GCE A LEVEL

eduqas
Part of WJEC

WJEC Eduqas GCE A LEVEL in

BIOLOGY

ACCREDITED BY OFQUAL

SPECIFICATION

Teaching from 2015
For award from 2017

Version 2 January 2019

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This Ofqual regulated qualification is not available for candidates in maintained schools and colleges in Wales.

SUMMARY OF AMENDMENTS

Version	Description	Page number
2	Components 1,2 and 3 all have a statement stating that the assessment will also include synoptic questions.	19,29 and 41
3	Change from ‘statement’ to ‘head of centre declaration. Change of date from 15 May to 5 May.	62

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WJEC Eduqas GCE A LEVEL in BIOLOGY

For teaching from 2015
For award from 2017

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A LEVEL BIOLOGY

SUMMARY OF ASSESSMENT

Component 1: Energy for Life
Written examination: **2 hours**
33⅓ % of qualification
100 marks

A range of short and longer structured compulsory questions.
Assessment of Core Concepts will also be included.

Component 2: Continuity of Life
Written examination: **2 hours**
33⅓ % of qualification
100 marks

A range of short and longer structured compulsory questions.
Assessment of Core Concepts will also be included.

Component 3: Requirements for Life
Written examination: **2 hours**
33⅓ % of qualification
100 marks

Section A: 80 marks
A range of short and longer structured compulsory questions based on the compulsory content of the component.
Assessment of Core Concepts will also be included.

Section B: 20 marks
Short and longer structured questions from a choice of 1 out of 3 options: Immunology and Disease; Human Musculoskeletal Anatomy or Neurobiology and Behaviour

Practical Endorsement
Non-exam assessment

Assessment of practical competency
Reported separately and not contributing to final grade.

This linear qualification will be available in the months of May/June each year. It will be awarded for the first time in Summer 2017.

Qualification Accreditation Number: 601/5706/9

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A LEVEL BIOLOGY

1 INTRODUCTION

1.1 Aims and objectives

The WJEC Eduqas A level in Biology provides a wide breadth of knowledge which touches on many varied aspects of a range of topics. These include the internal workings of organisms in physiology and the interdependence of living things in ecology, to social issues including human influence on the environment and the ethical considerations of genetics.

The study of biology encourages an appreciation of these issues and their implications as well as providing an insight into the living world. The inclusion of optional topics allows learners to gain a deeper insight into a wider range of biological topics. It is intended that the use of a variety of approaches will stimulate interest, promote understanding and engender an overall appreciation and sense of wonder at the living world.

This specification promotes an understanding of scientific method as the means to increase scientific knowledge and develop an enquiring and critical approach. Learners will develop an awareness that different perceptions, predictions and interpretations may be applied according to context.

Practical work is an intrinsic part of biology, and is greatly valued by higher education. It is imperative that practical skills are developed throughout this course and that an investigative approach is promoted.

The WJEC Eduqas A level in Biology aims to encourage learners to:

- develop essential knowledge and understanding of different areas of biology and how they relate to each other
- develop and demonstrate a deep appreciation of the skills, knowledge and understanding of scientific methods used within biology
- develop competence and confidence in a variety of practical, mathematical and problem solving skills
- develop their interest in and enthusiasm for biology, including developing an interest in further study and careers associated with the subject
- understand how society makes decisions about biological issues and how biology contributes to the success of the economy and society.

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1.2 Prior learning and progression

Any requirements set for entry to a course following this specification are at the discretion of centres. It is reasonable to assume that many learners will have achieved qualifications equivalent to Level 2 at KS4. Skills in Numeracy/Mathematics, Literacy/English and Information Communication Technology will provide a good basis for progression to this Level 3 qualification.

This specification builds on the skills, knowledge and understanding set out in the GCSE criteria/content for science. Some learners will have already gained knowledge, understanding, and skills through their study of biology at AS.

Mathematical requirements are specified in the subject criteria and repeated in Appendix C of this specification.

This specification provides a suitable foundation for the study of biology or a related area through a range of higher education courses, progression to the next level of vocational qualifications or employment. In addition, the specification provides a coherent, satisfying and worthwhile course of study for learners who do not progress to further study in this subject.

This specification is not age specific and, as such, provides opportunities for learners to extend their life-long learning.

1.3 Equality and fair assessment

This specification may be followed by any learner, irrespective of gender, ethnic, religious or cultural background. It has been designed to avoid, where possible, features that could, without justification, make it more difficult for a learner to achieve because they have a particular protected characteristic.

The protected characteristics under the Equality Act 2010 are age, disability, gender reassignment, pregnancy and maternity, race, religion or belief, sex and sexual orientation.

The specification has been discussed with groups who represent the interests of a diverse range of learners, and the specification will be kept under review.

Reasonable adjustments are made for certain learners in order to enable them to access the assessments (e.g. candidates are allowed access to a Sign Language Interpreter, using British Sign Language). Information on reasonable adjustments is found in the following document from the Joint Council for Qualifications (JCQ): *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications.*

This document is available on the JCQ website (www.jcq.org.uk). As a consequence of provision for reasonable adjustments, very few learners will have a complete barrier to any part of the assessment.

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2 SUBJECT CONTENT

This section outlines the knowledge, understanding and skills to be developed by learners studying A level Biology.

Learners should be prepared to apply the knowledge, understanding and skills specified in a range of theoretical, practical, industrial and environmental contexts.

Learners' understanding of the connections between the different elements of the subject and their holistic understanding of the subject is a requirement of all A level specifications. In practice this means that synoptic questions will be set in each component. These questions will require learners to draw upon knowledge from other parts of the specification.

Practical work is an intrinsic part of this specification. It is vitally important in developing a conceptual understanding of many topics and it enhances the experience and enjoyment of biology. The practical skills developed are also fundamentally important to learners going on to further study in biology and related subjects, and are transferable to many careers.

This section includes **specified practical work** that **must** be undertaken by learners in order that they are suitably prepared for the written examinations. The completion of this practical work will develop the practical skills listed in Appendix A. The requirements of the Practical Endorsement are detailed in Section 3.2. Appendix B lists the practical technique requirements with exemplification in the context of A level Biology.

Appendix C lists the mathematical requirements with exemplification in the context of A level Biology.

Each topic area includes an overview outlining the content and how it contributes to the wider aims of the specification. Knowledge of specific contexts and/or examples included in the overview will not be directly assessed.

All content in the specification should be introduced in such a way that it develops learners' ability to:

- use theories, models and ideas to develop scientific explanations
- use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas
- use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems
- carry out experimental and investigative activities, including appropriate risk management, in a range of contexts
- analyse and interpret data to provide evidence, recognising correlations and causal relationships
- evaluate methodology, evidence and data, and resolve conflicting evidence

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- know that scientific knowledge and understanding develops over time communicate information and ideas in appropriate ways using appropriate terminology
- consider applications and implications of science and evaluate their associated benefits and risks
- consider ethical issues in the treatment of humans, other organisms and the environment
- evaluate the role of the scientific community in validating new knowledge and ensuring integrity
- evaluate the ways in which society uses science to inform decision making.

Appendix D exemplifies the areas of the specification where these skills can be developed.

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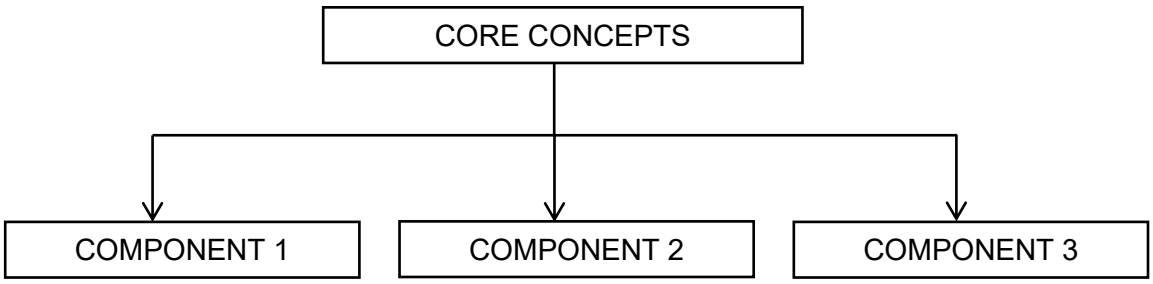
CORE CONCEPTS

The topics below contain concepts and knowledge which are fundamental to the functioning of living organisms. It is essential that learners achieve a good understanding of these. The Core Concepts may be assessed within **any** of the three components.



Core Concepts include the following topics:

1. Chemical elements are joined together to form biological compounds
2. Cell structure and organisation
3. Cell membranes and transport
4. Biological reactions are regulated by enzymes
5. Nucleic acids and their functions

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Core Concepts

1. Chemical elements are joined together to form biological compounds

Overview
All organisms are composed of biological molecules. These are fundamental to the functioning of living organisms. It is essential to understand how the structure of these molecules is related to their function.

Working scientifically
This topic contains a number of opportunities to use qualitative reagents to identify biological molecules. These skills can be further used to develop independent thinking in identifying unknown compounds.

Mathematical Skills
There are a number of mathematical skills that could be developed using data from this topic. These include making use of appropriate units; using ratios, fractions and percentages; construction and interpretation of tables and diagrams; using scatter diagrams to identify a correlation.

How Science Works
There are opportunities within this topic for learners to develop the ability to: use theories, models and ideas to develop scientific explanations in considering the structure of the biological molecules and communicate this information and ideas in appropriate ways using appropriate terminology. The practical work will allow learners to: carry out experimental and investigative activities, including appropriate risk assessments; use appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems. The consideration of the evidence of the implications of saturated and unsaturated fat gives opportunity to: consider applications and implications of science and evaluate their associated benefits and risks; evaluate the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the key elements present as inorganic ions in living organisms: Mg^{2+}, Fe^{2+}, Ca^{2+}, PO_4^{3-}

(b) the importance of water in terms of its polarity, ability to form hydrogen bonds, surface tension, as a solvent, thermal properties, as a metabolite

(c) the structure, properties and functions of carbohydrates: monosaccharides (triose, pentose, hexose sugars); disaccharides (sucrose, lactose, maltose); polysaccharides (starch, glycogen, cellulose, chitin)

(d) alpha and beta structural isomerism in glucose and its polymerisation into storage and structural carbohydrates, illustrated by starch, cellulose and chitin

(e) the chemical and physical properties which enable the use of starch and glycogen for storage and cellulose and chitin as structural compounds

(f) the structure, properties and functions of lipids as illustrated by triglycerides and phospholipids

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(g) the implications of saturated and unsaturated fat on human health

(h) the structure and role of amino acids and proteins

(i) the primary, secondary, tertiary and quaternary structure of proteins

(j) the relationship of the fibrous and globular structure of proteins to their function

Learners should be able to use given structural formulae (proteins, triglycerides and carbohydrates) to show how bonds are formed and broken by condensation and hydrolysis, including peptide, glycosidic and ester bonds.
(Learners should be able to recognise and understand but not reproduce the structural formulae of the above molecules.)

SPECIFIED PRACTICAL WORK

- Food tests to include: iodine-potassium iodide test for starch; Benedict's test for reducing and non-reducing sugars; biuret test for protein; emulsion test for fats and oils

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Core Concepts

2. Cell structure and organisation

Overview
All organisms are composed of cells. The cell theory is a unifying concept in biology. The theory states that new cells are formed from other existing cells, and that the cell is a fundamental unit of structure, function and organisation in all living organisms. The understanding of the ultrastructure of cells has been developed through advances in microscopy.

