SCQF level 6
Unit Specification

Biology: Metabolism and Survival Unit

SCQF: level 6 (6 SCQF credit points)

Unit code: H4KE 76

Unit outline

The general aim of this Unit is to develop skills of scientific inquiry, investigation and analytical thinking, along with knowledge and understanding of metabolism and survival.

Learners will apply these skills when considering the applications of metabolism and survival on our lives. This can be done by using a variety of approaches, including investigation and problem solving.

The Unit covers the key areas of:
metabolic pathways and their control; cellular respiration; metabolic rate; metabolism in conformers and regulators; metabolism and adverse conditions; environmental control of metabolism; genetic control of metabolism; ethical considerations in use of microorganisms, hazards and control of risks.

Learners will research issues, apply scientific skills and communicate information related to their findings, which will develop skills of scientific literacy.

Learners who complete this Unit will be able to:

1 Apply skills of scientific inquiry and draw on knowledge and understanding of the key areas of this Unit to carry out an experiment/practical investigation
2 Draw on knowledge and understanding of the key areas of this Unit and apply scientific skills

This Unit is available as a free-standing Unit. The *Unit Support Notes* in the Appendix provide advice and guidance on delivery, assessment approaches and development of skills for learning, skills for life and skills for work. Exemplification of the standards in this Unit is given in Unit Assessment Support.

Recommended entry

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by one or more of the following or equivalent qualifications and/or experience:

- National 5 Biology Course or relevant component Units

Equality and inclusion

This Unit Specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence. For further information, please refer to the Appendix: *Unit Support Notes.*

Standards

Outcomes and assessment standards

Outcome 1

The learner will:

1 Apply skills of scientific inquiry and draw on knowledge and understanding of the key areas of this Unit to carry out an experiment/practical investigation by:

1.1 Planning an experiment/practical investigation
1.2 Following procedures safely
1.3 Making and recording observations/measurements correctly
1.4 Presenting results in an appropriate format
1.5 Drawing valid conclusions
1.6 Evaluating experimental procedures

Outcome 2

The learner will:

2 Draw on knowledge and understanding of the key areas of this Unit and apply scientific skills by:

2.1 Making accurate statements
2.2 Solving problems

Evidence Requirements for the Unit

Assessors should use their professional judgement, subject knowledge and experience, and understanding of their learners, to determine the most appropriate ways to generate evidence and the conditions and contexts in which they are used.

The key areas covered in this Unit are:
metabolic pathways and their control; cellular respiration; metabolic rate; metabolism in conformers and regulators; metabolism and adverse conditions; environmental control of metabolism; genetic control of metabolism; ethical considerations in use of microorganisms, hazards and control of risks.

Evidence can be drawn from a variety of sources and presented in a variety of formats.

The following table describes the evidence for the assessment standards which require exemplification. Evidence may be presented for individual outcomes, or gathered for the unit. If the latter approach is used, it must be clear how the evidence covers each outcome.

Assessment Standard	**Evidence required**
Planning an experiment	The plan should include: ♦ a clear statement of the aim ♦ a hypothesis ♦ a dependent and independent variable ♦ variables to be kept constant ♦ measurements/observations to be made ♦ the equipment/materials ♦ a clear and detailed description of how the experiment/practical investigation should be carried out, including safety considerations
Presenting results in an appropriate format	One format from: table, line graph, chart, key, diagram, flow chart, summary, extended text or other appropriate format
Drawing a valid conclusion	Include reference to the aim
Evaluating experimental procedures	Suggest two improvements with justification
Making accurate statements	At least half of the statements should be correct across the key areas of this Unit
Solving problems	One of each: ♦ make generalisations/predictions ♦ select information ♦ process information, including calculations, as appropriate ♦ analyse information

Exemplification of assessment is provided in Unit assessment support packs.
Advice and guidance on possible approaches to assessment is provided in the Appendix: *Unit Support Notes.*

Assessment Standard Thresholds

Outcome 1

Candidates are not required to show full mastery of the assessment standards to achieve Outcome 1. Instead, five out of the six assessment standards for Outcome 1 must be met to achieve a pass. Candidates must be given the opportunity to meet all assessment standards. The threshold has been put in place to reduce the volume of re-assessment where that is required.

Transfer of evidence
Evidence of Outcome 1 in a unit is transferrable between the other units at SCQF level 6.

