SCQF level 7
Unit Specification

Biology: Cells and Proteins

SCQF: level 7 (8 SCQF credit points)

Unit code: J72Y 77

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 cells and proteins. Learners will use these skills when considering how applications of our understanding of cells and proteins can impact our lives, society, and the environment. Learners can develop and apply these skills using a variety of approaches, including investigating and problem solving.

The Unit covers the key areas of laboratory techniques for biologists; proteins; membrane proteins; communication and signalling; and protein control of cell division. 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 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:

- Higher Biology or Higher Human 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 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 or practical investigation by:

1.1 Planning and designing an experiment or practical investigation
1.2 Following procedures safely
1.3 Making and recording observations and measurements correctly
1.4 Analysing and presenting the results in an appropriate format
1.5 Drawing valid conclusions and giving explanations supported by evidence
1.6 Evaluating experimental procedures with justification

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 and giving clear descriptions or explanations
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 laboratory techniques for biologists; proteins; membrane proteins; communication and signalling; and protein control of cell division.

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

Assessment Standard	**Evidence required**
1.1 Planning and designing an experiment or practical investigation	The plan and design must include: ♦ a clear statement of the aim ♦ a hypothesis ♦ a dependent and independent variable ♦ variables to be kept constant ♦ measurements and observations to be made ♦ the equipment and materials ♦ a clear and detailed description of how the experiment or practical investigation should be carried out, including safety considerations
1.2 Following procedures safely	The learner must follow procedures safely.
1.3 Making and recording observations and measurements correctly	The learner must: ♦ make appropriate observations and measurements and repeat these, as appropriate ♦ record observations and measurements in an appropriate format
1.4 Analysing and presenting the results in an appropriate format	The learner must: ♦ analyse the results, process (including averages where appropriate) **and** present them in an appropriate format from: table, bar graph, line graph, chart, key, diagram, flow chart, summary, or other appropriate format

Assessment Standard	Evidence required
1.5 Drawing valid conclusions and giving explanations supported by evidence	Conclusions must refer to the aim of the experiment or practical investigation and be supported by the results. If results are inconclusive and the learner refers to evidence and the aim, to say that no conclusion can be drawn, then this would be valid and sufficient.
1.6 Evaluating experimental procedures with justification	The learner must: ♦ support their evaluation with justification(s) ♦ provide **at least two** possible improvements for the experiment or practical investigation
2.1 Making accurate statements and giving clear descriptions or explanations **and** 2.2 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 for the learner to make accurate statements for each key area of the Unit ♦ **at least one** opportunity for the learner to demonstrate each of the following problem-solving skills: — making generalisations and predictions — processing information — analysing information

Assessment Standard thresholds

Outcome 1

To pass Outcome 1, learners must achieve five out of the six Assessment Standards. This threshold reduces the volume of re-assessment, if it is required.

Assessors must give learners the opportunity to meet all Assessment Standards.

Transfer of evidence

Evidence for Outcome 1 in this Unit can be used as evidence for Outcome 1 in the SCQF level 7 Unit: Biology: Organisms and Evolution (J72V 77).

Evidence for the SCQF level 7 Unit: Investigative Biology (J730 77) can be used as evidence for Outcome 1 in this Unit. There is no requirement to match Assessment Standards.

Re-assessment

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

Outcome 2

Assessment Standards 2.1 and 2.2 are assessed holistically. To pass Outcome 2, learners must achieve 50% or more of the marks available in the holistic assessment.

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 learners.

Learners must have a full re-assessment opportunity (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

1.1 Reading
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 as 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

Key area	Depth of knowledge required	Suggested learning activities
1 Laboratory techniques for biologists (a) Health and safety Substances, organisms, and equipment in a laboratory can present a hazard	Hazards in the lab include toxic or corrosive chemicals, heat or flammable substances, pathogenic organisms, and mechanical equipment.	Become familiar with standard laboratory rules and with risk assessment.
Hazard, risk, and control of risk in the lab by risk assessment	Risk is the likelihood of harm arising from exposure to a hazard. Risk assessment involves identifying control measures to minimise the risk. Control measures include using appropriate handling techniques, protective clothing and equipment, and aseptic technique.	