Working scientifically
This topic gives learners opportunities to develop skills in light microscopy, observation and scientific drawing and interpreting electron micrographs.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the microscope work in this topic. These include making use of appropriate units; calculating and using ratios, fractions and percentages; using an appropriate number of significant figures and decimal places; making order of magnitude calculations; changing the subject of an equation; substitution of numerical values into algebraic equations.

How Science Works
The consideration of cell theory within this topic allows learners to consider that scientific knowledge and understanding develop over time. It also allows learners to evaluate the role of the scientific community in validating new knowledge and ensuring integrity. Understanding the ultrastructure of the cell allows learners to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas and communicate information and ideas in appropriate ways using appropriate terminology. The microscope work allows learners to carry out experimental and investigative activities, including appropriate risk assessments.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure and function of the following: mitochondria; endoplasmic reticulum (rough and smooth); ribosomes; Golgi body; lysosomes; centrioles; chloroplasts; vacuoles; nucleus; chromatin; nuclear envelope; nucleolus; plasmodesmata

(b) the structure of prokaryotic cells and viruses

(c) cell theory and the similarities and differences in the cell structures of eukaryotes(animal and plant), prokaryotes and viruses, including the examination of a range of electron micrographs of prokaryote and eukaryote cells to show structure

(d) the levels of organisation including aggregation of cells into tissues and tissues into organs and organs into organ systems and also the examination of a range of prepared slides showing examples of epithelia, muscle and connective tissue

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SPECIFIED PRACTICAL WORK

- Calibration of the light microscope at low and high power, including calculation of actual size of a structure and the magnification of a structure in a drawing

- Preparation and scientific drawing of a slide of living cells e.g. onion/ rhubarb/ *Amoeba* including calculation of actual size and magnification of drawing

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Core Concepts

3. Cell membranes and transport

Overview
Cell membranes are essential in the control of the movement of substances into and out of the cell. They also play a vital role in cell recognition.

Working scientifically
This topic gives learners opportunities to develop skills in investigative techniques, using appropriate apparatus to record quantitative measurements, including mass and length, in the determination of water potential. There is also the opportunity to use appropriate instrumentation such as a colorimeter when investigating factors affecting permeability of cell membranes of beetroot. Microscope techniques can be developed when measuring incipient plasmolysis.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic. These include the use of units, ratios, fractions and percentages; use of standard and decimal form; finding arithmetic means; estimating results; using significant figures; construction and interpretation of tables and diagrams; using mean, median and mode; use of standard deviation; identifying uncertainties in measurements; plotting variables from experimental data; understanding that $y = mx + c$ represents a linear relationship; calculating a rate of change from a graph showing a linear relationship; drawing and using the slope of a tangent to a curve as a measure of rate of change. In determining water potentials and solute potentials learners can develop the ability to solve algebraic equations. There is also opportunity to use data from the topic to calculate surface areas and volumes; use scatter diagrams; translate information between graphical, numerical and algebraic forms.

How Science Works
There are opportunities within this topic for learners to develop the ability to: use theories, models and ideas to develop scientific explanations in the understanding of the structure of the fluid mosaic model of the plasma membrane. Within the practical work and understanding of transport mechanisms there are opportunities to: use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas; carry out experimental and investigative activities, including appropriate risk assessments; evaluate methodology, evidence and data, and resolve conflicting evidence; communicate information and ideas in appropriate ways using appropriate terminology.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the principal components of the plasma membrane and the fluid-mosaic model

(b) the factors affecting permeability of the plasma membrane

(c) the following transport mechanisms: diffusion and factors affecting the rate of diffusion; osmosis and water potential; pinocytosis; facilitated diffusion; phagocytosis; secretion (exocytosis); active transport and the influence of cyanide

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SPECIFIED PRACTICAL WORK

- Determination of water potential by measuring changes in mass or length
- Determination of solute potential by measuring the degree of incipient plasmolysis
- Investigation into the permeability of cell membranes using beetroot

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Core Concepts

4. Biological reactions are regulated by enzymes

Overview
Enzymes are vital in controlling metabolism in organisms. Scientists' knowledge of their structure and function has enabled enzymes to be used extensively in industry.

Working scientifically
The enzyme investigations in this topic give learners opportunities to develop skills in investigative technique, using appropriate apparatus to record quantitative measurements, including temperature and pH and using laboratory apparatus to produce serial dilutions. There are also opportunities to use ICT such as computer modelling, or a data logger to collect data, or software to process data.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic. These include making use of appropriate units; using expressions in decimal and standard form; using ratios, fractions and percentages; finding arithmetic means; the construction of tables and diagrams, bar charts and histograms; translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; understanding that $y = mx + c$ represents a linear relationship; calculating a rate of change from a graph showing a linear relationship; drawing and using the slope of a tangent to a curve as a measure of rate of change.

How Science Works
The understanding of the enzyme model within this topic allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas; communicate information and ideas in appropriate ways using appropriate terminology. The practical work in addition, allows learners to: carry out experimental and investigative activities, including appropriate risk assessments; analyse and interpret data to provide evidence, recognising correlations and causal relationships; evaluate methodology, evidence and data, and resolve conflicting evidence.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) metabolism as a series of enzyme controlled reactions

(b) the protein nature of enzymes

(c) enzymes acting intracellularly or extracellularly

(d) active sites, interpreted in terms of three dimensional structure

(e) the theory of induced fit as illustrated by lysozyme

(f) the meaning of catalysis; the lowering of the activation energy

(g) the influence of temperature, pH, substrate and enzyme concentration on rate of activity and inactivation and denaturation of enzymes and the importance of buffers for maintaining a constant pH

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(h) the principles of competitive and non-competitive inhibition

(i) the importance of immobilised enzymes and that industrial processes use immobilised enzymes, allowing enzyme reuse and improving stability

SPECIFIED PRACTICAL WORK

- Investigation into the effect of temperature or pH on enzyme activity
- Investigation into the effect of enzyme or substrate concentration on enzyme activity

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Core Concepts

5. Nucleic acids and their functions

Overview
Nucleic acids are common to all living organisms and are essential for many functions including inheritance and metabolism.

Working scientifically
The extraction of DNA from living materials gives learners opportunities to develop skills in the use of laboratory apparatus and follow instructions. There are also a number of opportunities here to use ICT such as computer modelling to study protein synthesis and DNA replication.

How Science Works
Studying the structure of nucleotides, nucleic acids and protein synthesis allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; communicate information and ideas in appropriate ways using appropriate terminology. The consideration of the work of Meselson and Stahl and the 'one gene, one polypeptide' hypothesis allows the evaluation of the role of the scientific community in validating new knowledge and ensuring integrity.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of nucleotides (pentose sugar, phosphate, organic base)

(b) the structure of ATP

(c) the importance of chemical energy in biological processes

(d) the central role of ATP as an energy carrier and its use in the liberation of energy for cellular activity

(e) the structure of nucleic acids: DNA bases: purines and pyrimidines; complementary base pair rule; hydrogen bonding and the double helix; antiparallel strands

(f) the similarities and differences in the structure of RNA and DNA

(g) the two major functions of DNA; replication and protein synthesis

(h) the semi-conservative replication of DNA including the roles of DNA polymerase and helicase and be able to use evidence from the Meselson and Stahl experiments

(i) the term genetic code

(j) the triplet code for amino acids

(k) exons as regions of DNA that contain the code for proteins and that between the exons are regions of non-coding DNA called introns

(l) the transcription of DNA to produce messenger RNA

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(m) the translation of mRNA using ribosomes and the structure and function of transfer RNA, to synthesise proteins

(n) the 'one gene - one polypeptide' hypothesis

(o) the further modification and combination of some polypeptides

SPECIFIED PRACTICAL WORK

- Simple extraction of DNA from living material

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2.1 Component 1

ENERGY FOR LIFE
Written examination: 2 hours
33⅓ % of qualification

This component includes the following topics:

1. Importance of ATP
2. Photosynthesis uses light energy to synthesise organic molecules
3. Respiration releases chemical energy in biological processes
4. Microbiology
5. Population size and ecosystems
6. Human impact on the environment

The assessment will also include synoptic questions. These questions will require learners to draw upon knowledge from other parts of the specification.

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Energy for Life

1. Importance of ATP

Overview
ATP is the only source of immediate energy within the cell for many biological processes. It is often referred to as the 'universal energy currency'. An understanding of how ATP is produced is essential in the understanding of respiration and photosynthesis.

Working scientifically
The investigation into dehydrogenase activity gives learners opportunities to develop skills in: using appropriate apparatus to record a range of quantitative measurements (to include time, volume and temperature); the use of laboratory apparatus to produce serial dilutions; safely use organisms to measure plant or animal responses. There is also the opportunity here to use ICT such as computer modelling to study chemiosmosis.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic. These include using an appropriate number of significant figures and decimal places; using expressions in decimal and standard form; finding arithmetic means; using scatter diagrams; construction of frequency tables and diagrams.

How Science Works
The study of chemiosmosis within this topic allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; communicate information and ideas in appropriate ways using appropriate terminology.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the synthesis of ATP involving a flow of protons through the enzyme ATP synthetase, the process of chemiosmosis and the electrochemical gradient

(b) the similarity between mitochondrial and chloroplast membrane function in providing a proton gradient for ATP synthesis

(c) the proton gradient; maintained by proton pumps driven by potential energy associated with excited electrons

(d) the electron transport chain is formed from an alternate arrangement of pumps and electron carriers (names of proton pumps and electron carriers in the electron transport system are not required)

SPECIFIED PRACTICAL WORK

- Investigation of dehydrogenase activity using artificial hydrogen acceptors, as illustrated by methylene blue, DCPIP or tetrazolium compounds

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Energy for Life

2. Photosynthesis uses light energy to synthesise organic molecules

Overview
Most life on earth is dependent on photosynthesis. The process involves the synthesis of large organic molecules from simple inorganic molecules using light from the sun.

Working scientifically
This topic gives learners opportunities to develop skills in investigative techniques, including separating biological compounds using thin layer or paper chromatography to separate the chloroplast pigments; using appropriate apparatus in investigating factors affecting the rate of photosynthesis to record a range of quantitative measurements including time and volume; safely use organisms to measure plant responses; using ICT such as computer modelling to investigate the role of nitrogen and magnesium in plant growth, or a data logger and software to collect and process data in the photosynthesis investigation.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic. These include, in the chromatography investigation, changing the subject of an equation and substituting numerical values into algebraic equations. Within the photosynthesis investigative work: using an appropriate number of significant figures and decimal places; finding arithmetic means; construction and interpretation of tables and diagrams; using scatter diagrams; calculating standard deviation; translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; understanding that $y = mx + c$ represents a linear relationship; calculating a rate of change from a graph showing a linear relationship; drawing and using the slope of a tangent to a curve as a measure of rate of change; determining the intercept of a graph.

