SCQF level 6
Unit Specification

Human Biology: Human Cells

SCQF: level 6 (6 SCQF credit points)

Unit code: J4A3 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; mutations; human genomics; metabolic pathways; cellular respiration; and 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/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 *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 division and differentiation in human cells; structure and replication of DNA; gene expression; mutations; human genomics; metabolic pathways; cellular respiration; and energy systems in muscle cells.

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: Human Biology: Neurobiology and Immunology (J4A4 76) and Human Biology: Physiology and Health (J4A5 76).

Evidence for the achievement of Outcome 2 for this Unit is **not** transferable between the SCQF level 6 Units: Human Biology: Neurobiology and Immunology (J4A4 76) and Human Biology: Physiology and Health (J4A5 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

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
1 Division and differentiation in human cells		
(a) Division of somatic and germline cells	A somatic cell is any cell in the body other than cells involved in reproduction. Germline cells are gametes (sperm and ova) and the stem cells that divide to form gametes.	
Somatic stem cells divide by mitosis to form more somatic cells. Germline stem cells divide by mitosis and by meiosis.		
Division by mitosis produces more germline stem cells.	The nucleus of a germline stem cell can divide by mitosis to maintain the diploid chromosome number. Diploid cells have 23 pairs of homologous chromosomes.	
Division by meiosis produces haploid gametes.	The nucleus of a germline stem cell can divide by meiosis. It undergoes two divisions, firstly separating homologous chromosomes and secondly separating chromatids. Haploid gametes contain 23 single chromosomes. Further detail of the process of meiosis is not required.	

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(b) Cellular differentiation Cellular differentiation is the process by which a cell expresses certain genes to produce proteins characteristic for that type of cell. This allows a cell to carry out specialised functions. Embryonic and tissue stem cells Cells in the very early embryo can differentiate into all the cell types that make up the individual and so are pluripotent. Tissue stem cells are involved in the growth, repair and renewal of the cells found in that tissue. They are multipotent.	All the genes in embryonic stem cells can be switched on so these cells can differentiate into any type of cell. Tissue stem cells are multipotent as they can differentiate into all of the types of cell found in a particular tissue type. For example, blood stem cells located in bone marrow can give rise to red blood cells, platelets, phagocytes and lymphocytes.	View digital resources on the origin of blood cells and their functions.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(c) Therapeutic and research uses of stem cells Therapeutic uses involve the repair of damaged or diseased organs or tissues. Research uses involve stem cells being used as model cells to study how diseases develop or being used for drug testing. The ethical issues of using embryonic stem cells	The therapeutic uses of stem cells should be exemplified by how they are used in corneal repair and the regeneration of damaged skin. Stem cells from the embryo can self-renew, under the right conditions, in the lab. Stem cell research provides information on how cell processes, such as cell growth, differentiation and gene regulation work. Use of embryonic stem cells can offer effective treatments for disease and injury; however, it involves destruction of embryos.	Study potential therapeutic uses of stem cells. Debate the ethics surrounding stem cell research and the sources of stem cells.
(d) Cancer cells divide excessively because they do not respond to regulatory signals. This results in a mass of abnormal cells called a tumour. Cells within the tumour may fail to attach to each other, spreading through the body where they may form secondary tumours.		