Key area	Depth of knowledge required	Suggested learning activities
(b) Liquids and solutions		
Method and uses of linear and log dilution	Dilutions in a linear dilution series differ by an equal interval, for example 0·1, 0·2, 0·3 and so on. Dilutions in a log dilution series differ by a constant proportion, for example 10^{-1}, 10^{-2}, 10^{-3} and so on.	Become familiar with the use of measuring cylinders, pipettes, burettes, autopipettes, and syringes.
Production of a standard curve to determine an unknown	Plotting measured values for known concentrations to produce a line or curve allows the concentration of an unknown to be determined from the standard curve.	
Use of buffers to control pH	Addition of acid or alkali has very small effects on the pH of a buffer, allowing the pH of a reaction mixture to be kept constant.	Practise making solutions using buffers and measuring the pH with a meter or an indicator.
Method and uses of a colorimeter to quantify concentration and turbidity	Calibration with appropriate blank as a baseline; use of absorbance to determine concentration of a coloured solution using suitable wavelength filters; use of percentage transmission to determine turbidity, such as cells in suspension.	Use a colorimeter or spectrophotometer to calibrate a known solution and determine an unknown using, for example, Bradford protein assay.

Key area	Depth of knowledge required	Suggested learning activities
(c) Separation techniques		
Use of centrifuge to separate substances of differing density	More dense components settle in the pellet; less dense components remain in the supernatant.	
Paper and thin layer chromatography can be used for separating different substances such as amino acids and sugars	The speed that each solute travels along the chromatogram depends on its differing solubility in the solvent used. Details of how to carry out these procedures are not required.	
Principle of affinity chromatography and its use in separating proteins	A solid matrix or gel column is created with specific molecules bound to the matrix or gel. Soluble, target proteins in a mixture, with a high affinity for these molecules, become attached to them as the mixture passes down the column. Other non-target molecules with a weaker affinity are washed out.	
Principle of gel electrophoresis and its use in separating proteins and nucleic acids	Charged macromolecules move through an electric field applied to a gel matrix.	Use protein electrophoresis to identify different muscle proteins.
Native gels separate proteins by their shape, size and charge	Native gels do not denature the molecule so that separation is by shape, size and charge.	
SDS–PAGE separates proteins by size alone	SDS–PAGE gives all the molecules an equally negative charge and denatures them, separating proteins by size alone.	

Key area	Depth of knowledge required	Suggested learning activities
Proteins can be separated from a mixture using their isoelectric points (IEPs) If the solution is buffered to a specific pH, only the protein(s) that have an IEP of that pH will precipitate Proteins can also be separated using their IEPs in electrophoresis	IEP is the pH at which a soluble protein has no net charge and will precipitate out of solution. Soluble proteins can be separated using an electric field and a pH gradient. A protein stops migrating through the gel at its IEP in the pH gradient because it has no net charge. Further details of electrophoresis are not required.	Determine the isoelectric point of a soluble protein, such as casein.

Key area	Depth of knowledge required	Suggested learning activities
(d) Detecting proteins using antibodies Immunoassay techniques are used to detect and identify specific proteins		
These techniques use stocks of antibodies with the same specificity, known as monoclonal antibodies	Knowledge of monoclonal antibody production is not required.	Research the use of monoclonal antibodies in the diagnosis and detection of disease.
An antibody specific to the protein antigen is linked to a chemical 'label'	The 'label' is often a reporter enzyme producing a colour change, but chemiluminescence, fluorescence and other reporters can be used. In some cases the assay uses a specific antigen to detect the presence of antibodies.	Use the ELISA technique to identify the presence of specific antigens.
Western blotting is a technique, used after SDS–PAGE electrophoresis The separated proteins from the gel are transferred (blotted) onto a solid medium The proteins can be identified using specific antibodies that have reporter enzymes attached		

Key area	Depth of knowledge required	Suggested learning activities
(e) Microscopy Bright-field microscopy is commonly used to observe whole organisms, parts of organisms, thin sections of dissected tissue or individual cells Fluorescence microscopy uses specific fluorescent labels to bind to and visualise certain molecules or structures within cells or tissues		Refresh skills in the use of microscopes and making slides. Discuss the ethics of dissection in an educational context.