How Science Works
The consideration and understanding of the mechanism of photosynthesis allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas; communicate information and ideas in appropriate ways using appropriate terminology. The practical work encourages: the use of appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; carrying out of experimental and investigative activities, including appropriate risk assessments; analysis and interpretation of data to provide evidence, recognising correlations and causal relationships; evaluation of methodology, evidence and data, and resolve conflicting evidence.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the distribution of chloroplasts in relation to light trapping

(b) chloroplasts acting as transducers converting the energy of light photons into the chemical energy of ATP

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(c) the process of light harvesting and the absorption of various wavelengths of light by chlorophyll and associated pigments and the energy transfer to reaction centres

(d) the basic features of Photosystems I and II

(e) cyclic and non-cyclic photophosphorylation as sources of electrons for the electron transport chain

(f) photolysis as a source of electrons for Photosystem II

(g) the reduction of NADP by the addition of electrons and hydrogen ions in the stroma maintaining the proton gradient

(h) reduced NADP as a source of reducing power and ATP as a source of energy for the following reactions: the light-independent stage and the formation of glucose; uptake of carbon dioxide by ribulose bisphosphate to form glycerate-3-phosphate catalysed by Rubisco

(i) the reduction of glycerate-3-phosphate to produce triose phosphate (carbohydrate) with the regeneration of ribulose bisphosphate

(j) the production of other carbohydrates, lipids and amino acids from the triose phosphate (no details of the chemistry of these processes is needed)

(k) the concept of limiting factors in relation to photosynthesis

(l) the role of inorganic nutrients in plant metabolism as illustrated by the use of nitrogen and magnesium

SPECIFIED PRACTICAL WORK

- Investigation into the separation of chloroplast pigments by chromatography
- Investigation into factors affecting the rate of photosynthesis
- Investigation into the role of nitrogen and magnesium in plant growth

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Energy for Life

3. Respiration releases chemical energy in biological processes

Overview
Respiration is a process that occurs within the cells of all organisms. The process involves the release of chemical energy from the oxidation of complex organic molecules.

Working scientifically
The investigation into factors affecting the rate of respiration in yeast gives learners opportunities to develop investigative skills in the: use of appropriate apparatus to record a range of quantitative measurements; use of laboratory apparatus; safe use of organisms to measure plant or animal responses. There are also a number of opportunities here to use ICT such as computer modelling to study the biochemical processes involved in respiration.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic. These include making use of appropriate units; using expressions in decimal and standard form; using ratios, fractions and percentages; finding arithmetic means; construction and interpretation of tables and diagrams; translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; understanding that $y = mx + c$ represents a linear relationship; determining the intercept of a graph; calculating a rate of change from a graph showing a linear relationship; drawing and using the slope of a tangent to a curve as a measure of rate of change.

How Science Works
The understanding of the biochemical processes in respiration allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; communicate information and ideas in appropriate ways using appropriate terminology. Learners will also: carry out experimental and investigative activities, including appropriate risk assessments; analyse and interpret data to provide evidence, recognising correlations and causal relationships; evaluate methodology, evidence and data, and resolve conflicting evidence.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the need for all living organisms to carry out respiration in order to provide energy in the cell

(b) glycolysis as a source of triose phosphate, pyruvate, ATP and reduced NAD and resulting in the formation of acetyl Coenzyme A (the names of intermediates are not required)

(c) the Krebs cycle as a means of liberating energy from carbon-carbon bonds to produce ATP and reduced NAD with release of carbon dioxide

(d) the role of reduced NAD and FAD as a sources of electrons and protons for the electron transport system

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(e) the energy budget of the breakdown of glucose under aerobic and anaerobic conditions

(f) how lipids and amino acids are used in respiration

SPECIFIED PRACTICAL WORK

- Investigation into factors affecting the rate of respiration in yeast

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Energy for Life

4. Microbiology

Overview
This topic covers the classification and growth of bacteria and methods of counting them.

Working scientifically
The investigation into the number of bacteria in fresh and stale milk gives learners opportunities to develop skills in the use microbiological aseptic techniques and the use of laboratory apparatus to produce serial dilutions. Opportunities should be given to learners to prepare and observe bacteria stained using the Gram technique.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic and also in measuring bacterial growth. These include making use of appropriate units; using expressions in decimal and standard form; using ratios, fractions and percentages; using logarithms; using significant figures; finding arithmetic means; constructing and interpreting of tables and diagrams; translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; determining the intercept on a graph; drawing and using the slope of a tangent to a curve as a measure of rate of change.

How Science Works
The study of bacterial cell wall structure and Gram staining technique allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; communicate information and ideas in appropriate ways using appropriate terminology. The practical work allows: the use of appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; the carrying out of experimental and investigative activities, including appropriate risk assessments; analysis and the interpretation of data to provide evidence, recognising correlations and causal relationships.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the classification of bacteria according to their shape and by their reaction to the Gram stain as determined by their cell wall structure, including the preparation and examination of bacteria stained using Gram technique

(b) the methods by which microorganisms can be cultured in the laboratory

(c) the conditions necessary for bacterial growth and the principles of aseptic technique

(d) the methods used to monitor population growth in microorganisms including viable count, using serial dilutions, plating and counting colonies

SPECIFIED PRACTICAL WORK

- Investigation into the numbers of bacteria in fresh and stale milk, using techniques of serial dilution, plating and counting colonies

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Energy for Life

5. Population size and ecosystems

Overview
This topic covers populations and factors which regulate them. The nature of ecosystems and the efficiency of biomass transfer within them are also considered. Nutrient cycles play an important role in the recycling of resources within an ecosystem and it is important to understand the impact of human activity on these.

Working scientifically
This topic gives learners opportunities to develop skills in the use of ICT such as computer modelling in studying population change and predator-prey relationships. There is also opportunity for fieldwork in investigating the distribution and abundance of organisms in a habitat.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the study of biomass transfer in this topic and also in sampling techniques and statistical analysis. These include making use of appropriate units; using expressions in decimal and standard form; using ratios, fractions and percentages; use of significant figures; finding arithmetic means; construction and interpretation of tables and diagrams; translating information between graphical, algebraic and numerical forms; use of a scatter diagram; plotting variables from experimental data; determining the intercept on a graph; drawing and using the slope of a tangent to a curve as a measure of rate of change. Learners can develop skills in using logarithms in calculating and plotting population growth.

How Science Works
The study of populations and ecosystems will develop learners abilities to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas. The fieldwork will develop: the use of appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; the carrying out of experimental and investigative activities, including appropriate risk assessments; the analysis and interpretation of data to provide evidence, recognising correlations and causal relationships; the evaluation of methodology, evidence and data, and resolving conflicting evidence. The section on the human impact on nutrient cycles allows: the consideration of applications and implications of science and the evaluation of their associated benefits and risks; consideration of ethical issues in the treatment of humans, other organisms and the environment; evaluation of the role of the scientific community in validating new knowledge and ensuring integrity; evaluation of the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) populations and the way in which they grow - a simple quantitative treatment including immigration, emigration, birth and death rates

(b) graphs showing population growth and factors affecting population growth; competition; carrying capacity

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(c) the regulation of populations by density dependent and density independent factors

(d) the sampling techniques used to assess abundance and distribution of organisms in a habitat

(e) the concept of ecosystems, including that ecosystems range in size from very large to very small

(f) the sun is the source of energy for an ecosystem

(g) the concepts of habitat and community

(h) the transfer of biomass from plants to animals including trophic levels, efficiency of transfer; gross and net production and pyramids of biomass

(i) the principles of succession as illustrated by the colonisation of bare rock to form woodland

(j) the terms primary and secondary succession, pioneers, sere and climax community

(k) the importance of organic breakdown in recycling nutrients

(l) the carbon cycle

(m) the effects of human activities on the carbon cycle including that climate change affects the distribution of species and is a possible cause of extinction

(n) the role of bacteria in the nitrogen cycle and the significance of nitrates in producing proteins and nucleic acids

(o) the importance of human activities such as ploughing and drainage in producing the aerobic conditions needed for nitrification and the economic importance of the nitrogen cycle in relation to food production and fertiliser application

(p) the process of eutrophication and algal blooms and that drainage has adverse effects on habitats

SPECIFIED PRACTICAL WORK

- Investigation into the abundance and distribution of organisms in a habitat

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Energy for Life

6. Human impact on the environment

Overview
As the size of the human population increases, there is an increasing need to consider the detrimental effects that this can have on ecosystems. There needs to be effective management of the conflict between human needs and conservation in order to maintain sustainability of biological resources.

Working scientifically
There are a number of opportunities in this topic for independent research. This could involve experimental investigation; using online and offline research skills including using websites, textbooks and other printed scientific sources of information and the correct citation of sources of information.

How Science Works
The consideration of the wider human impact on the environment allows learners to develop the ability to: consider applications and implications of science and evaluate their associated benefits and risks; consider ethical issues in the treatment of humans, other organisms and the environment. The inclusion of the concept of planetary boundaries allows learners to: evaluate the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the reasons for species becoming endangered and causes of extinction

(b) how gene pools are conserved in the wild and in captivity

(c) the issues in agricultural exploitation - conflicts between production and conservation and possible means to resolve such conflicts as illustrated by deforestation and overfishing

(d) the increased human pressures on the environment including the need to achieve sustainability by changes in human attitudes and making informed choices

(e) the need for political decision making to be informed by knowledge based on sound scientific principles

(f) the concept of planetary boundaries

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2.2 Component 2

CONTINUITY OF LIFE

Written examination: 2 hours
33⅓ % of qualification

This component includes the following topics:

1. All organisms are related through their evolutionary history
2. Genetic information is copied and passed on to daughter cells
3. Sexual reproduction in humans
4. Sexual reproduction in plants
5. Inheritance
6. Variation and evolution
7. Application of reproduction and genetics

The assessment will also include synoptic questions. These questions will require learners to draw upon knowledge from other parts of the specification.

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Continuity of Life

1. All organisms are related through their evolutionary history

Overview
This topic covers biodiversity and classification. The variety of living organisms that exists today has evolved as a result of natural selection. Modern techniques have allowed more accurate classification to confirm evolutionary relationships.

Working scientifically
The approach to biodiversity in this topic gives learners opportunities to develop investigative skills. There are a number of opportunities for independent research. These could involve the use of sampling techniques in fieldwork; online and offline research skills including the use of websites, textbooks and other printed scientific sources of information and the correct citation of sources of information.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the specified practical fieldwork in this topic. These include using expressions in decimal and standard form; using ratios, fractions and percentages; selecting a statistical test; understanding simple probability; using scatter diagrams; construction and interpretation of frequency tables and diagrams; understanding the principles of sampling as applied to scientific data; substitution of numerical values to solve algebraic equations; translating information between graphical, numerical and algebraic forms.

How Science Works
The understanding of classification allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas. The comparison of three domain and five kingdom systems gives opportunity to: know that scientific knowledge and understanding develops over time; the evaluation of the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making. The use of fieldwork develops: appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; experimental and investigative activities, including appropriate risk assessments; analysis and interpretation skills, recognising correlations and causal relationships; evaluation of methodology, evidence and data, and resolving of conflicting evidence; consider ethical issues in the treatment of other organisms and the environment.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the classification of organisms into groups based on their evolutionary relationships and that classification places organisms into discrete and hierarchical groups with other closely related species

(b) the need for classification and its tentative nature

(c) the three domain classification system as compared with the five Kingdom classification system

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(d) the characteristic features of Kingdoms: Prokaryotae, Protoctista, Plantae, Fungi, Animalia

(e) the use of physical features and biochemical methods to assess the relatedness of organisms, including DNA 'genetic fingerprinting' and enzyme studies to show relatedness without the problem of morphological convergence

(f) the concept of species

(g) the use of the binomial system in naming organisms

(h) biodiversity as the number and variety of organisms found within a specified geographic region

(i) biodiversity varying spatially and over time and affected by many factors

(j) biodiversity can be assessed in a habitat e.g. Simpson's Diversity Index

(k) biodiversity can be assessed within a species at a genetic level by looking at the variety of alleles in the gene pool of a population, i.e. the proportion of polymorphic loci across the genome

(l) biodiversity can be assessed at a molecular level using DNA fingerprinting and sequencing

(m) biodiversity has been generated through natural selection

(n) the different types of adaptations of organisms to their environment including anatomical, physiological and behavioural adaptations

SPECIFIED PRACTICAL WORK

- Investigation into biodiversity in a habitat

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Continuity of Life

2. Genetic information is copied and passed on to daughter cells

Overview
This topic covers cell division. During the cell cycle, genetic information is copied and passed on to daughter cells.

