

Unit title: **Biochemistry of Macromolecules and Metabolic Pathways**

Unit code: **F/601/0217**

QCF level: **5**

Credit value: **15**

Aim

This unit enables learners to develop practical skills and examine the chemical characteristics of amino acids, monosaccharides, nucleotides and fatty acids. These are used to develop an understanding of the structure and function of related biological macromolecules.

Unit abstract

Biochemistry deals with the chemistry of those molecular substances that occur in living organisms in terms of their structure and the processes in which they are involved. It is a key element in many scientific areas including medicine, pharmacology, genetics and biotechnology.

Learners will examine how biological systems comprise macromolecules which are derived from building block molecules such as amino acids, sugars, nucleosides and fatty acids. They will develop an appreciation of how the structure and properties of macromolecules are determined by the chemical structure and functional group chemistry of the building block molecules. The structure of macromolecules, including proteins, polysaccharides, nucleic acids and lipids, are examined with a view to relating them to key biological functions such as enzyme metabolism or protein biosynthesis.

The unit will also enable learners to understand the key features of principal metabolic pathways and their relationship to each other. For example, they will develop an appreciation of the role played by gluconeogenesis in overcoming irreversible steps in glycolysis.

Learners will have the opportunity to develop a range of basic practical skills by carrying out scientific investigations in the laboratory that involve measurement, separation and purification, as related to the above topics.

Learning outcomes

On successful completion of this unit a learner will:

- 1 Understand the chemical principles that apply to the structures of biological building block molecules
- 2 Understand the structures of biological macromolecules and the relationships to biological functions
- 3 Understand the features of and links between the major metabolic pathways
- 4 Be able to use biochemical practical skills and cognate techniques.

Unit content

1 Understand the chemical principles that apply to the structures of biological building block molecules

Amino acids: functional group chemistry, acidic and basic properties, isoelectric points; chemical structure; side chain types and classification; optical isomerism; D and L classification; essential amino acids

Monosaccharides, aldoses and ketoses: functional group chemistry; reducing properties; reactivity of glycosidic hydroxyl groups; chemical structure; cyclic structure formation; α and β terminology; optical isomerism

Nucleosides and nucleotides: nitrogen bases; sites of attachment of sugar residues

Fatty acids: saturated; unsaturated; essential fatty acids

2 Understand the structures of biological macromolecules and the relationships to biological functions

Protein structure: primary (planar nature of the peptide bond and dihedral angles); secondary (helix and β sheet as a consequence of dihedral angles and hydrogen bonding); tertiary (types of intramolecular stabilising bonds); structure and properties of globular and fibrous proteins; quaternary e.g. haemoglobin

Enzymes: relationship between structure and function; enzymes as biological catalysts (active site structure, substrate binding, strain and specificity); properties of enzymes (pH_{opt} , T_{opt} , V_{max} , K_m); denaturation; enzyme inhibition limited to competitive and non-competitive; allosteric enzymes; collagen as a structural protein (role of glycine and proline, triple helix structure, fibril formation)

Polysaccharides: glycogen; starch; cellulose; relationship between storage polysaccharides and shape due to α glycosidic links; importance of branching; structural polysaccharides as a result of glycosidic links; enzymic hydrolysis of polysaccharides as a result of β glycosidic links; enzymic hydrolysis of polysaccharides as a source of monosaccharides and energy

Nucleic acids: structure of a strand of deoxyribonucleic acid (DNA); double helix and the role of hydrogen bonding; types of ribonucleic acid (RNA); outline of protein biosynthesis

Phospholipids: lipids as exemplified by triglycerides and phospholipids; phospholipids in membrane formation; effect of saturated to unsaturated fatty acid ratio on membrane fluidity

3 Understand the features of and links between the major metabolic pathways

Main metabolic pathways: glycolysis; fermentation; electron transport; fatty acid \square oxidation; gluconeogenesis; fatty acid synthesis

Processes controlling metabolism: free energy change; relationship between metabolism and free energy change; equilibrium; metabolic flux

Irreversible steps: irreversibility in terms of free energy changes; reverse of pathways as different chemical steps

Control of glycolysis and gluconeogenesis: factors that control catabolic pathways; factors that control anabolic pathways; phosphofructokinase (PFK1)

4 Be able to use biochemical practical skills and cognate techniques

Protein separation: methods used to separate or purify proteins e.g. gel filtration chromatography, ion exchange chromatography, affinity chromatography, polyacrylamide gel electrophoresis (PAGE)

