

Unit 13: Biochemistry and Biochemical Techniques

Unit code:	L/502/5552
QCF Level 3:	BTEC National
Credit value:	10
Guided learning hours:	60

● Aim and purpose

The aim of this unit is to develop the learners knowledge and techniques needed for the study of biochemistry. Learners will investigate biological molecules, enzymes, metabolic pathways and the structure of proteins.

● Unit introduction

When you look at an oak tree, a field of corn or perhaps a dog, you are seeing living organisms which function and live only by means of a series of interrelated chemical reactions. Biochemistry is a study of these chemical processes, without which life on Earth could not exist.

This unit considers the importance of water to biochemical processes in living organisms and the structure and functions of some of the unique biological molecules which occur in living organisms. The unit is essential for learners who wish to further their knowledge and understanding of biochemistry and these biological sciences.

The unit includes consideration of the biochemical techniques used to investigate the structures and functions of biological molecules. The different levels of structure of proteins are examined in some detail. The unit includes study of the characteristics of enzymes and investigation of the factors which affect their rate of activity. Finally some of the interrelationships between the molecules are examined by looking at anaerobic and aerobic metabolic pathways, including the electron transport chain and oxidative phosphorylation.

Learners should be encouraged to acquire laboratory skills such as setting up practical experiments, using laboratory equipment, carrying out qualitative and quantitative assay techniques, gel electrophoresis, colorimetry and chromatography. Biochemistry overlaps with many other areas of study such as pharmacology, physiology, microbiology and clinical chemistry.

● Learning outcomes

On completion of this unit a learner should:

- 1 Be able to investigate properties of water and biological molecules in living organisms
- 2 Understand the structure of proteins
- 3 Be able to investigate the factors that affect the activities of enzymes in biological systems
- 4 Know the difference between aerobic and anaerobic respiration.

Unit content

1 Be able to investigate properties of water and biological molecules in living organisms

Water properties: melting point; boiling point; polarity; hydrogen bonding; buffer; solvent

Biological molecules: carbohydrates; lipids eg triglycerides; proteins; nucleic acids (DNA, RNA, RNA overview only)

Structural characteristics: functional groups in monomer units (not nucleic acids); polymeric nature of biological macromolecules; multiple polymeric structures from a limited number of monomers; 3D structures of biological macromolecules

Laboratory techniques: commonly used laboratory techniques for carbohydrates, proteins and lipids eg thin layer chromatography, gel permeation chromatography, electrophoresis, gas-liquid chromatography

2 Understand the structure of proteins

Primary structure of proteins: sequence of amino acids; peptide backbone depending on amino acid involved; variable side chains

Secondary and tertiary structures of proteins: type of intramolecular bond related to amino acid side chain (S-S link, H-bond, hydrophobic bond); α -helix, β -pleated sheet; globular and fibrous proteins

Quaternary structure of protein: multiple sub-units; prosthetic groups

Examples of globular and fibrous proteins: haemoglobin; collagen

3 Be able to investigate the factors that affect the activities of enzymes in biological systems

Enzyme function: active site; induced fit

Principal biochemical properties: specificity; catalytic activity, effect of pH, temperature, substrate concentration, inhibitors, on catalytic rate, denaturisation (caused by extremes of temperature, acids and bases); role of co-factors and co-enzymes

Laboratory techniques: investigation of factors affecting enzyme activity eg vary pH, temperature, concentration

Commercial applications: enzymes in diagnostic testing and industry eg brewing

4 Know the difference between aerobic and anaerobic respiration

Definitions: metabolism, aerobic, anaerobic; catabolism; anabolism

Pathways: anaerobic and aerobic pathways of glucose metabolism; the electron transport chain and oxidative phosphorylation; cellular role of ATP; regulation of glycolysis

Pasteur effect: outline of fatty acid metabolism

Applications: metabolic end products of industrial importance, eg alcoholic beverages, RQ measurements

