SCQF level 6
Unit Specification

Human Biology: Human Cells

SCQF: level 6 (6 SCQF credit points)

Unit code: J20H 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 human cells. Learners will apply these skills when considering the applications of human cells 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:
division and differentiation in human cells; structure and replication of DNA; gene expression; genes and proteins in health and disease; human genomics; metabolic pathways; cellular respiration; energy systems in muscle cells.

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 or 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.

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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 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 *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 or practical investigation by:

1.1 Planning an experiment or 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:
division and differentiation in human cells; structure and replication of DNA; gene expression; genes and proteins in health and disease; human genomics; metabolic pathways; cellular respiration; energy systems in muscle cells.

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 from each: ♦ make generalisation/prediction ♦ 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 Division and differentiation in human cells (a) Somatic cells divide by mitosis to form more somatic cells. (b) Cellular differentiation is the process by which a cell develops more specialised functions by expressing the genes characteristic for that type of cell. (c) Stem cells — embryonic and tissue (adult) stem cells. Stem cells are unspecialised somatic cells that can divide to make copies of themselves (self-renew) and/or differentiate into specialised cells. Tissue (adult) stem cells are involved in the growth, repair and renewal of the cells found in that tissue. They are multipotent. The main body tissue types are epithelial, connective, muscle and nerve tissue. The body organs are formed from a variety of these tissues.	View audio visual resources on the origin of blood cells and their functions (red blood cells, platelets, phagocytes (eosinophils, neutrophils, basophils and monocytes) and lymphocytes (B-lymphocytes, T-lymphocytes and natural killer cells).	Once a cell becomes differentiated it only expresses the genes that produce the proteins characteristic for that type of cell. Tissue stem cells are multipotent as they can make all of the cell types found in a particular tissue type. For example, blood (haematopoietic) stem cells can make all of the cell types in the blood. Development of tissue (adult) stem cells in bone marrow into red blood cells, platelets and the various forms of phagocytes and lymphocytes. Epithelial cells cover the body surface and line body cavities, connective tissue includes blood, bone and cartilage cells, muscle cells

key areas	Suggested learning activities	Exemplification of key areas
		form muscle tissue and nerve cells form nervous tissue.
The cells of the early embryo can make all of the differentiated cell types of the body. They are pluripotent. When grown in the lab scientists call these embryonic stem cells.		The inner cell mass cells of an early embryo (blastocyst stage) are pluripotent as they can make nearly all of the cell types in the body. These cells can self-renew, under the right conditions, in the lab. It is then they are termed embryonic stem cells.
(d) Germline cells divide by mitosis to produce more germline cells or by meiosis to produce haploid gametes. Mutations in germline cells are passed to offspring.		During cell division the nucleus of a somatic cell divides by mitosis to maintain the diploid chromosome number. Diploid cells have 23 pairs of homologous chromosomes.
(e) Research and therapeutic uses of stem cells by reference to the repair of damaged or diseased organs or tissues. Stem cells can also be used as model cells to study how diseases develop or for drug testing. The ethical issues of stem cell use and the regulation of their use.	Case study on use of stem cells in repair of diseased or damaged organs (eg skin grafts, bone marrow transplantation and cornea repair). Case study on ethics of stem cell research and sources of stem cells. For example, embryos used for research must not be allowed to develop beyond 14 days, around the time a blastocyst would be implanted in a uterus. Sources of stem cells include embryonic stem cells, tissue stem cells and attempts to reprogram specialised cells to an embryonic state (induced pluripotent stem cells [iPS]).	Stem cell research provides information on how cell processes such as cell growth, differentiation and gene regulation work. The therapeutic uses of stem cells should be exemplified by reference to the repair of diseased or damaged organs, eg corneal transplants and skin grafts for burns.