Key area	Depth of knowledge required	Suggested learning activities
(f) Aseptic technique and cell culture Aseptic technique eliminates unwanted microbial contaminants when culturing micro-organisms or cells	Aseptic technique involves the sterilisation of equipment and culture media by heat or chemical means and subsequent exclusion of microbial contaminants.	Investigate methods of sterilisation of containers, equipment, and materials.
A microbial culture can be started using an inoculum of microbial cells on an agar medium, or in a broth with suitable nutrients	Many culture media exist that promote the growth of specific types of cells and microbes.	Culture bacterial, yeast, and algal cells using aseptic technique.
Animal cells are grown in medium containing growth factors from serum In culture, primary cell lines can divide a limited number of times, whereas tumour cells lines can perform unlimited divisions	Growth factors are proteins that promote cell growth and proliferation. Growth factors are essential for the culture of most animal cells.	Investigate some of the different types of culture media and their uses.
Plating out of a liquid microbial culture on solid media allows the number of colony-forming units to be counted and the density of cells in the culture estimated Serial dilution is often needed to achieve a suitable colony count		
Method and use of haemocytometer to estimate cell numbers in a liquid culture Vital staining is required to identify and count viable cells		Use a haemocytometer to make an estimate of cell count.

Key area	Depth of knowledge required	Suggested learning activities
2 Proteins (a) The proteome The proteome is the entire set of proteins expressed by a genome The proteome is larger than the number of genes, particularly in eukaryotes, because more than one protein can be produced from a single gene as a result of alternative RNA splicing Not all genes are expressed as proteins in a particular cell type The set of proteins expressed by a given cell type can vary over time and under different conditions	Genes that do not code for proteins are called non-coding RNA genes and include those that are transcribed to produce tRNA, rRNA, and RNA molecules that control the expression of other genes. Some factors affecting the set of proteins expressed by a given cell type are the metabolic activity of the cell, cellular stress, the response to signalling molecules, and diseased versus healthy cells.	

Key area	Depth of knowledge required	Suggested learning activities
(b) The synthesis and transport of proteins (i) Intracellular membranes Eukaryotic cells have a system of internal membranes, which increases the total area of membrane The endoplasmic reticulum (ER) forms a network of membrane tubules continuous with the nuclear membrane The Golgi apparatus is a series of flattened membrane discs Lysosomes are membrane-bound organelles containing a variety of hydrolases that digest proteins, lipids, nucleic acids and carbohydrates Vesicles transport materials between membrane compartments	Because of their size, eukaryotes have a relatively small surface area to volume ratio. The plasma membrane of eukaryotic cells is therefore too small an area to carry out all the vital functions carried out by membranes.	

Key area	Depth of knowledge required	Suggested learning activities
(ii) Synthesis of membrane components Lipids and proteins are synthesised in the ER	Rough ER (RER) has ribosomes on its cytosolic face while smooth ER (SER) lacks ribosomes.	
Lipids are synthesised in the smooth endoplasmic reticulum (SER) and inserted into its membrane		
The synthesis of all proteins begins in cytosolic ribosomes		
The synthesis of cytosolic proteins is completed there, and these proteins remain in the cytosol		
Transmembrane proteins carry a signal sequence, which halts translation and directs the ribosome synthesising the protein to dock with the ER, forming RER	A signal sequence is a short stretch of amino acids at one end of the polypeptide that determines the eventual location of a protein in a cell.	
Translation continues after docking, and the protein is inserted into the membrane of the ER		

Key area	Depth of knowledge required	Suggested learning activities
(iii) Movement of proteins between membranes Once the proteins are in the ER, they are transported by vesicles that bud off from the ER and fuse with the Golgi apparatus		
As proteins move through the Golgi apparatus they undergo post-translational modification	Molecules move through the Golgi discs in vesicles that bud off from one disc and fuse to the next one in the stack. Enzymes catalyse the addition of various sugars in multiple steps to form the carbohydrates.	Research post-translational modification and activity in trypsinogen and trypsin.
The addition of carbohydrate groups is the major modification		
Vesicles that leave the Golgi apparatus take proteins to the plasma membrane and lysosomes		
Vesicles move along microtubules to other membranes and fuse with them within the cell		

Key area	Depth of knowledge required	Suggested learning activities
(iv) The secretory pathway Secreted proteins are translated in ribosomes on the RER and enter its lumen The proteins move through the Golgi apparatus and are then packaged into secretory vesicles These vesicles move to and fuse with the plasma membrane, releasing the proteins out of the cell Many secreted proteins are synthesised as inactive precursors and require proteolytic cleavage to produce active proteins	Peptide hormones and digestive enzymes are examples of secreted proteins. Proteolytic cleavage is another type of post-translational modification. Digestive enzymes are one example of secreted proteins that require proteolytic cleavage to become active. Specific names of digestive enzymes are not required.	

