvilli for absorption and containing goblet cells for secretion of mucus); – villi increasing surface area for absorption; – crypts of Lieberkühn with Paneth cells (antimicrobial function to protect actively dividing stem cells at the bottom of the crypts); and – blood capillaries and lacteals for transporting products of digestion; • the adaptations of the epithelium for absorption to include a brush border of microvilli and numerous mitochondria: – the roles of diffusion, active transport and pinocytosis in absorption; and – absorption of amino acids and monosaccharides into blood capillaries and fats into lacteals (details of digestive enzymes **not** required); • the role of the muscularis mucosa in movement of the villi (improving contact with the products of digestion); • the role of the submucosa as a layer containing blood and lymphatic vessels; • the role of the muscularis externa in pendular movements, in local constrictions churning food, and in peristalsis in movement of food along the gut; and • the role of the serosa as a protective and supportive layer.

Content	Learning Outcomes
1.7 Tissues and organs (cont.)	Students should be able to: 1.7.3 demonstrate knowledge and understanding of the structure and function of a mesophytic leaf (a plant organ): • the tissue layers as the upper epidermis, palisade mesophyll, spongy mesophyll, xylem, phloem, lower epidermis and stomata; • the role of the upper epidermis with its waxy cuticle for conserving water; • the large surface area of the leaf as an adaptation for photosynthesis; • the role of the palisade mesophyll with its packed arrangement of cells and the distribution of chloroplasts for maximum light absorption; • the role of the spongy mesophyll with its loose arrangement of cells creating air spaces that facilitate diffusion of gases; • the role of xylem vessels within leaf veins (vascular bundles) in supplying the leaf with water and inorganic ions; • the role of phloem sieve-tubes in translocating sugars produced in photosynthesis away from the leaf; • the role of the lower epidermis with its waxy cuticle in reducing water loss; • the role of stomata (mostly in the lower epidermis) in gas exchange, surrounded by guard cells and closing at night to reduce transpirational water loss; and • the leaf as an organ with adaptations for maximising photosynthesis while minimising transpirational water loss.

Content	Learning Outcomes
1.7 Tissues and organs (cont.)	Students should be able to: *1.7.4 carry out practical work to include:* • *examining stained sections of the ileum using the light microscope and electron micrographs or photomicrographs to identify the villi (and associated blood capillaries and lacteals), crypts of Lieberkühn (and Paneth cells), mucosa, columnar epithelium, goblet cells, muscularis mucosa, submucosa, muscularis externa and serosa;* • *examining sections of a mesophytic leaf using the light microscope or photographs to identify the epidermal layers, waxy cuticles, palisade mesophyll, chloroplasts, spongy mesophyll, vascular tissue (xylem and phloem), and guard cells and stomata; and* • *making accurate drawings of sections of the ileum and the leaf to show the tissue layers and drawing block diagrams of tissues within the ileum and the leaf.*

3.2 Unit AS 2: Organisms and Biodiversity

This unit covers transport and exchange mechanisms in plants and mammals, adaptations of organisms and biodiversity with an emphasis on local contexts.

Assessment for this unit consists of a written examination that includes both short and extended questions. For more details, see Section 6.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(a) The principles of exchange and transport**	Students should be able to: 2.1.1 demonstrate knowledge and understanding of the relationship between an organism's size and its surface area to volume ratio: • surface area as the total number of cells in direct contact with the surrounding environment; • surface area affects the rate of exchange of materials at exchange surfaces; • volume as the total three-dimensional space occupied by metabolically active tissues; • volume of metabolically active tissue influences the demand for metabolites; • surface area influences the rate of supply of metabolites to tissues; • as an organism's size increases, its surface area increases less than its volume (many cells are not in direct contact with the surrounding environment); • large animals have a small surface area to volume ratio; and • small animals have a large surface area to volume ratio; and 2.1.2 demonstrate knowledge and understanding of the features of exchange surfaces that aid passive and active transport: • methods of increasing surface area; • thin separating surface; • concentration gradients; and • examples to include leaf mesophyll, root hairs, capillaries, red blood cells and alveoli.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(a) The principles of exchange and transport (cont.)**	Students should be able to: 2.1.3 demonstrate knowledge and understanding of the principle of mass transport: • the need for mass transport systems in flowering plants and mammals; and • examples to include water transport in xylem, translocation in phloem, and circulation and ventilation in a mammal;
(b) Gaseous exchange	2.1.4 demonstrate knowledge and understanding of the factors affecting the rate of gas exchange: • a large surface area for exchange; • a moist surface into which gases dissolve; • diffusion gradients for O_2 and CO_2; • a diffusion path; and • an appreciation of the relationship between the factors shown in Fick's law: $$\text{Diffusion rate} \propto \frac{\text{surface area of membrane} \times \text{difference in concentration across the membrane}}{\text{thickness of membrane}}$$ 2.1.5 demonstrate knowledge and understanding of gas exchange in plants: • exchanging of O_2 and CO_2 gases and the processes of respiration and photosynthesis; • net exchange of gases (mostly photosynthetic at midday, only respirational at night) and the compensation point; • mesophyll surface representing a large, moist surface area for exchange of gases; and • diffusion path: thinness of leaves, air space system through the spongy mesophyll and open stomata during the day facilitating CO_2 uptake.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(b) Gaseous exchange (cont.)**	Students should be able to: 2.1.6 demonstrate knowledge and understanding of gas exchange in a mammal: • mass flow of air to respiratory surface (maintaining diffusion gradients); • large surface area provided by alveoli; • thin respiratory surface (simple squamous epithelium of alveoli and simple squamous endothelium of a blood capillary wall); • moist outer surface of alveoli; • surfactant in moisture layer of alveoli to reduce surface tension; and • rich vascular supply (maintaining diffusion gradients); 2.1.7 demonstrate knowledge and understanding of the structure and functioning of the breathing system of a mammal: • respiratory tree (trachea, bronchi, bronchioles, alveolar ducts and alveoli); • intercostal muscles and ribcage, diaphragm; • mechanism of inspiration and expiration (nervous regulation **not** required); and • the effects of smoking to include cilia damage, bronchitis, emphysema and lung cancer; and *2.1.8 carry out practical work to include understanding how to use a simple respirometer to:* • *measure O_2 consumption (with KOH present);* and • *measure the net difference between CO_2 production and O_2 consumption (with no KOH present) and so determine CO_2 production.*

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(c) Transport in plants and transpiration**	Students should be able to: 2.1.9 demonstrate knowledge and understanding of plant tissues in relation to water (and ion) transport and translocation: • epidermis; • endodermis; • xylem (protoxylem and metaxylem) vessels and their distinctive lignification patterns; and • phloem tissue (sieve-tube elements and companion cells); 2.1.10 demonstrate knowledge and understanding of the uptake of water and mineral ions by root hairs: • water uptake involving osmosis; and • ion uptake involving active transport; 2.1.11 demonstrate knowledge and understanding of the apoplast and symplast pathways through plant tissues: • the apoplast pathway along cellulose cell walls; • the symplast pathway through protoplasts connected by plasmodesmata; • the apoplast and symplast pathways in the root and leaf; and • the role of the endodermis in ensuring the symplast pathway into the stele; and 2.1.12 demonstrate knowledge and understanding of transpiration and the factors influencing its rate: • stomata as the main route of transpiration; • the cuticle as a minor alternative route of transpiration; • internal factors to include leaf surface area, stomatal density and cuticle thickness; and • external factors including light intensity (influencing stomatal aperture), air currents, temperature, humidity and soil water availability.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(c) Transport in plants and transpiration (cont.)**	Students should be able to: 2.1.13 demonstrate knowledge and understanding of the movement of water (and dissolved ions) through xylem: • cohesion-tension theory; • transpiration creating a negative pressure within leaf xylem vessels resulting in the transpiration stream; • the cohesive and adhesive forces of water; and • the root pressure hypothesis; 2.1.14 demonstrate knowledge and understanding of the translocation of organic solutes through phloem: • involving energy expenditure and two-way flow; and • providing evidence for the above properties (theories of translocation **not** required); 2.1.15 demonstrate knowledge and understanding of the structural adaptations of xerophytes and hydrophytes: • xerophytic adaptations to include leaf curvature, reduced surface area, cuticular thickening, hairs, sunken stomata, succulent tissue, deep roots and spines; and • hydrophytic adaptations to include stomata mainly on the upper surface of leaves and a prominent air space system (aerenchyma); and
(d) Circulatory system in mammals	2.1.16 demonstrate knowledge and understanding of the layout of the mammalian circulatory (cardiovascular) system: • double circulation; and • the major blood vessels of the thorax and abdomen.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(d) Circulatory system in mammals (cont.)**	Students should be able to: 2.1.17 demonstrate knowledge and understanding of the histological structure and function of arteries, veins and capillaries: • squamous endothelium, smooth muscle, elastic and fibrous tissue in arteries and veins; • capillaries consisting of squamous endothelium; • arteries containing numerous elastic fibres (allowing distension of the artery and development of a pulse wave) and smooth muscle (allowing vasoconstriction or vasodilation to control blood supply to organs); • atherosclerosis and atheroma; and • veins containing abundant fibrous tissue for protection and valves and large lumen to facilitate the return of blood to the heart; and 2.1.18 demonstrate knowledge and understanding of the functioning of the mammalian heart: • structure, including the atria, ventricles, septa, AV-valves (tricuspid, bicuspid), chordae tendinae and papillary muscles; • the phases of the cardiac cycle as diastole, atrial systole and ventricular systole; • the flow of blood through the heart along pressure gradients involving the operation of valves; • myogenic stimulation and the wave of excitation through heart muscle: SA-node, AV-node, bundle of His and Purkinje fibres; • the changes in the volume of the heart chambers during the cardiac cycle; • the changes in pressure in the heart chambers and major arteries (aorta and pulmonary) during the cardiac cycle; • the heart sounds and the representation of the excitation wave in an electrocardiogram (ECG); and • investigation of blood vessels by angiograph for diagnosis of coronary heart disease, aneurysm, and atherosclerosis.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(d) Circulatory system in mammals (cont.)**	Students should be able to: *2.1.19 carry out practical work:* • *examining prepared slides and/or photographs of blood vessels (in section) to distinguish between arteries, veins and capillaries;* and • *dissecting the mammalian heart to identify heart chambers, AV valves, semilunar valves, chordae tendinae, papillary muscles, interventricular septum and major blood vessels: vena cavae, pulmonary artery and aorta;* 2.1.20 demonstrate knowledge and understanding of the composition and functions of mammalian body fluids, including: • adaptations of red blood cells for O_2 transport; • polymorphs and monocytes; • lymphocytes: – B-cells in antibody production; and – T-cells in cell-mediated immunity (details of the process of immunity **not** required); • plasma as the liquid component of blood transporting products of digestion, ions, carbon dioxide, urea, heat, prothrombin, fibrinogen and clotting factors; and • tissue fluid as the liquid medium bathing all cells within tissues and involved in exchange of metabolites with tissues; *2.1.21 carry out practical work examining stained blood films using light microscopes and/or photomicrographs to identify red blood cells, polymorphs, monocytes, lymphocytes and platelets;* and 2.1.22 demonstrate knowledge and understanding of the mechanism of blood clotting, including the role of platelets, thromboplastins (thrombokinase), prothrombin, clotting factors (for example Factors VIII and Xa, calcium ions, vitamin K), fibrinogen and fibrin.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(d) Circulatory systems in mammals (cont.)**	Students should be able to: 2.1.23 demonstrate knowledge and understanding of the structure and chemical composition of haemoglobin in relation to its role in O_2 transport, including: • conjugated protein, the prosthetic groups (haem) that contain Fe^{2+}; and • each haemoglobin molecule contains four haem groups, each of these can transport one molecule of oxygen; 2.1.24 demonstrate knowledge and understanding of the concept of partial pressure of oxygen and its effect on O_2 transport by haemoglobin, including: • loading haemoglobin with oxygen at higher pO_2; • unloading oxygen from haemoglobin at lower pO_2; • the effect initial binding of oxygen with haemoglobin has on subsequent oxygen loading by haemoglobin; and • the haemoglobin oxygen dissociation curve; and 2.1.25 demonstrate knowledge and understanding of the Bohr effect on O_2 transport by haemoglobin and the physiological advantage this gives a tissue, including: • increased pCO_2/temperature and/or decreased pH shifts the oxygen dissociation curve to the right; • increased pCO_2/temperature and/or decreased pH increases the dissociation of oxygen from haemoglobin; and • increased oxygen supply to tissues where the CO_2 and temperature have increased due to increased rate of respiration and meeting the increased demand for oxygen.

