SCQF level 6
Unit Specification

Biology: Metabolism and Survival

SCQF: level 6 (6 SCQF credit points)

Unit code: J4A7 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; cellular respiration; metabolic rate; metabolism in conformers and regulators; metabolism and adverse conditions; environmental control of metabolism; and genetic control of metabolism.

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 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
- free-standing SCQF level 5 Biology 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; cellular respiration; metabolic rate; metabolism in conformers and regulators; metabolism and adverse conditions; environmental control of metabolism; and genetic control of metabolism.

The following table describes the evidence for the Assessment Standards. Exemplification of assessment is provided in *Unit Assessment Support*.

Assessment Standard	**Evidence required**
Planning an experiment	The plan must 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
Following procedures safely	The learner must be seen to follow procedures safely.
Making and recording observations/measurements correctly	The raw data must be collated in a relevant format, for example a table.
Presenting results in an appropriate format	One format from: bar graph or line graph.
Drawing a valid conclusion	Must include reference to the aim and be supported by the results.
Evaluating experimental procedures	Provide one evaluative statement about the procedures used **and** suggest one improvement for the experiment. **or** Provide two evaluative statements about the procedures used. **or** Suggest two improvements for the experiment. Appropriate justification must also be provided, whichever option is chosen.

Assessment Standard	Evidence required
Making accurate statements and solving problems	Achieve at least 50% of the total marks available in a holistic assessment. A holistic assessment must include: ♦ an appropriate number of opportunities to make accurate statements for each key area of the Unit ♦ at least one opportunity to demonstrate each of the following problem-solving skills: — make generalisations/predictions — select information — process information, including calculations, as appropriate — analyse information

Assessment Standard thresholds

Outcome 1

Learners 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. Learners must be given the opportunity to meet all Assessment Standards.

Outcome 2

Learners are assessed using a holistic assessment that assesses Assessment Standards 2.1 and 2.2. To gain a pass for Outcome 2, learners must achieve 50% or more of the total marks available in the assessment.

Transfer of evidence

Evidence for the achievement of Outcome 1 for this Unit can be used as evidence for the achievement of Outcome 1 in the SCQF level 6 Units: Biology: DNA and the Genome (J4A6 76) and Biology: Sustainability and Interdependence (J4A8 76).

Evidence for the achievement of Outcome 2 for this Unit is **not** transferable between the SCQF level 6 Units: Biology: DNA and the Genome (J4A6 76) and Biology: Sustainability and Interdependence (J4A8 76).

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 must be carried out under the same conditions as the original assessment.

Outcome 1

Learners can re-draft their original Outcome 1 report or carry out a new experiment/practical investigation.

Outcome 2

Learners must have a full re-assessment opportunity, ie a holistic assessment. To achieve Outcome 2, learners must achieve 50% of the total 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:

- *Unit Assessment Support*

Developing skills, knowledge and understanding

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

Approaches to learning and teaching

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
1 Metabolic pathways (a) Metabolic pathways are integrated and controlled pathways of enzyme-catalysed reactions within a cell. Metabolic pathways can have reversible steps, irreversible steps and alternative routes. Reactions within metabolic pathways can be anabolic or catabolic. Anabolic reactions build up large molecules from small molecules and require energy. Catabolic reactions break down large molecules into smaller molecules and release energy.		
(b) Protein pores, pumps and enzymes are embedded in membranes.	No requirement to know details of sodium–potassium pump.	
(c) Metabolic pathways are controlled by the presence or absence of particular enzymes and the regulation of the rate of reaction of key enzymes.		Carry out enzyme induction experiments, such as the breakdown of ONPG by beta galactosidase in *E. coli*, with lactose acting as an inducer.