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:	To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:
P1 identify the structure and function of biological molecules [IE1]	M1 interpret data obtained from experiments designed to separate biological molecules	D1 discuss the relationship between structure and function for carbohydrates and lipids
P2 use laboratory separative techniques for the characterisation of biological molecules [IE2; TW1; SM2; EP2]		
P3 describe the primary and secondary structures of proteins [IE1]	M2 explain the tertiary and quaternary structures of proteins	D2 discuss the relationship between the structure and function of proteins
P4 describe the structural features of an enzyme [IE1]	M3 explain how the rates of enzyme reactions are affected by changes in temperature	D3 explain why enzyme activity is affected by pH
P5 use laboratory methods to investigate factors that affect the enzyme rate of reaction [IE2; TW1; SM2; EP2]		
P6 identify the main differences between anaerobic and aerobic glucose degradation. [CT2]	M4 compare the sites of ATP production and consumption during aerobic and anaerobic breakdown of glucose in cells.	D4 evaluate the regulation of glycolysis in terms of energy requirements in cells.

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit builds on the concepts that learners have covered in mandatory *Unit 1: Fundamentals of Science* and optional *Unit 16: Chemistry for Biological Technicians*.

A visit to an industrial state-of-the-art laboratory is strongly recommended. If this is not possible for all learners, then tutors are strongly advised to take any opportunity to visit one themselves. This would give tutors an appreciation of the differences between industrial laboratories and centre-based laboratories to improve their delivery the unit.

Although laboratory equipment availability at centres will influence the type of practical work to be undertaken, appropriate laboratory practical exercises should be employed whenever possible. This will help learners appreciate the need to develop practical skills in order to characterise biological molecules and develop an understanding of their involvement in living systems. The following examples are given as a guide to the type of practical work that could be included in this unit:

- structure of carbohydrates – characterisation by polarimetry
- separation or purification of amino acids and/or proteins – thin layer chromatography of amino acids, electrophoretic separation of proteins
- characterisation of lipids – gas liquid chromatography of fatty acids
- study of enzyme activity – effect of pH, temperature, concentration.
- At any stage of delivery, if it is difficult to provide a particular practical experience, raw experimental data should be supplied for learners to interpret.

The main focus of learning outcome 1 is for learners to understand the diverse, polymeric nature and shapes of biological macromolecules. For each class of biological molecules listed, learners should demonstrate structural diversity arising from differing combinations and sequences of a limited number of monomers. Some knowledge of the chemical structure of the functional groups of the monomers is required: this gives a better understanding of the overall polymeric structure and the biological properties which these groups confer on the polymers. For example, with carbohydrates the aim is to provide sufficient knowledge of the functional groups of monosaccharides to understand that a storage carbohydrate consists of a highly branched polymeric structure, with some bonds that are readily hydrolysed to give a number of easily oxidised (degraded) monomer units. Tutors should outline the structural characteristics of a selected group of biological molecules (such as proteins). This could be supplemented with a practical study of a separation technique and an explanation of the relationship between behaviour and structural characteristics. For the groups of biological molecules not investigated practically, experimental data could be provided.

Learning outcome 2 should build on the knowledge of biological molecules gained so far. It is important that learners understand the relationship between the different levels of structure in proteins. They should know that the primary structure of a protein dictates its shape and therefore its function.

The aim of learning outcome 3 is to explain the characteristics and functions of enzymes. Building on their knowledge of protein structure, learners will be able to understand that the conformation of enzymes is essential for their activity. They should appreciate that the active site is lined with side chains which confer an affinity for specific substrate molecules. Learners should also be able to understand the factors that affect the rate of activity by carrying out practical investigations. The commercial use of enzymes should also be mentioned.