key areas	Suggested learning activities	Exemplification of key areas
(f) Cancer cells divide excessively to produce a mass of abnormal cells (called a tumour). These cells do not respond to regulatory signals and may fail to attach to each other. If the cancer cells fail to attach to each other they can spread through the body to form secondary tumours.	Ethical issues could include regulations on the use of human embryos and the use of iPS cells.	
2 Structure and replication of DNA (a) Structure of DNA — nucleotides contain deoxyribose sugar, phosphate and base. DNA has a sugar–phosphate backbone, complementary base pairing — adenine with thymine and guanine with cytosine. The two DNA strands are held together by hydrogen bonds and have an antiparallel structure, with deoxyribose and phosphate at 3' and 5' ends of each strand. (b) Chromosomes consist of tightly coiled DNA and are packaged with associated proteins. (c) Replication of DNA by DNA polymerase and primer. DNA is unwound and unzipped to form two template strands. DNA polymerase needs a primer to start replication and can only add complementary DNA nucleotides to the deoxyribose (3') end of a DNA strand.	Case study examining the experimental evidence of the bacterial transformation experiments of Griffiths and identification of DNA as the transforming agent by Avery, phage experiments of Hershey and Chase, Chargaff's base ratios and the X-ray crystallography of Wilkins and Franklin. Watson and Crick's double helix model as an evidence based conclusion. Case study on Meselson and Stahl experiments on DNA replication.	All cells store their genetic information in the base sequence of DNA. The genotype is determined by the sequence of DNA bases. DNA is the molecule of inheritance and can direct its own replication. Prior to cell division, DNA is replicated by a DNA polymerase. This process occurs at several locations on a DNA molecule.

key areas	Suggested learning activities	Exemplification of key areas
This results in one strand being replicated continuously and the other strand replicated in fragments which are joined together by ligase. **3 Gene expression** (a) Phenotype is determined by the proteins produced as the result of gene expression. Only a fraction of the genes in a cell are expressed. Gene expression is influenced by intra- and extra-cellular environmental factors. Gene expression is controlled by the regulation of both transcription and translation. (b) Structure and functions of RNA. RNA is single stranded, contains uracil instead of thymine and ribose instead of deoxyribose sugar. Messenger RNA (mRNA) carries a copy of the DNA code from the nucleus to the ribosome. Ribosomal RNA (rRNA) and proteins form the ribosome. Each transfer RNA (tRNA) carries a specific amino acid.		
(c) Transcription of DNA into primary and mature RNA transcripts in the nucleus. This should include the role of RNA polymerase and complementary base pairing. The introns of the primary transcript of mRNA are non-coding and are removed in RNA splicing. The exons are coding regions and	Modelling transcription and translation using virtual and physical resources.	mRNA is transcribed from DNA in the nucleus and translated into proteins by ribosomes in the cytoplasm. RNA polymerase moves along DNA unwinding and unzipping the double helix and synthesising a primary transcript of RNA by complementary base pairing. Genes have introns (non-coding regions of genes)

key areas	Suggested learning activities	Exemplification of key areas
are joined together to form mature transcript. This process is called RNA splicing. (d) Translation of mRNA into a polypeptide by tRNA at the ribosome. tRNA folds due to base pairing to form a triplet anticodon site and an attachment site for a specific amino acid. Triplet codons on mRNA and anticodons translate the genetic code into a sequence of amino acids. Start and stop codons exist. Codon recognition of incoming tRNA, peptide bond formation and exit of tRNA from the ribosome as polypeptide is formed. (e) Different proteins can be expressed from one gene as a result of alternative RNA splicing and post-translational modification. Different mRNA molecules are produced from the same primary transcript depending on which RNA segments are treated as exons and introns. Post-translation protein structure modification by cutting and combining polypeptide chains or by adding phosphate or carbohydrate groups to the protein. **4 Genes and proteins in health and disease** (a) Proteins are held in a three dimensional shape by peptide bonds, hydrogen bonds, interactions between individual amino acids. Polypeptide chains fold to form the three dimensional shape of the protein.	Separation and identification of fish proteins by agarose gel electrophoresis. Investigation of the shape and structure	and exons (coding regions of genes). Proteins have a large variety of structures and shapes resulting in a wide range of functions. Amino acids are linked by peptide bonds to form polypeptides.