Content	Learning Outcomes
2.1 Transport and exchange mechanisms **(d) Circulatory systems in mammals (cont.)**	Students should be able to: 2.1.26 demonstrate knowledge and understanding that myoglobin's affinity for oxygen is higher than that of haemoglobin, enabling aerobic respiration to continue for longer and delaying the onset of anaerobic respiration: • myoglobin as a pigment present in red muscle; • oxygen dissociation curve for myoglobin is displaced to the left of that for haemoglobin; and • oxygen only dissociates from myoglobin when the pO_2 in muscle tissue is very low; and 2.1.27 demonstrate knowledge and understanding of how altitude affects the way haemoglobin transports O_2: • lower pO_2 in air at higher altitude; • haemoglobin of high altitude dwellers saturates with oxygen at a lower pO_2 than the haemoglobin of lower altitude dwellers; and • increased red blood cell production by athletes during high altitude training.

Content	Learning Outcomes
2.2 The adaptation of organisms	Students should be able to: 2.2.1 demonstrate knowledge and understanding of how organisms adapt to their environment, including: • adaptation as a combination of behavioural, physiological and morphological ways in which an organism meets a particular environmental challenge; • studying organisms in their habitat; and • referring to xerophytic and hydrophytic adaptations given in 2.1.15; 2.2.2 demonstrate knowledge and understanding of how ecological factors influence the distribution of organisms, including: • climatic factors (temperature ranges, availability of water, light intensity, light quality and day length); • edaphic factors (pH values, availability of macronutrients and micronutrients, and aeration of soils); • biotic factors (limits on populations imposed by competitors, predators and the accumulation of waste); and • the term ecological niche; and 2.2.3 *carry out practical work to include the qualitative and quantitative techniques used to investigate the distribution and relative abundance of plants and animals in a habitat:* • *sampling procedures to include:* – *random sampling;* – *line transect;* and – *belt transect;* • *sampling devices, including quadrats, pin frames, pitfall traps, sweep nets and pooters;* • *estimating species abundance, density, frequency and percentage cover;* and • *appreciating and, where possible, measuring the biotic and abiotic factors that may be influencing the distribution of organisms.*

Content	Learning Outcomes
2.3 Biodiversity	Students should be able to: 2.3.1 demonstrate knowledge and understanding that the biochemical basis of life is similar for all organisms and that all living organisms contain the biochemicals carbohydrates, lipids, nucleic acids and proteins; 2.3.2 demonstrate knowledge and understanding that biodiversity involves variation among living organisms at all levels of biological organisation, including: • genetic diversity as the diversity of genes within a species; • species diversity as the diversity among species in an ecosystem; and • ecosystem diversity as the variety of ecosystems in the biosphere; 2.3.3 measure species diversity and know that genetic diversity can be measured: • species diversity is measured using Simpson's index; • the formula for Simpson's index is: $$D = \frac{\sum n_i(n_i\text{-}1)}{N(N\text{-}1)}$$ where *N* is the total percentage cover or total number of organisms of all species and *n* is the percentage cover of a species or number of organisms of a particular species; and • for plant species the percentage cover in a quadrat is usually used (as it is usually very difficult to count all the individual plants) or frequency, for animal species the number of organisms of a species is used; and 2.3.4 demonstrate knowledge and understanding of the principle of taxonomy, including: • nomenclature – scientific naming of organisms using the binomial system; and • systematics – placing organisms into groups based on their similarities and differences.

Content	Learning Outcomes
2.3 Biodiversity (cont.)	Students should be able to: 2.3.5 demonstrate knowledge and understanding of the concept of a species as a group of individuals of common ancestry that closely resemble each other and are normally capable of interbreeding to produce fertile offspring; 2.3.6 demonstrate knowledge and understanding of the other taxa within which species can be grouped, including: • genus as a group of similar and closely related species; • family as a group of apparently related genera; • order as a group of apparently related families; • class as a group of orders within a phylum; • phylum as a group of organisms constructed on a similar plan; and • kingdom as the largest and most inclusive group; and 2.3.7 demonstrate knowledge and understanding of phylogenetic taxonomy as a way to classify sets of species according to ancestral relationships, including establishing relationships between organisms according to a number of measurable features: • morphology and anatomy (external and internal features); • cell structure (prokaryote/eukaryote); • biochemistry (comparisons of DNA, RNA and the amino acid sequences in proteins); and • closely related organisms having a high degree of agreement in the molecular structure of DNA (base sequence), RNA (base sequence) and protein (amino acid sequence), while the molecules of organisms distantly related usually show a pattern of dissimilarity.

Content	Learning Outcomes
2.3 Biodiversity (cont.)	Students should be able to: 2.3.8 demonstrate knowledge and understanding of the five kingdom system of classification: • prokaryotae; • protoctista; • fungi; • plantae; and • animalia; 2.3.9 demonstrate an awareness of other systems of classification, for example the archaea as a separate domain (super-kingdom), distinct from both the bacteria domain and eukarya (eukaryote) domain; 2.3.10 demonstrate knowledge and understanding of the features of prokaryotae, for example a rod-shaped bacterium, including: • structure of prokaryotae cells; and • reproduction by division; 2.3.11 demonstrate knowledge and understanding of the features of protoctista: • eukaryotic; • unicellular or showing limited differentiation; and • that some are heterotrophs, for example paramecium, and others are autotrophs, for example pleurococcus; 2.3.12 demonstrate knowledge and understanding of the features of fungi, for example moulds, including: • lysotrophs (decomposers); • consisting of hyphae with chitinous cell walls; and • feeding by extracellular digestion; and 2.3.13 demonstrate knowledge and understanding of the features of plantae including that plants: • are autotrophs (producers); • have chlorophyll in chloroplasts; and • have cellulose cell walls.

Content	Learning Outcomes
2.3 Biodiversity (cont.)	Students should be able to: 2.3.14 demonstrate knowledge and understanding of the features of animalia, including that animals are heterotrophs and capable of locomotion;
2.4 Human impact on biodiversity	2.4.1 demonstrate knowledge and understanding that agricultural practices can have an impact on biodiversity, including: • those that can promote biodiversity by developing a variety of habitats and/or providing different foods sources, for example: – polyculture versus monoculture; – crop rotation; – hedgerow conservation and maintenance; – using predator strips at field margins; and – integrated pest management and biological control versus pesticide use; • the additional advantages and disadvantages of the agricultural practices listed above; and • intensive agricultural practices that result in increased food production, as well as economic benefits, but have biodiversity costs; 2.4.2 demonstrate knowledge and understanding of the significant consequences on biodiversity that can be caused by pollution of waterways by, for example: • organic pollution by slurry and silage effluent; and • mineral enrichment (eutrophication) as a result of fertiliser run-off; and 2.4.3 demonstrate knowledge and understanding of the effects these organic pollutants and mineral enrichment have on biological oxygen demand (BOD), and on flora and fauna in waterways, and strategies to reduce the incidence of these types of aquatic pollution.

Content	Learning Outcomes
2.4 Human impact on biodiversity (cont.)	Students should be able to: 2.4.4 demonstrate an awareness that there is a range of initiatives to conserve habitats and promote biodiversity, including: • Areas of Special Scientific Interest (ASSI); • Special Areas of Conservation; • Biodiversity Action Plans (students should access one or more of these to become aware of the habitats and species discussed for their own district council area); • Department of Agriculture and Rural Development (DARD) agri-environment schemes; and • Northern Ireland priority habitat and species lists (2010); and 2.4.5 demonstrate knowledge and understanding of global warming and climate change, including: • consequences for flora and fauna, for example local extinctions or shifts in ecological ranges; and • potential consequences for species and ecosystem biodiversity.

3.3 Unit AS 3: Practical Skills in AS Biology

This unit includes a series of required practical assessments and a 1 hour written examination assessing practical skills. Students should complete at least **seven** of the practical tasks listed below and record evidence of completing these tasks in their lab books (or equivalent) used for this purpose. We will request samples of lab books (or equivalent) as part of the moderation process.

The 1 hour written examination will assess the practical skills developed throughout the AS course, detailed in italics in the specification content for Units AS 1 and AS 2, and the assessed practical tasks listed below.

Please see Section 7 for guidance on carrying out and marking the assessed practical tasks.

Content	Learning Outcomes
(a) Assessed practical tasks	Students should be able to carry out practical work by completing at least **seven** of the following practical tasks: • use qualitative reagents to identify biological molecules; • carry out chromatography of amino acids; • complete **up to two** enzyme experiments, for example the effect of temperature, pH, substrate concentration, enzyme concentration on enzyme activity and/or an illustration of enzyme immobilisation; • use a colorimeter to follow the course of a starch-amylase catalysed reaction (or other appropriate reaction, for example factors affecting membrane permeability in beetroot), including understanding how to make and use serial dilutions as and where appropriate; • use a graticule and stage micrometer in measuring cell size at both low and high powers; • measure the average water potential of cells in plant tissue; • measure the average solute potential of cells at incipient plasmolysis; • prepare and stain root tip squashes to observe mitosis; • complete accurate block diagrams of sections of the ileum or a leaf observed under the microscope; • dissect a mammalian heart; and • sampling techniques (in the field), including measuring abiotic or biotic factors (**up to two** investigations may be counted).

Content	Learning Outcomes
(b) Practical skills written examination	Students should be able to describe and demonstrate the practical skills developed during the AS course, which will be assessed in a 1 hour written examination containing structured questions set in the context of the practical tasks listed in part (a) of this unit and the other practical tasks listed in italics as part of the content for Units AS 1 and AS 2.

3.4 Unit A2 1: Physiology, Co-ordination and Control, and Ecosystems

This unit covers homeostasis including the kidney and excretion, immunity, co-ordination and control in plants and animals, and ecosystems.

Assessment for this unit consists of a written examination that includes both short and extended questions. For more details, see Section 6.

Content	Learning Outcomes
4.1 Homeostasis	Students should be able to:
(a) Principles of homeostasis	4.1.1 demonstrate knowledge and understanding of the concept of homeostasis and the components of homeostatic mechanisms, including: • homeostasis as the maintenance of a constant state; • the control system as having a sensor (receptor) that monitors the factor being controlled; • a corrective mechanism brings about changes resulting in regulation of this factor; and • a negative feedback system stops the corrective mechanism and prevents over-correction;
(b) The kidney and excretion	4.1.2 demonstrate knowledge and understanding of the role of the mammalian kidney in excretion and osmoregulation, including: • removal of toxic waste products of metabolism (urea and creatine); and • maintenance of optimal water potential of body fluids; and 4.1.3 demonstrate knowledge and understanding of the gross structure of the mammalian kidney and excretory system to include recognising the cortex, medulla, pyramids, pelvis, ureters, bladder and urethra in photographs or diagrams.

Content	Learning Outcomes
4.1 Homeostasis **(b) The kidney and excretion (cont.)**	Students should be able to: 4.1.4 demonstrate knowledge and understanding of the structure of the nephron, including: • Bowman's capsule with podocytes; • proximal convoluted tubule consisting of a cuboidal epithelium containing numerous mitochondria and with surface microvilli and basal invaginations; • loop of Henlé: – descending limb with a cuboidal epithelium, which is permeable to water; and – ascending limb, which is impermeable to water; and • distal convoluted tubule and collecting duct consisting of a cuboidal epithelium; 4.1.5 demonstrate knowledge and understanding of the structure of the filter: • squamous endothelium of the blood capillaries in the glomerulus; • basement membrane as the effective filter; and • podocytes in the wall of the Bowman's capsule; and 4.1.6 demonstrate knowledge and understanding of the mechanism of ultrafiltration: • afferent arterioles are wider in diameter than efferent arterioles; • high blood pressure within glomerular capillaries as the main driving force for filtration; • osmotic gradient from the filtrate in the nephron into the glomerular capillaries opposes the blood pressure; • resistance to further filtration due to back pressure of the filtrate in the nephron; and • know which components of blood are commonly filtered and which are not and the reasons why.

