

Unit 16: Understand the Principles and Carry Out the Practice of Biochemistry and Microbiology

Unit code:	J/600/9439
QCF Level 3:	BTEC National
Credit value:	10
Guided learning hours:	60

● Aim and purpose

This unit aims to introduce learners to biochemistry and microbiology skills and knowledge and how these can be applied in practice. It is designed for learners in centre-based settings looking to progress into the sector or onto further/higher education.

Learners will explore key processes that underpin life and investigate the lifecycle, hazards and benefits of a range of microorganisms.

● Unit introduction

Knowledge of biochemistry is essential in the life sciences to more understand the key processes that underpin life. Micro-organisms are of great importance in industry and an understanding of the way in which they operate can aid the learner significantly in laboratory applications.

This unit provides an introduction to the principles of biochemistry and microbiology.

An understanding of cellular chemistry and energy production as well as the structure of macromolecules will enable learners to appreciate the everyday physiological demands animals must meet.

The roles of micro-organisms in the world are greatly varied: they can be useful, but at the same time can present hazards to health. An awareness of these differing roles will enable learners to work safely with micro-organisms within a laboratory setting.

Biochemistry and microbiology are of particular importance to those learners wishing to advance their knowledge of animal health and nutrition, environmental health, veterinary nursing and analytical and/or diagnostic settings.

● Learning outcomes

On completion of this unit a learner should:

- 1 Know the principles of biochemistry in relation to cellular structure and function
- 2 Understand the production of adenosine triphosphate (ATP) from glucose by aerobic and anaerobic respiration
- 3 Understand enzyme kinetics
- 4 Understand the growth and reproduction of bacteria, viruses and fungi
- 5 Know the hazards and uses of micro-organisms
- 6 Be able to isolate and classify bacteria.

Unit content

1 Know the principles of biochemistry in relation to cellular structure and function

Structural representation: ball and stick, skeletal diagrams, Haworth projections, functional group abbreviations

Carbohydrates: monosaccharides (aldoses and ketoses), disaccharides, oligosaccharides; storage and structural polysaccharides

Proteins: primary (translation of amino acid sequence and peptide bond formation), secondary (α helix, β sheets), tertiary (ionic bonds, disulphide bridges, hydrogen bonds, hydrophobic-hydrophilic interactions) and quaternary structures; functions of fibrous and globular proteins

Lipids: fatty acids (saturated and unsaturated); triacylglycerols, phospholipid bilayers, micelles, functions of lipids: energy production, heat production, insulation, waxes

Biological membranes: formation, composition, fluidity, transport across (passive, active and facilitated)

2 Understand the production of adenosine triphosphate from glucose by aerobic and anaerobic respiration

Glycolysis: production of pyruvate (energy investment and generation phases)

Anaerobic respiration: fermentation of pyruvate to ethanol and carbon dioxide, or lactate; ATP yield

Aerobic respiration: pyruvate oxidation, citric acid cycle, electron transport chain and oxidative phosphorylation; ATP yield

3 Understand enzyme kinetics

Enzyme action: biological catalysts, reaction rates and reaction order; induced fit hypothesis, lock-and-key model

Factors affecting kinetics: concentration of enzyme and substrate; temperature; pH; reversible inhibition (competitive and non-competitive) and irreversible inhibition

4 Understand the growth and reproduction of bacteria, viruses and fungi

Growth: growth curves in batch cultures (lag, exponential, stationary, death); measurements of growth (total cell counts, viable cell counts, cell mass, turbidity); continuous cultures.

Environmental factors affecting growth: temperature, pH, water, oxygen

Requirements for growth: photoautotrophs, photoheterotrophs, chemolithotrophs, chemoheterotrophs, absorptive heterotrophs; temperature, pH; parasitic and mutualistic relationships

Bacteria: asexual reproduction, conjugation, transformation, transduction; plasmids.