Key area	Depth of knowledge required	Suggested learning activities
(c) Protein structure, ligand binding and conformational change (i) Amino acid sequence determines protein structure Proteins are polymers of amino acid monomers		Use amino acid chromatography to distinguish between different amino acids.
Amino acids are linked by peptide bonds to form polypeptides	Recognise the chemical structure of a peptide bond from a diagram.	
Amino acids have the same basic structure, differing only in the R group present	R groups of amino acids vary in size, shape, charge, hydrogen bonding capacity and chemical reactivity.	
Amino acids are classified according to their R groups: basic (positively charged); acidic (negatively charged); polar; hydrophobic	Classify amino acids according to the R group present. Names and structures of individual amino acids are not required.	Determine the isoelectric point of a protein and explain the result using understanding of protein structure.
The wide range of functions carried out by proteins results from the diversity of R groups		Carry out molecular modelling, for example computer-aided drug design.
The primary structure is the sequence in which the amino acids are synthesised into the polypeptide		Carry out primary structure comparisons of enzymes from different evolutionary backgrounds, for example alcohol dehydrogenase from different organisms.

Key area	Depth of knowledge required	Suggested learning activities
Hydrogen bonding along the backbone of the protein strand results in regions of secondary structure — alpha helices, parallel or anti-parallel beta-pleated sheets, or turns The polypeptide folds into a tertiary structure This conformation is stabilised by interactions between R groups: hydrophobic interactions; ionic bonds; London dispersion forces; hydrogen bonds; disulfide bridges	Disulfide bridges are covalent bonds between R groups containing sulfur.	
Quaternary structure exists in proteins with two or more connected polypeptide subunits	Quaternary structure describes the spatial arrangement of the subunits.	
A prosthetic group is a non-protein unit tightly bound to a protein and necessary for its function	The ability of haemoglobin to bind oxygen is dependent upon the non-protein haem group.	Analyse haemoglobin dissociation curves.
Interactions of the R groups can be influenced by temperature and pH	Increasing temperature disrupts the interactions that hold the protein in shape; the protein begins to unfold, eventually becoming denatured. The charges on acidic and basic R groups are affected by pH. As pH increases or decreases from the optimum, the normal ionic interactions between charged groups are lost, which gradually changes the conformation of the protein until it becomes denatured.	

Key area	Depth of knowledge required	Suggested learning activities
(ii) Ligand binding changes the conformation of a protein A ligand is a substance that can bind to a protein R groups not involved in protein folding can allow binding to ligands Binding sites will have complementary shape and chemistry to the ligand As a ligand binds to a protein-binding site the conformation of the protein changes This change in conformation causes a functional change in the protein Allosteric interactions occur between spatially distinct sites Many allosteric proteins consist of multiple subunits (have quaternary structure)	The binding of a substrate molecule to one active site of an allosteric enzyme increases the affinity of the other active sites for binding of subsequent substrate molecules. This is of biological importance because the activity of allosteric enzymes can vary greatly with small changes in substrate concentration.	

Key area	Depth of knowledge required	Suggested learning activities
Allosteric proteins with multiple subunits show co-operativity in binding, in which changes in binding at one subunit alter the affinity of the remaining subunits		
Allosteric enzymes contain a second type of site, called an allosteric site		Investigate the action of aspartate transcarbamoylase as an example of an allosteric enzyme of biological importance.
Modulators regulate the activity of the enzyme when they bind to the allosteric site		
Following binding of a modulator, the conformation of the enzyme changes and this alters the affinity of the active site for the substrate	Positive modulators increase the enzyme's affinity for the substrate, whereas negative modulators reduce the enzyme's affinity.	
The binding and release of oxygen in haemoglobin shows co-operativity	Changes in binding of oxygen at one subunit alter the affinity of the remaining subunits for oxygen.	
The influence and physiological importance of temperature and pH on the binding of oxygen	A decrease in pH or an increase in temperature lowers the affinity of haemoglobin for oxygen, so the binding of oxygen is reduced. Reduced pH and increased temperature in actively respiring tissue will reduce the binding of oxygen to haemoglobin promoting increased oxygen delivery to tissue. Effects of DPG are not required.	