Content	Learning Outcomes
4.1 Homeostasis **(b) The kidney and excretion (cont.)**	Students should be able to: 4.1.7 demonstrate knowledge and understanding of the mechanism of selective reabsorption: • in the proximal convoluted tubule there is active transport of salt, glucose and amino acids from the filtrate into the cuboidal epithelium and then into the capillaries of the vasa recta system; • lowering of the solute potential in the cuboidal epithelium and blood capillaries; • resultant osmotic gradient responsible for the bulk of water reabsorbed; and • in the distal convoluted tubule/collecting ducts there is facultative reabsorption of water dependent on the permeability of the epithelial lining which, in turn, is dependent on the level of ADH in the blood; and 4.1.8 demonstrate knowledge and understanding of the role of the loop of Henlé: • the loss of water from the descending limb concentrates the filtrate at the apex of the loop; • subsequent exit of sodium and chloride ions from the ascending limb into the surrounding medulla tissue; and • the creation of a salt gradient in the medulla tissue for the osmotic recovery of water from the filtrate as it passes through the: – descending limb of the loop of Henlé; – distal convoluted tubule; and – collecting duct.

Content	Learning Outcomes
4.1 Homeostasis **(b) The kidney and excretion (cont.)**	Students should be able to: 4.1.9 demonstrate knowledge and understanding of the mechanism of osmoregulation in a mammal: • osmoreceptors in the hypothalamus are sensitive to the solute potential of the blood; • variation in the synthesis of ADH by the hypothalamus in relation to the solute potential of the blood; • ADH stored and released from the pituitary gland into the bloodstream; and • ADH increases the permeability of the distal convoluted tubule and collecting ducts to water; 4.1.10 demonstrate knowledge and understanding of the principle of negative feedback as exemplified by the role of ADH in osmoregulation in mammals: • the solute potential of the blood is lowered during exercise; • the corrective mechanism involves increased ADH synthesis and release into the bloodstream; • consequent increased reabsorption of water from the filtrate into the blood; and • increased solute potential of the blood results in decreased ADH secretion, thereby inactivating the corrective mechanism;
4.2 Immunity	4.2.1 demonstrate knowledge and understanding of the natural barriers to infection in humans such as skin, acid, tears (containing lysozyme), mucus and blood clotting; and 4.2.2 demonstrate knowledge and understanding of the terms: • antigen – substance capable of stimulating the production of specific and complementary antibodies; and • antibody – globular proteins that are specific and complementary to particular antigens that can react with antigens leading to their destruction (details of antibody structure and classification of antibody types **not** required).

Content	Learning Outcomes
4.2 Immunity (cont.)	Students should be able to: 4.2.3 demonstrate knowledge and understanding of the difference between antibody-mediated and cell-mediated immunity: • antibody-mediated immunity involving division of particular B-lymphocytes after exposure to foreign antigens to form: – plasma cells capable of synthesising and secreting specific antibodies; and – memory cells providing long-term immunity; • concept of delay in such antibody-mediated reactions and consequences for the infected individual; • cell-mediated immunity involving the role of T-lymphocytes; • division of T-lymphocytes sensitised by viral antigens, abnormal self-antigens (tumours) or transplanted foreign tissue antigens to form a pool of different types of T-lymphocytes: – killer T-cells capable of direct enzymatic destruction of foreign invading antigens; – helper T-cells which co-operate with B-cells in the formation of some types of antibody; – memory T-cells providing long-term immunity to specific antigens; and – suppressor T-cells which deactivate the immune response of both B- and T-cells; and 4.2.4 demonstrate knowledge and understanding of an antigen-antibody reaction: • agglutination involving formation of a specific antigen/antibody complex; • phagocytosis of this complex by polymorphs; and • destruction of the antigen by intracellular digestion involving lysosomal enzymes.

Content	Learning Outcomes
4.2 Immunity (cont.)	Students should be able to: 4.2.5 demonstrate knowledge and understanding of active and passive immunity: • active immunity involves an individual's own immune system producing specific antibodies, T-cells and memory cells to particular foreign antigens; • passive immunity being either natural or artificial and involving donation of antibodies from another source, including: – placental (uterine) transfer (natural); – colostral transfer (natural); – serum taken from a person recovering from a clinical infection in the context of the outbreak of a new or virulent disease with no known treatment (artificial); and – monoclonal antibodies from another species (artificial); • active immunity providing long-term immunity whereas passive immunity provides short-term immunity only; and • the importance to society and the economy of vaccination in protecting individuals and populations from disease; and 4.2.6 demonstrate knowledge and understanding of the concept of transplant rejection: • transplanted or transfused tissue from a donor exposes a recipient's immune system to foreign antigens; and • production of specific T-cells or B-cells that attack and destroy the introduced tissue.

Content	Learning Outcomes
4.2 Immunity (cont.)	Students should be able to: 4.2.7 demonstrate knowledge and understanding of the principle of immunosuppression and its consequences: • inactivation of specific B-cell and T-cell responses using irradiation by X-rays or using drugs that inhibit DNA replication; • introduced foreign antigens are not recognised and therefore produce no immune response; and • an individual with a suppressed immune system is more susceptible to infection; 4.2.8 demonstrate knowledge and understanding of human blood antigens and the basis of blood group polymorphism: • blood group specified by the antigen type present on the surface membrane of red blood cells; • four blood groups recognised in the ABO system (A, B, AB, O); • individuals possessing a particular type of antigen cannot possess complementary antibodies in their plasma; • rhesus antigen (antigen D) may also occur on the surface membrane of red blood cells; • anti-rhesus (anti-D) antibodies do not naturally occur in any individual; and • production of anti-rhesus antibodies when a rhesus negative mother is exposed to the rhesus antigens of her rhesus positive baby and the consequences for that child and future children; and 4.2.9 demonstrate knowledge and understanding of the principles of blood transfusion compatibility: • comparing donor antigens and recipient's plasma antibodies to determine compatibility; and • antibodies in donated blood have a negligible effect on the recipient's red blood cells.

Content	Learning Outcomes
4.2 Immunity (cont.)	Students should be able to: 4.2.10 demonstrate knowledge and understanding of the consequences of transfusion incompatibility: • formation of antigen or antibody complexes resulting in agglutination of red blood cells; and • potential for blockage of the blood or O_2 supply to a tissue and the consequences; 4.2.11 demonstrate knowledge and understanding of the consequences of antibiotic resistance in bacteria and the importance to society and the economy of discovering new antibacterials or antimicrobials: • biology of resistance with factors affecting spread: – epidemics and pandemics; – animals, for example bats, as reservoirs of viruses; and • the importance to society and the economy of discovering new sources of antibiotics within natural environments; 4.2.12 understand the use of antibodies in the detection of proteins as biomarkers of disease processes, including: • enzyme-linked immunosorbent assay (ELISA); and • the detection of cytokines as biomarkers of inflammation; and *4.2.13 carry out practical work:* • *investigations with microorganisms involving aseptic techniques, for example the effect of different antibiotics/e-strips on bacteria or the preparation of a streak plate to isolate single colonies;* and • *investigating the antimicrobial properties of plants.*

Content	Learning Outcomes
4.3 Co-ordination and control **(a) Plants**	Students should be able to: 4.3.1 demonstrate knowledge and understanding of the role of phytochromes in the control of flowering in long-day and short-day plants: • phytochromes as pigments found in the leaves of flowering plants; • phytochromes occur in two interchangeable forms: – P_{660} which absorbs red light and rapidly converts to P_{730}; and – P_{730} which absorbs far-red light to rapidly convert to P_{660} and slowly converts to P_{660} in the dark; • concept of a critical length of night (dark period) required to remove P_{730}; • understand that removal of P_{730} is required for short-day plants to flower; • understand that non-removal of P_{730} allows long-day plants to flower; and • understand that artificial manipulation of the photoperiod (and the consequent effect on the levels of P_{660} or P_{730} present in the leaves) allows plants to flower out-of-season; and 4.3.2 demonstrate knowledge and understanding of the role of plant growth substances (hormones) in stem elongation: • auxins promote cell elongation; • cytokinins promote cell division; and • gibberellins promote elongation of internodal regions.

Content	Learning Outcomes
4.3 Co-ordination and control **(b) Animals**	Students should be able to: 4.3.3 demonstrate knowledge and understanding of the structure of a neurone, recognising the following components in *photomicrographs and electron micrographs (TEM)* and diagrams: • dendrons and dendrites; • cell body; • axon; • Schwann cell and myelin sheath; and • node of Ranvier; and 4.3.4 demonstrate knowledge and understanding of the generation and transmission of nerve impulses: • resting potential/polarisation of the axon; • concept of a threshold stimulus; • all-or-nothing law; • depolarisation and development of an action potential; • propagation of action potentials along an axon by a flow of current in a series of localised circuits; • concept of a refractory period following the development of an action potential when a further stimulus will not elicit another action potential; • requirement of repolarisation before a further action potential can develop; and • the factors that influence the speed of impulse conduction: – diameter of the axon; and – myelination of the axon and saltatory conduction. (The ionic bases for neurone resting and action potentials **not** required.)

Content	Learning Outcomes
4.3 Co-ordination and control **(b) Animals (cont.)**	Students should be able to: 4.3.5 demonstrate knowledge and understanding of synaptic transmission and recognise the following structures in *photomicrographs, electron micrographs* and diagrams: • structure of synapses, including: – synaptic bulb; – synaptic vesicles (containing neurotransmitter chemical); – pre-synaptic membrane; – synaptic cleft; and – post-synaptic membrane; • exocytosis of neurotransmitter (acetylcholine, noradrenaline and GABA) from the pre-synaptic membrane on arrival of an impulse; • diffusion of neurotransmitter across the synaptic cleft; • specific receptors on post-synaptic membrane; • development of an excitatory post-synaptic potential (EPSP), depolarisation and an action potential in the post-synaptic membrane; • role of acetylcholinesterase; and • development of an inhibitory post-synaptic potential (IPSP) at inhibitory synapses that: – hyperpolarises the post-synaptic membrane; and – makes the generation of an action potential much less likely.

Content	Learning Outcomes
4.3 Co-ordination and control **(b) Animals (cont.)**	Students should be able to: 4.3.6 demonstrate knowledge and understanding of the gross structure of the mammalian eye and the functioning of its component parts in normal vision: • conjunctiva, cornea, iris, pupil, lens, ciliary body and suspensory ligaments, aqueous and vitreous humour, retina, fovea, choroid, sclera, blind spot, optic nerve, rods and cones; • role of circular and radial muscles in the iris in the control of pupil diameter; • role of the ciliary body and suspensory ligaments in alteration of the curvature of the lens, and thereby achieving the refraction required for accommodation when viewing near and distant objects; • role of the pigment in the choroid layer preventing internal reflection; • the relative distribution of rods and cones in the retina; • convergence of rods allowing summation of sub-threshold light stimuli and thereby increased visual sensitivity; • convergence of rods results in decreased visual acuity; • visual acuity and colour vision provided by cones; • dark adaptation in rods involving the re-synthesis of rhodopsin that had been broken down during exposure to light; • binocular vision allowing: – good distance and depth perception; – wide visual fields; and – stereoscopic vision; and *4.3.7 carry out practical work including examining prepared slides or photomicrographs of the mammalian eye to identify the conjunctiva, cornea, iris, pupil, ciliary body, suspensory ligaments, aqueous and vitreous humours, retina, choroid, sclera, blind spot, optic nerve, rods and cones.*

Content	Learning Outcomes
4.3 Co-ordination and control **(b) Animals (cont.)**	Students should be able to: 4.3.8 demonstrate knowledge and understanding of the structure and function of voluntary (skeletal) muscle as an effector: • recognising the differences between muscle, muscle fibres and myofibrils; • recognising the components of a sarcomere (A-band, I-band, H-band/zone, Z-lines, M-line) in photomicrographs, electron micrographs and diagrams; • recognising the changes in these components that occur within a sarcomere on contraction/relaxation; and • the sliding filament theory of contraction, including: – attachment of myosin heads to actin filaments in the presence of calcium ions in the sarcoplasm; – change in orientation of myosin heads resulting in movement of actin filaments over myosin rods; and – process requires ATP expenditure (the role of proteins **not** required); and *4.3.9 carry out practical work to include examining skeletal muscle, cardiac muscle and smooth muscle to recognise the characteristic features of each using prepared slides, photomicrographs and electron micrographs as appropriate.*

Content	Learning Outcomes
4.4 Ecosystems **(a) Populations**	Students should be able to: 4.4.1 demonstrate knowledge and understanding of how populations grow: • the phases of population growth: – lag phase; – exponential (log) phase; – stationary phase; and – decline phase; • competition for resources and/or accumulation of waste in influencing the exponential and stationary phases; • the availability of resources (renewable or non-renewable) in influencing the stationary and decline phases; • ecological terms to include: – population; – resource; – competition; – biotic potential; – carrying capacity; and – environmental resistance; 4.4.2 demonstrate knowledge and understanding of the distinction between r- and K-selected species to include: • features of r-selected species; • features of K-selected species; and • growth curves for r- and K-selected species (population growth equations **not** required); and 4.4.3 demonstrate knowledge and understanding of how populations may interact: • competition as a -/- interaction, which generally leads to the elimination of one species; • mutualism as a +/+ interaction; • predation, parasitism and grazing as +/- interactions; and • the effect of interspecific competition and predator–prey interaction on growth curves.