Re-assessment
Candidates can be given the opportunity to re-draft their original Outcome 1 report or to carry out a new experiment/practical investigation.

Outcome 2

There is no requirement to pass assessment standard 2.1 (making accurate statements) and assessment standard 2.2 (solving problems) independently. Candidates can be assessed using a single test that contains marks and a cut-off score.
A suitable unit assessment will cover all of the key areas (assessment standard 2.1) **and** assess each of the problem-solving skills (assessment standard 2.2).

Where a candidate achieves 50% or more of the total marks available in a single unit assessment, they will pass Outcome 2 for that unit. Existing unit assessment support packs (UASPs) can be used, or centres can replace the questions with suitable alternatives of a similar standard

Unit assessment support pack 1 contains questions on all of the key areas (AS 2.1) and questions covering each of the problem solving skills (AS 2.2), and may be adapted for use as a single assessment. The number of marks available for each question should be combined to give the total number of marks available. A cut-off score of 50% should be applied to the unit assessments.

Outcome 2: assessment activity 2 – tests contain questions covering assessment standards 2.1 and 2.2 in a single assessment. These do not require to be adapted.

Important note: Centres can continue to assess AS 2.1 and 2.2 separately using the existing UASPs. If this option is chosen, 50% or more of the KU statements (AS 2.1) made by candidates must be correct in the unit assessment and at least one correct response for each problem solving skill (AS 2.2) is required to pass outcome 2. However, if a candidate is given more than one opportunity in a unit assessment to provide a response for a problem solving skill, then they must answer 50% or more correctly.

Re-assessment

SQA's guidance on re-assessment is that there should only be one or, in exceptional circumstances, two re-assessment opportunities. Re-assessment should be carried out under the same conditions as the original assessment. It is at the teacher or lecturer's discretion how they re-assess their candidates. Candidates may be given a full re-assessment opportunity, or be re-assessed on individual key areas and/or problem-solving skills. As there is no requirement to pass assessment standard 2.1 (making accurate statements) and assessment standard 2.2 (solving problems) independently, candidates must achieve 50% of the marks available in the re-assessment.

Development of skills for learning, skills for life and skills for work

It is expected that learners will develop broad, generic skills through this Unit. The skills that learners will be expected to improve on and develop through the Unit are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and drawn from the main skills areas listed below. These must be built into the Unit where there are appropriate opportunities.

1 Literacy

1.2 Writing

2 Numeracy

2.1 Number processes
2.2 Money, time and measurement
2.3 Information handling

5 Thinking skills

5.3 Applying
5.4 Analysing and evaluating
5.5 Creating

Amplification of these is given in SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work.* The level of these skills should be at the same SCQF level of the Unit and be consistent with the SCQF level descriptor. Further information on building in skills for learning, skills for life and skills for work is given in the Appendix: *Unit Support Notes.*

Appendix: Unit support notes

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing this Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Assessment Support packs*

Developing skills, knowledge and understanding

Teachers and lecturers are free to select the skills, knowledge, understanding and contexts which are most appropriate for delivery in their centres.

Approaches to learning and teaching

key areas	Suggested learning activities	Exemplification of key areas
1 Metabolic pathways and their control (a) Introduction to metabolic pathways — integrated and controlled pathways of enzyme-catalysed reactions within a cell.	Case study on the toxic effects of venoms, toxins and poisons on metabolic pathways.	
(i) Anabolic (energy requiring) and catabolic (energy releasing) pathways — can have reversible and irreversible steps and alternative routes.		Metabolic pathways involve biosynthetic processes (anabolism) and the breakdown of molecules (catabolism) to provide energy and building blocks.
(ii) Membranes form surfaces and compartments for metabolic pathways. The high surface area to volume ratio of small compartments allows high concentrations and reaction rates. Protein pores, pumps and enzymes embedded in phospholipid membranes.	Examine photomicrographs to compare ultrastructure of prokaryotes and eukaryotes and compartments and membranes in mitochondria and chloroplasts.	Membranes can form compartments to localise the metabolic activity of the cell.
(b) Control of metabolic pathways (presence or absence of particular enzymes and the regulation of the rate of reaction of key enzymes within the pathway).	Enzyme induction experiments such as ONPG and lactose metabolism in *E. coli* and PGlo experiments.	Regulation can be controlled by intra- and extra cellular signal molecules.
(i) Induced fit and the role of the active site of enzymes including shape and substrate affinity and orientation of reactants. Products have a low affinity for the active site. Activation energy. The effects of substrate and end product concentration on the direction and rate of enzyme reactions. Enzymes often act in groups or as multi-enzyme complexes.	Activation energy experiments, comparing heat, manganese dioxide and catalase action on hydrogen peroxide. Experiments on reaction rate with increasing substrate concentration.	The role of the active site in orientating reactants, lowering the activation energy of the transition state and the release of products with low affinity for the active site. Most metabolic reactions are reversible and the presence of a substrate or the removal of a product will drive a sequence of reactions in a particular direction.