Working scientifically
The specified practical work in this topic gives learners opportunities to use the light microscope and to produce annotated scientific drawings from observation. There is also the opportunity for learners to produce their own slide of dividing cells in a root tip.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the microscope work in this topic. These include making use of appropriate units; using ratios, fractions and percentages; using an appropriate number of significant figures and decimal places; making order of magnitude calculations; changing the subject of an equation; substitution of numerical values into algebraic equations.

How Science Works
The understanding of cell division within this topic for learners to develop the ability to: use theories, models and ideas to develop scientific explanations; communicate information and ideas in appropriate ways using appropriate terminology. The significance of unrestricted division leading to cancerous growth could lead to the consideration of applications and implications of science and evaluating their associated benefits and risks.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) interphase and the main stages of mitosis

(b) the significance of mitosis as a process in which daughter cells are provided with identical copies of genes and the process of cytokinesis

(c) the significance of mitosis in terms of damage and disease: repeated cell renewal, damage repair and healing and unrestricted division leading to cancerous growth

(d) the main stages of meiosis (names of subdivisions of prophase 1 not required) and cytokinesis

(e) the differences between mitosis and meiosis, including that mitosis produces genetically identical daughter cells whereas meiosis produces non-identical daughter cells

SPECIFIED PRACTICAL WORK

- Scientific drawing of cells from slides of root tip to show stages of mitosis
- Scientific drawing of cells from prepared slides of developing anthers to show stages of meiosis

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Continuity of Life

3. Sexual reproduction in humans

Overview
Sexual reproduction is the production of offspring with a new combination of alleles resulting from the fusion of male and female gametes.

Working scientifically
There are opportunities in this topic to develop microscope skills in the observation of the histology of ovary and testis.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the endocrine control section in this topic. These include: construction and interpretation of tables and diagrams; calculation of magnification; translating information between graphical, numerical and algebraic forms; determining the intercept of a graph.

How Science Works
The understanding of the hormonal control of female reproduction allows learners to communicate information and ideas in appropriate ways using appropriate terminology.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure and function of the reproductive systems in humans, including the examination of histology of ovary and testis

(b) the processes of spermatogenesis and oogenesis to produce spermatozoa and secondary oocytes; sexual intercourse; fertilisation and implantation

(c) the endocrine control of reproduction in the female: including the menstrual cycle, birth and lactation by reference to follicle stimulating hormone, luteinising hormone, oestrogen, progesterone, oxytocin and prolactin and human chorionic gonadotrophin

(d) the role of the placenta including hormonal control

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Continuity of Life

4. Sexual reproduction in plants

Overview
This topic covers the process of reproduction in flowering plants.

Working scientifically
There are a number of opportunities in this topic to develop practical skills. These include microscope skills in the observation of the histology of ovary and anther; the use of appropriate apparatus in recording quantitative measurements in an investigation into the digestion of starch agar; the safe use of instruments in the dissection of the reproductive organs of flowers.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the practical section in this topic. These include within the microscope work: making order of magnitude calculations; changing the subject of an equation; substitution of numerical values into algebraic equations; making use of appropriate units; using an appropriate number of significant figures and decimal places. Within the investigation work: finding arithmetic means; calculating mean median and mode; construction and interpretation of tables and diagrams; translating information between graphical, numerical and algebraic forms; plotting two variables from experimental or other data.

How Science Works
The understanding of the reproductive systems and processes in plants allow opportunities to: use theories, models and ideas to develop scientific explanations. The investigation of germinating seeds allows: the use of appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; experimental and investigative activities, including appropriate risk assessments; analysis and interpretation of data to provide evidence; evaluation of methodology, evidence and data, and resolving of conflicting evidence.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the generalised structure of flowers to be able to compare wind and insect pollinated flowers

(b) the development of pollen and ovules, including examination of prepared slides of anther and ovary

(c) cross and self-pollination

(d) the process of double fertilisation

(e) the formation and structure of seed and fruit as shown by broad bean and maize

(f) the process of germination of *Vicia faba* (broad bean)

(g) the effect of gibberellin

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SPECIFIED PRACTICAL WORK

- Investigation of the digestion of starch agar using germinating seeds
- Dissection of wind and insect-pollinated flowers
- Scientific drawing of a low power plan of a prepared slide of an anther, including calculation of actual size and magnification of drawing

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Continuity of Life

5. Inheritance

Overview
This topic covers genetics. Genetics is the study of the inheritance of characteristics. The effect of epigenetics affecting the expression of these characteristics is also included.

Working scientifically
This topic gives learners opportunities to develop skills in the use of ICT such as computer modelling in studying gene segregation.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially within the use of the chi squared test in this topic. These include: using ratios, fractions and percentages; using significant figures; understanding simple probability; selecting and using a statistical test.

How Science Works
The principles of inheritance allow learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas. Investigating gene segregation develops: the use of appropriate methodology to answer scientific questions and solve scientific problems; experimental and investigative activities, including appropriate risk assessments; analysis and interpretation of data to provide evidence, recognising correlations; evaluation of methodology, evidence and data, and resolve conflicting evidence. The understanding of epigenetics allows learners to: know that scientific knowledge and understanding develops over time. The study of genetic disorders allows the consideration of the applications and implications of science and evaluation of their associated benefits and risks; consideration of ethical issues in the treatment of humans, other organisms and the environment; evaluation of the role of the scientific community in validating new knowledge and ensuring integrity.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) alleles as different forms of the same gene

(b) the principles of monohybrid Mendelian inheritance including simple crosses involving codominance

(c) the principles of dihybrid Mendelian inheritance including simple crosses involving linkage

(d) the use of a chi squared test

(e) sex linkage as illustrated by haemophilia and Duchenne muscular dystrophy

(f) gene mutation as illustrated by sickle cell anaemia and chromosome mutation as illustrated by Down's syndrome

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(g) the effect of mutagens, carcinogens and oncogenes

(h) the control of gene expression by factors other than changes in the DNA sequence; the study of this is called epigenetics

SPECIFIED PRACTICAL WORK

- Experiment to illustrate gene segregation including the use of the chi squared test in assessing the significance of genetic outcomes

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Continuity of Life

6. Variation and evolution

Overview
This topic covers the mechanisms of evolution and speciation. Darwinian evolution depends on variation within a population and allows survival of a population in a constantly changing environment.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills especially with the use of the Student t test in this topic. These include: constructing and interpreting frequency tables and diagrams, bar charts and histograms; finding arithmetic means; understanding the terms mean, median and mode; understanding measures of dispersion, including standard deviation and range; using ratios, fractions and percentages; using significant figures; understanding simple probability; understand the principles of sampling; using a scatter diagram; selecting and using a statistical test; plotting experimental data.

How Science Works
The study of evolution and speciation allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas. The use of the Student t test to investigate continuous variation allows learners to: use appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; carry out experimental and investigative activities, including appropriate risk assessments; analyse and interpret data to provide evidence, recognising correlations and causal relationships; evaluate methodology, evidence and data, and resolve conflicting evidence. When considering the human impact of selection pressures there are opportunities to: consider ethical issues in the treatment of humans, other organisms and the environment; evaluate the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) genetic and environmental factors producing variation between individuals

(b) variation as continuous and discontinuous; heritable and non-heritable

(c) the effect of inter- and intra-specific competition on breeding success and survival

(d) the impact of selective agencies (e.g. supply of food, breeding sites, climate, human impact) on the survival of organisms

(e) the concept of gene pool and genetic drift

(f) the effect of selection changing the frequency of alleles in a population

(g) the use of the Hardy-Weinberg principle and equation

(h) the conditions under which the Hardy-Weinberg principle applies

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(i) the concepts of isolation and speciation

(j) the separation of populations by geographical, behavioural, morphological, seasonal and other isolation mechanisms including hybrid sterility

(k) Darwin's theory of evolution that existing species have arisen through modification of ancestral species by natural selection

SPECIFIED PRACTICAL WORK

- Investigation of continuous variation in a species (including use of the Student's t test)

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Continuity of Life

7. Application of reproduction and genetics

Overview
This topic covers gene technology and its applications, including the sequencing of genomes, the use of PCR and recombinant DNA technology. The ethical implications of these technologies are also considered.

Working scientifically
This topic gives learners opportunities to develop skills in the use of ICT such as computer modelling in modelling PCR and gene sequencing. There are a number of opportunities for independent research.

How Science Works
By studying the application of sequencing and gene technologies learners develop abilities to: know that scientific knowledge and understanding develops over time; consider ethical issues in the treatment of humans, other organisms and the environment; evaluate the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the Human Genome Project and its extension to the 100K Genome Project

(b) the ethical issues surrounding the use of this knowledge and its application to the screening of embryos for genetic disorders e.g. cystic fibrosis, Huntington's disease, thalassaemia

(c) how the genomes from other organisms have also been sequenced, including the mosquito, *Anopheles gambiae* and the *Plasmodium* parasite that it transmits and that better methods to control malaria may be developed as a result

(d) the use of PCR and electrophoresis to produce a genetic fingerprint; the forensic use of genetic fingerprinting

(e) the formation of recombinant DNA by insertion of foreign DNA into bacterial plasmids and the cloning of the bacteria to produce useful molecules as illustrated by insulin

(f) issues surrounding the use of gene technologies to produce genetically modified crops by inserting a gene from one organism into another to convey disease resistance e.g. in GM tomatoes or a desired characteristic e.g. in GM soya

(g) the advantages and disadvantages of using gene therapy for the treatment of disease as illustrated by muscular dystrophy

(h) the use of genomics and its possible impact on healthcare of the future

(i) the issues surrounding the use of stem cells for replacing damaged tissues and organs

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2.3 Component 3

REQUIREMENTS FOR LIFE

Written examination: 2 hours
33⅓ % of qualification

This component includes the following topics:

1. Adaptations for gas exchange
2. Adaptations for transport
3. Adaptations for nutrition
4. Homeostasis and the kidney
5. The nervous system

The assessment will also include synoptic questions. These questions will require learners to draw upon knowledge from other parts of the specification.

Choice of one option from three:

A. Immunology and Disease

B. Human Musculoskeletal Anatomy

C. Neurobiology and Behaviour

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Requirements for Life

1. Adaptations for gas exchange

Overview
This topic is an overview of the adaptations of a variety of organisms for gas exchange. As organisms increase in size and complexity with increasing metabolic rate, there is an increased need for specialised gas exchange surfaces and ventilation mechanisms. The importance of the surface area to volume ratio in organisms is a theme running throughout the topic.

Working scientifically
This topic gives learners opportunities to develop skills in: safely using instruments for dissection in dissecting a fish head; microscope techniques and use of a graticule; producing scientific drawings with annotations.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills. The consideration of the surface area to volume ratio in different organisms and concentration gradients allows: use of appropriate units; using expressions in decimal and standard form; using ratios; calculating the areas and volumes of regular shapes; translating information between graphical and numerical forms. The investigation into stomatal numbers allows: finding arithmetic means; calculating mean, median and mode; constructing and interpreting tables and diagrams; estimating results; plotting experimental data. The microscope work allows: making order of magnitude calculations; changing the subject of an equation; substitution of numerical values into algebraic equations.