Content	Learning Outcomes
4.4 Ecosystems **(a) Populations (cont.)**	Students should be able to: 4.4.4 demonstrate knowledge and understanding of the biological control of pest species: • definition of a pest species; • use of predators or competitors as biological control organisms; • advantages of biological control over chemical control; and • features of effective biological control; 4.4.5 demonstrate knowledge and understanding of the dynamics of populations: • factors influencing population size seasonally and from year to year; and • changes in population size determined by: – birth; – death; – immigration; and – emigration; and *4.4.6 carry out practical work:* • *investigating the growth of a yeast population using a haemocytometer:* – *components of a culture medium for a yeast population;* and – *use of haemocytometer to include counting cells over a grid of determined volume and calculating cell density;* and • *estimating the size of an animal population using a simple capture–mark–recapture technique:* – *marking techniques;* – *assumptions made when using a capture–mark–recapture technique;* and – *estimation of population size using the above technique.*

Content	Learning Outcomes
4.4 Ecosystems **(b) Communities**	Students should be able to: 4.4.7 demonstrate knowledge and understanding of the concept of an ecological community as a biotic component of an ecosystem and involving interactions between autotrophic and heterotrophic populations; 4.4.8 demonstrate knowledge and understanding of the concept of an ecosystem as a community of different species that are interdependent and interact with each other and their abiotic environment, involving energy flow and nutrient and gas exchanges; and 4.4.9 demonstrate knowledge and understanding of the process of community development: • initial colonisation of a habitat by pioneer species; • succession as a change in the species composition in a community with time, culminating in a climax community; • climax community as the stable end stage of a succession that is in equilibrium with the environment; • biotic and climatic climaxes; • primary succession as a relatively slow process of community development in a previously unoccupied area; and • secondary succession as a predictable, repeatable and faster process of community development in an area where the climax community was destroyed by fire, flooding, wind damage or human interference.

Content	Learning Outcomes
4.4 Ecosystems **(c) Ecological energetics**	Students should be able to: 4.4.10 demonstrate knowledge and understanding of food chains and food webs, including the role of producers and consumers (herbivores and carnivores) in grazing food chains and detritivores and decomposers in detritus food chains; 4.4.11 demonstrate knowledge and understanding of trophic levels: • primary producers as the first trophic level; • net primary production (NPP) as the gross primary production (GPP) less respiration; and • other trophic levels to include primary, secondary and tertiary consumers, and detritivores and decomposers; and 4.4.12 demonstrate knowledge and understanding of the quantitative relationship between trophic levels: • pyramid relationships and their relative usefulness: – pyramids of numbers; – pyramids of biomass; and – pyramids of energy (productivity); • calculating the efficiency of energy transfer through trophic levels; • reasons for the low percentage of solar radiation absorbed by plants in photosynthesis; and • reasons for the reduction in energy at progressive trophic levels: – losses to the decomposer food chain; – losses through egestion and excretion; – the difficulty of digesting plant material (for example cellulose) and the relatively high losses via egestion in primary consumers (herbivores); – losses through respiration (with energy dissipated as heat); and – the relatively high losses via respiration in endotherms (mammals and birds).

Content	Learning Outcomes
4.4 Ecosystems **(c) Ecological energetics (cont.)**	Students should be able to: 4.4.13 demonstrate knowledge and understanding of the implications for agriculture, including: • extra energy cost of producing animal products; and • aspects of intensive farming methods: – using fertilisers to increase primary productivity; – confinement to improve respiration/production ratio; and – using high energy foods such as silage and high protein foods;
(d) Nutrient cycling	4.4.14 demonstrate knowledge and understanding of the cycling of carbon in the ecosystem: • respiration, combustion and decomposition as processes that add carbon dioxide to the atmosphere; and • photosynthesis as a process that removes carbon dioxide from the atmospheric pool; and 4.4.15 demonstrate knowledge and understanding of the role of decomposers, nitrifying bacteria and N_2-fixing bacteria to provide nitrogen in a suitable form for plants: • decomposers releasing ammonium compounds; • nitrifying bacteria oxidising ammonium compounds to nitrate; • N_2-fixing bacteria synthesising organic nitrogen-containing compounds (amino acids); and • Denitrification returning N_2 to the atmospheric pool.

3.5 Unit A2 2: Biochemistry, Genetics and Evolutionary Trends

This unit covers the biochemical processes of respiration and photosynthesis. Students explore genetics on a number of levels: DNA as the genetic code, gene technology, patterns of inheritance and the mechanism of change in population genetics that contributes to evolutionary trends. Students also learn about a variety of phyla in the plant and animal kingdoms.

Assessment for this unit consists of a written examination that includes both short and extended questions. For more details, see Section 6.

Content	Learning Outcomes
5.1 Respiration	Students should be able to: 5.1.1 demonstrate knowledge and understanding of the nature and function of ATP: • adenine, ribose and phosphate as components of ATP; • the ATP/ADP cycle coupling respiration with energy use; and • using ATP in synthesis, mechanical work and active transport; and 5.1.2 demonstrate knowledge and understanding of glycolysis: • a process common to aerobic and anaerobic respiration; • occurs in the cytoplasm; • involves the phosphorylation of glucose and its conversion to fructose bisphosphate, a process that uses 2 ATP; • involves the formation of two triose phosphate molecules from each fructose bisphosphate molecule, each of which eventually forms pyruvate; • the conversion of each triose phosphate molecule to pyruvate produces reduced NAD (NADH) as a source of reducing power as well as producing 2 ATP; and • the relatively small net yield of ATP from glycolysis (2 ATP per glucose molecule) (other intermediates in glycolysis are **not** required).

Content	Learning Outcomes
5.1 Respiration (cont.)	Students should be able to: 5.1.3 demonstrate knowledge and understanding of aerobic respiration including glycolysis followed by further oxidation of pyruvate via the Krebs cycle in the mitochondrial matrix and by electron transport at the mitochondrial cristae; 5.1.4 demonstrate knowledge and understanding of anaerobic respiration: • glycolysis and further reactions that produce no more ATP but regenerate NAD; and • ethanol and carbon dioxide production in plants and fungi, and lactate production in animals; 5.1.5 demonstrate knowledge and understanding of the Krebs cycle: • the oxidative decarboxylation of pyruvate to produce reduced NAD (NADH) and an acetyl group (C2) which combines with co-enzyme A; • acetyl co-enzyme A enters the Krebs cycle by reacting with a C4 acid to produce a C6 acid that undergoes oxidative decarboxylation in a series of reactions to produce the original C4 acid plus reduced NAD (NADH), FADH and ATP; • the net yield of reduced NAD (NADH), FADH and ATP from one molecule of pyruvate; and • the Krebs cycle as a focal point, linking carbohydrate, fat and protein metabolism; and 5.1.6 demonstrate knowledge and understanding of the electron transport chain: • NAD, flavoprotein, co-enzyme Q and the cytochromes as links in the chain at progressively lower energy levels; • oxygen as the ultimate hydrogen acceptor; • the points at which ATP is synthesised; and • the net yield of ATP for each pair of hydrogen atoms starting at reduced NAD (NADH) or reduced flavoprotein.

Content	Learning Outcomes
5.1 Respiration (cont.)	Students should be able to: 5.1.7 demonstrate knowledge and understanding of the comparison between aerobic and anaerobic respiration to include: • that aerobic respiration produces a larger yield of ATP than anaerobic respiration, although aerobic respiration depends on the availability of oxygen; • the significance of anaerobic respiration in providing ATP without using oxygen; • the different strategies for anaerobic respiration in animals, plants and fungi, for example: – in animals extra ATP is generated rapidly, over and above that produced aerobically (for a burst of activity over a short period of time) resulting in an oxygen debt; and – in plants and fungi anaerobic respiration allows survival for some time in anaerobic conditions; and • oxygen debt as the additional oxygen required to further metabolise accumulated lactate and/or resynthesise depleted ATP; 5.1.8 demonstrate knowledge and understanding of the respiratory quotient (RQ) including: • measuring the RQ as the ratio of CO_2 produced to oxygen consumed in a respiring organism; and • using RQ to identify respiratory substrates and detect anaerobic respiration; and *5.1.9 carry out practical work to include:* • *using the respirometer to calculate oxygen uptake, carbon dioxide production and RQ values;* and • *demonstrating the role of hydrogen acceptors using redox indicators (for example methylene blue).*

Content	Learning Outcomes
5.2 Photosynthesis	Students should be able to: 5.2.1 demonstrate knowledge and understanding of the sites in the chloroplast where the reactions of photosynthesis occur: • light-dependent stage on the thylakoids; and • light-independent stage in the stroma; 5.2.2 demonstrate knowledge and understanding of the light-dependent stage of photosynthesis: • photoactivation of photosystem I (PSI) and photosystem II (PSII) resulting in the passage of electrons from PSII to PSI (the Z-scheme) coupled with the production of ATP (photophosphorylation) (cyclic photophosphorylation **not** required); • the final acceptor of PSI electrons as NADP (with H^+ from the dissociation of water) producing reduced NADP (NADPH); and • the replacement of PSII electrons from hydroxide ions (OH^-) resulting from the dissociation of water with the release of oxygen; and 5.2.3 demonstrate knowledge and understanding of the light-independent stage of photosynthesis: • CO_2 fixation, catalysed by the enzyme rubisco, and reduction in a C3 plant in terms of reaction with ribulose bisphosphate (C5) producing two molecules of glycerate phosphate (C3) which is reduced by NADPH to a triose phosphate with the consumption of ATP; • the recycling of 5/6 of the triose phosphate to regenerate ribulose bisphosphate; and • using the remaining 1/6 in the synthesis of C6 sugars and other compounds (CAM and C4 metabolism **not** required).

Content	Learning Outcomes
5.2 Photosynthesis (cont.)	Students should be able to: 5.2.4 demonstrate knowledge and understanding that light is absorbed by chlorophyll and associated pigments: • absorption spectra showing peak absorption by different pigments; and • action spectrum showing which wavelengths of light promote the optimum rate of photosynthesis; 5.2.5 demonstrate knowledge and understanding of the external factors that limit the rate of photosynthesis: • photosynthesis measured as CO_2 uptake or O_2 production; • gross photosynthesis, net photosynthesis and the compensation point; and • light availability, CO_2 availability and temperature limiting the rate of photosynthesis; and *5.2.6 carry out practical work:* • *paper chromatography of plant pigments:* – *preparing and running the chromatogram; and* – *calculating R_f values;* and • *demonstrating the role of hydrogen acceptors using redox indicator (for example DCPIP).*

Content	Learning Outcomes
5.3 DNA as the genetic code	Students should be able to: 5.3.1 demonstrate knowledge and understanding of the nature of the genetic code: • that a gene is a sequence of bases on the DNA molecule that codes for a sequence of amino acids in a polypeptide chain; • the genetic code as a non-overlapping, degenerate, three base code; and • exons and introns; 5.3.2 demonstrate knowledge and understanding of the process of transcription in synthesising proteins: • as a process involving the unpairing of the bases in one region of the DNA helix followed by the synthesis of a strand of mRNA carrying a triplet code sequence complementary to the template strand of DNA; and • the structure of mRNA and the role of RNA polymerase; 5.3.3 demonstrate knowledge and understanding of the process of translation in synthesising proteins: • translation as the 'reading' of a triplet mRNA code at a ribosome during which tRNA molecules carrying complementary anticodons pair with mRNA codons bringing specific amino acids into position on ribosomal sites (peptidyl and aminoacyl) for condensation to form a polypeptide or protein; and • the structure and function of tRNA and ribosomes; and 5.3.4 demonstrate knowledge and understanding of the one gene/one polypeptide theory: • a gene codes for one polypeptide; and • enzymes as proteins whose synthesis is controlled by DNA (and since enzymes control metabolic pathways they influence the phenotype of an organism).