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
2 Structure and replication of DNA (a) Structure of DNA — nucleotides (deoxyribose sugar, phosphate and base), sugar–phosphate backbone, base pairing (adenine–thymine and guanine–cytosine), by hydrogen bonds and double-stranded antiparallel structure, with deoxyribose and phosphate at 3′ and 5′ ends of each strand respectively, forming a double helix.	The base sequence of DNA forms the genetic code.	Examine research that led to an understanding of the structure of DNA. Studies could include Chargaff's base ratios, X-ray crystallography of Wilkins and Franklin, and Watson and Crick's development of the double helix model.
(b) Replication of DNA by DNA polymerase and primers DNA polymerase adds DNA nucleotides, using complementary base pairing, to the deoxyribose (3′) end of the new DNA strand that is forming. Fragments of DNA are joined together by ligase.	Prior to cell division, DNA is replicated by a DNA polymerase. DNA polymerase needs primers to start replication. A primer is a short strand of nucleotides that binds to the 3′ end of the template DNA strand allowing polymerase to add DNA nucleotides. DNA is unwound and hydrogen bonds between bases are broken to form two template strands. DNA polymerase can only add DNA nucleotides in one direction resulting in the leading strand being replicated continuously and the lagging strand replicated in fragments.	Carry out digital or physical modelling of DNA replication. Examine Meselson and Stahl's experiments on DNA replication.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
(c) Polymerase chain reaction (PCR) amplifies DNA using complementary primers for specific target sequences. Repeated cycles of heating and cooling amplify the target region of DNA. Practical applications of PCR	In PCR, primers are short strands of nucleotides that are complementary to specific target sequences at the two ends of the region of DNA to be amplified. DNA is heated to between 92 and 98°C to separate the strands. It is then cooled to between 50 and 65°C to allow primers to bind to target sequences. It is then heated to between 70 and 80°C for heat-tolerant DNA polymerase to replicate the region of DNA. PCR can amplify DNA to help solve crimes, settle paternity suits and diagnose genetic disorders.	Carry out PCR using a thermal cycler or water baths. Use gel electrophoresis to analyse DNA samples (from kits) to determine criminality or paternity.
3 Gene expression (a) Gene expression involves the transcription and translation of DNA sequences. Transcription and translation involve three types of RNA (mRNA, tRNA and rRNA).	Only a fraction of the genes in a cell are expressed. RNA is single-stranded and is composed of nucleotides containing ribose sugar, phosphate and one of four bases: cytosine,	Carry out digital or physical modelling of transcription and translation.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
	guanine, adenine and uracil.	
Messenger RNA (mRNA) carries a copy of the DNA code from the nucleus to the ribosome.	mRNA is transcribed from DNA in the nucleus and translated into proteins by ribosomes in the cytoplasm. Each triplet of bases on the mRNA molecule is called a codon and codes for a specific amino acid.	
Transfer RNA (tRNA) folds due to complementary base pairing. Each tRNA molecule carries its specific amino acid to the ribosome. Ribosomal RNA (rRNA) and proteins form the ribosome.	A tRNA molecule has an anticodon (an exposed triplet of bases) at one end and an attachment site for a specific amino acid at the other end.	
(b) The role of RNA polymerase in transcription of DNA into primary mRNA transcripts	RNA polymerase moves along DNA, unwinding the double helix and breaking the hydrogen bonds between the bases. RNA polymerase synthesises a primary transcript of mRNA from RNA nucleotides by complementary base pairing.	
RNA splicing forms a mature mRNA transcript. The introns of the primary transcript are	Uracil in RNA is complementary to adenine.	

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
non-coding regions and are removed. The exons are coding regions and are joined together to form the mature transcript.	 The order of the exons is unchanged during splicing.	
(c) tRNA is involved in the translation of mRNA into a polypeptide at a ribosome. Translation begins at a start codon and ends at a stop codon. Anticodons bond to codons by complementary base pairing, translating the genetic code into a sequence of amino acids. Peptide bonds join the amino acids together. Each tRNA then leaves the ribosome as the polypeptide is formed.		
(d) Different proteins can be expressed from one gene as a result of alternative RNA splicing. Different mature mRNA transcripts are produced from the same primary transcript depending on which exons are retained.		
(e) Amino acids are linked by peptide bonds to form polypeptides. Polypeptide chains fold to form the three-dimensional shape of a protein, held together by hydrogen bonds and other interactions between individual	Details of other interactions and levels of protein structure are not required.	Use digital resources to examine the shape and structure of proteins.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
amino acids. Proteins have a large variety of shapes, which determine their functions. Phenotype is determined by proteins produced as the result of gene expression.	 Environmental factors also influence phenotype.	
4 Mutations (a) Mutations are changes in the DNA that can result in no protein or an altered protein being synthesised.		Carry out experiments to investigate the effects of UV radiation on UV-sensitive yeast.
(b) Single gene mutations involve the alteration of a DNA nucleotide sequence as a result of the substitution, insertion or deletion of nucleotides. Nucleotide substitutions — missense, nonsense and splice-site mutations	Missense mutations result in one amino acid being changed for another. This may result in a non-functional protein or have little effect on the protein. Nonsense mutations result in a premature stop codon being produced, which results in a shorter protein. Splice-site mutations result in some introns being retained and/or some exons not being	Study human conditions caused by single gene mutations. Examples could include sickle-cell disease (missense), phenylketonuria (PKU) (missense), Duchenne muscular dystrophy (nonsense) and beta thalassemia (splice-site mutation).