Key area	Depth of knowledge required	Suggested learning activities
(iii) Reversible binding of phosphate and the control of conformation The addition or removal of phosphate can cause reversible conformational change in proteins This is a common form of post-translational modification Protein kinases catalyse the transfer of a phosphate group to other proteins The terminal phosphate of ATP is transferred to specific R groups Protein phosphatases catalyse the reverse reaction Phosphorylation brings about conformational changes, which can affect a protein's activity The activity of many cellular proteins, such as enzymes and receptors, is regulated in this way Some proteins are activated by phosphorylation while others are inhibited	Adding a phosphate group adds negative charges. Ionic interactions in the unphosphorylated protein can be disrupted and new ones created.	Research examples of proteins regulated by phosphorylation, such as glycogen phosphorylase.

Key area	Depth of knowledge required	Suggested learning activities
3 Membrane proteins (a) Movement of molecules across membranes Knowledge of the fluid mosaic model of cell membranes		Research the history of evidence-based models of membrane structure as an example of refinement of scientific ideas.
Regions of hydrophobic R groups allow strong hydrophobic interactions that hold integral membrane proteins within the phospholipid bilayer	Integral membrane proteins interact extensively with the hydrophobic region of membrane phospholipids.	
Some integral membrane proteins are transmembrane proteins		
Peripheral membrane proteins have hydrophilic R groups on their surface and are bound to the surface of membranes, mainly by ionic and hydrogen bond interactions		
Many peripheral membrane proteins interact with the surfaces of integral membrane proteins		
The phospholipid bilayer is a barrier to ions and most uncharged polar molecules		

Key area	Depth of knowledge required	Suggested learning activities
Some small molecules, such as oxygen and carbon dioxide, pass through the bilayer by simple diffusion Facilitated diffusion is the passive transport of substances across the membrane through specific transmembrane proteins To perform specialised functions, different cell types have different channel and transporter proteins		
Most channel proteins in animal and plant cells are highly selective	Channels are multi-subunit proteins with the subunits arranged to form water-filled pores that extend across the membrane.	
Some channel proteins are gated and change conformation to allow or prevent diffusion Ligand-gated channels are controlled by the binding of signal molecules, and voltage-gated channels are controlled by changes in ion concentration		Research CFTR mutation and cystic fibrosis.
Transporter proteins bind to the specific substance to be transported and undergo a conformational change to transfer the solute across the membrane	Transporters alternate between two conformations so that the binding site for a solute is sequentially exposed on one side of the bilayer, then the other.	Research glucose transporters in mammalian cells.

Key area	Depth of knowledge required	Suggested learning activities
Active transport uses pump proteins that transfer substances across the membrane against their concentration gradient A source of metabolic energy is required for active transport Some active transport proteins hydrolyse ATP directly to provide the energy for the conformational change required to move substances across the membrane	Pumps that mediate active transport are transporter proteins coupled to an energy source. ATPases hydrolyse ATP.	

Key area	Depth of knowledge required	Suggested learning activities
(b) Ion transport pumps and generation of ion gradients For a solute carrying a net charge, the concentration gradient and the electrical potential difference combine to form the electrochemical gradient that determines the transport of the solute Ion pumps, such as the sodium-potassium pump, use energy from the hydrolysis of ATP to establish and maintain ion gradients The sodium-potassium pump transports ions against a steep concentration gradient using energy directly from ATP hydrolysis It actively transports sodium ions out of the cell and potassium ions into the cell The pump has high affinity for sodium ions inside the cell; binding occurs; phosphorylation by ATP; conformation changes; affinity for sodium ions decreases; sodium ions released outside of the cell; potassium ions bind outside the cell; dephosphorylation; conformation changes; potassium ions taken into cell; affinity returns to start	A membrane potential (an electrical potential difference) is created when there is a difference in electrical charge on the two sides of the membrane. For each ATP hydrolysed, three sodium ions are transported out of the cell and two potassium ions are transported into the cell. This establishes both concentration gradients and an electrical gradient.	