Content	Learning Outcomes
5.3 DNA as the genetic code (cont.)	Students should be able to: 5.3.5 demonstrate knowledge and understanding of the concept of epigenetics: • the term epigenetics as the study of changes in gene expression that are mitotically heritable and that do not involve a change in the DNA sequence; • epigenetic mechanisms to include methylation and histone modification; and • epigenetic changes are influenced by the environment, can change as a person ages and can be different between tissues as well as between cells of the same tissue;
5.4 Gene technology	5.4.1 demonstrate knowledge and understanding of the polymerase chain reaction (PCR): • as a technique for amplifying a sample of DNA; • that the process involves repetition of a three-step cycle: – heating to separate the DNA strands; – cooling to allow annealing of DNA primers complementary to base sequences on opposite strands at each end of the target DNA; and – use of heat-stable DNA polymerase to extend the primers; and • the range of uses of PCR; and 5.4.2 demonstrate knowledge and understanding of using DNA probes to locate a specific section of DNA: • that a DNA probe is a short length of DNA with a known base sequence; • that probes can be fluorescent and therefore useful as a marker; and • that the probe will base pair with any complementary nucleic acid strands.

Content	Learning Outcomes
5.4 Gene technology (cont.)	Students should be able to: 5.4.3 demonstrate knowledge and understanding that differences in nucleotide sequences can be identified by: • assessing differences in nucleotide sequences as a measure of genetic variation; and • different genetic markers, for example microsatellite repeat sequences (MRSs) and single nucleotide polymorphisms (SNPs); 5.4.4 demonstrate knowledge and understanding of microarray technology: • it enables rapid gene expression profiling or gene sequence variation of thousands of genes in an individual; • it involves DNA bound (hybridised) to a microarray chip; • it binds the sample DNA to a probe on the chip which can produce a signal that can be fluorescent or chemiluminescent; and • it digitally analyses the chip to calculate the strength of the signal produced at each spot, with the strength of the signal representing the level of gene expression in the individual; and 5.4.5 demonstrate knowledge and understanding of genetic fingerprinting and have an appreciation of its potential uses to include: • using restriction endonucleases to cut chromosomal DNA and the subsequent separation of fragments according to size (using gel electrophoresis) to produce unique profiles; and • using DNA probes to locate specific DNA fragments.

Content	Learning Outcomes
5.4 Gene technology (cont.)	Students should be able to: 5.4.6 demonstrate knowledge and understanding of the stages involved in gene transfer: • methods used to obtain donor DNA, for example using restriction endonucleases and reverse transcriptase; • using DNA probes to locate the DNA fragment within the desired gene; • incorporating the donor genes into a 'vector', for example bacteriophages and bacterial plasmids; • transforming recipient cells, for example *Escherichia coli*, *Saccharomyces cerevisiae*; • using marker genes to identify transformed cells, for example antibiotic resistance and fluorescent marker genes; and • producing large numbers of transformed cells; and 5.4.7 demonstrate knowledge and understanding of the role of genetically modified (GM) microorganisms: • the wide range of substances that GM bacteria produce; and • using GM viruses to treat disease, for example killing human cancer cells and treating bacterial infections.

Content	Learning Outcomes
5.4 Gene technology (cont.)	Students should be able to: 5.4.8 demonstrate knowledge and understanding of the role of transgenic organisms, such as improving desirable traits, by inserting genes into: • animals to: – encourage faster growth rate and better food quality traits; – produce substances of medical and pharmaceutical value; and – use as models in human disease research; and • plants to: – produce higher crop yields, increased variety or better food quality traits; – produce pest and disease resistant crops; and – cultivate GM crops that grow in unfavourable environments; and 5.4.9 demonstrate knowledge and understanding of gene therapy: • absent or faulty genes may cause genetic diseases; • adding a functional copy of a gene into a cell can restore metabolism and eliminate disease; • the advantages and problems of somatic-cell gene therapy; • the types of vector that can be used in the gene transfer; • the ethical and technical issues surrounding germ-line gene therapy; and • that gene therapy: – has successfully treated some diseases, for example haemophilia B; and – requires repeated rounds of treatment to manage symptoms of other diseases, for example cystic fibrosis.

Content	Learning Outcomes
5.4 Gene technology (cont.)	Students should be able to: 5.4.10 demonstrate knowledge and understanding of the process of gene sequencing: • genome of an organism as the complete DNA sequence (on one set of chromosomes in diploid, eukaryotic organisms); • genome sequencing as determining the order of nucleotides and so the genetic code; • that the genomes of many organisms have been sequenced, including some that are extinct, for example Neanderthals; • that knowledge of the genetic code allows primary protein structure to be determined (and that molecular modelling software can predict secondary, tertiary and quaternary structure); • that the Human Genome Project was set up to map and sequence 3 billion nucleotides in the human genome and to identify all the genes present (approximately 21000); and • that sequencing has become more rapid and less expensive; and 5.4.11 demonstrate knowledge and understanding that the inactivation or replacement of genes helps to understand gene and organism function: • genes may be made inoperative by being disabled, removed or replaced with defective alleles (details of techniques **not** required); • this technique provides clues to the role genes play in a cell or organism; • the mouse (knockout and knockin mouse) as a model organism for the study of genes; and • inactivation or replacement can be used to study the development of genetic disorders and drug therapies.

Content	Learning Outcomes
5.4 Gene technology (cont.)	Students should be able to: 5.4.12 demonstrate knowledge and understanding of the term pharmacogenetics: • as the effect that the genotype has on an individual's drug response; • that personalised medicine deals with genetic differences specific to an individual patient, where certain patients can respond differently to treatment with certain drugs, for example codeine; • that using microarrays can identify genetic differences between individuals that result in different responses to drugs; • that personalised medicine explores how treatment can be personalised to improve clinical outcome; and • that the development of 'designer drugs' can be matched to an individual's genetic profile; 5.4.13 demonstrate knowledge and understanding of the social, legal, ecological and ethical issues of the benefits and risks of gene technology: • the social and ethical implications of genetic modification and genome sequencing; • the potential risks associated with genetically modifying organisms; and • safety precautions currently used, for example bacterial strains ill-adapted to the human physiology, 'suicide genes' and containment mechanisms; and *5.4.14 carry out practical work including gel electrophoresis of DNA and/or extraction of DNA.*

Content	Learning Outcomes
5.5 Genes and patterns of inheritance	Students should be able to: 5.5.1 demonstrate knowledge and understanding of the terms genotype and phenotype: • definition of the terms genotype and phenotype; • role of the genotype and the environment in determining an organism's phenotype; and • homozygosity and heterozygosity; 5.5.2 demonstrate knowledge and understanding of the relationship between chromosomes, genes and alleles: • the definition of the term gene; • genes are located on chromosomes; • alleles are alternative forms of the same gene; and • alleles are located at the same locus on homologous chromosomes in diploid organisms; and 5.5.3 demonstrate knowledge and understanding of the inheritance of traits showing discontinuous variation, including: • monohybrid inheritance; • Mendel's first law of inheritance as the law of segregation of factors; • dominance and recessiveness; • codominance; • lethal allelic combinations; • multiple alleles; • test crosses as crossing with the recessive individual to find the genotype of an individual with a dominant trait; • dihybrid inheritance; • Mendel's second law of inheritance as the law of independent assortment of factors; • Mendel's laws and meiosis; and • solving inheritance patterns: – genetic diagrams using a standard format; and – Punnett square when appropriate (when there is more than one type of gamete possible from both parents).

Content	Learning Outcomes
5.5 Genes and patterns of inheritance (cont.)	Students should be able to: 5.5.4 demonstrate knowledge and understanding of sex determination and sex linkage: • autosomes and sex chromosomes; • sex determination in mammals (XX and XY); and • the inheritance of sex-linked characters (recessive and dominant); 5.5.5 demonstrate knowledge and understanding of gene interaction: • gene interaction, including epistasis; and • the inheritance of traits showing gene interaction; and 5.5.6 demonstrate knowledge and understanding of the inheritance of traits showing continuous variation (polygenic inheritance): • continuous variation as due to the additive effects of genes (polygenes); and • the effects of the environment in contributing to continuous variation.

Content	Learning Outcomes
5.6 Population genetics	Students should be able to: 5.6.1 demonstrate knowledge and understanding of the concept of the gene pool as the total sum of the alleles in a population; 5.6.2 demonstrate knowledge and understanding of the Hardy–Weinberg equation as $p^2 + 2pq + q^2 = 1$ and its use, applying it to calculate allele, genotype and phenotype frequencies in an outbreeding population: • the allele frequencies as p and q (where p + q = 1) for alleles A and a respectively; • the genotype frequencies as p^2, 2pq and q^2 for genotypes AA, Aa and aa respectively; • determining the allele and genotype frequencies from the frequency of the recessive trait (q^2); • the Hardy–Weinberg principle as the situation when a genetic equilibrium is maintained and in which, at fertilisation, alleles combine randomly; • the conditions that must be met to apply the Hardy–Weinberg equation; and • the influence of mutation, non-random fertilisation, migration and selection on allele and/or genotype frequencies; and 5.6.3 demonstrate knowledge and understanding of the source and maintenance of genetic variation: • heterozygotes as important reservoirs of genetic variation in populations; • mutation as a source of genetic variation; • gene mutation (limited to base deletions and substitutions); • chromosome mutation; and • sexual reproduction with cross-fertilisation as a means of maintaining genetic variation.

Content	Learning Outcomes
5.6 Population genetics (cont.)	Students should be able to: 5.6.4 demonstrate knowledge and understanding of selection and its contribution to maintaining polymorphic populations and evolutionary change in populations, including: • fitness as those features that allow an organism to be adapted to its environment; • selection as a process operating on the genetic variation in a population; • selection as the differential perpetuation of alleles to subsequent generations, involving both survival and reproduction; • selection as a process maintaining the fitness of the population; • types of selection, confined to stabilising and directional selection; • stabilising selection favouring the modal/intermediate variants in a population; • directional selection favouring one extreme variant in a population; • that natural selection does not create useful adaptations but rather edits genetically inheritable features in a population, increasing the frequency of some and decreasing the frequency of others over time; • polymorphic populations as a means of investigating stabilising and directional selection; • evolutionary change as the change in the frequencies of alleles in a population; and • examples of directional selection in action leading to evolutionary change in populations.

Content	Learning Outcomes
5.6 Population genetics (cont.)	Students should be able to: 5.6.5 demonstrate knowledge and understanding of the concept of species and the process of speciation: • a species as a group of individuals of common ancestry that closely resemble each other, and are normally capable of interbreeding to produce fertile offspring; • allopatric speciation leading to new species diverging genetically when geographically isolated; and • reproductive isolating mechanisms maintaining the genetic divergence; and
5.7 Kingdom plantae	5.7.1 demonstrate knowledge and understanding of the key features of a moss with particular reference to their restriction to moist habitats: • multicellular plants, not differentiated into leaves, stem and roots; • no cuticle or stomata (except in spore-producing structures); • rhizoids for attachment rather than water absorption; • rhizoids do not deeply penetrate soils, moss distribution is therefore limited to areas with water and ions close to the surface; • support is by turgor within the cells (as no vascular tissue is present); and • dispersal by spores that germinate in moist conditions, but are only partially resistant to desiccation.

Content	Learning Outcomes
5.7 Kingdom plantae (cont.)	Students should be able to: 5.7.2 demonstrate knowledge and understanding of the key features of a fern in terms of adaptations to terrestrial life: • greater adaptation to terrestrial life (compared to mosses); • multicellular plants that are well differentiated and possess a vascular system; • greater differentiation with true roots, stems and leaves; • possess a waterproof cuticle and fine control over stomata; • support is by turgor within cells and by the woody xylem vessels and other strengthening elements of the vascular bundles; and • dispersal by spores that germinate in moist conditions, but are only partially resistant to desiccation; 5.7.3 demonstrate knowledge and understanding of the key features of a flowering plant (angiosperm) in terms of adaptation to terrestrial life: • angiosperms possess the water-retention and support features as listed in 5.7.2 for ferns, but also have other water-retention features: – many of the features enabling adaptation to a range of terrestrial habitats are more highly evolved than in ferns, for example the development of xylem tissue to form wood (in trees) and xerophytic adaptations (see 2.1.15); and – dispersal by seeds which are able to withstand desiccation due to their tough outer coat and which germinate in moist conditions; and *5.7.4 carry out practical work to include the study of appropriate living and preserved specimens, prepared slides and photographs.*

Content	Learning Outcomes
5.8 Kingdom Animalia	Students should be able to: 5.8.1 demonstrate knowledge and understanding of the body form of the Phylum Cnidaria (for example hydra and jellyfish): • all forms are multicellular and radially symmetrical; and • the body is supported by the aqueous medium and there is also a hydrostatic skeleton formed by the fluid-filled enteron; 5.8.2 demonstrate knowledge and understanding of the body form of the Phylum Platyhelminthes (for example planarian and liver fluke): • all forms are bilaterally symmetrical and flattened dorso-ventrally; • single opening to the gut (mouth); and • no specialised skeletal system but supported by body tissue; and 5.8.3 demonstrate knowledge and understanding of the body form of the Phylum Annelida (for example earthworm and lugworm): • bilaterally symmetrical, round in transverse section and metamerically segmented; • gut has both a mouth and an anus and shows regional specialisation; and • hydrostatic skeleton is formed from the segmental body cavities.

