Unit title: Molecular Biology and Genetics

Unit code: **D/601/0225**

QCF level: **5**

Credit value: **15**

Aim

This unit enables learners to understand the processes responsible for the maintenance, transmission and expression of genetic information at a molecular level and carry out experimental techniques associated with them.

Unit abstract

In recent times there has been a revolution in terms of understanding the processes responsible for the maintenance, transmission and expression of genetic information at the molecular level. Molecular biology seeks to explain the relationships between the structure and function of biological molecules and how these relationships contribute to the operation and control of biochemical processes. This unit will enable learners to understand the structure and function of macromolecules and macromolecular complexes of DNA, RNA and protein. The unit will also enable learners to understand the processes of replication, transcription and translation, and how gene regulation is controlled. Learners will be able to predict how alleles are transferred within populations. The factors that alter the gene pool of a population and contribute to variation within the population will also be discussed. The unit enables learners to understand the human genome and proteome projects and their applications.

The new experimental technologies involved in manipulating DNA, RNA and protein not only yield fundamental information about these molecules, but also have important practical applications. For example, in the development of new and safe products such as therapeutics and vaccines, in the diagnosis of genetic disease and in disease therapy. This unit enables learners to learn how to manipulate genetic material in vitro and gives them the opportunity to profile and amplify DNA. Learners will gain an understanding of genetic engineering and its importance.

The unit also provides learners with the opportunity to explore bioinformatics methods and their applications.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the processes of information transfer from DNA to protein

2 Understand factors involved in the regulation of gene expression

3 Be able to carry out experimental techniques involved in manipulating DNA, RNA and protein

4 Be able to determine patterns of inheritance

5 Understand how changes in gene frequencies result in changes in populations.

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Unit content

1 Understand the processes of information transfer from DNA to protein

Sub-cellular organelles: nucleus; cytoplasm; endoplasmic reticulum; ribosomes

Organisation of Deoxyribonucleic acid (DNA): nucleotide sub-units of DNA; nitrogenous bases; phosphodiester linkages; formation of the double helix; formation of chromosomes; introns; exons

Protein structure: amino acids; peptide bond; primary structure; secondary structure; tertiary structure; quaternary structure

Structure of Ribonucleic acid (RNA): ribose; uracil; messenger RNA, codon, transfer RNA

Transcription of DNA: RNA polymerase, promoter, upstream; downstream; termination signals; leader sequence; coding sequence; stop codon; messenger RNA processing

Translation of messenger ribonucleic acid (mRNA): properties of transfer RNA; initiation; elongation; termination

2 Understand factors involved in the regulation of gene expression

Operons: promoters; operators; repressor genes

Negative and positive control: negative control (structure of the lactose operon, inducible genes, inducer molecules, repressible genes, co-repressor); positive control (structure of the tryptophan operon, catabolite gene activator protein-cyclic adenosine monophosphate (CAP-cAMP) complex)

3 Be able to carry out experimental techniques involved in manipulating DNA, RNA and protein

DNA replication: RNA primer; origin of replication; replication fork; DNA polymerase; leading strand; lagging strand; Okazaki fragments; DNA ligase

DNA and mRNA isolation: DNA extraction eg agarose gel electrophoresis, polyacrylamide gel electrophoresis, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-Page), DNA fingerprinting, cesium chloride gradient, affinity chromatography, western blot, southern blot, northern blot

Polymerase chain reaction (PCR): PCR cycle; template; primers; enzymes; optimisation; variations

Production of recombinant DNA: restriction endonucleases; ligase; reverse transcriptase

Transformation: complementary DNA (cDNA); host; cloning vectors; bacteriophages; plasmid

Bioinformatics: methods eg gene prediction software, sequence alignment software, BLAST program

4 Be able to determine patterns of inheritance

Terminology: gene; allele; locus; homozygous; heterozygous; dominant; recessive; genotype; phenotype

Exemplar crosses: monohybrid; punnet square; dihybrid; autosomal linkage; two-point test cross; frequency of crossing over; chi-square test; sex-linked traits; multiple alleles; co-dominance; pleitropy; epistasis; polygenic inheritance

Inherited diseases: autosomal recessive traits eg phenylketonuria (PKU), cystic fibrosis, sickle cell anaemia; autosomal dominant traits eg Huntington's disease, pedigree analysis

5 Understand how changes in gene frequencies result in changes in populations

Mutations: base substitution mutations; missense mutations; nonsense mutations; frameshift mutations; transposons; hotspots; mutagens; mutations and disease

Hardy-Weinberg principle: gene pool; allele frequency; genetic equilibrium; five conditions for Hardy-Weinberg equilibrium; application of Hardy-Weinberg principle

Genetic drift: explanation of genetic drift; genetic bottlenecks; the founder effect; gene flow

Natural selection: stabilising; directional; disruptive; polymorphism; heterozygote advantage; frequency dependent selection

Human genome project: history of the human genome project; bioinformatics and evolution; ethical issues