How Science Works
The study of the mechanisms by which gas exchange occurs allow learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas. The practical work encourages: use of appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; experimental and investigative activities, including appropriate risk assessments; analysis and interpretation of data to provide evidence, recognising correlations and causal relationships; evaluation of methodology, evidence and data, and resolving of conflicting evidence.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the adaptations for gas exchange which allow an increase in body size and metabolic rate

(b) gas exchange in small animals across their general body surface

(c) the comparison of gas exchange mechanisms in *Amoeba*, flatworm and earthworm

(d) the common features of the specialised respiratory surfaces of larger animals and the adaptation of respiratory surfaces to environmental conditions - fish have gills for aquatic environments and mammals have lungs for terrestrial environments

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(e) the need for large active animals with high metabolic rates to have ventilating mechanisms to maintain gradients across respiratory surfaces

(f) ventilation in bony fish and comparison of counter current flow with parallel flow

(g) the structure and function of the human breathing system, including examination of microscope slides of T.S. lung and trachea

(h) ventilation in humans and how gases are exchanged

(i) the adaptations of the insect tracheal system to life in a terrestrial environment

(j) the structure of the angiosperm leaf

(k) the role of leaf structures in allowing the plant to photosynthesise effectively

(l) the role of the leaf as an organ of gas exchange, including stomatal opening and closing

SPECIFIED PRACTICAL WORK

- Investigation into stomatal numbers in leaves
- Dissection of fish head to show the gas exchange system
- Scientific drawing of a low power plan of a prepared slide of T.S. dicotyledon leaf e.g. *Ligustrum* (privet), including calculation of actual size and magnification of drawing

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Requirements for Life

2. Adaptations for transport

Overview
This topic is an overview of the adaptations of a variety of organisms for transport. As organisms increase in size and complexity, there is an increased need for specialised transport mechanisms.

Working scientifically
This topic gives learners many opportunities to develop practical skills in: safely using instruments for dissection in a heart dissection; microscope techniques and use of a graticule; producing scientific drawings with annotations; using a potometer to record quantitative measurements.

Mathematical Skills
The study of dissociation curves, analysis of electrocardiogram traces and transpiration investigation give a number of opportunities for the development of mathematical skills. These include: use of appropriate units; using ratios; solving algebraic equations; use of significant figures; finding arithmetic means; constructing and interpreting tables; calculating mean, median and mode; estimating results; calculating the areas, circumferences and volumes of regular shapes; translating information between graphical, numerical and algebraic forms; plotting two variables from experimental or other data; understanding that $y = mx + c$ represents a linear relationship; calculating rate of change from a graph; determining the intercept of a graph.

How Science Works
The study of the increasingly complex transport mechanisms in organisms allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas; communicate information and ideas in appropriate ways using appropriate terminology. The practical work encourages: use of appropriate methodology, including information and communication technology (ICT) to answer scientific questions and solve scientific problems; experimental and investigative activities, including appropriate risk assessments; analysis and interpretation of data to provide evidence, recognising correlations and causal relationships; evaluation of methodology, evidence and data, and resolving of conflicting evidence.
The study of phloem transport gives opportunities for the following: evaluation of methodology, evidence and data, and resolving of conflicting evidence; knowing that scientific knowledge and understanding develops over time.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the similarities and differences in the vascular systems of animal groups:

- Earthworm — vascularisation, closed circulatory system and pumps, carriage of respiratory gases in blood
- Insects — open circulatory system, dorsal tube-shaped heart, lack of respiratory gases in blood
- Fish — single circulatory system
- Mammal — double circulatory system

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(b) the mammalian circulatory system including the structure and function of heart and blood vessels and the names of the main blood vessels associated with the human heart

(c) the cardiac cycle and the maintenance of circulation to include graphical analysis of pressure changes, the role of sino-atrial node and Purkyne/ Purkinje fibres and the analysis of electrocardiogram traces to show electrical activity

(d) the function of red blood cells and plasma in relation to transport of respiratory gases, dissociation curves of haemoglobin of mammal (adult and foetus), including examination of microscope slides of erythrocytes

(e) the dissociation curves of some animals adapted to low oxygen level habitats e.g. llama, lugworm

(f) the Bohr effect and chloride shift

(g) the transport of nutrients, hormones, excretory products and heat in the blood

(h) the formation of tissue fluid and its importance as a link between blood and cells

(i) the structure of the dicotyledon root, including examination of microscope slides of T.S. dicotyledon root

(j) the absorption of water by the root

(k) the movement of water through the root: apoplast, symplast and vacuolar pathways

(l) the structure and the role of the endodermis

(m) the detailed structure of xylem as seen by the light and electron microscope, including examination of microscope slides of T.S. dicotyledon primary stem

(n) the movement of water from root to leaf including the transpiration stream and cohesion-tension theory

(o) the effect of environmental factors affecting transpiration

(p) the adaptations shown by some angiosperms: hydrophytes, xerophytes, including examination of microscope slides of T.S. leaves of marram grass and water lily

(q) the detailed structure of phloem as seen by the light and electron microscope

(r) the translocation of organic materials from source to sink, including the ideas surrounding phloem transport: diffusion; cytoplasmic strands; mass flow models; experimental evidence that solutes e.g. sucrose, are carried in the phloem; use of aphids and autoradiographs

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SPECIFIED PRACTICAL WORK

- Investigation into transpiration using a simple potometer
- Scientific drawing of a low power plan of a prepared slide of T.S artery and vein, including calculation of actual size and magnification of drawing
- Dissection of mammalian heart

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Requirements for Life

3. Adaptations for nutrition

Overview
This topic is an overview of the adaptations for nutrition in a variety of organisms. As organisms increase in size and complexity, there is an increased need for specialised digestive systems.

Working scientifically
There are a number of opportunities in this topic to develop practical skills. These include microscope skills in the observation of the histology of T.S. duodenum and ileum; observation of skulls and dentition of a herbivore and a carnivore; observation of specimens and slides of tapeworm e.g. *Taenia.*

Mathematical Skills
The comparison of the adaptations for nutrition in different organisms allows a number of opportunities for the development of mathematical skills. These include: use of appropriate units; using ratios; solving algebraic equations; estimating results; translating information between graphical, numerical and algebraic forms. Microscope work allows: making order of magnitude calculations; changing the subject of an equation; substitution of numerical values into algebraic equations.

How Science Works
The study of the different nutrition mechanisms within this topic allow learners to develop the ability to: analyse and interpret data to providing evidence, recognise correlations and causal relationships; communicate information and ideas in appropriate ways using appropriate terminology; consider applications and implications of science and evaluate their associated benefits and risks.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the terms autotrophic and heterotrophic and that autotrophic organisms can be photoautotrophic or chemoautotrophic

(b) the terms saprotrophic/ saprobiotic, holozoic, parasitic in relation to heterotrophic organisms

(c) saprotrophic nutrition involving the secretion of enzymes, external digestion of food substances followed by absorption of the products of digestion into the organism, e.g. fungi

(d) holozoic nutrition; the internal digestion of food substances

(e) nutrition in unicellular organisms, e.g. *Amoeba*, food particles are absorbed and digestion is carried out intracellularly

(f) the adaptation of multicellular organisms for nutrition showing increasing levels of adaptation from a simple, undifferentiated, sac-like gut with a single opening, e.g. *Hydra*, to a tube gut with different openings for ingestion and egestion and specialised regions for the digestion of different food substances

(g) the adaptations of the human gut to a mixed, omnivorous diet that includes both plant and animal material, including examination of microscope slides of duodenum and ileum

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(h) the efficient digestion of different food substances requiring different enzymes and different conditions

(i) the adaptations of herbivore guts and dentition, in particular ruminants to a high cellulose diet and the adaptations of carnivore guts and dentition to a high protein diet, including examination of skulls and dentition of a herbivore and a carnivore

(j) parasites; highly specialised organisms that obtain their nutrition at the expense of a host organism e.g. *Taenia* and *Pediculus,* including examination of specimens and slides of tapeworm e.g. *Taenia*

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Requirements for Life

4. Homeostasis and the kidney

Overview
This topic covers homeostasis and the functions of the kidney.

Working scientifically
This topic gives learners opportunities to develop skills in: safely using instruments for dissection in dissecting a kidney; microscope skills in observation of prepared sections of kidney and observation of electron micrographs of sections of kidney.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills. These include: use of appropriate units; use of significant figures and decimal places; use of ratios, fractions and percentages; construction and interpretation of frequency tables and diagrams; use of a scatter diagram; translating information between graphical, numerical and algebraic forms; making order of magnitude calculations; changing the subject of an equation; substitution of numerical values into algebraic equations, plotting experimental data.

How Science Works
Study of homeostasis allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; analyse and interpret data to provide evidence, recognising correlations and causal relationships; communicate information and ideas in appropriate ways using appropriate terminology. The consideration of the effects of kidney failure and treatment allows learners to consider the applications and implications of science and evaluate their associated benefits and risks; consider ethical issues in the treatment of humans, other organisms and the environment; evaluate the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the concept of homeostasis and its importance in maintaining the body in a state of dynamic equilibrium

(b) the role of negative feedback in restoring conditions to their original levels and the role of positive feedback in enhancing the size of a stimulus

(c) the structure of the mammalian kidney and the nephron, including examination of microscope slides and electron micrographs of kidney

(d) the functions of the mammalian kidney including nitrogenous excretion and water regulation

(e) the adaptations of the cells of the proximal tubule for reabsorption

(f) the contribution of the endocrine glands to homeostatic balance as illustrated by the role of the posterior pituitary gland in the secretion of antidiuretic hormone

(g) the role of antidiuretic hormone

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(h) the effects of kidney failure and its potential treatments

(i) the need for different excretory products and adaptations of the loop of Henlé in different environments

SPECIFIED PRACTICAL WORK

- Dissection of kidney

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Requirements for Life

5. The nervous system

Overview
This topic covers the structure and function of the human nervous system. There is also comparison with less complex organisms.

Working scientifically
This topic gives learners opportunities to develop skills in: microscopy in observation of prepared sections of T.S. spinal cord; use of ICT in the modelling of the analysis of oscilloscope traces.

Mathematical Skills
The study of nervous transmission allows a number of opportunities for the development of mathematical skills. These include: use of appropriate units; use of significant figures and decimal places; construction and interpretation of frequency tables and diagrams; translating information between graphical, numerical and algebraic forms.

How Science Works
The structure and function of the nervous system allows opportunities for learners to develop the ability to: use theories, models and ideas to develop scientific explanations; use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas; analyse and interpret data to provide evidence, recognising correlations and causal relationships; communicate information and ideas in appropriate ways using appropriate terminology; consider applications and implications of science and evaluate their associated benefits and risks; consider ethical issues in the treatment of humans, other organisms and the environment.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the components of a nervous response; from the detection of internal and external stimuli by receptors to the response by the effector

(b) the main areas of the spinal cord, including examination of T.S. spinal cord

(c) the basic pattern of spinal nerves in relation to the spinal cord including the dorsal root and ventral root

(d) the simple reflex arc as the basis for rapid, protective, involuntary actions

(e) the structure of a nerve net in Cnidaria and be able to draw comparisons with the nervous systems in more complex organisms

(f) the structure of a motor neurone including drawing and labelling of diagram

(g) the nature and transmission of the nerve impulse

(h) how to analyse oscilloscope traces showing the passage of an action potential

(i) factors affecting speed of conduction of a nervous impulse in other organisms

(j) the structure and role of a synapse

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(k) the process of synaptic transmission

(l) the effect of chemicals e.g. organophosphates and psychoactive drugs on the transmission of impulses

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OPTIONS (choice of 1 option from 3)

OPTION A: IMMUNOLOGY AND DISEASE

Overview
This option covers the variety of organisms that cause disease and studies the way that humans have developed defence mechanisms against them. This includes the use of antibiotics and the immune response.