key areas	Suggested learning activities	Exemplification of key areas
	of fibrous and globular proteins using RasMol or Protein Explorer software.	
(b) Mutations result in no protein or a faulty protein being expressed.	Experiments investigating the effects of UV radiation on UV sensitive yeast.	Genetic disorders are caused by changes to genes or chromosomes that result in the proteins not being expressed or the proteins expressed not functioning correctly.
Single gene mutations involve the alteration of a DNA nucleotide sequence as a result of the substitution, insertion or deletion of nucleotides. Nature of single-nucleotide substitutions including: missense, nonsense and splice-site mutations. Nucleotide insertions or deletions result in frame-shift mutations or an expansion of a nucleotide sequence repeat. The effect of these mutations on the structure and function of the protein synthesised and the resulting effects on health.	Single gene mutation case studies: Sickle-cell disease (missense) PKU (missense) Beta (β) thalassemia (splice-site mutation) Duchenne muscular dystrophy (DMD) (nonsense) Tay-Sachs syndrome (frameshift insertion) Cystic fibrosis (frameshift deletion) Fragile X syndrome (nucleotide sequence repeat expansion) Huntingdon's disease (nucleotide sequence repeat expansion)	Missense (replacing one amino acid codon with another), nonsense (replacing an amino acid codon with a premature stop codon — no amino acid is made and the process stops) and splice-site mutations (creating or destroying the codons for exon-intron splicing).
Chromosome structure mutations — deletion; duplication; translocation. The substantial changes in chromosome mutations often make them lethal.	Chromosome mutation case studies: Cri-du-chat syndrome (deletion of part of the short arm of chromosome 5) Chronic myeloid leukaemia (CML) (reciprocal translocation of a gene from chromosome 22 fused with a gene on chromosome 9)	The structure of a chromosome can be altered. These mutations can take the form of a deletion (loss of a segment of a chromosome), duplication (repeat of a segment of a chromosome) or translocation (the rearrangement of chromosomal material involving two or more chromosomes).
5 Human genomics	Familial Down's syndrome (in 5% of	The sequence of bases can be determined for

key areas	Suggested learning activities	Exemplification of key areas
(a) Sequencing DNA. Bioinformatics is the use of computer technology to identify DNA sequences. Systematics compares human genome sequence data and genomes of other species to provide information on evolutionary relationships and origins. Personalised medicine is based on an individual's genome. Analysis of an individual's genome may lead to personalised medicine through understanding the genetic component of risk of disease. (b) Amplification and detection of DNA sequences.	cases one parent has the majority of chromosome 21 translocated to chromosome 14). Genome determination case studies including the human genome project and the comparison of individual genomes using single nucleotide polymorphisms (SNPs). Bioinformatics case studies. Use genome data to identify stop and start codons and known protein coding sequences. Case study on evolution of primates and bears using Geneious software. The information gained from DNA studies can provide information on the structure of the genes and proteins involved in disease. Rational drug design synthesises specific drugs that will bind to these proteins or prevent their	individual genes and entire genomes. The enormous amount of data produced by DNA and protein sequencing can be managed and analysed using computer technology and shared over the internet. Computer programs can be used to identify gene sequences by looking for coding sequences similar to known genes, start sequences or sequences lacking stop codons. Computer programs can be used to identify base sequences that correspond to the amino acid sequence of a protein. The importance of distinguishing between neutral and harmful mutations and the complex nature of many diseases. Pharmacogenetics and the use of genome information in the choice of effective drugs. The polymerase chain reaction (PCR) is a

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Polymerase Chain Reaction (PCR) amplification of DNA using complementary primers for specific target sequences. DNA heated to separate strands then cooled for primer binding. Heat-tolerant DNA polymerase then replicates the region of DNA. Repeated cycles of heating and cooling amplify this region of DNA. Arrays of DNA probes are used to detect the presence of specific sequences in samples of DNA. The probes are short single stranded fragments of DNA that are complementary to a specific sequence. Fluorescent labelling allows detection. Applications of DNA profiling allow the identification of individuals through comparison of regions of the genome with highly variable numbers of repetitive sequences of DNA.	synthesis by binding to a specific region of DNA preventing transcription or by binding to mRNA preventing translation, for example interfering RNA (RNAi). Case study on the use and application of PCR including practical using thermal cycler or water baths. Case studies on the medical uses of DNA probes in: detecting single gene mutations, genotype microarrays and gene expression microarrays manufactured from RNA transcripts. DNA fingerprinting (Alec Jeffreys).	technique for the amplification of DNA *in vitro*. In PCR, primers are complementary to specific target sequences at the two ends of the region to be amplified. Cooling allows primers to bind to target sequences. By screening a cell sample from a patient for the presence or absence of a particular sequence, a diagnosis of disease status or risk of disease onset can be made.
6 Metabolic pathways (a) Anabolic pathways require energy and involve biosynthetic processes. Catabolic pathways release energy and involve the breakdown of molecules. These pathways can have reversible and irreversible steps		Metabolism encompasses the integrated and controlled pathways of enzyme catalysed reactions within a cell. Metabolic pathways may exist that can bypass