Key area	Depth of knowledge required	Suggested learning activities
The sodium-potassium pump is found in most animal cells, accounting for a high proportion of the basal metabolic rate in many organisms In the small intestine, the sodium gradient created by the sodium-potassium pump drives the active transport of glucose The glucose transporter responsible for this glucose symport transports sodium ions and glucose at the same time and in the same direction	In intestinal epithelial cells the sodium-potassium pump generates a sodium ion gradient across the plasma membrane. Sodium ions enter the cell down their concentration gradient; the simultaneous transport of glucose pumps glucose into the cell against its concentration gradient. Details of the apical and basal membranes are not required.	

Key area	Depth of knowledge required	Suggested learning activities
4 Communication and signalling (a) Co-ordination Multicellular organisms signal between cells using extracellular signalling molecules	Steroid hormones, peptide hormones, and neurotransmitters are examples of extracellular signalling molecules.	
Receptor molecules of target cells are proteins with a binding site for a specific signal molecule Binding changes the conformation of the receptor, which initiates a response within the cell		
Different cell types produce specific signals that can only be detected and responded to by cells with the specific receptor	Signalling molecules may have different effects on different target cell types due to differences in the intracellular signalling molecules and pathways that are involved.	Research examples of degenerative diseases.
In a multicellular organism, different cell types may show a tissue-specific response to the same signal		

Key area	Depth of knowledge required	Suggested learning activities
(b) Hydrophobic signals and control of transcription Hydrophobic signalling molecules can diffuse directly through the phospholipid bilayers of membranes, and so bind to intracellular receptors		
The receptors for hydrophobic signalling molecules are transcription factors	Transcription factors are proteins that when bound to DNA can either stimulate or inhibit initiation of transcription.	
The steroid hormones oestrogen and testosterone are examples of hydrophobic signalling molecules		
Steroid hormones bind to specific receptors in the cytosol or the nucleus		
The hormone-receptor complex moves to the nucleus where it binds to specific sites on DNA and affects gene expression	The hormone-receptor complex binds to specific DNA sequences called hormone response elements (HREs). Binding at these sites influences the rate of transcription, with each steroid hormone affecting the gene expression of many different genes.	Research sex hormone disorders.

Key area	Depth of knowledge required	Suggested learning activities
(c) Hydrophilic signals and transduction Hydrophilic signalling molecules bind to transmembrane receptors and do not enter the cytosol	Peptide hormones and neurotransmitters are examples of hydrophilic extracellular signalling molecules.	
Transmembrane receptors change conformation when the ligand binds to the extracellular face; the signal molecule does not enter the cell, but the signal is transduced across the plasma membrane		
Transmembrane receptors act as signal transducers by converting the extracellular ligand-binding event into intracellular signals, which alters the behaviour of the cell		
Transduced hydrophilic signals often involve G-proteins or cascades of phosphorylation by kinase enzymes	G-proteins relay signals from activated receptors (receptors that have bound a signalling molecule) to target proteins such as enzymes and ion channels. Details of G-proteins subunits are not required.	
Phosphorylation cascades allow more than one intracellular signalling pathway to be activated	Phosphorylation cascades involve a series of events with one kinase activating the next in the sequence and so on. Phosphorylation cascades can result in the phosphorylation of many proteins as a result of the original signalling event.	

Key area	Depth of knowledge required	Suggested learning activities
Binding of the peptide hormone insulin to its receptor results in an intracellular signalling cascade that triggers recruitment of GLUT4 glucose transporter proteins to the cell membrane of fat and muscle cells	Binding of insulin to its receptor causes a conformational change that triggers phosphorylation of the receptor. This starts a phosphorylation cascade inside the cell, which eventually leads to GLUT4-containing vesicles being transported to the cell membrane.	Research data from glucose tolerance tests.
Diabetes mellitus can be caused by failure to produce insulin (type 1) or loss of receptor function (type 2) Type 2 is generally associated with obesity Exercise also triggers recruitment of GLUT4, so can improve uptake of glucose to fat and muscle cells in subjects with type 2		Research health effects associated with type 2 diabetes and the success rate of treatment programmes. Write a review of data from studies of health and wellbeing, considering the importance of publishing negative results.