Working scientifically
This topic gives learners opportunities to develop skills in: use of microbiological aseptic techniques; microscope skills in observation of prepared slides of pathogenic organisms.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills. These include: use of appropriate units; use of significant figures and decimal places; translating information between graphical, numerical and algebraic forms; plotting two variables from experimental or other data; determining the intercept of a graph; calculating rate of change from a graph showing a linear relationship.

How Science Works
The study of disease and immune response allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; analyse and interpret data to provide evidence, recognising correlations and causal relationships; communicate information and ideas in appropriate ways using appropriate terminology; consider ethical issues in the treatment of humans, other organisms and the environment; evaluate the role of the scientific community in validating new knowledge and ensuring integrity; evaluate the ways in which society uses science to inform decision making.

Immunology and Disease

1. Disease

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the meaning of the following terms: pathogenic, infectious, carrier, disease reservoir, endemic, epidemic, pandemic, vaccine, antibiotic, antigen, antibody, resistance, vector, toxin, antigenic types

(b) the human body acting as a host to other living organisms

(c) the following diseases in terms of: the types of organisms; source of infection; tissue affected; mode of transmission; prevention; control methods and treatment, including vaccines:
- Bacterial infections: cholera; tuberculosis
- Viral infections: smallpox; influenza
- Protoctistan infections: malaria

(d) the relationship between the pathogenicity of viruses and their mode of reproduction

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Immunology and Disease

2. Antibiotics

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the control of bacterial infections by antibiotics which can be bacteriostatic or bactericidal in their mode of action and that antibiotics can be broad or narrow spectrum

(b) the modes of action of penicillin and tetracycline and how the structure of the bacterial cell wall in Gram negative bacteria affords protection against many antibiotics and immune defences

(c) how the overuse of antibiotics has resulted in the spread of antibiotic resistance amongst pathogenic bacteria

3. Immune response

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the natural barriers in the body which reduce the risk of infection, including natural skin flora, connective tissue, localised inflammation, phagocytosis, clotting, tears, mucus and ciliated epithelium

(b) how specific immune responses are developed as a result of exposure to foreign antigens

(c) humoral immune responses, involving the production and secretion of antigen-specific antibodies

(d) cell -mediated immunity, by direct cell contact involving the destruction of pathogens, infected cells and cancerous cells

(e) the role of T lymphocytes and B lymphocytes in cell-mediated and humoral immune responses

(f) specific immune responses induced naturally or artificially to produce an active, long-lived response or acquired passively resulting in short-term protection

(g) the principles of the active immune response can be used medically to immunise against disease, e.g. rubella, without infection by the pathogen

(h) the use of injection of antibodies to provide passive, emergency treatment against an infection, e.g. the treatment of rabies

(i) the different levels of effectiveness of immunisation programmes against different diseases

(j) the ethics which must be taken into consideration when designing vaccination programmes

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OPTION B: HUMAN MUSCULOSKELETAL ANATOMY

Overview
This option covers the structure and function of the skeletal and muscular systems of the human body and some conditions that affect them.

Working scientifically
This topic gives learners opportunities to develop skills in: microscopy, in observation of prepared slides of T.S. and L.S. compact bone and skeletal muscle; safe use of dissection instruments in the dissection of a chicken leg to show structure.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills. These include: use of appropriate units; use of significant figures; translating information between graphical, numerical and algebraic forms; plotting two variables from experimental or other data; determining the intercept of a graph; calculating rate of change from a graph showing a linear relationship

How Science Works
The study of skeletal tissues and anatomy allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; analyse and interpret data to provide evidence, recognising correlations and causal relationships; communicate information and ideas in appropriate ways using appropriate terminology; consider ethical issues in the treatment of humans, other organisms and the environment; evaluate the ways in which society uses science to inform decision making.

1. Skeletal tissues

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of cartilage including hyaline cartilage, yellow elastic cartilage, white fibrous cartilage

(b) the components of compact bone, a matrix which is 30% organic (mainly the protein collagen) and 70% inorganic (the main component being hydroxy-apatite containing calcium and phosphate)

(c) the functions of the organic and inorganic components of compact bone

(d) the functions of osteoblasts and osteoclasts; bone is constantly being broken down and reformed by cells called osteoblasts embedded in the matrix which lay down the inorganic component of the matrix and osteoclasts which break it down

(e) the structure and function of the Haversian systems

(f) rickets and osteomalacia as disorders of bone caused by a calcium or vitamin D deficiency

(g) the causes, symptoms and treatment of osteoporosis and brittle bone disease

(h) the structure and ultra-structure of skeletal muscle

(i) the sliding filament theory to include structure of the thin filaments (actin with two accessory proteins, tropomyosin and troponin) and thick filaments (myosin)

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(j) the differences between ‘fast twitch’ and ‘slow twitch’ muscles

(k) the effects of anaerobic conditions including the role of creatinine phosphate and the build-up of lactic acid in muscles

(l) the use of glycogen and protein as the main sources of energy during muscle contraction

2. Structure and function of human skeleton

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of the appendicular and axial skeleton (pectoral and pelvic girdles, forelimb and hind limb)

(b) the types of fractures that can occur in the skeleton and their causes

(c) the structure and function of the vertebral column, general structure of a vertebra and the differences between cervical, thoracic and lumbar vertebrae and be able to relate them to their function

(d) medical conditions which affect posture, their causes and treatment

(e) the functions of the skeleton, including support, muscle attachment, protection, production of red blood cells and as a store of calcium

3. Joints

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the different types of joint in the human; immovable/fused; gliding joints; hinge; ball and socket

(b) the cause and treatment of osteoarthritis

(c) the cause and treatment of rheumatoid arthritis

(d) the concept of joints acting as levers including examples of 1st order, 2nd order and 3rd order levers

(e) the structure of a typical synovial joint including the roles of cartilage, synovial membrane, synovial fluid, ligaments

(f) the antagonistic muscle action in the human forelimb including the role of tendons

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OPTION C: NEUROBIOLOGY AND BEHAVIOUR

Neurobiology and Behaviour

Overview
This option covers the structure and function of the brain and the technologies that are used to study it. It also looks at different forms of behaviour and the effects these have on an organism's chances of survival.

Working scientifically
This topic gives learners opportunities to develop skills in: applying investigative approaches and safely and ethically using organisms to measure animal responses when using choice chambers for woodlice.

Mathematical Skills
There are a number of opportunities for the development of mathematical skills. These include: use of appropriate units; use of significant figures and decimal places; translating information between graphical, numerical and algebraic forms.

How Science Works
The study of brain and behaviour allows learners to develop the ability to: use theories, models and ideas to develop scientific explanations; analyse and interpret data to provide evidence, recognising correlations and causal relationships; communicate information and ideas in appropriate ways using appropriate terminology; consider applications and implications of science and evaluate their associated benefits and risks; consider ethical issues in the treatment of humans, other organisms and the environment.

1. The Brain

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of the human brain – the position of the cerebrum, hypothalamus, hippocampus, cerebellum and medulla oblongata

(b) the main functions of the cerebrum, hypothalamus, cerebellum and medulla oblongata

(c) the role of the sympathetic and parasympathetic nervous systems

(d) the hypothalamus as the link between nervous and endocrine regulation

(e) the role of the sensory areas and motor areas of the cortex

(f) the relationship between the sizes of the relevant parts of the cerebrum and the complexity of innervation of the different parts of the body as illustrated by the sensory homunculus and the motor homunculus

(g) the role of the areas of the cerebrum involved in language comprehension and speech

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Neurobiology and Behaviour

2. Neuroscience

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the different techniques used for studying the brain without invasive neurosurgery including functional magnetic resonance imaging (fMRI), computerised tomography (CT), positron emission tomography (PET) and electroencephalography (EEG)

(b) how the brain develops and that there are critical periods for certain aspects of human learning and language acquisition

(c) neuroplasticity; changes in neural pathways which enable the brain to respond to changes in the environment and to compensate for injury or disease

(d) how the expression of genes can affect brain development and the impact this may have on an individual's behaviour

(e) how altered gene expression in childhood could predispose adults to an increased risk of mental illness

3. Behaviour

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) innate behaviour and the advantage to organisms of escape reflexes, kineses and taxes as exemplified by woodlice

(b) learned behaviours; including being able to describe habituation, imprinting, classical and operant conditioning

(c) primates, including humans, living in very complex societies and exhibiting behaviours such as imitation and insight

(d) the advantages and disadvantages of living in social groups

(e) the social structure of some insects; based on a caste system and that communication between individuals is brought about by innate behaviours

(f) social structure in vertebrates achieved through dominance hierarchies in which animals are able to recognise each other as individuals and possess some abilities to learn

(g) the advantage of territorial and courtship behaviours in increasing reproductive success

(h) the role of sexual selection in the evolution of territorial and courtship behaviours

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3 ASSESSMENT

3.1 Assessment objectives and weightings

Below are the assessment objectives for this specification. Learners must:

AO1
Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures

AO2
Apply knowledge and understanding of scientific ideas, processes, techniques and procedures:
- in a theoretical context
- in a practical context
- when handling qualitative data
- when handling quantitative data

AO3
Analyse, interpret and evaluate scientific information, ideas and evidence including in relation to issues, to:
- make judgements and reach conclusions
- develop and refine practical design and procedures

The table below shows the weighting of each assessment objective for each component and for the qualification as a whole.

	AO1	AO2	AO3
Component 1	10%	15%	8.3%
Component 2	10%	15%	8.3%
Component 3	10%	15%	8.3%
Overall weighting	30%	45%	25%

For each series:
- the weighting for the assessment of mathematical skills will be a minimum of 10%
- the weighting for the indirect assessment of practical skills will be a minimum of 15%

The ability to select, organise and communicate information and ideas coherently using appropriate scientific conventions and vocabulary will be tested across the assessment objectives.

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3.2 Arrangements for non-exam assessment

PRACTICAL ENDORSEMENT

The assessment of practical skills is a compulsory requirement of the course of study for A level qualifications in Biology. It will appear on all learners' certificates as a separately reported result, alongside the overall grade for the qualification. The arrangements for the assessment of practical skills will be common to all awarding organisations. These arrangements will include:

- A minimum of 12 practical activities to be carried out by each learner which, together, meet the requirements of Appendix A part (b) (Practical skills identified for direct assessment and developed through teaching and learning) and Appendix A part (c) (Use of apparatus and techniques) from the prescribed subject content, published by the Department for Education.

- Teachers will assess learners against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The CPAC (see pages 60 and 61) are based on the requirements of Appendix A parts (b) and (c) of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass.

- Each learner will keep an appropriate record of their assessed practical activities.

- Learners who demonstrate the required standard across all the requirements of the CPAC will receive a 'pass' grade.

- The practical activities prescribed in this specification (the specified practicals) provide opportunities for demonstrating competence in all the skills identified, together with the use of apparatus and techniques for each subject. However, learners can also demonstrate these competences in any additional practical activity undertaken throughout the course of study which covers the requirements of Appendix A part (c).

- There will be no separate assessment of practical skills for AS qualifications.

- Learners will answer questions in the AS and A level examination papers that assess the requirements of Appendix A part (a) (Practical skills identified for indirect assessment and developed through teaching and learning) from the prescribed subject content, published by the Department for Education.