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 processes of information transfer from DNA to protein	1.1 explain the role of subcellular organelles 1.2 describe the organisation of DNA in prokaryotic and eukaryotic cells 1.3 review the structure of proteins and RNA 1.4 explain the process of transcription and translation
LO2 Understand factors involved in the regulation of gene expression	2.1 discuss the structure of operons 2.2 explain the features of positive and negative control
LO3 Be able to carry out experimental techniques involved in manipulating DNA, RNA and protein	3.1 explain the process of DNA replication 3.2 safely perform techniques to isolate DNA and mRNA 3.3 describe the Polymerase Chain Reaction 3.4 illustrate the stages in the production of recombinant DNA 3.5 carry out genetic transformations, using safe practices 3.6 use bioinformatics software to interpret data
LO4 Be able to determine patterns of inheritance	4.1 explain the terminology used in determining patterns of inheritance 4.2 construct appropriate crosses from information provided to show patterns of inheritance 4.3 relate inherited diseases to patterns of inheritance

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO5 Understand how changes in gene frequencies result in changes in populations	5.1 explain how mutations provide the variation necessary for evolution to occur within a given species 5.2 assess the significance of the Hardy-Weinberg principal as it relates to evolution 5.3 explain how in genetic drift random events change allele frequencies 5.4 discuss factors influencing natural selection using appropriate examples 5.5 discuss the human genome project.

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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 F/601/0217: Biochemistry of Macromolecules and Metabolic Pathways*
- *Unit reference number J/601/0218: Physiology of Cellular Systems in Animals*
- *Unit reference number L/601/0222: Laboratory Management*
- *Unit reference number M/601/0228: The Immune Response System*
- *Unit reference number M/601/0231: Infectious Diseases*

Essential requirements

Delivery

Unit delivery must emphasise how molecular biology yields fundamental information about the structure and function of biological molecules. How manipulating DNA, RNA and protein has practical applications in the development of therapeutics, vaccines and foodstuffs, and in the diagnosis of genetic disease and in gene therapy must be covered. Digital presentations, illustrations and CD ROMs should be available to illustrate the structure of DNA, RNA, proteins and operons. Digital presentations should also be used to illustrate the processes of transcription, translation, operon control and DNA replication.

Experimental work has been central to developments in molecular biology and genetics, and as a result must form the basis of delivery where possible. Where complex experiments may not be feasible, case studies could be used. Group resource-based research work and learner-led seminars could also be helpful.

The use of case histories must be integrated where possible into laboratory investigations. Diagnostic kits should be used as part of the laboratory programme. Tutors must emphasise the importance of health and safety throughout the delivery and assessment of learning outcome 3. Learners must understand the importance of adhering to laboratory health and safety guidelines when working with serum and live tissue. Practical tasks must include risk analyses consistent with COSHH guidelines.

Industry links, work placements and visits from personnel with technical expertise in using molecular biology techniques would enhance delivery of this unit.

Assessment

Learning outcome 1 involves understanding the structure of DNA, RNA and protein. It also involves understanding how the genetic code on DNA is used to produce proteins.

Learning outcome 2 involves understanding how gene transcription in prokaryotes is controlled. Evidence could include a time-constrained assessment.

Learning outcome 3 involves carrying out laboratory investigations, handling specimens safely, interpreting results and applying them to case histories or medical situations. The techniques used will depend on the equipment available in the centre but must include DNA extraction, electrophoresis, genetic transformation, comparative proteomics and BLAST searches as a minimum. Learners may provide evidence by performing appropriate molecular biology techniques and interpreting the results. Where equipment is not available, for example thermocyclers for PCR, evidence could include general reviews, presentations, literature searches and interpretation exercises. Assessor observation records should be completed to confirm achievement.

Learning outcome 4 involves being able to predict patterns of inheritance. Evidence must include carrying out genetic crosses to include monohybrid, dihybrid, two-point test crosses and sex linkage studies. Evidence could also be produced from experimental work involving Drosophila and clover.

Learning outcome 5 involves understanding how changes in gene frequencies result in changes in populations. Evidence can be derived from carrying out Hardy-Weinberg problems. General reviews, literature searches and interpretation exercises are also appropriate for providing evidence. In addition, the completion of comparative proteomics experiments, and the construction of cladograms, can be used to provide evidence.

Resources

Learners require laboratory access, ideally with facilities that enable them to study a reasonable range of common molecular biology methods. Molecular biology teaching kits containing workbooks, review questions and interpretation exercises are now available commercially and should be used where possible.

Learners will need access to appropriate tutorial support and library resources. The use of DVDs, computer teaching programmes and CD ROM simulations of experiments should be encouraged. Learners will also need suitable access to the internet in order to use genetic databases. Visits to centres with molecular biology facilities would be advantageous.

Employer engagement and vocational contexts

Understanding molecular biology and genetics is of fundamental importance in understanding the processes responsible for the maintenance, transmission and expression of genetic information. The new experimental technologies involved in manipulating the molecules associated with the transfer of genetic information and protein expression have many practical applications in the development of therapeutics, vaccines and foodstuffs. They are also valuable tools in the understanding, diagnosis and development of treatments for genetic diseases. The unit gives learners opportunities to appreciate the importance of molecular biology technology as a valuable tool in industry and diagnostic research.

Learners will have an opportunity to learn many of the current molecular techniques and how to use the genetic databases that are now available as a result of the human genome project. Learners will benefit from visiting industrial molecular biology facilities to observe genetic engineering in operation.

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