Viruses: intracellular parasites, virions; phages, vectors

Fungi: asexual reproduction: sporangia, conidia, fission, budding; sexual reproduction: mating types

5 Know the hazards and uses of micro-organisms

Hazards: pathogens (cell damage, toxins, autoimmunity); *Salmonella* spp, *Vibrio cholera*, *Mycobacterium tuberculosis*, *Plasmodium* spp, HIV

Relevant legislation: Control of Substances Hazardous to Health Regulations 2002, Schedule 3; approved list of biological agents

Uses: production of human insulin and antibiotics, bacterial insecticides, DNA fingerprinting, probiotics, brewing, cheese making; *Rhizobium*

6 Be able to isolate and classify bacteria

Isolation of bacteria: aseptic technique, sterilisation methods, disinfection methods; agar and broth preparation, plate pouring, plate inoculation, broth inoculation, incubation

Classification of bacteria: binomial nomenclature; microscopy, oil immersion; selective media, antibiotic sensitivity; conventional bacterial taxonomy using keys, molecular taxonomy; Bergey's Manual

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 describe the structure of carbohydrates, proteins and lipids [IE, RL]	M1 compare the structure and function of fibrous and globular proteins	D1 analyse the structure of biological membranes
P2 outline the function of carbohydrates, proteins and lipids within an animal [IE]		
P3 explain the process of <ul style="list-style-type: none"> ◇ glycolysis ◇ citric acid cycle ◇ oxidative phosphorylation [IE]		
P4 compare aerobic and anaerobic respiration [IE]		
P5 evaluate models of enzyme action [IE, RL]		
P6 compare types of enzyme inhibition [IE], RL]		
P7 review the effect of environmental changes on enzyme reaction rates [IE]		
P8 compare the reproduction of micro-organisms [IE]		
P9 examine the growth requirements of micro-organisms [EP, RL]		

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:
P10 describe key uses of micro-organisms with reference to animal and human health [IE, RL]		
P11 outline the relevance of COSHH legislation with reference to working with micro-organisms [IE, SM]		
P12 identify hazards associated with handling micro-organisms [IE, SM]		
P13 isolate a monoculture from a mixed culture bacteria under aseptic conditions [SM, RL]	M2 describe the microbial colonisation of an environment.	D2 evaluate strategies to avoid antibiotic resistance in micro-organisms.
P14 use microbiological tests to classify a bacteria using a key. [SM, RL]		

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 CT – creative thinkers	RL – reflective learners TW – team workers	SM – self-managers EP – effective participators
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Essential guidance for tutors

Delivery

Delivery of this unit will involve practical and written assessments, written assessment, visits to suitable collections and will link to industrial experience placements.

Work placements should be monitored regularly in order to ensure the quality of the learning experience. It would be beneficial if learners and supervisors were made aware of the requirements of this unit before any work-related activities take place, so that naturally occurring evidence can be collected at the time. For example, learners may have the opportunity to carry out basic microbial techniques and they should be encouraged to ask for observation records and/or witness statements to be provided as evidence of this. Guidance on the use of observation records and witness statements is provided on the Edexcel website.

Visiting expert speakers could add to the relevance of the subject for learners. For example, a veterinary laboratory technician could talk about their work, the methods they use and how their work progresses animal health. A visit to an operational biochemical/microbiological laboratory would add to the relevance of the subject and contextualise the area of study to the working environment.

Health and safety issues relating to working in a laboratory must be stressed and regularly reinforced, risk assessments undertaken prior to practical activities, with adequate personal protective equipment (PPE) provided and used as necessary. When working with any Level 2 or higher micro-organism suitable laboratory operator and product protection must be considered, for example class II microbiological cabinets.

Tutors should consider integrating the delivery, private study and assessment for this unit with other relevant units and assessment instruments learners are taking as a part of their programme of study.

Learning outcomes 1 and 2 are directly linked and could be delivered by formal lectures, discussion and independent learner research.

Learning outcome 3 covers enzyme kinetics, which is likely to entail a large practical element.

Learning outcomes 4, 5 and 6 require a varied approach to deliver a rounded microbiology instruction.

It is expected that formal lectures, discussion, and independent learner research would play a part in the delivery of these outcomes and, where possible, delivery should be based on laboratory practical work.

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 gives **an indication of the volume of learning it would take the average learner** to achieve the learning outcomes. It is **indicative and is one way of achieving the credit value**.

Learning time should address all learning (including assessment) relevant to the learning outcomes, regardless of where, when and how the learning has taken place.

Topic and suggested assignments/activities and/assessment

Introduction and overview.

Standard scientific format of reports, how to locate references and how to reference sources.

Assignment 1: Macromolecules: Structure and Function (P1, P2, M1, D1)

Tutor introduces assignment brief.