key areas	Suggested learning activities	Exemplification of key areas
and alternative routes.		steps in a pathway.
(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. Regulation can be controlled by intra and extracellular signal molecules.	Enzyme induction experiments such as ONPG and lactose metabolism in *E. coli* and PGlo experiments.	Metabolic pathways are controlled by the presence or absence of particular enzymes in the metabolic pathway and through the regulation of the rate of reaction of key enzymes within the pathway. Genes for some enzymes are continuously expressed. These enzymes are always present in the cell and their control involves regulation of their rate of reaction. 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.
Induced fit and the role of the active site of enzymes including shape and substrate affinity. Activation energy.	Activation energy experiments, comparing heat, manganese dioxide and catalase action on hydrogen peroxide.	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.
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.	Experiments on reaction rate with increasing substrate concentration. DNA and RNA polymerases are part of multi-enzyme complexes.	
Control of metabolic pathways through competitive (binds to active site), non-competitive (changes shape of active site) and feedback inhibition (end product binds to an enzyme that catalyses a reaction early in the pathway).	Investigate the inhibition of beta galactosidase by galactose and its reversal by increasing ONPG concentration. Experiments on product inhibition with	Competitive inhibition can be reversed by increasing substrate concentration.

key areas	Suggested learning activities	Exemplification of key areas
7 Cellular respiration (a) Glucose broken down, removal of hydrogen ions and electrons by dehydrogenase enzymes releasing ATP.	phosphatase.	The metabolic pathways of cellular respiration are central to metabolism. They yield energy and are connected to many other pathways. ATP is used to transfer energy to synthetic pathways and other cellular processes where energy is required.
(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. Experiments using phosphorylated substrates, (eg glucose-1-phosphate) using suitable positive and negative controls in the design of an experiment.	The first phosphorylation leads to a product that can continue to a number of pathways and the second phosphorylation, catalysed by phosphofructokinase, is an irreversible reaction leading only to the glycolytic pathway. Pyruvate progresses to the citric acid cycle if oxygen is available.
(c) Metabolic pathways of cellular respiration. The breakdown of glucose to pyruvate in the cytoplasm in glycolysis, and the progression pathways in the presence or absence of oxygen (fermentation). The phosphorylation of intermediates in glycolysis in an energy investment phase and the direct generation of ATP in an energy pay-off stage. The role of the enzyme phosphofructokinase in this pathway. The formation of citrate. 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	Experiments with yeast dehydrogenase 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
steps of the cycle. This cycle results in the generation of ATP, the release of carbon dioxide and the regeneration of oxaloacetate in the matrix of the mitochondria. Dehydrogenase enzymes remove hydrogen ions and electrons which are passed to the coenzymes NAD or FAD to form NADH or $FADH_2$ in glycolysis and citric acid pathways. NADH and $FADH_2$ release the high-energy electrons to the electron transport chain on the mitochondrial membrane and this results in the synthesis of the bulk of the ATP. (d) ATP synthesis — high energy electrons are used to pump hydrogen ions across a membrane and flow of these ions back through the membrane synthesises ATP using the membrane protein ATP synthase. The final electron acceptor is oxygen, which combines with hydrogen ions and electrons to form water. Substrates for respiration. The role of starch, glycogen, other sugar molecules, amino acids and fats in the respiratory pathway.	Experiments with yeast dehydrogenase, eg using resazurin. Investigation of different sugars as respiratory substrates in yeast. Research different use of substrates during exercise and starvation.	The electron transport chain as a collection of proteins attached to a membrane. NADH and $FADH_2$ release the high-energy electrons to the electron transport chain where they pass along the chain, releasing energy. The energy is used to pump H ions across the inner mitochondrial membrane. The return flow of H ions drives ATP synthase and produces the bulk of the ATP generated by cellular respiration. The return flow of these ions rotates part of the membrane protein ATP synthase, catalysing the synthesis of ATP. Starch and glycogen are broken down to glucose for use as a respiratory substrate. Other sugar molecules can be converted to glucose or glycolysis intermediates for use as respiratory substrates. Proteins can be broken down to amino acids and converted to intermediates of glycolysis and the citric acid cycle for use as respiratory substrates. Fats can also be broken down to intermediates of

