Unit 18: Genetics and Genetic Engineering

Unit code: T/502/5559

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to develop understanding of the principles of Mendelian genetics and to develop knowledge and practical techniques used in commercial, analytical and research laboratories.

Unit introduction

To study genetics is to study the basis of life itself. Building on the knowledge of DNA structure which is covered in *the Biochemistry and Biochemical Techniques unit*, this unit will enable learners to appreciate that genes control all of the characteristics of living organisms. Learners will also understand how the mechanisms of cell division and chromosome replication lead to complex patterns of inheritance and evolution.

Massive advances in DNA technology over the last 20 years mean that molecular biology and genetics are central in fields as diverse as forensics, epidemiology, screening for diseases and archaeology. The tools and the knowledge now available allow manipulation of the 'blueprints' of life and the creation of 'novel' organisms. Current research is moving towards gene therapies which may enable correction of genetic diseases such as cystic fibrosis.

Learners will develop an understanding of the techniques at the heart of modern genetics and molecular biology – extracting DNA, DNA fingerprinting, transforming cells and amplifying DNA using the polymerase chain reaction (PCR).

The cutting edge of genetics is moving forward at an extraordinary rate, creating enormous potential for applications. Geneticists can be found in many fields of forensic work, in epidemiology, in screening for diseases and in searching for cures. The ever-growing biotechnology industry depends heavily on the work of geneticists and molecular biologists to provide both new products and the means to mass-produce them.

Applications of genetics in agriculture include modified crops with enhanced nutritional value, flavour, shelf-life or resistance to pests and disease. Environmental applications allow us to map migration of species and populations, and to identify animals illegally taken from the wild.

Scientists must also recognise the broader implications of their work. Learners are required to examine the impact of selected examples of genetic technology on industry, society and the ethical values of individuals and organisations.

Learning outcomes

On completion of this unit a learner should:

1 Understand the process of protein synthesis

2 Be able to investigate the process of cell division in eukaryotic cells

3 Understand the principles of Mendelian genetics

4 Be able to apply basic techniques of DNA technology.

Unit content

1 Understand the process of protein synthesis

Structure of nucleic acids: DNA; RNA; mRNA; tRNA

Stages: transcription; translation; amino acid activation

Genetic code: triplet codes; codon; anticodon; degenerate code

2 Be able to investigate the process of cell division in eukaryotic cells

Structure and function of the human chromosome: centromere; chromatids; autosomes; sex chromosomes; chromosome number; homologous and non-homologous chromosomes

Cell division: the cell cycle; interphase; stages of mitosis and meiosis, centrioles, cytokinesis (in animal cells); diploid/haploid numbers; sex determination

Demonstrate: root tip squash to demonstrate mitosis; lily anther squash to demonstrate meiosis

3 Understand the principles of Mendelian genetics

Principles of classical genetics: Mendel's laws of inheritance, Mendelian ratios; principle of independent assortment; interpretation of mono and dihybrid phenotypic ratios from practical investigation from primary or secondary source information; continuous and discontinuous variation; effects of environmental changes

Modern genetics: genes; genotype; alleles; dominance and codominance; linkage; sex linkage eg haemophilia; chromosome mutation eg Down's syndrome; dominant and recessive disorders eg Huntington's disease, sickle cell anaemia, cystic fibrosis

4 Be able to apply basic techniques of DNA technology

DNA extraction: chromosomal or plasmids

Gel electrophoresis of DNA fragments: use of restriction enzymes; principles of electrophoresis

Transformation of cells: use of vectors; plasmids; use of marker genes; DNA ligase; screening to identify transformed cells

Amplification of DNA: polymerase chain reaction and its applications

Examples of genetic engineering: GM crops; gene therapy; insulin and human growth hormone production; impact eg commercial, social, ethical