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
Nucleotide insertions or deletions result in frame-shift mutations.	included in the mature transcript. Frame-shift mutations cause all of the codons and all of the amino acids after the mutation to be changed. This has a major effect on the structure of the protein produced.	Study human conditions caused by frame-shift mutations. Examples could include Tay-Sachs disease (frame-shift insertion) and cystic fibrosis (frame-shift deletion).
(c) Chromosome structure mutations — duplication, deletion, inversion and translocation The substantial changes in chromosome mutations often make them lethal.	Duplication is where a section of a chromosome is added from its homologous partner. Deletion is where a section of a chromosome is removed. Inversion is where a section of chromosome is reversed. Translocation is where a section of a chromosome is added to a chromosome, not its homologous partner.	Study human conditions caused by chromosome structure mutations, for example: ♦ Cri-du-chat syndrome — caused by deletion of part of the short arm of chromosome 5. ♦ Haemophilia A — one cause is an inversion within the gene that produces a clotting factor (factor VIII). ♦ Chronic myeloid leukaemia — caused by a reciprocal translocation of sections of chromosome 22 and chromosome 9.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
5 Human genomics (a) The genome of an organism is its entire hereditary information encoded in DNA. A genome is made up of genes and other DNA sequences that do not code for proteins. In genomic sequencing, the sequence of nucleotide bases can be determined for individual genes and entire genomes.	Computer programs can be used to identify base sequences by looking for sequences similar to known genes. To compare sequence data, computer and statistical analyses (bioinformatics) are required.	Study the procedures used to determine the human genome. Study potential uses of bioinformatics.
(b) An individual's genome can be analysed to predict the likelihood of developing certain diseases. Pharmacogenetics and personalised medicine	Pharmacogenetics is the use of genome information in the choice of drugs. An individual's personal genome sequence can be used to select the most effective drugs and dosage to treat their disease (personalised medicine).	

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
6 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.		Use simple respirometers to measure metabolic rate. Carry out experiments to measure metabolic rate using oxygen, carbon dioxide and temperature probes.
(b) Metabolic pathways are controlled by the presence or absence of particular enzymes and the regulation of the rate of reaction of key enzymes. 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.	Carry out enzyme induction experiments, such as the breakdown of ONPG by beta galactosidase in *E. coli*, with lactose acting as an inducer. Carry out activation energy experiments, comparing heat, manganese dioxide and catalase action on hydrogen peroxide.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
	The substrate molecule(s) have a high affinity for the active site and the subsequent products have a low affinity allowing them to leave the active site.	
The effects of substrate and product concentration on the direction and rate of enzyme reactions	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 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.
	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.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
7 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. 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.		Carry out experiments using different sugars as respiratory substrates for yeast. Carry out experiments using glucose-1-phosphate (a phosphorylated form of glucose). Carry out experiments on the inhibition of the citric acid cycle by malonic acid using DCPIP as an indicator of dehydrogenase activity.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
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.		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. 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.	The electron transport chain is a series of carrier proteins attached to the inner mitochondrial membrane.	
(c) 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.

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
8 Energy systems in muscle cells (a) Lactate metabolism During vigorous exercise, the muscle cells do not get sufficient oxygen to support the electron transport chain. Under these conditions, pyruvate is converted to lactate. This conversion involves the transfer of hydrogen ions from the NADH produced during glycolysis to pyruvate in order to produce lactate. This regenerates the NAD needed to maintain ATP production through glycolysis. Lactate accumulates and muscle fatigue occurs. The oxygen debt is repaid when exercise is complete. This allows respiration to provide the energy to convert lactate back to pyruvate and glucose in the liver.		
(b) Types of skeletal muscle fibres Slow-twitch muscle fibres contract relatively slowly but can sustain contractions for longer. They are useful for endurance activities, such as 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	

Human cells		
Key areas	**Depth of knowledge required**	**Suggested learning activities**
	slow-twitch muscle fibres is fats. Fast-twitch muscle fibres can generate ATP through glycolysis only and have fewer mitochondria and a lower blood supply compared to slow-twitch muscle fibres. The major storage fuel of fast-twitch muscle fibres is glycogen.	
Fast-twitch muscle fibres contract relatively quickly, over short periods. They are useful for activities, such as sprinting or weightlifting. 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.		Compare the ratios of slow-twitch muscle fibres to fast-twitch muscle fibres between elite athletes in different sports.

Administrative information

Published: June 2020 (version 1.0)

Superclass: RH

History of changes to National Unit Specification

Version	Description of change	Authorised by	Date