Topic and suggested assignments/activities and/assessment

Representing chemical structures.

Structure and functions of carbohydrates, proteins and lipids.

Biological membranes.

Assignment 2: Metabolic Pathways (P3, P4)

Tutor introduces assignment brief.

Introduction to energy metabolism: glycolysis, the citric acid cycle and oxidative phosphorylation.

Anaerobic and aerobic respiration.

Personal study.

Section review.

Assignment 3: Enzyme Kinetics (P5, P6, P7)

Tutor introduces assignment brief.

Enzyme action.

Enzyme kinetics and factors that affect kinetics.

Enzyme kinetic practical/review of reaction rates.

Personal study.

Section review.

Assignment 4: Microbiology (P8, P9, P10, P11, P12, M2, D2)

Tutor introduces assignment brief.

Assignment 5: Practical Lab Book (P13, P14)

Tutor introduces assignment brief.

Introduction to micro-organisms – epidemiology practical demonstration.

Microscopy, plate pouring, aseptic technique.

Plate and broth inoculation.

Bacteria: classification and reproduction.

Bacteria: growth curves, bacterial culturing.

Aseptic technique, isolation of bacteria.

Bacteria: hazards and uses.

Viruses: features, reproduction, hazards, uses.

Fungi: features, reproduction, hazards, uses.

Legislation.

Personal study.

Assignment 4: Microbiology (P8, P9, P10, P11, P12, M2, D2)

Unit review.

Assessment

P1 and P2 require learners to describe the structures and functions of macromolecules. At least three structures for each class of macromolecule must be drawn and described. Evidence could take the form of an illustrated essay, pictorial presentation, annotated poster(s), or a project.

To achieve P3, learners must explain the processes of glycolysis, the citric acid cycle and oxidative phosphorylation. They must describe intermediate molecules, energy storage and release at each stage and discuss the role of each process fully. P3 may link to P1, P2 and P4, with suitable evidence in the same formats as for P1.

For P4, learners must compare aerobic and anaerobic respiration, using each of the points in the unit content as a basis. Suitable evidence would be annotated posters, presentation of posters or pictorial presentations.

P5 requires learners to evaluate models of enzyme action. At least two models must be explored, with explanations of mechanisms and arguments for the most likely mechanisms put forward. An illustrated essay assessing P5 and P6 at the same time would be suitable evidence.

P6 requires learners to compare types of enzyme inhibition, covering those types listed in the unit content as a minimum. P6 could be assessed alongside P5 and P7 as part of an illustrated essay, or as part of a practical investigation into enzyme inhibition.

For P7, learners must review the effect of environmental changes on enzyme reaction rates. This may be as part of an investigation or as a literature review, covering the effects of temperature, pH, substrate and enzyme concentration and including construction and analysis of graphs of data. Suitable evidence would be a discussion of a practical investigation which could also cover P5 and P6.

P8 and P9 must encompass bacteria, viruses and fungi and the methods they use to reproduce. Growth requirements for each must be covered fully, with ranges given and exceptions noted. Named species should be given as examples throughout. The definition of microbial growth (cell number, not size) should be made clear in the assessment. Suitable evidence could be in the form of a project, report or illustrated essay. Assessment could be undertaken at the same time as P10, P11, P12, M2 and D2.

P10, P11 and P12 are directly linked and should be assessed together. Learners should be reminded here that they are not limited to the specification and may add (not substitute) micro-organisms that may be of particular relevance to a work setting or personal interest. At least five separate species of micro-organisms must be covered. These criteria lend themselves to independent learner research and evidence for these could be illustrated essays, seminar presentations or advisory leaflets.

P13 and P14 must be assessed practically. Learners must isolate a monoculture from a mixed culture under aseptic conditions. Microbiological tests may be carried out on the isolated monoculture or the tutor may wish to provide specific bacterial cultures for learners to identify. The tutor may directly observe the learner during practical sessions, where evidence would be observation records completed by the learner and the tutor. Other suitable evidence would be a laboratory notebook or file with detailed observations of the activities carried out, including safety precautions and PPE.

M1 requires learners to compare the structure and function of fibrous and globular proteins. At least three examples of each must be described. Evidence for this could be in the form of an annotated poster or presentation with notes. It may also be assessed at the same time as P1, P2 or D1.