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
Induced fit and the role of the active site of an enzyme in affecting activation energy and the affinity of the substrate and products for the active site	Induced fit occurs when the active site changes shape to better fit the substrate after the substrate binds.	
The effects of substrate and product concentration on the direction and rate of enzyme reactions	The substrate molecule(s) has a high affinity for the active site and the subsequent products have a low affinity, allowing them to leave the active site. Some 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.	Carry out activation energy experiments, comparing heat, manganese dioxide and catalase action on hydrogen peroxide. Carry out experiments on the effect of increasing substrate concentration on reactions. Examples could include using hydrogen peroxide and adding filter paper discs soaked in catalase.
Control of metabolic pathways through competitive, non-competitive and feedback inhibition of enzymes	Competitive inhibitors bind at the active site, preventing the substrate from binding. Competitive inhibition can be reversed by increasing substrate concentration. Non-competitive inhibitors bind away from the active site but change the shape of the active site, preventing the substrate from binding. Non-competitive inhibition cannot be reversed by increasing substrate concentration.	Carry out experiments on the effect of inhibitors on reactions. Examples could include the inhibition of beta galactosidase by galactose and its reversal by increasing ONPG concentration.

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
	Feedback inhibition occurs when the end-product in the metabolic pathway reaches a critical concentration. The end-product then inhibits an earlier enzyme, blocking the pathway, and so prevents further synthesis of the end-product.	Carry out experiments on end-product inhibition using phosphatase and phenolphthalein phosphate.
2 Cellular respiration (a) Metabolic pathways of cellular respiration Glycolysis is the breakdown of glucose to pyruvate in the cytoplasm. ATP is required for the phosphorylation of glucose and intermediates during the energy investment phase of glycolysis. This leads to the generation of more ATP during the energy pay-off stage and results in a net gain of ATP. In aerobic conditions, pyruvate is broken down to an acetyl group that combines with coenzyme A forming acetyl coenzyme A.		Carry out experiments using different sugars as respiratory substrates for yeast. Carry out experiments using glucose-1-phosphate (a phosphorylated form of glucose).

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
In the citric acid cycle the acetyl group from acetyl coenzyme A combines with oxaloacetate to form citrate. During a series of enzyme-controlled steps, citrate is gradually converted back into oxaloacetate, which results in the generation of ATP and release of carbon dioxide. The citric acid cycle occurs in the matrix of the mitochondria. Dehydrogenase enzymes remove hydrogen ions and electrons and pass them to the coenzyme NAD, forming NADH. This occurs in both glycolysis and the citric acid cycle. The hydrogen ions and electrons from NADH are passed to the electron transport chain on the inner mitochondrial membrane.		Research how Hans Krebs discovered the citric acid cycle. Carry out experiments on the inhibition of the citric acid cycle by malonic acid using DCPIP as an indicator of dehydrogenase activity. Carry out experiments with yeast dehydrogenase using resazurin dye as an indicator.
(b) ATP synthesis — electrons are passed along the electron transport chain, releasing energy.	The electron transport chain is a series of carrier proteins attached to the inner mitochondrial membrane.	

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
This energy allows hydrogen ions to be pumped across the inner mitochondrial membrane. The flow of these ions back through the membrane protein ATP synthase results in the production of ATP. Finally, hydrogen ions and electrons combine with oxygen to form water.		
(c) Fermentation In the absence of oxygen, fermentation takes place in the cytoplasm. In animal cells, pyruvate is converted to lactate in a reversible reaction. In plants and yeast, ethanol and carbon dioxide are produced in an irreversible reaction. Fermentation results in much less ATP being produced than in aerobic respiration.		
(d) The role of ATP in the transfer of energy	ATP is used to transfer energy to cellular processes that require energy.	Carry out experiments on ATP-dependent reactions, such as luminescent reactions using luciferase.