Key area	Depth of knowledge required	Suggested learning activities
(d) Nerve impulse transmission (i) Generation of a nerve impulse Resting membrane potential is a state where there is no net flow of ions across the membrane The transmission of a nerve impulse requires changes in the membrane potential of the neuron's plasma membrane An action potential is a wave of electrical excitation along a neuron's plasma membrane Neurotransmitters initiate a response by binding to their receptors at a synapse Depolarisation of the plasma membrane as a result of the entry of positive ions triggers the opening of voltage-gated sodium channels, and further depolarisation occurs	Neurotransmitter receptors are ligand-gated ion channels. Depolarisation is a change in the membrane potential to a less negative value inside.	Carry out *Daphnia* heart rate investigation. The action of chemical agonists can be assessed. This could provide an opportunity to focus on aspects of experimental design associated with pilot studies, measurement accuracy, sample size and replication.

Key area	Depth of knowledge required	Suggested learning activities
Inactivation of the sodium channels and the opening of potassium channels restores the resting membrane potential Depolarisation of a patch of membrane causes neighbouring regions of membrane to depolarise and go through the same cycle, as adjacent voltage-gated sodium channels are opened When the action potential reaches the end of the neuron it causes vesicles containing neurotransmitter to fuse with the membrane — this releases neurotransmitter, which stimulates a response in a connecting cell	Binding of a neurotransmitter triggers the opening of ligand-gated ion channels at a synapse. Ion movement occurs and there is depolarisation of the plasma membrane. If sufficient ion movement occurs, and the membrane is depolarised beyond a threshold value, the opening of voltage-gated sodium channels is triggered and sodium ions enter the cell down their electrochemical gradient. This leads to a rapid and large change in the membrane potential. A short time after opening, the sodium channels become inactivated. Voltage-gated potassium channels then open to allow potassium ions to move out of the cell to restore the resting membrane potential.	

Key area	Depth of knowledge required	Suggested learning activities
Restoration of the resting membrane potential allows the inactive voltage-gated sodium channels to return to a conformation that allows them to open again in response to depolarisation of the membrane Ion concentration gradients are re-established by the sodium-potassium pump, which actively transports excess ions in and out of the cell	Following repolarisation the sodium and potassium ion concentration gradients are reduced. The sodium-potassium pump restores the sodium and potassium ions back to resting potential levels.	

Key area	Depth of knowledge required	Suggested learning activities
(ii) Initiation of a nerve impulse in response to an environmental stimulus: the vertebrate eye		Investigate vision experimentally.
The retina is the area within the eye that detects light and contains two types of photoreceptor cells: rods and cones	Rods function in dim light but do not allow colour perception. Cones are responsible for colour vision and only function in bright light.	Carry out a fish eye dissection.
In animals the light-sensitive molecule retinal is combined with a membrane protein, opsin, to form the photoreceptors of the eye		
In rod cells the retinal-opsin complex is called rhodopsin		
Retinal absorbs a photon of light and rhodopsin changes conformation to photoexcited rhodopsin		
A cascade of proteins amplifies the signal		
Photoexcited rhodopsin activates a G-protein, called transducin, which activates the enzyme phosphodiesterase (PDE)	A single photoexcited rhodopsin activates hundreds of molecules of G-protein. Each activated G-protein activates one molecule of PDE.	

Key area	Depth of knowledge required	Suggested learning activities
PDE catalyses the hydrolysis of a molecule called cyclic GMP (cGMP) This results in the closure of ion channels in the membrane of the rod cells, which triggers nerve impulses in neurons in the retina A very high degree of amplification results in rod cells being able to respond to low intensities of light In cone cells, different forms of opsin combine with retinal to give different photoreceptor proteins, each with a maximal sensitivity to specific wavelengths: red, green, blue or UV	Each active PDE molecule breaks down thousands of cGMP molecules per second. The reduction in cGMP concentration as a result of its hydrolysis affects the function of ion channels in the membrane of rod cells.	

Key area	Depth of knowledge required	Suggested learning activities
5 Protein control of cell division (a) The cytoskeleton and cell division The cytoskeleton gives mechanical support and shape to cells		
It consists of different protein structures including microtubules, which are found in all eukaryotic cells	Microtubules are hollow cylinders composed of the protein tubulin. They radiate from the microtubule organising centre (MTOC) or centrosome. Knowledge of other cytoskeleton proteins is not required.	Research and consider the effects of colchicine and paclitaxel on the cytoskeleton.
Microtubules control the movement of membrane-bound organelles and chromosomes		
Cell division requires remodelling of the cytoskeleton		
Formation and breakdown of microtubules involves polymerisation and depolymerisation of tubulin		
Microtubules form the spindle fibres that are active during cell division		