Content	Learning Outcomes
5.8 Kingdom Animalia (cont.)	Students should be able to: 5.8.4 demonstrate knowledge and understanding of the body form of the Phylum Arthropoda (for example insect and spider): • bilaterally symmetrical and typically a fixed number of metameric segments in each region (for example head, thorax and abdomen in insects); • the presence of jointed limbs; • the gut has both a mouth and an anus and shows regional specialisation; and • an understanding that the basic body plan of insects has facilitated rapid evolutionary development in many directions (including flight) to make the arthropods (particularly the insects) the most successful animal group in terms of both number of species and overall number of individuals; 5.8.5 demonstrate knowledge and understanding of the body form of the Phylum Chordata (for example mammal and bird): • bilaterally symmetrical and segmented; • the gut has both a mouth and an anus and shows regional specialisation; and • support normally provided by a spinal column with a jointed system of calcified bones; and *5.8.6 carry out practical work to include the study of appropriate living and preserved specimens, prepared slides and photographs.*

3.6 Unit A2 3: Practical Skills in Biology

This unit includes a series of practical tasks and a 1 hour 15 minute written examination assessing practical skills. Students should complete at least **five** of the practical tasks listed below and record evidence of completing these tasks in their lab books (or equivalent) used for this purpose. We will request samples of lab books (or equivalent) as part of the moderation process.

The 1 hour 15 minute written examination assesses the practical skills developed throughout the A2 course, detailed in italics in the specification content for units A2 1 and A2 2, and the assessed practical tasks listed below. The written examination may also assess the skills required to write a short bibliography, detailing source references.

Please see Section 7 for guidance on carrying out and marking the assessed practical tasks.

Content	Learning Outcomes
(a) Assessed practical tasks	Students should be able to carry out practical work by completing at least **five** of the following practical tasks: • investigate microorganisms involving aseptic techniques, for example the effect of different antibiotics or e-strips on bacteria or the preparation of a streak plate to isolate single colonies; • investigate the antimicrobial properties of plants; • investigate microbial, for example yeast, population growth using a haemocytometer; • use a respirometer (may be completed as a teacher-led demonstration) to calculate oxygen uptake, carbon dioxide production and/or RQ values; • demonstrate the role of hydrogen acceptors using redox indicator (in photosynthesis or respiration); • use paper chromatography to identify plant pigments; • one of the following DNA practical tasks can be included (but knowledge of first two listed required for written examination): – carry out gel electrophoresis of DNA; – extraction of DNA; or – other investigation addressing gene technology; and • dissect a small animal, animal organ or part of a plant with an emphasis on developing manipulative skills (the task must be reasonably complex, for example insect mouthparts or a leaf scrape to produce an epidermal layer for examination under the microscope).

Content	Learning Outcomes
(b) Practical skills written examination	Students should be able to describe and demonstrate the practical skills developed during the A2 course, which will be assessed in a 1 hour and 15 minute written examination containing structured questions set in the context of the practical tasks listed in part (a) of this unit and the other practical tasks listed in italics as part of the unit content for A2 1 and A2 2.

4 Scheme of Assessment

4.1 Assessment opportunities

Each unit is available for assessment in summer each year. It is possible to resit individual AS and A2 assessment units once and count the better result for each unit towards an AS or A level qualification. Candidates' results for individual assessment units can count towards a qualification until we withdraw the specification.

4.2 Assessment objectives

There are three assessment objectives for this specification. Candidates must:

- demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures **(AO1);**
- apply knowledge and understanding of scientific ideas, processes, techniques and procedures:
  - in a theoretical context;
  - in a practical context;
  - when handling qualitative data; and
  - when handling quantitative data **(AO2); and**
- analyse, interpret and evaluate scientific information, ideas and evidence to:
  - make judgements and reach conclusions; and
  - develop and refine practical design and procedures **(AO3)**.

4.3 Assessment objective weightings

The table below sets out the assessment objective weightings for each assessment unit and the overall A level qualification:

Percentage Assessment Objective Weightings					
	AO1	**AO2**	**AO3**	**AS**	**A level**
AS 1	5.2–6.0	6.0–6.8	3.2–4.0	15	15
AS 2	5.2–6.0	6.0–6.8	3.2–4.0	15	15
AS 3	3.6–4.0	4.0–4.4	1.6–2.0	10	10
A2 1	7.0–8.0	10.0–11.0	6.0–7.0		24
A2 2	7.0–8.0	10.0–11.0	6.0–7.0		24
A2 3	4.0–5.0	4.0–5.0	3.0–4.0		12
Total	**30–35**	**40–45**	**25–30**	**40**	**100**

4.4 Quality of written communication

In AS and A level Biology, candidates must demonstrate their quality of written communication. They need to:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- select and use a form and style of writing that suit their purpose and complex subject matter; and
- organise information clearly and coherently, using specialist vocabulary where appropriate.

Quality of written communication is assessed in responses to questions and tasks that require extended writing.

4.5 Synoptic assessment at A2

The A2 assessment units include some synoptic assessment, which encourages candidates to develop their understanding of the subject as a whole. In our GCE Biology, synoptic assessment involves:

- building on material from the AS units;
- bringing together and making connections between areas of knowledge and skills that they have explored throughout the course;
- applying knowledge and understanding of more than one area to a particular situation or context; and
- using ideas and skills that permeate biology.

4.6 Higher order thinking skills

The A2 assessment units provide opportunities to demonstrate higher order thinking skills by incorporating:

- a wider range of question types to address different skills;
- questions with an increased incline of difficulty and a decrease in structuring;
- more demanding evaluative tasks; and
- synoptic assessment, including questions that require candidates to make more connections between sections of the specification.

4.7 Mathematical skills

Sections in **bold** are assessed at A2 only.

Mathematical skills	**Exemplification of mathematical skill in GCE Biology (assessment is not limited to the examples given below)**
Arithmetic and numerical computation	
Recognise and use appropriate units in calculations	Candidates may be tested on their ability to: • convert between units, for example mm^3 to cm^3, as part of volumetric calculations; • work out the unit for a rate, for example breathing rate;
Recognise and use expressions in decimal and standard form	• use an appropriate number of decimal places in calculations, for example for a mean; • carry out calculations using numbers in standard and ordinary form, for example magnification; • understand standard form when applied to areas such as the 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, for example: 0.0050 mol dm^{-3} is equivalent to: 5.0×10^{-3} mol dm^{-3};
Use ratios, fractions and percentages	• calculate percentage yields; • calculate surface area to volume ratio; • use scales for measuring; • represent phenotypic ratios (monohybrid and dihybrid crosses); and
Estimate results	• estimate results to sense check that the calculated values are appropriate.

Mathematical skills	Exemplification of mathematical skill in GCE Biology (assessment is not limited to the examples given below)
Handling Data	
Use an appropriate number of significant figures	Candidates 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;
Find arithmetic means	• find the mean of a range of data, for example the mean number of stomata in the leaves of a plant;
Construct and interpret frequency tables and diagrams, bar charts and histograms	• represent a range of data in a table with clear headings, units and consistent decimal places; • interpret data from a variety of tables, for example data relating to organ function; • plot a range of data in an appropriate format, for example enzyme activity over time represented on a graph; • interpret data from a variety of graphs, for example explain electrocardiogram traces;
Understand simple probability	• use the terms probability and chance appropriately; • understand the probability associated with genetic inheritance;
Understand the principles of sampling as applied to scientific data	• analyse random data collected by an appropriate means, for example use Simpson's index to calculate the biodiversity of a habitat;
Understand the terms mean, median and mode	• calculate or compare the mean, median and mode of a set of data, for example height, mass or size of a group of organisms; and
Use a scatter diagram to identify a correlation between two variables	• interpret a scatter diagram, for example the effect of lifestyle factors on health.

Mathematical skills	**Exemplification of mathematical skill in GCE Biology (assessment is not limited to the examples given below)**
Make order of magnitude calculations	Candidates may be tested on their ability to: • use and manipulate the magnification formula $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$
Select and use a statistical test	• **select and use:** – **the chi-squared test to find the significance of the difference between observed and expected results;** – **the student's t-test; and/or** – **95 percent confidence limits;**
Understand measures of dispersion, including standard deviation and range	• **calculate the standard deviation;** • **understand why standard deviation might be a more useful measure of dispersion for a given set of data, for example where there is an outlying result;**
Algebra	
Understand and use the symbols =, <, <<, >>, >, , ~	No exemplification required;
Change the subject of an equation	• use and manipulate equations, for example magnification;
Substitute numerical values into algebraic equations using appropriate units for physical quantities	• use a given equation, for example Simpson's index $D = \frac{\sum n_i(n_i\text{-}1)}{N(N\text{-}1)}$
Solve algebraic equations	• solve equations in a biological context, for example: cardiac output = stroke volume × heart rate; and
Use logarithms in relation to quantities that range over several orders of magnitude	• **understand a logarithmic scale in the context of microbiology, for example growth rate of a microorganism such as yeast.**

Mathematical skills	Exemplification of mathematical skill in GCE Biology (assessment is not limited to the examples given below)
Graphs	
Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: • understand that data may be presented in a number of formats and use this data, for example dissociation curves;
Plot two variables from experimental or other data	• select an appropriate format for presenting data, for example bar charts, histograms, graphs and scatter diagrams;
Understand that $y = mx + c$ represents a linear relationship	• predict or sketch the shape of a graph with a linear relationship, for example the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme;
Determine the intercept of a graph	• read off an intercept point from a graph, for example in osmosis experiments;
Calculate rate of change from a graph showing a linear relationship	• calculate a rate from a graph, for example rate of transpiration;
Draw and use the slope/gradient of a curve as a measure of rate of change	• use the slope or gradient of a graph to estimate the rate of change; and
Geometry	
Calculate the surface areas and volumes of regular shapes	• calculate the surface area and volume of rectangular shapes, for example calculate the surface area or volume of a cell.

4.8 Reporting and grading

We report the results of individual assessment units on a uniform mark scale that reflects the assessment weighting of each unit.

We award AS qualifications on a five grade scale from A to E, with A being the highest. We award A level qualifications on a six grade scale from A* to E, with A* being the highest. To determine candidates' grades, we add the uniform marks obtained in individual assessment units.

To be awarded an A*, candidates need to achieve a grade A on their full A level qualification and at least 90 percent of the maximum uniform marks available for the A2 units. If candidates fail to attain a grade E, we report their results as unclassified (U).

The grades we award match the grade descriptions in Section 5 of this specification.

5 Grade Descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded depends in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of candidates' performance in the assessment may be balanced by better performances in others.

The requirement for all AS and A level specifications to assess candidates' quality of written communication will be met through assessment objectives AO1, AO2 and AO3.

AS Grade Descriptions

Grade	Description
AS **Grade A**	For **AO1**, candidates characteristically: • demonstrate detailed knowledge and understanding of a range of biological concepts and processes; • demonstrate detailed knowledge and understanding of subject- specific material; and • select, organise and present information in a variety of forms using scientific terminology. For **AO2**, candidates characteristically: • demonstrate understanding of the range of biological processes; • apply skills, knowledge and understanding of processes, techniques and equipment to design an appropriate scientific investigation; • demonstrate safe and skilful practical techniques; • make observations with appropriate precision and record these methodically; • research and communicate ideas clearly and logically; • describe significant trends and patterns shown by data presented in tabular or graphical form; • explain and interpret phenomena with few errors and present arguments and evaluations clearly; • apply principles and concepts in familiar and new contexts; and • carry out structured calculations with few errors and demonstrate good understanding of underlying relationships.