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
3 Metabolic rate (a) Measurement of oxygen consumption, carbon dioxide and heat production to compare metabolic rates	Metabolic rate can be measured using respirometers, oxygen probes, carbon dioxide probes and calorimeters.	Use simple respirometers to measure metabolic rate. Carry out experiments to measure metabolic rate using oxygen, carbon dioxide and temperature probes.
(b) Organisms with high metabolic rates require more efficient delivery of oxygen to cells. Comparative anatomy and physiology of heart chambers and circulatory systems in amphibians, reptiles, mammals and birds, and heart and circulation in fish	Birds and mammals have higher metabolic rates than reptiles and amphibians, which, in turn, have higher metabolic rates than fish. Birds and mammals have a complete double circulatory system, consisting of two atria and two ventricles. Amphibians and most reptiles have an incomplete double circulatory system, consisting of two atria and one ventricle. Fish have a single circulatory system, consisting of one atrium and one ventricle. Complete double circulatory systems enable higher metabolic rates to be maintained. There is no mixing of oxygenated and deoxygenated blood and the oxygenated blood can be pumped out at a higher pressure. This enables more efficient oxygen delivery to cells.	

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
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 — temperature, salinity and pH	
(b) Conformers' internal environment is dependent upon external environment. Conformers use behavioural responses to maintain optimum metabolic rate. Conformers have low metabolic costs and a narrow range of ecological niches.	Behavioural responses by conformers allow them to tolerate variation in their external environment to maintain optimum metabolic rate.	Research the response of a conformer to a change in an environmental factor. Compare marine and estuarine invertebrates and their response to variation in salinity.
(c) Regulators maintain their internal environment regardless of external environment. Regulators use metabolism to control their internal environment, which increases the range of possible ecological niches. This regulation requires energy to achieve homeostasis. This increases their metabolic costs.		

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(d) Thermoregulation by negative feedback — the role of the hypothalamus, nerves and effectors	The hypothalamus is the temperature monitoring centre. Information is communicated by electrical impulses through nerves to the effectors, which bring about corrective responses to return temperature to normal.	
The role of corrective responses to an increase in body temperature — sweating, vasodilation of blood vessels and decreased metabolic rate	Sweating — body heat used to evaporate water in the sweat, cooling the skin. Vasodilation — increased blood flow to the skin increases heat loss. Decreased metabolic rate — less heat produced.	Carry out experiments using thermistors or infrared thermometers on skin temperature and its regulation in humans.
The corrective responses to a decrease in body temperature — shivering, vasoconstriction of blood vessels, hair erector muscles contracting and increased metabolic rate	Shivering — muscle contraction generates heat. Vasoconstriction — decreased blood flow to skin decreases heat loss. Hair erector muscles contract — traps layer of insulating air. Increased metabolic rate — more heat produced.	

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(e) Importance of regulating temperature (thermoregulation) for optimal enzyme activity and high diffusion rates to maintain metabolism		
5 Metabolism and adverse conditions Many environments vary beyond the tolerable limits for normal metabolic activity for any particular organism. Some animals have adapted to survive these adverse conditions while others avoid them. (a) Surviving adverse conditions by dormancy Dormancy is part of some organisms' life cycle to allow survival during a period when the costs of continued normal metabolic activity would be too high. The metabolic rate can be reduced during dormancy to save energy. Dormancy can be predictive or consequential.	During dormancy there is a decrease in metabolic rate, heart rate, breathing rate and body temperature. Predictive dormancy occurs before the onset of adverse conditions. Consequential dormancy occurs after the onset of adverse conditions.	Research aspects of surviving adverse conditions.

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
Some mammals survive during winter and low temperatures by hibernating. Aestivation allows survival in periods of high temperature or drought. Daily torpor is a period of reduced activity in some animals with high metabolic rates.		
(b) Avoiding adverse conditions by migration Migration avoids metabolic adversity by expending energy to relocate to a more suitable environment. Migratory behaviour can be innate and learned. Specialised techniques are used to study long-distance migration.	Examples of specialist techniques are satellite tracking and leg rings.	Evaluate procedures and results of studies investigating triggers for migration and navigation adaptations. Research the genetic control of migratory behaviour in studies of populations of birds.
6 Environmental control of metabolism Micro-organisms are archaea, bacteria and some species of eukaryotes.	Micro-organisms use a wide variety of substrates for metabolism and produce a range of products from their metabolic pathways. Micro-organisms are used because of their adaptability, ease of cultivation and speed of growth.	