key areas	Suggested learning activities	Exemplification of key areas
(ii) Control of metabolic pathways through competitive, non-competitive and feedback inhibition of enzymes.	Investigate the inhibition of beta galactosidase by galactose and its reversal by increasing ONPG concentration. Experiments on product inhibition with phosphatase.	Genes for some enzymes are continuously expressed. These enzymes are always present in the cell and they are controlled through the regulation of their rates of reaction. Competitive inhibition can be reversed by increasing substrate concentration.
2 Cell respiration (a) Glucose is broken down, hydrogen ions and electrons are removed by dehydrogenase enzymes and ATP is released.		Cellular respiration pathways are present in cells from all three domains of life. The metabolic pathways of cellular respiration are of central importance to cells. They yield energy and are connected to many other pathways.
(b) The role of ATP in the transfer of energy and the phosphorylation of molecules by ATP.	Experiments on ATP dependent reactions, eg luciferase, luminescent reactions. Investigate a phosphorylated substrate (eg glucose-1-phosphate) using suitable positive and negative controls in the design of an experiment.	ATP is used to transfer energy to synthetic pathways and other cellular processes where energy is required. The return flow of H ions rotates part of the membrane protein ATP synthase, catalysing the synthesis of ATP.
(c) Metabolic pathways of cellular respiration. The breakdown of glucose to pyruvate in the cytoplasm in glycolysis. The phosphorylation of intermediates in glycolysis in an energy investment phase leading to the direct generation of more ATP in an energy pay-off stage giving a net gain	Research how Hans Krebs discovered the citric acid cycle. Experiments on inhibition of citric acid cycle with malonic acid and DCPIP as an indicator of dehydrogenase activity.	

key areas	Suggested learning activities	Exemplification of key areas
of ATP. Pyruvate is broken down to an acetyl group that combines with coenzyme A to be transferred to the citric acid cycle as acetyl coenzyme A. Acetyl coenzyme A combines with oxaloacetate to form citrate followed by the enzyme mediated steps of the cycle. This cycle results in the generation of ATP, release of CO2, and the regeneration of oxaloacetate in the matrix of the mitochondria. In the absence of oxygen pyruvate undergoes fermentation to lactate or ethanol and CO2. Dehydrogenase enzymes remove H ions and electrons, which are passed to coenzymes NAD or FAD (forming NADH or FADH2) in glycolysis and citric acid pathways. The H ions and high energy electrons are passed to the electron transfer chain on the inner mitochondrial membrane and results in the synthesis of ATP.	Experiments with yeast dehydrogenase, eg using resazurin.	The electron transport chain as a collection of proteins attached to a membrane. Energy is released and ATP synthase generates ATP.
(d) ATP synthesis — high energy electrons are used to pump H ions across a membrane and the flow of these ions synthesises ATP by the membrane protein ATP synthase.		

key areas	Suggested learning activities	Exemplification of key areas
Oxygen is the final electron acceptor, combines with H ions and electrons, forming water.		
(e) Substrates for respiration - starch and glycogen are broken down to glucose; other sugars are converted to glucose or glycolysis intermediates; fats and proteins can be converted to intermediates of glycolysis and the citric acid cycle.	Investigation of different sugars as respiratory substrates in yeast. Research different use of substrates during exercise and starvation.	
3 Metabolic rate (a) Measurement of oxygen consumption, carbon dioxide and heat production to compare metabolic rates.	Investigate metabolic rate using oxygen, carbon dioxide and temperature probes.	Comparison of metabolic rates of different organisms at rest.
(b) High metabolic rates require efficient delivery of oxygen to cells. Comparative anatomy and physiology of heart chambers, circulation and lung arrangement in amphibians, reptiles, mammals and birds, and heart and circulation in fish.		
(c) Physiological adaptations of animals for low oxygen niches.	Case study on adaptations to survive low-oxygen niches.	As oxygen is consumed during aerobic respiration, high metabolic rates require efficient delivery of oxygen to cells. Low oxygen niches eg high altitude, deep diving. The variation in atmospheric oxygen concentration over a long geological timescale and how this relates to maximum terrestrial body size.
(d) The use of maximum oxygen uptake as a measure of fitness in humans.		