Grade	Description
	For **AO3**, candidates characteristically: • analyse and offer a valid evaluation of biological information, issues and viewpoints; • interpret, explain, evaluate and communicate the results of their own experimental and investigative activities in appropriate contexts; and • reach valid conclusions and communicate findings clearly in a structured manner appropriate to the task.
AS **Grade E**	For **AO1**, candidates characteristically: • demonstrate some knowledge and understanding of some biological concepts and processes; • show basic knowledge and understanding of subject-specific material with significant omissions; and • demonstrate some organisational skills and present information using basic terminology. For **AO2**, candidates characteristically: • demonstrate some understanding of biological processes; • apply skills, knowledge and understanding of process, techniques and equipment to devise and plan some aspects of a scientific investigation; • demonstrate safe practical techniques; • make observations and measurements and record them; • research and communicate ideas appropriately; • describe some trends or patterns shown by data presented in tabular or graphical form; • provide basic explanations and interpretations of some phenomena, presenting very limited evaluations; • apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; and • carry out some steps in calculations. For **AO3**, candidates characteristically: • offer some limited evaluation of biological information, issues and viewpoints; • interpret, explain and communicate some aspects of the results of experimental and investigative activities in appropriate contexts; and • draw some limited conclusions and communicate findings.

A2 Grade Descriptions

Grade	Description
A2 **Grade A**	For **AO1**, candidates characteristically: • demonstrate thorough knowledge and understanding of a wide range of biological concepts and processes; • show thorough knowledge and understanding of subject-specific material; and • select, organise and present information clearly in appropriate forms using scientific terminology. For **AO2**, candidates characteristically: • demonstrate thorough understanding of a range of biological processes and concepts; • describe significant trends and patterns shown by complex data presented in tabular or graphical form; • demonstrate safe and skilful practical techniques; • make observations with appropriate precision and record these methodically; • explain and interpret phenomena with few errors and present arguments and evaluations clearly and logically; • apply principles and concepts in familiar and new contexts; • carry out structured calculations with little or no guidance and demonstrate good understanding of the underlying relationships; and • link together appropriate facts, principles and concepts from different areas of the specification. For **AO3**, candidates characteristically: • accurately and competently analyse and interpret biological information, issues and viewpoints; • interpret, explain, evaluate and communicate the results of experimental and investigative activities in appropriate contexts; and • reach substantiated and valid conclusions and communicate findings accurately and appropriately to the task.

Grade	Description
A2 **Grade E**	For **AO1**, candidates characteristically: • demonstrate some knowledge and understanding of the main biological concepts and processes; • show some knowledge and understanding of subject-specific material with significant omissions; and • select, organise and present information using basic scientific terminology. For **AO2**, candidates characteristically: • demonstrate some understanding of the main biological processes and concepts; • describe and provide a limited explanation of trends or patterns shown by complex data presented in tabular or graphical form; • demonstrate safe practical techniques; • make observations and measurements and record them; • provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations; • apply given principles or concepts in familiar and new contexts involving some steps in the argument; • carry out routine calculations where help is given; and • collate some facts, principles and concepts from different areas of the specification. For **AO3**, candidates characteristically: • show some attempt to analyse and interpret biological information, issues and viewpoints with varying degrees of success; • interpret, explain and communicate some aspects of experimental and investigative activities in appropriate contexts; and • draw some straightforward conclusions and communicate findings broadly appropriate to the task.

6 Guidance on External Assessment

There are six external assessment units in this specification, three at AS level and three at A2:

- Unit AS 1: Molecules and Cells;
- Unit AS 2: Organisms and Biodiversity;
- Unit AS 3: Practical Skills in AS Biology (also involves internal assessment);
- Unit A2 1: Physiology, Co-ordination and Control, and Ecosystems;
- Unit A2 2: Biochemistry, Genetics and Evolutionary Trends; and
- Unit A2 3: Practical Skills in Biology (also involves internal assessment).

The external assessment focuses on:

- candidates' knowledge and understanding of the content of each unit;
- how they can apply this knowledge and understanding in both theoretical and practical contexts and when handling qualitative and quantitative data; and
- how they can analyse, interpret and evaluate scientific information to make judgements, reach conclusions and to develop and refine practical design and procedures.

6.1 Unit AS 1: Molecules and Cells and Unit AS 2: Organisms and Biodiversity

- 1 hour 30 minute external examination paper in each unit
- Section A: 60 marks structured questions
- Section B: 15 marks essay
- a total of 75 marks

6.2 Unit AS 3: Practical Skills in AS Biology

- 1 hour external examination paper
- 7–10 structured questions
- 50 marks through external assessment plus 21 marks through internal assessment giving a total of 71 marks

6.3 Unit A2 1: Physiology, Co-ordination and Control, and Ecosystems and Unit A2 2: Biochemistry, Genetics and Evolutionary Trends

- 2 hour 15 minute external examination paper in each unit
- Section A: 82 marks structured questions
- Section B: 18 marks essay
- a total of 100 marks

6.4 Unit A2 3: Practical Skills in Biology

- 1 hour 15 minute external examination paper
- 8–10 structured questions
- 60 marks through external assessment plus 15 marks through internal assessment giving a total of 75 marks

7 Guidance on Internal Assessment

There are two units containing internal assessment in this specification, one at AS level and one at A2:

- Unit AS 3: Practical Skills in AS Biology (21 marks available through internal assessment); and
- Unit A2 3: Practical Skills in Biology (15 marks available through internal assessment).

The internal assessment focuses on the direct assessment of candidates' practical skills.

7.1 Skills assessed by internal assessment

Teachers assess candidates' performance in a range of practical tasks. The skills assessed include:

- the ability to carry out the methodology specific to the practical task;
- the ability to collect data while managing any associated tasks;
- the ability to record data in tables and/or graphs as appropriate;
- the ability to draw evidence-based conclusions; and
- skills appropriate to individual practical tasks, for example the completion of block diagrams.

Section 7.3 provides detail on marking the practical tasks.

7.2 Completing practical tasks

Internal assessment is likely to involve both work in the classroom and independent study. It is essential to manage the assessment conditions in a way that ensures the assessment remains reliable and fair. Please note the requirements below.

Area	Assessment Conditions
Supervision	Teachers should supervise candidates' work to: – monitor their progress; – prevent plagiarism and check that the work that candidates submit is their own; – comply with health and safety requirements; – provide advice and guidance if there are any problems; and – ensure that the work aligns with the specification requirements and can be marked using the criteria set out for each unit.
Authenticity	Teachers must be aware of any third party copyright or intellectual property issues in candidates' work. They must sign a declaration to certify that, to the best of their knowledge, all the work that candidates have submitted for assessment is their own.
Collaboration	The work of individual candidates may be informed by working with others, but each candidate must demonstrate the specific skills involved in completing the practical tasks.
Resources	Candidates must appropriately reference all the materials they use in their work, including any online resources.

7.3 Marking the tasks

Teachers should use their professional judgement to apply the criteria below in marking the candidates' work.

If candidates do more than seven tasks at AS or five tasks at A2, choose the best-scoring tasks for submission of marks.

Each of the practical tasks from the list should be given the mark 3, 2, 1 or 0, as identified below. The mark should reflect the totality of the practical task, including carrying out the task and recording evidence of its completion.

- Award a score of **3** to candidates who show **competence**, **independence** and **skill** in fully completing and fully recording the practical task.

- Award a score of **2** to candidates who fall short in one or two of the above qualities in the performance of the task but, who nonetheless, show satisfactory practical skills.

- Award a score of **1** to candidates who make an attempt at the practical task, but who show significant weaknesses in carrying out and/or recording the task.

- Award a **zero mark** to candidates who fail to attempt the practical task.

Note: The nature of recording (written evidence) should be appropriate for, and dependent on, the task involved. A concise method, table, graph and conclusion should be presented only when this would normally be expected in the type of investigation involved. In, for example, the completion of a block diagram of a section through the ileum (as observed under the microscope) the completed block diagram itself would suffice as evidence of the practical task being fully recorded. However, CCEA will provide guidance on the evidence expected for each of those practicals listed as assessed practical tasks.

For up-to-date advice on plagiarism, or any kind of candidate malpractice, see *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* on the Joint Council for Qualifications website at www.jcq.org.uk

7.4 Internal standardisation

Centres with more than one teaching group **must** carry out internal standardisation of their internal assessment tasks before submitting their marks to us. This is to ensure, as far as possible, that each teacher has applied the assessment criteria consistently. It may be necessary to adjust an individual teacher's marking:

- to bring it into line with that of other teachers in the centre; and
- to match the standards established at the agreement trial.

If marks do change, centres must amend the total/final marks on their Candidate Record Sheets.

7.5 Moderation

Centres should submit selected samples of candidates' internally assessed work to us for moderation. We initially require samples from each centre, selected according to criteria that we supply each year. During the moderation process, if necessary, we may ask centres to submit all candidates' work.

We may adjust centres' marking to bring the assessment of candidates' work into line with our agreed standards.

We issue full instructions each year on:

- our moderation procedures;
- which samples we require; and
- the deadlines for submitting marks and samples to us.

Teachers and centre staff may contact us at any stage for advice or support relating to internal assessment.

8 Links and Support

8.1 Support

The following resources are available to support this specification:

- our Biology microsite at www.ccea.org.uk
- specimen assessment materials; and
- guidance notes for teachers including information on practical skills.

We also intend to provide:

- past papers and mark schemes;
- Chief Examiner's reports;
- Principal Moderator's reports;
- schemes of work;
- agreement trials;
- support days for teachers;
- centre support visits; and
- exemplification of standards.

8.2 Curriculum objectives

This specification supports centres to build on the broader Northern Ireland Curriculum objectives to develop the young person:

- as an individual;
- as a contributor to society; and
- as a contributor to the economy and environment.

It can contribute to meeting the requirements of the Northern Ireland Entitlement Framework at post-16 and the provision of a broad and balanced curriculum.

Curriculum Progression from Key Stage 4

This specification builds on learning from Key Stage 4 and gives students opportunities to develop their subject knowledge and understanding further.

Students will also have opportunities to continue to develop the **Cross-Curricular Skills** and the **Thinking Skills and Personal Capabilities** shown on the next page. The extent of this development depends on the teaching and learning methodology the teacher uses.

Cross-Curricular Skills

- Communication:
  - Talking and Listening
  - Reading
  - Writing
- Using Mathematics
- Using ICT

Thinking Skills and Personal Capabilities

- Problem Solving
- Working with Others
- Self-Management

For further guidance on the skills and capabilities in this subject, please refer to the supporting schemes of work.

8.3 Examination entries

Entry codes for this subject and details on how to make entries are available on our Qualifications Administration Handbook microsite, which you can access at www.ccea.org.uk

Alternatively, you can telephone our Examination Entries, Results and Certification team using the contact details provided.

8.4 Equality and inclusion

We have considered the requirements of equality legislation in developing this specification and designed it to be as free as possible from ethnic, gender, religious, political and other forms of bias.

GCE qualifications often require the assessment of a broad range of competences. This is because they are general qualifications that prepare students for a wide range of occupations and higher level courses.

During the development process, an external equality panel reviewed the specification to identify any potential barriers to equality and inclusion. Where appropriate, we have considered measures to support access and mitigate barriers.

We can make reasonable adjustments for students with disabilities to reduce barriers to accessing assessments. Students with physical impairment may instruct a practical assistant to set up equipment. Students with visual impairment may find elements of the assessment difficult, but technology may help them to take readings and make observations. For this reason, very few students will have a complete barrier to any part of the assessment.

It is important to note that where access arrangements are permitted, they must not be used in any way that undermines the integrity of the assessment. You can find information on reasonable adjustments in the Joint Council for Qualifications document *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications*, available at www.jcq.org.uk

8.5 Contact details

If you have any queries about this specification, please contact the relevant CCEA staff member or department:

- Specification Support Officer: Nuala Tierney
  (telephone: (028) 9026 1200, extension 2270, email: ntierney@ccea.org.uk)

- Subject Officer: Edith Finlay
  (telephone: (028) 9026 1200, email: efinlay@ccea.org.uk)

- Examination Entries, Results and Certification
  (telephone: (028) 9026 1262, email: entriesandresults@ccea.org.uk)

- Examiner Recruitment
  (telephone: (028) 9026 1243, email: appointments@ccea.org.uk)

- Distribution
  (telephone: (028) 9026 1242, email: cceadistribution@ccea.org.uk)

- Support Events Administration
  (telephone: (028) 9026 1401, email: events@ccea.org.uk)

- Information Section (including Freedom of Information requests)
  (telephone: (028) 9026 1200, email: info@ccea.org.uk)

- Moderation
  (telephone: (028) 9026 1200, extension 2236, email: moderationteam@ccea.org.uk)

- Business Assurance (Complaints and Appeals Manager: Heather Clarke)
  (telephone: (028) 9026 1244, email: hclarke@ccea.org.uk).