Learners should know the differences between anaerobic and aerobic respiration covered in learning outcome 4. The metabolic pathways should be presented in the form of a diagram so that learners see interrelationships. Stages at which there are common intermediates and sites of production of ATP, NADH and FADH should be highlighted. Anaerobic glycolysis should be considered in both yeast and muscle cells, emphasising the different end products and the effect of their buildup on continued glycolysis.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to unit and programme of assignments.
Introduction to biological molecules: carbohydrates; lipids, triglyceride; proteins; nucleic acids.
Structure and function of carbohydrates, aldehydes, ketones, monosaccharides, disaccharides, polysaccharides; use molymods to reinforce the 3D structure.
Structure and function of lipids, triglycerides, insulation, buoyancy; use molymods to reinforce the 3D structure.
Over view of proteins: 3D shape, growth, immune protection, enzymatic catalyst; use molymods to reinforce the 3D structure.
Over view of nucleic acids: transfer of genetic information.
Assignment 1: Biological Molecules (P1)
Correctly name and label monomers and polymers.
Assignment 2: Structure and Function of Biological Molecules (P2, M1, D1)
Separation of amino acids by chromatography (or other suitable separation practical) and production of an illustrated report to show how the structure of specific molecules allows them to perform their function.
Structure of proteins; side groups; amino acids structure; peptide bonds; primary, secondary, tertiary; and quaternary structure.
Assignment 3: Protein Structure (P3, M2, D2)
Presentation or flow chart describing the levels of structure in proteins.
Introduction to enzymes as biological catalysts; discussion of enzyme function to include active site, ES complex, induced fit model of enzyme action.
Assignment 4: Enzyme Structure and Function (P4, P5)
Practical investigation of at least one of the factors which influence enzyme activity.
Learner internet search on the factors that affect the rate of enzyme action: pH, temperature, substrate concentration, inhibitors, co-factors and co-enzymes.
Assignment 5: Factors Affecting Enzyme Activity (M3, D3)
Investigation of factors which affect enzyme activity.
Commercial applications: enzymes in diagnostic testing and industry, eg brewing.
Introduction to respiration: metabolism etc.
Overview of aerobic and anaerobic respiration, using animations and suitable diagrams from textbooks and the internet.
Details of glycolysis.
Details of the link reaction and Krebs's cycle including oxidative phosphorylation.
Details of the ETC.

Topic and suggested assignments/activities and/assessment

The cellular role of ATP; regulation of glycolysis including the Pasteur effect.

Outline of fatty acid metabolism.

Metabolic end products of industrial importance.

Assignment 6: Metabolic Pathways (P6, M4, D4)

Series of questions requiring short and long answers to lead learners through the steps of anaerobic and aerobic respiration.

Review of unit and programme of assignments.

Assessment

All the pass grade criteria must be met in order for a learner to achieve this unit.

For P1 and P2, learners must identify the structure and function of biological molecules and investigate separative techniques used in analysis of these molecules.

At merit level, learners will be able to discuss the structure and the function of biological molecules, in a clear and concise manner. For M1, learners require an understanding of the complex nature of biological molecules (outline structure, and shape where appropriate) and how structural diversity can arise from a relatively limited number of monomer units. Detailed chemical structures are not required: only those functional groups directly related to biological properties should be considered.

Distinction grade criteria require learners to demonstrate the ability to apply biochemical principles in the interpretation of information. They must do this largely unaided and they must integrate information of various types and from various sources. For example, they could find and discuss relevant examples to illustrate their conclusions.

For D1, learners should discuss how the structure of carbohydrates and lipids for example cellulose and phospholipids, enables them to perform their functions.

For P3, learners must describe how the primary sequence of proteins determines the secondary structure. This could take the form of a flow diagram or illustrated report. For M2, learners should build on the work produced for P3 to show their understanding of the complexity of protein structure. For D2, learners should discuss how the structure of a named protein for example haemoglobin, enables it to perform its functions. Like D1, D2 can be produced as presentations or an annotated report. Learners should be encouraged to use informative diagrams.

For P4, learners must describe the general structure and shape of an enzyme. In particular, the role of amino acid side chains in stabilising the shape should be covered.

For M3, learners must explain how enzyme rates are affected by temperature. They must account for the concepts of optimum temperature and loss of activity due to denaturation. Learners must demonstrate a clear understanding of the effect of temperature on the stabilising amino acid side chains in proteins and the consequent loss of shape. Observations from the laboratory investigations of enzyme rates should be correctly interpreted in terms of basic enzyme structure. For D3, learners must explain why changes in pH disrupt enzyme conformation and lead to denaturation.

For P5, at least two factors that affect reaction rate, for example temperature and substrate concentration, should also be investigated practically and reported. For P6, learners should describe the differences between aerobic and anaerobic respiration and could produce a diagrammatic representation of the differences in ATP production at various sites.

For M4, learners must identify sites of energy production (ATP, NADH, FADH₂) in glycolysis and the TCA cycle. They must include the role of electron transport in recycling NADH and other reduced co-enzymes with the production of ATP.