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(a) Variations in growth media and control of environmental factors When culturing micro-organisms, their growth media require raw materials for biosynthesis as well as an energy source. Culture conditions: sterility, control of temperature, oxygen levels and pH	Many micro-organisms produce all the complex molecules required for biosynthesis, for example amino acids, vitamins and fatty acids. Other micro-organisms require these to be supplied in the growth media. An energy source is derived from chemical substrates or from light in photosynthetic micro-organisms. Sterile conditions in fermenters reduce competition with desired micro-organisms for nutrients and reduce the risk of spoilage of the product.	Carry out experiments to investigate the growth of microbes under different cultural and environmental conditions using standard laboratory equipment and simple fermenters.
(b) Phases of growth and changes in culture conditions Phases — lag, log/exponential, stationary and death	The lag phase is where enzymes are induced to metabolise substrates. The log/exponential phase contains the most rapid growth of micro-organisms due to plentiful nutrients. The stationary phase occurs due to the	

Metabolism and survival		
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	nutrients in the culture media becoming depleted and the production of toxic metabolites. Secondary metabolites are also produced, such as antibiotics. In the wild these metabolites confer an ecological advantage by allowing the micro-organisms that produce them to outcompete other micro-organisms. The death phase occurs due to the toxic accumulation of metabolites or the lack of nutrients in the culture.	
Growth curves of micro-organisms	Use of semi-logarithmic scales in producing or interpreting growth curves of micro-organisms.	
Viable and total cell count	Viable cell counts involve counting only the living micro-organisms, whereas total cell counts involve counting viable and dead cells. Only viable cell counts show a death phase where cell numbers are decreasing.	
7 Genetic control of metabolism (a) Wild strains of micro-organisms can be improved by mutagenesis, or recombinant DNA technology.	Exposure to UV light and other forms of radiation or mutagenic chemicals results in mutations, some of which may produce an improved strain of micro-organism.	

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(b) Recombinant DNA technology involves the use of recombinant plasmids and artificial chromosomes as vectors.	A vector is a DNA molecule used to carry foreign genetic information into another cell and both plasmids and artificial chromosomes are used as vectors during recombinant DNA technology. Artificial chromosomes are preferable to plasmids as vectors when larger fragments of foreign DNA are required to be inserted.	
The role of the restriction endonucleases and ligase in recombinant DNA technology	Restriction endonucleases cut open plasmids and specific genes out of chromosomes, leaving sticky ends. Complementary sticky ends are produced when the same restriction endonuclease is used to cut open the plasmid and the gene from the chromosome. Ligase seals the gene into the plasmid.	
Recombinant plasmids and artificial chromosomes contain restriction sites, regulatory sequences, an origin of replication and selectable markers.	Restriction sites contain target sequences of DNA where specific restriction endonucleases cut. Regulatory sequences control gene expression and origin of replication allows	

Metabolism and survival		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
As a safety mechanism, genes are often introduced that prevent the survival of the micro-organism in an external environment.	self-replication of the plasmid or artificial chromosome. Selectable markers, such as antibiotic resistance genes protect the micro-organism from a selective agent (antibiotic) that would normally kill it or prevent it growing. Selectable marker genes present in the vector ensure that only micro-organisms that have taken up the vector grow in the presence of the selective agent (antibiotic).	
Use of recombinant yeast cells to produce active forms of the protein that are inactive in bacteria	Recombinant yeast cells may be used, as plant or animal recombinant DNA expressed in bacteria may result in polypeptides being incorrectly folded.	Research ethical considerations in the use of micro-organisms — hazards and control of risks. For example, recombinant DNA technology is used to produce human proteins to treat disease — these could mutate and become pathogens or escape into the wild environment.

Administrative information

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Superclass: RH

History of changes to National Unit Specification

Version	Description of change	Authorised by	Date