For M2, learners must describe the colonisation of an environment by only one species of bacteria, virus or fungi. They must refer to growth curves and preferred/optimum conditions. Suitable evidence would be an article for a hypothetical magazine, an illustrated time line/graph, an illustrated essay or as part of a project. If resources are available, learners could use stop motion photography and provide a commentary, with an accompanying transcript, as part of the evidence. Assessment for M2 may be linked to P13 and/or D2.

D1 should be a detailed analysis of the structure of biological membranes (covering composition, role of constituents, how molecules are transported etc) related to their function. Suitable evidence would be a seminar presentation, annotated poster or as part of a project. Assessment for D1 could be linked to P1, P2 and M1.

D2 requires learners to first examine and explain how antibiotic resistance comes about and then evaluate strategies that may be used in animal health in order to avoid it. An extended, illustrated essay would be suitable evidence. Links may be made to assessment for P10, P11, P12, P13, P14 and M2.

Programme of suggested assignments

The following table shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the 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, P2, M1, D1	Macromolecules: Structure and Function	Write an illustrated essay describing the structure and functions of carbohydrates, proteins and lipids. For merit level, include a full comparison of fibrous and globular proteins. For distinction level, you should describe the structure of biological membranes and relate this to their functions.	Written.
P3, P4	Metabolic Pathways	Design a poster or series of posters to explain the processes of glycolysis, the citric acid cycle and oxidative phosphorylation, leading on to a comparison of aerobic and anaerobic respiration. The poster(s) must be suitable for presentation at a course event, where you may have to answer questions about each of the processes: you should make short notes on the processes and submit them with your poster. Ensure your poster includes annotated diagrams of glycolysis, the citric acid cycle and oxidative phosphorylation.	Written/ presentation.
P5, P6, P7	Enzyme Kinetics	Prepare and carry out an investigation into the rate of reaction of amylase on a starch substrate. The background research should include an explanation of enzyme action and inhibition, including definitions of reaction rates. Environmental factors, such as temperature, pH, enzyme and substrate concentrations must be reviewed. You should fully investigate two of the variables that you discuss, construct suitable graphs and draw conclusions from the evidence you obtain.	Written/ practical investigation.

Criteria covered	Assignment title	Scenario	Assessment method
P8, P9, P10, P11, P12, M2, D2	Microbiology	<p>You are an adviser on microbiology to the UK government. As a result of some recent outbreaks of disease and public unrest about antibiotic use, as part of your job you must submit a report to inform ministers on bacteria, viruses and fungi. So that the ministers can decide on how to respond, you must include the following in your report:</p> <ul style="list-style-type: none"> • comparisons on how bacteria, viruses and fungi reproduce • what conditions micro-organisms require in order to grow (including comments on how growth may be slowed). <p>For at least five species:</p> <ul style="list-style-type: none"> • key uses of mo's with reference to human and animal health • hazards associated with working with microorganisms • current COSHH legislation and advice on working with micro-organisms. <p>For merit level, include a description of how a named species of microbe colonises an environment, including time frames and preferred growth conditions – include an annotated growth curve</p> <p>For distinction level, describe how antibiotic resistance comes about and evaluate strategies to avoid antibiotic resistance in micro-organisms. Use a micro-organism that is of particular relevance in animal health as a basis for your discussion.</p> <p>Remember, a summary of the conclusions you draw from this will form your advice to the ministers.</p>	Written.
P13, P14	Practical Lab Book	<p>The isolation of a monoculture from a mixed culture bacteria using aseptic technique and the resulting identification of that bacterium (or other bacterium provided by the tutor) using a series of microbiological tests and a key should be incorporated within the learner's lab book. The results and discussions of these practicals will be assessed.</p>	Practical.

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

This unit forms part of the BTEC land-based sector suite. This unit has particular links with:

Level 3
Chemistry for Biology Technicians
Understand the Principles of Inheritance and Genetic Manipulation
Understand the Principles of Chemistry for Biological and Medical Science

Essential resources

Laboratory facilities are required, with access to microscopes, standard glassware and biological reagents. Internet and library access is very important so that learners can study a good range of level 3 (and specialist microbiological) scientific textbooks.

Employer engagement and vocational contexts

Learners should take advantage of any opportunities for work placements in laboratory settings.