key areas	Suggested learning activities	Exemplification of key areas
Regulation of the pathways of cellular respiration by feedback inhibition — regulation of ATP production, by inhibition of phosphofructokinase by ATP and citrate, synchronisation of rates of glycolysis and citric acid cycle.		glycolysis and the citric acid cycle. The cell conserves its resources by only producing ATP when required. ATP supply increases with increasing rates of glycolysis and the citric acid cycle, and decreases when these pathways slow down. If the cell produces more ATP than it needs, the ATP inhibits the action of phosphofructokinase slowing the rate of glycolysis. The rates of glycolysis and the citric acid cycle are synchronised by the inhibition of phosphofructokinase by citrate. If citrate accumulates, glycolysis slows down and when citrate consumption increases glycolysis increases the supply of acetyl groups to the citric acid cycle.
8 Energy systems in muscle cells (a) Creatine phosphate breaks down to release energy and phosphate that is used to convert ADP to ATP at a fast rate. This system can only support strenuous muscle activity for around 10 seconds, when the creatine phosphate supply runs out. It is restored when energy demands are low.	Case study: effects of creatine supplements on fitness and sporting performance.	During strenuous muscle activity the cell rapidly breaks down its reserves of ATP to release energy. Muscle cells have an additional source of energy in creatine phosphate that can be used to replenish ATP pools during rigorous bouts of exercise. This system can only support strenuous muscle activity for around 10 seconds, when the creatine phosphate supply runs out. When muscle energy demand is low, ATP from cellular respiration is used to restore the levels creatine phosphate.

key areas	Suggested learning activities	Exemplification of key areas
(b) Lactic acid metabolism. Oxygen deficiency, conversion of pyruvate to lactic acid, muscle fatigue, oxygen debt.		During vigorous exercise, the muscle cells do not get sufficient oxygen to support the electron transport chain. Under these conditions, pyruvate is converted to lactic acid. This conversion involves the transfer of hydrogen from the NADH produced during glycolysis to pyruvic acid to produce lactic acid. This regenerates the NAD needed to maintain ATP production through glycolysis. Lactic acid accumulates in muscle causing fatigue. Oxygen debt repaid when exercise is complete allows respiration to provide the energy to convert lactic acid back to pyruvic acid and glucose in the liver.
(c) Types of skeletal muscle fibres Differences between slow twitch and fast twitch muscle fibres. Slow twitch (Type 1) muscle fibres contract more slowly, but can sustain contractions for longer and so are good for endurance activities. Fast twitch (Type 2) muscle fibres contract more quickly, over short periods, so are good	Case study: comparison of the ratios of slow twitch muscle fibres to fast twitch muscle fibres amongst elite athletes in different sports.	Slow twitch muscle fibres are good for endurance activities like long distance running, cycling or cross-country skiing. Slow twitch muscle fibres rely on aerobic respiration to generate ATP and have many mitochondria, a large blood supply and a high concentration of the oxygen storing protein myoglobin. The major storage fuel of slow twitch muscles fibres is fats. Fast twitch muscle fibres are good for activities like sprinting or weightlifting. Fast twitch muscle fibres can generate ATP through glycolysis only and have few mitochondria and a lower blood supply than slow twitch muscle fibres. The major storage fuels of fast twitch muscles fibres are

key areas	Suggested learning activities	Exemplification of key areas
for bursts of activity.		glycogen and creatine phosphate. Most human muscle tissue contains a mixture of both slow and fast twitch muscle fibres. Athletes show distinct patterns of muscle fibres that reflect their sporting activities.

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 and 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
5.0	Unit code updated	Qualifications Manager	July 2019