Appendix 1

Glossary of terms used in written examinations

The GCE Biology (AS/A2) examining and revising teams have produced this glossary to help students understand what we are looking for when we use certain terms in an examination question. The glossary includes commonly used terms and phrases, but is not intended to be a complete list.

Remember: students **must** carefully study each question as a whole until they are sure exactly what the question is asking of them. The mark allocations will often be a good guide as to how much detail we are expecting in an answer.

The terms below are in alphabetical order. Many of the examples we give are extracts from questions that have been set in past CCEA Biology examinations at Advanced level.

Term	Definition
Account	When writing an account use continuous prose. For example: Give an account of the ways in which point mutations contribute to variation. In an **illustrated account**, use diagrams to supplement the prose account. For example: Give an illustrated account of meiosis.
Calculate	Show all the stages involved in solving a numerical problem. Make sure the answer stands out clearly, and use the correct units if appropriate. For example: Calculate the actual length of the mitochondrion in micrometres (µm). Show all working out.
Comment on	Point out the features that are worth noting in a structure, process or set of results. Give brief explanation(s) where appropriate. For example: Comment on the changes in distribution of the plant species present along the transect.
Compare	State the similarities and/or differences between two or more items. For example: Compare the gas exchange surfaces in a typical leaf with those of a mammal.
Contrast	State the difference(s) between two or more items. For example: Contrast the actions of the nervous and endocrine systems in mammals.

Term	Definition
Compare and contrast	State, point by point, the similarities and differences between two or more items. For example: Compare and contrast the structure of plant and animal cells.
Define	State briefly the meaning of a term. For example: Define the term 'population' as used in ecology.
Describe briefly/concisely	State the main features of an item. For example: Describe, concisely, the structure of a mitochondrion.
Describe fully	Use continuous prose, with diagrams where appropriate, to give a full account. For example: Describe fully the process of urine formation in a mammal.
Describe how you would	Give an account of the essential features of experimental design for the procedure called for by the question. For example: Describe how to investigate the effect of temperature on the activity of a named enzyme.
Determine	Use the information given to arrive at the correct answer by reasoning. It is not necessary to include a numerical calculation. *Example 1:* Determine the genotypes and phenotypes of the offspring of a cross between two heterozygous Himalayan rabbits. *Example 2:* From the graph, determine the optimum pH of the enzyme.
Diagrams and drawings	A **diagram** is a picture representing the essential features of a structure. A **drawing** is a true record of the appearance of a structure as observed in a photograph, photomicrograph or electron micrograph. Use clear pencil lines to show the essential features represented in the diagram or observed in the photograph. Label these features, as appropriate, using straight label lines, which should not cross. *Example 1:* In the space below, draw a labelled diagram of a synapse.

Term	Definition
Diagrams and drawings (cont.)	*Example 2:* In the space below, produce a labelled drawing to show your interpretation of Photograph C. In an **annotated** diagram or drawing, brief explanatory notes should be given next to the labels. *Example:* Make an annotated diagram to describe plasmolysis in a plant cell. A **block diagram/block drawing** shows locations of tissues but not individual cells. *Example:* Draw a labelled block diagram to show the location of tissues, as seen in transverse section, in the ileum. A **flow diagram** is an abbreviated account of a process, using arrows to show the sequence. *Example:* Using a suitable flow diagram, outline the process of blood clotting.
Discuss	Use continuous prose to give a critical account of all the relevant points, inter-relating them where appropriate. *Example:* Discuss the factors that may affect the growth rate of a green plant.
Distinguish between	State the essential difference between the meaning of two biological terms. *Example:* Distinguish between a chromosome and a gene.
Explain	Apply understanding to give scientific reasons for a biological phenomenon or a set of results. *Example 1:* Explain the results obtained for this enzyme between 0 and 30°C. (In this example, it is important not to simply describe the results in question.)

Term	Definition
Identify	Recognise a feature from a photograph, diagram or written description and state the biological term used to describe it. *Example:* Identify the structure labelled A in Photograph X.
List	The facts should be numbered and stated as briefly as possible. Single words may be enough. *Example:* List three different useful products of genetic engineering in microorganisms.
Outline	Present the essential points in the form of sentences. *Example*: Outline three distinct differences between prokaryotes and eukaryotes.
State	Give a brief answer to the question, in the form of a single word or concise sentence. *Example:* State the appropriate null hypothesis.
Suggest	This means that any reasonable explanation of the information will be acceptable. There is often not a single correct answer. *Example:* Suggest a new hypothesis for the cause of beriberi in the light of this discovery.
What is meant by?	Demonstrate an understanding of a biological phenomenon. The mark value will show how much detail is needed. *Example:* What is meant by 'reproductive isolation'?

Appendix 2

Statistics sheets

Statistical formulae and tables

1 Definition of symbols

n = sample size

$\bar{x}$ = sample mean

$\hat{\sigma}$ = estimate of the standard deviation

These parameters are obtained using a calculator and statistical functions, remembering to use the function for $\hat{\sigma}$ – which may be designated a different symbol on the calculator – with $(n-1)$ denominator.

2 Practical formulae

2.1 ***Estimation of the standard deviation (error) of the mean*** $(\hat{\sigma}_{\bar{x}})$

$$\hat{\sigma}_{\bar{x}} = \sqrt{\frac{\hat{\sigma}^2}{n}}$$

2.2 ***Confidence limits for population mean***

$$\bar{x} \pm t\sqrt{\frac{\hat{\sigma}^2}{n}}$$

which can be rewritten, in terms of $(\hat{\sigma}_{\bar{x}})$ as

$$\bar{x} \pm t(\hat{\sigma}_{\bar{x}})$$

where t is taken from t tables for the appropriate probability and $n-1$ degrees of freedom.

3 Tests of significance

3.1 Student's *t test*

Different samples are denoted by subscripts; thus for example, $\bar{x}_1 \text{ and } \bar{x}_2$ are the sample means of sample 1 and sample 2 respectively.

The following formula for t is that to be used.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\hat{\sigma}_1^{\,2}}{n_1} + \frac{\hat{\sigma}_2^{\,2}}{n_2}}}$$

which can be rewritten in terms of $\hat{\sigma}_{\bar{x}}$, as

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\hat{\sigma}_{\bar{x}_1}^{\,2} + \hat{\sigma}_{\bar{x}_2}^{\,2}}}$$

with $n_1 + n_2 - 2$ degrees of freedom

3.2 *Chi squared test*

Using the symbols O = observed frequency, E = expected frequency and Σ = sum of

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

with $n-1$ degrees of freedom (where n is the number of categories).

Table 1: Student's *t* values

d.f.	$p = 0.1$	0.05	0.02	0.01	0.002	0.001
1	6.314	12.706	31.821	63.657	318.31	636.62
2	2.920	4.303	6.965	9.925	22.327	31.598
3	2.353	3.182	4.541	5.841	10.214	12.924
4	2.132	2.776	3.747	4.604	7.173	8.610
5	2.015	2.571	3.365	4.032	5.893	6.869
6	1.943	2.447	3.143	3.707	5.208	5.959
7	1.895	2.365	2.998	3.499	4.785	5.408
8	1.860	2.306	2.896	3.355	4.501	5.041
9	1.833	2.262	2.821	3.250	4.297	4.781
10	1.812	2.228	2.764	3.169	4.144	4.587
11	1.796	2.201	2.718	3.106	4.025	4.437
12	1.782	2.179	2.681	3.055	3.930	4.318
13	1.771	2.160	2.650	3.012	3.852	4.221
14	1.761	2.145	2.624	2.977	3.787	4.140
15	1.753	2.131	2.602	2.947	3.733	4.073
16	1.746	2.120	2.583	2.921	3.686	4.015
17	1.740	2.110	2.567	2.898	3.646	3.965
18	1.734	2.101	2.552	2.878	3.610	3.922
19	1.729	2.093	2.539	2.861	3.579	3.883
20	1.725	2.086	2.528	2.845	3.552	3.850
21	1.721	2.080	2.518	2.831	3.527	3.819
22	1.717	2.074	2.508	2.819	3.505	3.792
23	1.714	2.069	2.500	2.807	3.485	3.767
24	1.711	2.064	2.492	2.797	3.467	3.745
25	1.708	2.060	2.485	2.787	3.450	3.725
26	1.706	2.056	2.479	2.779	3.435	3.707
27	1.703	2.052	2.473	2.771	3.421	3.690
28	1.701	2.048	2.467	2.763	3.408	3.674
29	1.699	2.045	2.462	2.756	3.396	3.659
30	1.697	2.042	2.457	2.750	3.385	3.646
40	1.684	2.021	2.423	2.704	3.307	3.551
60	1.671	2.000	2.390	2.660	3.232	3.460
120	1.658	1.980	2.358	2.617	3.160	3.373
∞	1.645	1.960	2.326	2.576	3.090	3.291

Table 2: χ^2 values

d.f.	p = 0.900	0.500	0.100	0.050	0.010	0.001
1	0.016	0.455	2.71	3.84	6.63	10.83
2	0.211	1.39	4.61	5.99	9.21	13.82
3	0.584	2.37	6.25	7.81	11.34	16.27
4	1.06	3.36	7.78	9.49	13.28	18.47
5	1.61	4.35	9.24	11.07	15.09	20.52
6	2.20	5.35	10.64	12.59	16.81	22.46
7	2.83	6.35	12.02	14.07	18.48	24.32
8	3.49	7.34	13.36	15.51	20.09	26.13
9	4.17	8.34	14.68	16.92	21.67	27.88
10	4.87	9.34	15.99	18.31	23.21	29.59
11	5.58	10.34	17.28	19.68	24.73	31.26
12	6.30	11.34	18.55	21.03	26.22	32.91
13	7.04	12.34	19.81	22.36	27.69	34.53
14	7.79	13.34	21.06	23.68	29.14	36.12
15	8.55	14.34	22.31	25.00	30.58	37.70
16	9.31	15.34	23.54	26.30	32.00	39.25
17	10.09	16.34	24.77	27.59	33.41	40.79
18	10.86	17.34	25.99	28.87	34.81	42.31
19	11.65	18.34	27.20	30.14	36.19	43.82
20	12.44	19.34	28.41	31.41	37.57	45.32
21	13.24	20.34	29.62	32.67	38.93	46.80
22	14.04	21.34	30.81	33.92	40.29	48.27
23	14.85	22.34	32.01	35.17	41.64	49.73
24	15.66	23.34	33.20	36.42	42.98	51.18
25	16.47	24.34	34.38	37.65	44.31	52.62
26	17.29	25.34	33.56	38.89	45.64	54.05
27	18.11	26.34	36.74	40.11	46.96	55.48
28	18.94	27.34	37.92	41.34	48.28	56.89
29	19.77	28.34	39.09	42.56	49.59	58.30
30	20.60	29.34	40.26	43.77	50.89	59.70
40	29.05	39.34	51.81	55.76	63.69	73.40
50	37.69	49.33	63.17	67.50	76.15	86.66
60	46.46	59.33	74.40	79.08	88.38	99.61
70	55.33	69.33	85.53	90.53	100.43	112.32
80	64.28	79.33	96.58	101.88	112.33	124.84
90	73.29	89.33	107.57	113.15	124.12	137.21
100	82.36	99.33	118.50	123.34	135.81	149.45

Summary of Changes since First Issue

(Most recent changes are indicated in red on the latest version)

Revision History Number	Date of Change	Page Number	Change Made
Version 1	N/A	N/A	First issue
Version 2	28 April 2017	49	4.3.3 *'photomicrographs and electron micrographs (TEM)'* italicised
		50	4.3.5 *'photomicrographs, electron micrographs'* italicised
		74	5.7.1 'not' changed to 'only partially'
		75	5.7.2 'adaptions' changed to 'adaptations'; and 'not' changed to 'only partially'. 5.7.3 'adaption' changed to 'adaptation'; and last indented point reworded.

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