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 compare and contrast the structure of various nucleic acids [IE1; CT2]	**M1** explain how genetic information can be stored in a sequence of nitrogenous bases in DNA	**D1** explain the steps involved in biosynthesis of protein including the roles of RNA
P2 identify the stages of mitosis and meiosis in eukaryotic cells [IE1; CT2]	**M2** describe the behaviour of chromosomes during cell division using the results of the practical investigations	**D2** analyse the correlation between observed pattern of dihybrid inheritance and the expected pattern
P3 carry out practical investigations to record stages of cell division [IE2; TW1; SM2; EP3]		
P4 explain how the behaviour of chromosomes leads to variation [IE4]	**M3** apply principles of modern Mendelian genetics to predict patterns of monohybrid, dihybrid inheritance and variation	
P5 explain monohybrid and dihybrid inheritance ratios [IE4]		
P6 carry out basic DNA techniques [IE2; TW1; SM2; EP3]	**M4** describe digestion of DNA by restriction endonucleases and electrophoresis of fragments.	**D3** explain the steps involved in producing a genetically modified organism.
P7 identify applications of genetic engineering. [IE1]		

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

A visit to an industrial state-of-the-art laboratory is strongly recommended. Learners should appreciate the sophistication of modern-day high-tech laboratories compared with the basic equipment available in educational laboratories. Differences include the analytical machinery which is in common use, multiple transfer conditions, the clear demarcation of 'clean' and 'contaminated' areas (not only in biological and animal laboratories, but even in many chemistry ones) and the separate space for computers, desks etc that learners may not be aware of.

This unit is intended to have a practical element, and it would benefit learners to carry out practical work in both Mendelian and molecular genetics.

For learning outcome 1, learners should show their understanding of the structure and function of the DNA molecule and use this as a basis to describe the process of protein synthesis. They must emphasise the role of nitrogen base pairing and sequence in relation to the storage of information.

For learning outcome 2, which involves the study of cell division, it would be preferable for learners to complement practical activities using root tips and other preparations, with electronic simulations. Learners are expected to be able to use microscopes competently and should have the opportunity to carry out a practical examination of both forms of cell division. Mitosis in a garlic or onion tip would be a straightforward practical, with the anther or locust testis squash for meiosis.

In learning outcome 3, inheritance in *Drosophila melanogaster* can be investigated using quite affordable kits from suitable suppliers and does not require any specialist equipment beyond an incubator. If that is deemed impractical, enough data to allow a chi-squared analysis can be gathered from counts using sources such as corn cob sets. Chi-squared analysis can be carried out using a spreadsheet if desired. Alternatively, electronic simulations can be found on CD ROM or by online subscriptions to facilities such as Virtual FlyLab.

For learning outcome 4, the basic techniques of DNA technology are now quite easy to demonstrate in simplified form in the laboratory. DNA can be extracted from plant tissue very simply, and kits are available for extraction of DNA from cheek cells. Protocols for DNA or plasmid extraction, gel electrophoresis and cell transformation can be obtained from sources such as the National Centre for Biotechnology Education at the University of Reading, and Bio-Rad. These protocols are designed to be affordable within the resources of schools and colleges.

The polymerase chain reaction can be carried out manually using water baths. While this is a laborious process, it gives the learners a clearer picture of the steps involved in the process than a PCR machine does.

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 protein synthesis. Structure of nucleic acids: DNA, RNA, mRNA, tRNA.
Genetic code, triplet codes, codon, anticodon, degenerate code transcription, translation, amino acid activation.
Assignment 1: Protein Synthesis (P1, M1, D1)
Chromosome structure and function.
Cell division including cell cycle and the stages of mitosis and meiosis. Haploid and diploid number. Sex determination.
Assignment 2: Cell Division Correctly Identify all stages from micrographs/diagrams or online. **(P2)**
Assignment 3: Mitosis and Meiosis Mitosis in root tips – complete practical and produce accurate drawings of mitotic figures. Answer questions on the role of meiosis in variation. Report on the behaviour of chromosomes during cell division. **(P3, P4, M2)**
Introduction to Mendelian genetics. Mendel's laws. Mono- and dihybrid crosses, including dominant, recessive and co-dominant alleles.
Dihybrid problem solving.
Sex linkages.
Drosophila or simulated breeding experiments.
Assignment 4: Mendelian Genetics Using actual and/or simulated data explain mono and dihybrid inheritance ratios. Solve mono- and dihybrid problems. Analysis of the expected and observed patterns of inheritance. **(P4, P5, M3, D2)**
Introduction to molecular biology techniques. Learner internet search.
Assignment 5: DNA Techniques Complete extraction of DNA from plant matter or cheek cells and write up a report on the technique. **(P6)**
Details of molecular biology.
Explanation of PCR – what it is and what it is used for. If possible, practical demonstration of the technique.
From gene to transgenic organism. Insulin, growth hormone, GM soya etc. internet research to identify different GM products.
Assignment 6: Applications of Genetic Engineering Learners to share their research results and then to produce individual presentations. Describe examples of GM products. Discuss issues. **(P7)**
Assignment 7: Genetic Engineering Process Describe the digestion of DNA by restriction endonucleases and its separation by electrophoresis. Describe, using diagrams or other appropriate means, how a named genetically modified organism is produced. **(M4, D3)**
Review of unit and programme of assignments.