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Criteria for the assessment of practical competency in A level Biology (CPAC)	
Competency	**Practical Mastery:** In order to achieve a **pass,** learners will need to have met the following expectations. Learners will be expected to develop these competencies through the acquisition of the technical skills specified in Appendix A part (c). Learners can demonstrate these competencies in any practical activity undertaken throughout the course of study. The practical activities prescribed in the subject specification, which cover the requirements of appendix A part (c), will provide opportunities for demonstrating competence in all the skills identified together with the use of apparatus and practical techniques for each subject. Learners may work in groups but must be able to demonstrate and record independent evidence of their competency. This must include evidence of independent application of investigative approaches and methods to practical work. Teachers who award a pass to their learners need to be confident that the learner consistently and routinely exhibits the competencies listed below before completion of the A level course.
1. Follows written procedures	Correctly follows written instructions to carry out the experimental techniques or procedures.
2. Applies investigative approaches and methods when using instruments and equipment	Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
3. Safely uses a range of practical equipment and materials	Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary when carrying out experimental techniques and procedures in the lab or field. Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.

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4.	Makes and records observations	Makes accurate observations relevant to the experimental or investigative procedure. Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
5.	Researches, references and reports	Uses appropriate software and/or tools to process data, carry out research and report findings. Cites sources of information demonstrating that research has taken place, supporting planning and conclusions.

Marking and Standardisation
The practical work is assessed by teachers. WJEC Eduqas will support teachers in making judgements against the criteria for assessment.

In co-ordination with other exam boards, WJEC Eduqas will monitor how centres provide learners with opportunities to develop and demonstrate the required practical skills and how they mark the assessments.

Every centre will be monitored at least once in a two-year period in respect of at least one of the A level science subjects.

In common with other exam boards, WJEC Eduqas will require centres to provide a head of centre declaration annually by 5 May confirming they have taken reasonable steps to ensure that learners:

- have undertaken the minimum number of practical activities, and
- have made a contemporaneous record of their work.

If a centre fails to provide a statement, or provides a false statement, this will be treated as malpractice and/or maladministration. Learners will only get a certificate for the practical endorsement if they achieve at least a grade E in the examined part of the qualification.

Practical endorsement results for each learner need to be submitted by centres to WJEC Eduqas by 15 May each year.

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4 TECHNICAL INFORMATION

4.1 Making entries

This is a linear qualification in which all assessments must be taken at the end of the course. Assessment opportunities will be available in the months of May/June each year, from 2017, until the end of the life of this specification.

A qualification may be taken more than once. Candidates must resit all examination components in the same series.

The endorsement grade for NEA may be carried forward for the life of the specification, even if it was awarded by a different awarding body. If a candidate resits an NEA component (rather than carrying forward the previous NEA endorsement grade), it is the new grade that will be used, even if this is 'Not Classified'.

Where a candidate has certificated on two or more previous occasions, the most recent NEA endorsement grade is carried forward, even if this is 'Not Classified'.

The entry code appears below.

WJEC Eduqas A level Biology: A400QS

The current edition of our *Entry Procedures and Coding Information* gives up-to-date entry procedures.

4.2 Grading, awarding and reporting

A level qualifications are reported as a grade from A* to E. Results not attaining the minimum standard for the award will be reported as U (unclassified).

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APPENDIX A

WORKING SCIENTIFICALLY

The practical skills can be split into those which can be assessed indirectly through written examinations (Part (a)) and those that will be assessed directly by teachers through appropriate practical activities (Part (b)).

Part (a) - Practical skills identified for indirect assessment and developed through teaching and learning

Question papers will assess learners' abilities to:

Independent thinking

- solve problems set in practical contexts
- apply scientific knowledge to practical contexts

Use and application of scientific methods and practices

- comment on experimental design and evaluate scientific methods
- present data in appropriate ways
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled

Numeracy and the application of mathematical concepts in a practical context

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
- consider margins of error, accuracy and precision of data

Instruments and equipment

- know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

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Part (b) - Practical skills identified for direct assessment and developed through teaching and learning

Practical work carried out throughout the course will enable learners to develop the following skills.

Independent thinking

- apply investigative approaches and methods to practical work

Use and apply scientific methods and practices

- safely and correctly use a range of practical equipment and materials
- follow written instructions
- make and record observations
- keep appropriate records of experimental activities
- present information and data in a scientific way
- use appropriate software and tools to process data, carry out research and report findings

Research and referencing

- use online and offline research skills including websites, textbooks and other printed scientific sources of information
- correctly cite sources of information

Instruments and equipment

- use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

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Part (c) – Use of apparatus and techniques

The practical work specified in the subject content section has been chosen to facilitate learners in developing the skills and acquiring the techniques listed below.

Practical techniques to be gained by learners

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

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APPENDIX B

PRACTICAL TECHNIQUE REQUIREMENTS AND EXEMPLIFICATION

	Technique	Specification Reference	Specified practical work which exemplifies the practical technique
1	use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)	Core concepts 3	Determination of water potential measuring changes in mass/length
		Core concepts 3	Determination of solute potential by measuring the degree of incipient plasmolysis
		Core concepts 3	Investigation into the permeability of cell membranes using beetroot
		Core concepts 4	Investigation into the effect of temperature or pH on enzyme activity
		Core concepts 4	Investigation into the effect of enzyme or substrate concentration on enzyme activity
		Energy for Life 1	Investigation of dehydrogenase activity
		Energy for Life 2	Investigation into factors affecting the rate of photosynthesis
		Energy for Life 3	Investigation into factors affecting the rate of respiration in yeast
		Requirements for Life 2	Investigation into transpiration using a simple potometer
2	use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer	Core concepts 3	Investigation into the permeability of cell membranes using beetroot
		Requirements for Life 2	Investigation into transpiration using a simple potometer
3	use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions	Core concepts 4	Investigation into the effect of temperature or pH on enzyme activity
		Core concepts 4	Investigation into the effect of enzyme or substrate concentration on enzyme activity
		Energy for Life 1	Investigation of dehydrogenase activity
		Energy for Life 4	Investigation into the numbers of bacteria in fresh and stale milk

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4	use of light microscope at high power and low power, including use of a graticule	Core concepts 2	Calibration of light microscope
		Continuity of Life 4	Low power plan of anther including calculation of actual size and magnification of drawing
		Requirements for Life 1	Low power plan of TS leaf including calculation of actual size and magnification of drawing
		Requirements for Life 2	Low power plan of TS artery and vein including calculation of actual size and magnification of drawing
5	produce scientific drawing from observation with annotations	Core concepts 2	Scientific drawing of living cells
		Continuity of Life 2	Preparation and drawing of cells of root tip
		Continuity of Life 2	Scientific drawing of cells of anther
6	use qualitative reagents to identify biological molecules	Core concepts 1	Food tests
		Energy for Life 1	Investigation of dehydrogenase activity
7	separate biological compounds using thin layer / paper chromatography or electrophoresis	Energy for Life 2	Investigation into the separation of chloroplast pigments by chromatography
8	safely and ethically use organisms to measure • plant or animal responses • physiological functions	Energy for Life 2	Investigation into the role of nitrogen and magnesium in plant growth
		Energy for Life 3	Investigation into factors affecting the rate of respiration in yeast
		Energy for Life 4	Investigation into the numbers of bacteria in fresh and stale milk
		Continuity of Life 4	Investigation of the digestion of starch agar using germinating seeds
		Continuity of Life 5	Experiment to illustrate gene segregation
		Requirements for Life 2	Investigation into transpiration using a simple potometer
		Continuity of Life 1	Investigation into biodiversity
9	use microbiological aseptic techniques, including the use of agar plates and broth	Energy for Life 4	Investigation into the numbers of bacteria in fresh and stale milk

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10	safely use instruments for dissection of an animal organ, or plant organ	Continuity of Life 4	Dissection of wind and insect pollinated flowers
		Requirements for Life 1	Dissection of fish head
		Requirements for Life 2	Dissection of mammalian heart
		Requirements for Life 4	Dissection of mammalian kidney
11	use sampling techniques in fieldwork	Energy for Life 5	Investigation into the abundance and distribution of organisms in an environment
		Continuity of Life 1	Investigation into biodiversity in a habitat
		Continuity of Life 6	Investigation of continuous variation
12	use ICT such as computer modelling, or data logger to collect data, or use software to process data	Energy for Life 2	Investigation into the role of nitrogen and magnesium in plant growth
		Continuity of Life 6	Investigation of continuous variation
		Continuity of Life 5	Experiment to illustrate gene segregation
		Requirements for Life 2	Investigation into transpiration using a simple potometer
		Continuity of Life 1	Investigation into biodiversity in a habitat
		Energy for Life 2	Investigation into factors affecting the rate of photosynthesis

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APPENDIX C

MATHEMATICAL REQUIREMENTS AND EXEMPLIFICATION

Mathematical skills	Exemplification of mathematical skill in the context of A level Biology (assessment is not limited to the examples given below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
Arithmetic and numerical computation		
Recognise and make use of appropriate units in calculations	Learners may be tested on their ability to: • convert between units, e.g. mm^3 to cm^3 as part of volumetric calculations • work out the unit for a rate e.g. breathing rate	C1(c), C1(f), C1(h), C2(c), C2(d), C3(b),C3(c), C4(g), C4(h),1.2 (c),1.2(k), 1.3(e),1.4 (d), 1.5 (h), 2.2 (a), 2.2(d), 2.3(c), 2.4(b), 3.1(a), 3.1(c), 3.1(d), 3.2(a), 3.2(c), 3.2(d), 3.2(o), 3.3(i), 3.4(c), 3.5(h)
Recognise and use expressions in decimal and standard form	Learners may be tested on their ability to: • use an appropriate number of decimal places in calculations, e.g. for a mean • carry out calculations using numbers in standard and ordinary form, e.g. use of magnification • understand standard form when applied to areas such as size of organelles • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. 0.0050 mol dm^{-3} is equivalent to 5.0×10^{-3} mol dm^{-3}	C2(a), C2(c), C2(d), C3(b), C3(c), C4(g), C4(h), 1.1(a), 1.3(e), 1.4 (d), 1.5(d), 1.5 (h), 2.1(j), 2.2 (a), 2.2(d), 3.1(a), 3.1(c), 3.1(d), 3.2(d), 3.4(d), 3.5(h)

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Use ratios, fractions and percentages	Learners may be tested on their ability to: • calculate percentage yields • calculate surface area to volume ratio • use scales for measuring • represent phenotypic (monohybrid and dihybrid crosses)	C1(c), C1(f), C1(h), C2(a), C2(c), C2(d),C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(e), 1.4(d), 1.5(a), 1.5(b), 1.5(d), 1.5(h), 2.1(j), 2.1 (k), 2.1(l), 2.2(a), 2.2(d), 2.5(b), 2.5(c), 2.6(h), 3.1(a), 3.1(c), 3.1(d), 3.2(d), 3.2(o), 3.3(i), 3.4(i)
Estimate results	Learners may be tested on their ability to: • estimate results to sense check that the calculated values are appropriate	C3(b), C3(c), 3.1(a), 3.2(a) 3.3(i)
Use calculators to find and use power, exponential and logarithmic functions	Learners may be tested on their ability to: • estimate the number of bacteria grown over a certain length of time	1.4(d),1.5 (b)
Handling data		
Use an appropriate number of significant figures	Learners 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	C2(a), C2(c), C2(d), C3(b), C3(c), C4(g), C4(h), 1.1(a), 1.2(k), 1.4(d), 1.5 (b), 2.1(j), 2.1(k), 2.1(l), 2.4(b), 2.5(d), 2.6(h), 3.1(a), 3.1(c), 3.1(d), 3.2(d), 3.4(c)
Find arithmetic means	Learners may be tested on their ability to: • find the mean of a range of data, e.g. the mean number of stomata in the leaves of a plant	C3(b), C3(c), C4(g), C4(h), 1.1(a), 1.2(k), 1.3(a), 1.4(d), 1.5(d), 2.4(f), 2.6(b) 3.1(l), 3.2(o)