Indicative reading for learners

Textbooks

Brock T, Madigan M, Martinko J, Parker J, Dunlop P V and Clark D P – *Brock Biology of Microorganisms* (Pearson Education, 2008) ISBN 9780321536150

Heritage J, Evans E G V, Killington R A – *Introductory Microbiology* (Cambridge University Press, 1996) ISBN 9780521449779

Holt J – *Bergey's Manual of Determinative Bacteriology* (Lippincott, Williams and Wilkins, 2003) ISBN 978068300603

Indge B – *Complete A-Z Biology Handbook* (Hodder & Stoughton, 2003) ISBN 9780340872734

Lowrie P and Wells S – *Microbiology and Biotechnology* (Cambridge University Press, 2000) ISBN 9780521787239

Sadava D, Heller H C, Orians G H, Purves W K, and Hillis D M – *Life: The Science of Biology* (W H Freeman, 2009) ISBN 9780716799016

Voet D and Voet J – *Biochemistry* (John Wiley & Sons, 2004) ISBN 9780471398417

Journals

Biochemical Journal

Biological Sciences Review

Journal of Biochemistry

Journal of Biological Chemistry

Journal of Chemical Education

Journal of Clinical Microbiology

Websites

Bergey's Manual Trust	www.bergeys.org
Biology Guide	ww.biologyguide.net
Biology Mad	www.biologymad.com
Gondar Design Science	www.purchon.com/biology/animal.htm
HSE approved list of biological agents	www.hsegov.uk/pubns/misc208.pdf
HSE COSHH legislation explanation	www.hsegov.uk/biosafety/law.htm
Key Skill Company	www.keyskill.com
Microbiology Online	www.microbiologyonline.org.uk
Pharmaceutical Achievers Antibiotics in Action)	www.chemheritage.org/educationalservices/pharm/antibiot/activity/cultur.htm
Science Teacher Programme (how to culture bacteria in the laboratory)	www.scienceteacherprogram.org/biology/Ayetiwa99.html
Society for General Microbiology	www.microbiologyonline.org.uk

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies the PLTS opportunities that have been included within the assessment criteria of this unit:

Skill	When learners are ...
Independent enquirers	<ul style="list-style-type: none"> selecting information to describe structures and functions of carbohydrate, proteins and lipids explaining metabolic processes comparing aerobic and anaerobic respiration evaluating models of enzyme action describing key uses of micro-organisms describing the relevance of COSHH legislation identifying hazards of working with micro-organisms
Self-managers	<ul style="list-style-type: none"> researching the relevance of COSHH legislation to working with micro-organisms and identifying hazards of handling micro-organisms isolating monocultures from mixed cultures of bacteria using microbiological tests to identify bacteria
Reflective Learners	<ul style="list-style-type: none"> communicating ideas about macromolecule structure, models of enzyme action, growth requirements for micro-organisms, uses of micro-organisms and isolating monocultures of bacteria describing the use of microbiological tests to identify bacteria.

Although PLTS opportunities 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	<ul style="list-style-type: none"> researching roles of proteins analysing structures found in biological membranes researching functions of biological membranes investigating microbial colonisation researching antibiotic resistance and strategies to avoid it
Self-managers	<ul style="list-style-type: none"> investigating microbial colonisation organising information about antibiotic resistance.

● Functional Skills – Level 2

Skill	When learners are ...
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	carrying out research about micro-organisms
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	using the internet to find information about structures of macromolecules and biological membranes
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 written assignments and presentations
Bring together information to suit content and purpose	using the internet to gain resources about uses of micro-organisms
Present information in ways that are fit for purpose and audience	producing written assignments in a variety of ways producing presentations using relevant software
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	calculating rates of enzyme-catalysed reactions investigating growth curves of micro-organisms
Select and apply a range of skills to find solutions	carrying out investigations into enzyme kinetics carrying out investigations into growth requirements of micro-organisms
Use appropriate checking procedures and evaluate their effectiveness at each stage	carrying out investigations into enzyme kinetics
Draw conclusions and provide mathematical justifications	comparing effects of environmental factors on rates of reactions
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	gathering resources to produce written assignments involving evaluation of models of enzyme action and strategies to avoid antibiotic resistance
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing written assignments producing scientific reports.