Key area	Depth of knowledge required	Suggested learning activities
(b) The cell cycle The cell cycle consists of interphase and mitotic (M) phase	Interphase involves growth and DNA synthesis including G1, a growth phase; S phase, during which the DNA is replicated; and G2, a further growth phase.	Stain actively dividing plant meristem tissue and calculate a mitotic index.
Mitotic phase involves mitosis and cytokinesis	In mitosis the chromosomal material is separated by the spindle microtubules. This is followed by cytokinesis, in which the cytoplasm is separated into two daughter cells.	
Mitosis consists of prophase, metaphase, anaphase and telophase	Prophase — DNA condenses into chromosomes each consisting of two sister chromatids. Nuclear membrane breaks down; spindle microtubules extend from the MTOC by polymerisation and attach to chromosomes via their kinetochores in the centromere region. Metaphase — chromosomes are aligned at the metaphase plate (equator of the spindle). Anaphase — as spindle microtubules shorten by depolymerisation, sister chromatids are separated, and the chromosomes are pulled to opposite poles.	

Key area	Depth of knowledge required	Suggested learning activities
	Telophase — the chromosomes decondense and nuclear membranes are formed around them.	

Key area	Depth of knowledge required	Suggested learning activities
(c) Control of the cell cycle Progression through the cell cycle is controlled by checkpoints	Checkpoints are mechanisms within the cell that assess the condition of the cell during the cell cycle and halt progression to the next phase until certain requirements are met.	Use an online simulation of mitotic checkpoint control.
Cyclin proteins that accumulate during cell growth are involved in regulating the cell cycle	Cyclins combine with and activate cyclin-dependent kinases (CDKs). Active cyclin-CDK complexes phosphorylate proteins that regulate progression through the cycle. If sufficient phosphorylation is reached, progression occurs.	Investigate cell cycle mutation in yeast *Schizosaccharomyces pombe*.
At the G1 checkpoint, retinoblastoma protein (Rb) acts as a tumour suppressor by inhibiting the transcription of genes that code for proteins needed for DNA replication		
Phosphorylation by G1 cyclin-CDK inhibits the retinoblastoma protein (Rb)	This allows transcription of the genes that code for proteins needed for DNA replication. Cells progress from G1 to S phase.	
At the G2 checkpoint, the success of DNA replication and any damage to DNA is assessed		

Key area	Depth of knowledge required	Suggested learning activities
DNA damage triggers the activation of several proteins including p53 that can stimulate DNA repair, arrest the cell cycle or cause cell death		
A metaphase checkpoint controls progression from metaphase to anaphase	At the metaphase checkpoint, progression is halted until the chromosomes are aligned correctly on the metaphase plate and attached to the spindle microtubules.	
An uncontrolled reduction in the rate of the cell cycle may result in degenerative disease		Research the role of cell cycle regulators in degenerative diseases such as Alzheimer's and Parkinson's.
An uncontrolled increase in the rate of the cell cycle may result in tumour formation A proto-oncogene is a normal gene, usually involved in the control of cell growth or division, which can mutate to form a tumour-promoting oncogene		Research the types of mutations associated with cancer, for example the influence of environmental factors and viruses, the conversion of proto-oncogenes into oncogenes, and mutations in tumour-suppressing genes.

Key area	Depth of knowledge required	Suggested learning activities
(d) Control of programmed cell death (apoptosis) Apoptosis is triggered by cell death signals that can be external or internal	The production of death signal molecules from lymphocytes is an example of an external death signal. DNA damage is an example of an internal death signal.	
External death signal molecules bind to a surface receptor protein and trigger a protein cascade within the cytoplasm		
An internal death signal resulting from DNA damage causes activation of p53 tumour-suppressor protein		
Both types of death signal result in the activation of caspases (types of protease enzyme) that cause the destruction of the cell		
Apoptosis is essential during development of an organism to remove cells no longer required as development progresses or during metamorphosis		Research and consider apoptosis in development of tetrapod limbs.
Cells may initiate apoptosis in the absence of growth factors		Research the challenges in overcoming apoptosis in maintaining animal cell culture lines.

Administrative information

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History of changes to National Unit Specification

Version	Description of change	Authorised by	Date