key areas	Suggested learning activities	Exemplification of key areas
4 Metabolism in conformers and regulators (a) The ability of an organism to maintain its metabolic rate is affected by external abiotic factors.		Abiotic factors such as temperature, salinity and pH.
(b) Conformers internal environment is dependent upon external environment. Conformers may have low metabolic costs and a narrow ecological niche. Behavioural responses to maintain optimum metabolic rate.	Case study on the response of a conformer to a change in an environmental factor. Comparisons of marine and estuarine invertebrates and their response to variation in salinity.	Conformers may have a narrow ecological niche unless they can tolerate or resist variation in their external environment.
(c) Regulators use metabolism to control their internal environment, which increases the range of possible ecological niches. Regulation requires energy to achieve homeostasis.	Experiments using thermistors or infra-red thermometers on skin temperature and its regulation in humans.	
(d) Negative feedback control and thermoregulation in mammals including the role of the hypothalamus, nerves, effectors and skin).		
(e) Importance of regulating temperature for optimal enzyme controlled reaction rates and diffusion rates to maintain metabolism.		
5 Metabolism and adverse conditions (a) Surviving adverse conditions. Metabolic rate is reduced. Dormancy is part of some organisms' lifecycle and may be predictive or consequential. Examples of dormancy include hibernation and aestivation. Hibernation is often defined in terms of	Research and scientific presentation on aspects of surviving adverse conditions. Seed dormancy experiments. Research seed banks and the practicalities of maintaining viable stocks.	Many environments vary beyond the tolerable limits for normal metabolic activity for any particular organism. To allow survival during a period when the costs of continued normal metabolic activity would be too high, the metabolic rate can

key areas	Suggested learning activities	Exemplification of key areas
mammals. Aestivation allows survival in periods of high temperature or drought. Daily torpor as a period of reduced activity in organisms with high metabolic rates.		be reduced. Dormancy is part of some organisms' lifecycle and may be predictive or consequential. Examples of dormancy include hibernation and aestivation. (Exemplify terms and relationships and the 'uncertainty' of categorising.)
(b) Avoiding adverse conditions by migration. Migration avoids metabolic adversity by expending energy to relocate to a more suitable environment. Long-distance migration studies. Innate and learned influences on migratory behaviour.	Evaluate procedures and results of studies investigating triggers for migration, navigation adaptations. Research the genetic control of migratory behaviour in studies of populations of the blackcap.	The use of specialised techniques in studies of long-distance migration, such as individual marking and types of tracking to overcome the difficulties involved in the study of migratory vertebrates and invertebrates. The design of experiments to investigate the innate and learned influences on migratory behaviour.
(c) Extremophiles — some species have enzymes that are extremely tolerant and allow them to thrive in environments that would be lethal to almost all other species. Examples of extremophiles include thermophilic bacteria living in hot springs or seabed vents which may generate ATP by removing high energy electrons from inorganic molecules.	Research different types of extremophiles. Research use of H2 in methanogenic bacteria and H2S in sulphur bacteria	Use of heat-tolerant DNA polymerase from thermophilic bacterium in PCR.
6 Environmental control of metabolism Microorganisms to include archaea, bacteria and some species of eukaryota.		Microorganisms include species that use a wide variety of substrates for metabolism and produce a range of products from their