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Construct and interpret frequency tables and diagrams, bar charts and histograms	Learners may be tested on their ability to: • represent a range of data in a table with clear headings, units and consistent decimal places • interpret data from a variety of tables, e.g. data relating to organ function • plot a range of data in an appropriate format, e.g. enzyme activity over time represented on a graph • interpret data for a variety of graphs, e.g. explain electrocardiogram traces	C1(c), C1(f), C1(h), C3(b), C3(c), C4(g), C4(h), 1.1(a), 1.2(k), 1.3(a), 1.4(d), 1.5(a), 1.5(b), 1.5(d), 1.5(h), 2.1(h), 2.3(c), 2.4(f), 2.4(g), 2.6(b), 3.1(d), 3.1(e), 3.1(f), 3.1(l), 3.2(c), 3.2(d), 3.2(e), 3.2(f), 3.2(o),3.4(a), 3.5(h)
Understand simple probability	Learners may be tested on their ability to: • use the terms probability and chance appropriately • understand the probability associated with genetic inheritance	2.1(j), 2.5(b), 2.5(c), 2.5(d), 2.6(b)
Understand the principles of sampling as applied to scientific data	Learners may be tested on their ability to: • analyse random data collected by an appropriate means, e.g. use Simpson's Diversity Index to calculate the biodiversity of a habitat	1.6(d), 2.1(j), 2.6(b)
Understand the terms mean, median and mode	Learners may be tested on their ability to: • calculate or compare the mean, median and mode of a set of data, e.g. height/mass/size of a group of organisms	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a), 1.4(d), 1.5(d) 2.4(f), 2.6(b), 3.1(l), 3.2(o)
Use a scatter diagram to identify a correlation between two variables	Learners may be tested on their ability to: • interpret a scattergram, e.g. the effect of life style factors on health	C1(c), C1(f), C1(h), C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a), 1.4(d), 1.5(a), 1.5(b), 1.5(d), 1.5(h), 2.1(h), 2.3(c), 2.4(f), 2.4(g), 2.6(b), 3.1(d), 3.1(e), 3.1(f), 3.1(l), 3.2(e), 3.2(o), 3.4(a)

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Make order of magnitude calculations	Learners may be tested on their ability to: • use and manipulate the magnification formula magnification = $\frac{\text{size of image}}{\text{size of real object}}$	C2(a), C2(c), C2(d), 2.2(a), 3.1(g), 3.2(i), 3.3(g), 3.4(c)
Select and use a statistical test	Learners may be tested on their ability to select and use: • the chi squared test to test the significance of the difference between observed and expected results • the Student's t-test • the correlation coefficient	1.5(d), 2.1(j), 2.5(d), 2.6(b)
Understand measures of dispersion, including standard deviation and range	Learners may be tested on their ability to: • calculate the standard deviation • understand why standard deviation might be a more useful measure of dispersion for a given set of data e.g. where there is an outlying result	C3(b), C3(c), C4(g), C4(h), 1.2(k),1.4(d), 1.6(d), 2.6(b)
Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Learners may be tested on their ability to: • calculate percentage error where there are uncertainties in measurement	C3(b), C3(c), C4(g), C4(h)
Algebra		
Understand and use the symbols: =, <, <<, >>, >, ∝, ~.	No exemplification required.	C2(a), C2(b), C3(b), C3(c), 3.1(a), 3.1(b)
Change the subject of an equation	Learners may be tested on their ability to: • use and manipulate equations, e.g. magnification	C2(a), C2(c), C2(d), C3(c), 2.2(a), 2.6(h)
Substitute numerical values into algebraic equations using appropriate units for physical quantities	Learners may be tested on their ability to: • use a given equation e.g. Simpson's Diversity Index	C2(a), C2(c), C2(d), C3(c), 2.1(j), 2.2(a), 2.4(b), 2.6(h), 3.1(g), 3.3(g), 3.4(c)
Solve algebraic equations	Learners may be tested on their ability to: • solve equations in a biological context, e.g. cardiac output = stroke volume x heart rate	C2(a), C2(c), C2(d), C3(c), 2.1(j), 2.2(a), 2.4(b), 2.6(h), 3.1(g), 3.3(g)

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Use logarithms in relation to quantities that range over several orders of magnitude	Learners may be tested on their ability to: ● use a logarithmic scale in the context of microbiology, e.g. growth rate of a microorganism such as yeast	1.4(d),1.5 (b)

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Graphs		
Translate information between graphical, numerical and algebraic forms	Learners may be tested on their ability to: ● understand that data may be presented in a number of formats and be able to use these data, e.g. dissociation curves	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a), 1.4(d), 1.5(a), 1.5(b), 1.5(d), 1.5(h), 2.1(h), 2.3(c), 2.4(f), 2.4(g), 2.6(b), 3.1(d), 3.1(e), 3.1(f), 3.1(l), 3.2(c), 3.2(d), 3.2(e), 3.2(f), 3.2(o), 3.3(g), 3.4(a), 3.5(h)
Plot two variables from experimental or other data	Learners may be tested on their ability to: ● select an appropriate format for presenting data, bar charts, histograms, graphs and scattergrams	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a), 1.4(d), 1.5(a), 1.5(b), 1.5(h), 2.1(h), 2.4(f), 2.4(g), 2.6(b), 3.1(e), 3.1(f), 3.1(l), 3.2(o), 3.4(a)
Understand that $y = mx + c$ represents a linear relationship	Learners may be tested on their ability to: ● predict/sketch the shape of a graph with a linear relationship, e.g. the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a)
Determine the intercept of a graph	Learners may be tested on their ability to: ● read off an intercept point from a graph, e.g. compensation point in plants	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a),1.4(d), 1.5(b), 2.3(c), 3.2(o)
Calculate rate of change from a graph showing a linear relationship	Learners may be tested on their ability to: ● calculate a rate from a graph, e.g. rate of transpiration	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a),1.4(d), 1.5(b), 3.2(o)
Draw and use the slope of a tangent to a curve as a measure of rate of change	Learners may be tested on their ability to: ● use this method to measure the gradient of a point on a curve, e.g. amount of product formed plotted against time when the concentration of enzyme is fixed	C3(b), C3(c), C4(g), C4(h), 1.2(k), 1.3(a),1.4(d), 1.5(b), 3.2(o)

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Geometry and trigonometry		
Calculate the circumferences, surface areas and volumes of regular shapes	Learners may be tested on their ability to: • calculate the circumference and area of a circle • calculate the surface area and volume of rectangular prisms, of cylindrical prisms and of spheres e.g. calculate the surface area or volume of a cell	C3(b), C3(c), 3.1(a), 3.2(o), 3.2(p)

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APPENDIX D

HOW SCIENCE WORKS REQUIREMENTS AND EXEMPLIFICATION

How Science Works Skill	Areas of the specification which exemplify the how science works skill (assessment is not limited to the examples below)
use theories, models and ideas to develop scientific explanations	C1(d), C2(c), C3(a), C4(d), C4(d), C5(a), C5(e), C5(h), C5(l), C5(m), 1.1(a), 1.2(f), 1.3(b), 1.3(c), 1.4(a), 1.5(a), 2.1(a), 2.1(b), 2.2(a), 2.2(d), 2.4(d), 2.5(b), 2.5(c), 2.5(h), 2.6(h), 2.6(l), 3.1(a), 3.1(f), 3.2(c), 3.2(k), 3.2(o), 3.2(r), 3.4(a), 3.4(b), 3.5(j), 3.5(k)
use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas	C1(b), C2(a), C2(b), C3(c), C4(g), 1.2(k), 1.5(a), 2.1(j), 2.1(k), 2.1(l), 2.5(h), 2.6(l), 3.1(c), 3.1(k), 3.2(a), 3.2(c), 3.2(o), 3.5(e)
use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems	C1(c), C1(e), C1(h), C3(c), 1.2(k), 1.2(l), 1.4(d), 1.5(d), 2.1(j), 2.4(f), 2.5(b), 2.5(c), 2.6(b), 3.1(f), 3.1(c), 3.1(k), 3.2(a), 3.2(o)
carry out experimental and investigative activities, including appropriate risk management, in a range of contexts	C1(c), C1(e), C1(h), C2(c), C2(d), C3(c), C4(g), C5(e), 1.2(k), 1.2(l), 1.3(a), 1.4(a), 1.4(d), 1.5(d), 2.1(j), 2.4(f), 2.5(d), 2.6(b), 3.1(k), 3.2(o)
analyse and interpret data to provide evidence, recognising correlations and causal relationships	C3(c), C4(g), 1.2(k), 1.2(l), 1.3(a), 1.4(d), 1.5(d), 2.1(j), 2.3(c), 2.4(f), 2.5(d), 2.6(b), 3.1(k), 3.2(c), 3.2(d), 3.2(e), 3.2(o), 3.3(g), 3.3(i), 3.4(a), 3.4(i), 3.5(h)
evaluate methodology, evidence and data, and resolve conflicting evidence	C3(c), C4(g), 1.2(k), 1.3(a), 1.5(d), 2.1(j), 2.4(f), 2.5(d), 2.6(b), 3.1(k), 3.2(o)
know that scientific knowledge and understanding develops over time	C2(c), C4(e), 2.1(c), 2.1(e), 2.5(h), 2.7(c), 2.7(d), 3.2(r)
communicate information and ideas in appropriate ways using appropriate terminology	C1(c), C1(e), C1(h), C2(a), C4(g), C5(a), C5(e), C5(h), C5(l), C5(m), 1.1(a), 1.2(f), 1.3(b), 1.3(c), 2.2(a), 2.2(d), 2.3(a), 2.3(b), 2.3(c), 2.6(b), 3.2(c), 3.2(d), 3.3(a), 3.3(b)
consider applications and implications of science and evaluate their associated benefits and risks	C1(g), C4(i), 1.5(m), 1.5(n), 1.5(o), 1.6(a), 1.6(b), 1.6(c), 2.2(c), 2.5(f), 2.5(g), 3.3(j), 3.4(h), 3.5(l)
consider ethical issues in the treatment of humans, other organisms and the environment	1.5(m), 1.5(n), 1.5(o), 1.6(a), 1.6(b), 1.6(c), 2.1(k), 2.1(i),2.2(c), 2.5(g), 2.5(h), 2.6(d), 2.7(b), 2.7(f), 2.7(i), 3.4(h), 3.5(l)

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evaluate the role of the scientific community in validating new knowledge and ensuring integrity	C5(h), 1.5(m), 1.5(n), 1.5(o), 1.6(d), 1.6(e), 1.6(f), 2.1(b), 2.1(c), 2.1(e), 2.1(i), 2.2(c), 2.5(h), 2.6(l), 2.7(f), 2.7(g), 2.7(h), 2.7(i), 3.4(h)
evaluate the ways in which society uses science to inform decision making.	C1(i), 1.5(m), 1.5(n), 1.5(o), 1.6(d), 1.6(e), 1.6(f), 2.1(b), 2.1(c), 2.1(i), 2.2(c), 2.6(d), 2.7(a), 2.7(f), 2.7(h), 3.4(h)

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