Determination of unknown concentrations: selected biological molecules e.g. determination of concentrations of glucose, an amino acid or bovine serum albumin by colorimetry

Determination of enzyme characteristics: characteristics e.g. specific activity, T_{opt} , pH_{opt} , V_{max} , K_m , type of inhibition

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Understand the chemical principles that apply to the structures of biological building block molecules	1.1 explain the principal properties and classification of amino acids 1.2 explain the principal properties and classification of monosaccharides, aldoses and ketoses 1.3 explain the principal properties and classification of nucleosides and nucleotides 1.4 explain the principal properties and classification of fatty acids
LO2 Understand the structures of biological macromolecules and the relationships to biological functions	2.1 discuss the differences in protein structure at primary, secondary and tertiary level between globular and fibrous proteins 2.2 explain the structure, catalytic function and characteristic properties of enzymes 2.3 review the major features of storage and structural polysaccharides 2.4 outline briefly the roles of the nucleic acids in protein biosynthesis with reference to the structural differences between DNA and different types of RNA 2.5 explain the structural features and properties of phospholipids that enable them to form membranes
LO3 Understand the features of and links between the major metabolic pathways	3.1 summarise the function of the main metabolic pathways and the relationships between them 3.2 review the processes that control metabolic pathways 3.3 explain the apparent irreversible steps in glycolysis and the role of gluconeogenesis in overcoming them 3.4 explain the control of glycolysis and gluconeogenesis exhibited by phosphofructokinase (PFK1)

<p>Learning outcomes On successful completion of this unit a learner will:</p>	<p>Assessment criteria for pass The learner can:</p>
<p>LO4 Be able to use biochemical practical skills and cognate techniques</p>	<p>4.1 plan types of protein separation in terms of the theory and practice involved</p> <p>4.2 carry out a separation and purification of protein from a simple mixture, using safe practices</p> <p>4.3 determine experimentally the concentration of an unknown biological molecule, using safe practices</p> <p>4.4 determine experimentally the characteristics of an enzyme, using safe practices.</p>

Guidance

Links

This unit has particular links with the following units within this qualification:

- *Unit reference number T/601/0215: Cell Biology*
- *Unit reference number L/601/0219: Laboratory Techniques for Applied Biology*
- *Unit reference number F/601/0220: Analysis of Scientific Data and Information*
- *Unit reference number K/601/0292: Chemistry for Applied Biologists*
- *Unit reference number Y/601/0224: Neurophysiology and Homeostatic Control of the Human Body*
- *Unit reference number D/601/0225: Molecular Biology and Genetics*
- *Unit reference number M/601/0228: The Immune Response System*
- *Unit reference number K/601/0227: Pharmacological Principles of Drug Actions.*

Essential requirements

Delivery

Throughout the unit, chemical structures must be used wherever possible. For learning outcome 1, learners must appreciate the differences between D and L isomers, as well as alpha and beta anomeric structures.

For learning outcome 2, for the structure of DNA, nitrogen bases should be represented by the letters ATCG.

For learning outcome 3, awareness of the links between pathways is essential.

For learning outcome 4, learners must cover three types of protein separation in terms of the theory and practice involved.

Assessment

For learning outcome 1, learners must demonstrate an ability to represent chemical structures of compounds with one chiral centre in 2D and 3D forms as well as their knowledge of the fundamental principles of building block molecules. There should be an appreciation of the biochemical significance relating to functional group(s) within these molecules.

For learning outcome 2, learners must be able to show how the structure of the biological macromolecules enables them to perform the functions they are involved in. Again, particular emphasis should be placed on the chemistry underlying functions such as the catalytic activity of enzymes or the role of nucleotides in protein synthesis.

Evidence for learning outcome 3 needs to detail the biochemical reactions involved in the major metabolic pathways and recognise the importance of free energy (G) changes in these reactions. The relationship between the different pathways, especially glycolysis and gluconeogenesis, should be emphasised.

Learning outcome 4 requires learners to demonstrate practical skills and cognate techniques.

Resources

Learners need access to well-equipped laboratory facilities to carry out practical investigations. Tutorial support, library and ICT resources are also required for learners to undertake independent research.

Employer engagement and vocational contexts

Learners will benefit from visits to laboratories that are engaged in investigations or research into biochemical processes. For example, medical laboratories, agri-food research and/or veterinary science. These facilities would enable learners to observe the application of biochemistry and biochemical techniques within a particular context.