For D4, learners must identify the sites of regulation of glycolysis in response to changing concentrations of for example ATP, ADP, hydrogen ions and citrate. They must evaluate the importance of each in terms of energy requirements in cells. The effect of the build-up of lactic acid (and its removal) during anaerobic glycolysis in muscle cells should be included.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1	Biological Molecules	You are interviewing for a position within a biochemistry laboratory and you have to complete a test to identify and label monomers and polymers.	Diagrams or tables to name and label.
P2, M1, D1	Structure and Function of Biological Molecules	You have successfully gained a position as a trainee science technician at the laboratory and have been asked to conduct an experiment to separate amino acids.	Practical experiment and illustrated report.
P3, M2, D2	Protein Structure	You are delivering a BTEC class at the local college as a representative from your laboratory. You must present a flow chart to describe the levels of structure in proteins.	Presentation or flow chart.
P4, P5	Enzyme Structure and Function	As part of your traineeship you will spend time at a local brewery to investigate how the production of beer relates to enzyme activity.	Practical experiment and report.
M3, D3	Factors Affecting Enzyme Activity		
P6, M4, D4	Metabolic Pathways	On your return you are asked to share your knowledge about anaerobic and aerobic respiration and their relevance to industry.	Response paper.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Applied Science sector suite. This unit has particular links with the following units in this qualification:

Level 3

Chemistry for Biology Technicians

Genetics and Genetic Engineering

Essential resources

Learners should have access to a suitably equipped laboratory, relevant books and internet access for online research.

Employer engagement and vocational contexts

Where possible, learners should visit a molecular biology laboratory in either an academic or a commercial setting. Hands-on workshops are available in many centres such as the Science Learning Centres (www.sciencelearningcentres.org.uk) and the Manchester Museum (www.museum.manchester.ac.uk/learning/post-16). Visits from speakers from academia or industry would be helpful.

Indicative reading for learners

Textbooks

Alberts B et al – *Essential Cell Biology* (Garland Science, 2003) ISBN 9780815334811

Hames D and Hooper N – *Instant Notes in Biochemistry (Instant Notes Series)* (Bios Scientific Publishers, 2005) ISBN 9780415367783

Purves W K – *Life: The Science of Biology Volume 1 The Cell and Heredity* (WH Freeman & Co Ltd, 2001) ISBN 9780716738732

Salway J G – *Metabolism at a Glance, 3rd Edition* (Blackwell Publishing, 2003) ISBN 9781405107167

Websites

www.bbc.co.uk/science/humanbody

BBC science

www.nature.com

Nature website

www.societyofbiology.org

Society of Biology

www.wellcome.ac.uk

The Wellcome Trust

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	[IE1] identifying questions to answer when researching biological molecules, proteins and enzymes [IE2] planning and carrying out investigations in the laboratory
Creative thinkers	[CT2] asking questions to extend own thinking when identifying differences between anaerobic and aerobic glucose degradation
Team workers	[TW1] collaborating with others in the laboratory
Self-managers	[SM2] working towards goals, showing initiative, commitment and perseverance when executing experiments
Effective participators	[EP2] presenting a persuasive case for action when planning investigations.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	[IE4] analysing and evaluating information such as the regulation of glycolysis [IE6] interpreting data from experiments and supporting conclusions with evidence
Creative thinkers	[CT5] trying out alternative explanations and following ideas through
Reflective learners	[RL6] communicating learning in various ways through verbal or written presentations
Self-managers	[SM3] organising time and resources when planning investigations
Effective participators	[RL3] proposing practical ways forward when planning investigations.

● Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using appropriate software to produce graphs and tables
ICT – Find and select information	
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	searching for examples of the uses of enzymes in diagnostic testing and industry
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: <ul style="list-style-type: none"> • text and tables • images • numbers • records 	producing a report following practical investigations
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	carrying out practical investigations, getting relevant information from the right sources
Identify the situation or problem and the mathematical methods needed to tackle it	manipulating data from the enzyme activity practical
Select and apply a range of skills to find solutions	carrying out multi-stage calculations to do with amounts and sizes, scales or proportions, handling statistics and using formulae
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	interpreting data/commenting on error analysis
Draw conclusions and provide mathematical justifications	drawing conclusions from practical investigations
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	discussing aspects of 3D structures of biological macromolecules discussing advantages and disadvantages of separation of biological molecules
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching the factors that affect the rate of enzyme action
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing a report on a practical investigation.