key areas	Suggested learning activities	Exemplification of key areas
		metabolic pathways. Microorganisms are used because of their adaptability, ease of cultivation and speed of growth.
(a) Variations in growth media and control of environmental factors. Microorganisms require an energy source (chemical or light) and raw materials from simple chemical compounds for biosynthesis. Many microorganisms can produce all the complex molecules required, including amino acids required for protein synthesis. Other microorganisms require more complex compounds to be added to the growth media, including vitamins and fatty acids. Culture conditions include sterility to eliminate any effects of contaminating microorganisms, control of temperature, control of oxygen levels by aeration and control of pH by buffers or the addition of acid or alkali.	Investigate the growth of microbes under different cultural and environmental conditions using standard laboratory equipment and simple fermenters. Isolate yeast from grapes using selective media and appropriate growing conditions.	Energy is derived either from chemical substrates or from light in photosynthetic microorganisms. Growth media can be composed of specific substances or can contain complex ingredients such as beef extract.
(b) Phases of growth and doubling or mean generation time of exponential growth and changes in culture conditions. Phases to include lag (enzymes induced), log/exponential, stationary (culture depleted and secondary metabolites produced) and death (lack of substrate and toxic		Interpretation of exponential growth on normal and semi-logarithmic scales.

key areas	Suggested learning activities	Exemplification of key areas
accumulation of metabolites). Viable and total cell count.		
(c) Control of metabolism through the addition of metabolic precursors, inducers or inhibitors to give a required product. Secondary metabolism can confer an ecological advantage by producing substances not associated with growth.	Experiments on the induction of enzymes in microorganisms. Research industrial processes that use microorganisms. Suitable processes that involve underpinning biology include: citric acid production, glutamic acid production, penicillin production and therapeutic proteins such as insulin, human growth hormone and erythropoietin.	
7 Genetic control of metabolism (a) Wild strains of microorganisms can be improved by mutagenesis, selective breeding and culture or recombinant DNA. Some bacteria can transfer plasmids or chromosomal DNA to each other or take up DNA from the environment to produce new strains. Fungi such as yeast can produce new phenotypes by sexual reproduction.	Investigate transfer of DNA using bacteria. Experiments investigating the effects of UV radiation on UV sensitive yeast.	Exposure to UV light and other forms of radiation or mutagenic chemicals results in mutations some of which may produce an improved strain. Mutant strains are often genetically unstable and revert to the wild type in continuous culture. Some bacteria can transfer plasmids or pieces of chromosomal DNA to each other (horizontal transfer) or take up DNA from their environment to produce new strains. In fungi and yeast, new genotypes can be brought about by sexual reproduction between existing strains.
(b) Recombinant DNA technology, plasmids and artificial chromosomes. Restriction endonucleases, marker genes, restriction sites, origin of replication,	Case study on bacterial transformation.	Restriction endonucleases cut target sequences of DNA and can leave sticky ends. Vectors with complementary sticky ends

key areas	Suggested learning activities	Exemplification of key areas
selective markers and regulatory sequences. Use of ligase in recombinant DNA. Genes can be introduced that remove inhibitory controls or amplify specific metabolic steps in a pathway to increase yield. As a safety mechanism, genes are often introduced that prevent the survival of the microorganism in an external environment. Control of gene expression in recombinant plasmids and artificial chromosomes. Use of recombinant yeast cells to avoid polypeptides being folded incorrectly or lacking post translational modifications.		are then combined with target sequences using ligase. Genes that remove inhibitory controls or amplify specific metabolic steps in a pathway can be introduced to increase yield. Recombinant plasmids and artificial chromosomes contain marker genes and restriction sites in addition to genes for self-replication and regulatory sequences to allow the control of gene expression. Recombinant yeast cells may be used as plant or animal recombinant DNA expressed in bacteria may result in incorrect folding or may lack post-translational modifications.
8 Ethical considerations in the use of microorganisms — hazards and control of risks.	Research the development of a microbiological product from discovery to market.	

Administrative information

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Superclass: RH

History of changes to National Unit Specification

Version	Description of change	Authorised by	Date
2.0	Page 1 – the description of key areas under 'Unit outline' has been revised to give more information Page 4 – in Outcome 1.3, the word 'accurately' has been replaced by 'correctly'. Page 5 – the Evidence requirements have been rewritten to better explain what is required Page 5 – information has been added on Transfer of Evidence	Qualifications Development Manager	April 2014
3.0	Assessment Standards 2.2 & 2.3 removed	Qualifications Development Manager	June 2014
4.0	Level changed from Higher to SCQF level 6. Unit support notes added. Assessment standard threshold added.	Qualifications Manager	September 2018