Assessment

Assessment should be based on a learner's portfolio of practical activities and their understanding of the underpinning science.

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

For P1, learners should show their understanding of the structure of nucleic acids (DNA, RNA, mRNA, tRNA) which could take the form of a table of comparison.

For P2 and P3 learners must identify the stages of meiosis and mitosis. This should be accompanied by drawings from the microscope which clearly represent the relevant stages – preferably from the learners' own slide preparations or if necessary from prepared slides. Their investigations could involve use of a root tip squash, meiosis as shown in anther or locus testis squashes.

For P4 and 5 learners should perform practical investigations into patterns of mono and dihybrid inheritance. Drosophila experiments performed in groups will allow learners to develop handling skills and microscope techniques to enable interpretation of ratios. If this is not possible, simulations such as 'Rebops' will give learners a good understanding of the processes involved. For P5, learners can use the their own experimental data or be given a suitable data set which will allow interpretation.

For P6 learners must produce a portfolio of basic DNA technology. These reports must be based on the learners' own activities. Learners could extract DNA from plant material, for example onions or pulses. This is an extremely straightforward procedure which requires no specialised equipment. Kits are also available to extract DNA from cheek cells.

For P7, researched information on current uses of genetically engineered products and procedures should be presented as a report or oral presentation. Reference to social, commercial and ethical impact of these should be included.

For a merit grade, all the pass grade criteria and all the merit grade criteria must be met.

For M1, learners could produce an annotated report or poster which clearly explains the relationship between the sequence of bases in DNA and the sequence of amino acids in proteins.

For M2, learners should be encouraged to use visuals (for example diagrams, photographs) where possible to indicate an understanding of the chromosome and gene behaviour during cell division.

For M3, learners should be able to complete and comment on dihybrid crosses involving independent and linked genes. They should also be able to predict the outcomes of crosses between non-affected, affected and carriers of particular disorders.

For M4, learners could produce an annotated flow chart which explains digestion of DNA by restriction endonucleases and its separation by electrophoresis.

For a distinction grade, all the pass, merit and distinction grade criteria must be met.

For D1, learners must show a clear understanding of protein synthesis and the roles of mRNA and tRNA. This could be in the form or an extended report or a PowerPoint presentation. The use of diagrams or other visuals should be encouraged.

For D2, an analysis of their own experimental data is preferable but if this is not possible a suitable data set should be provided, for example corn cob sets. It is preferable that learners to perform chi-squared analysis on the data. Chi-squared analysis can be carried out using a spreadsheet if desired.

For D3, learners should clearly show an understanding of the steps involved in genetic engineering. This could take the from of an annotated flow diagram. It is important that a named example is used and that the steps and reagents are described accurately.

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, M1, D1	Protein Synthesis	You are about to start work in a molecular biology laboratory and you have been asked to demonstrate your understand of DNA, RNA and protein synthesis.	Report on Nucleic acid structure and function including all of the steps involved in protein synthesis.
P2	Cell Division	Your role will involve correctly identifying the stages in cell division in mitotic and meiotic cells.	Correctly identify all stages from micrographs/diagrams or online.
P3, P4, M2	Mitosis and Meiosis	For demonstration purposes, the lab has asked you to make some preparations of root tips which show mitosis.	Practical work and Report.
P4, P5, M3, D2	Mendelian Genetics	Your work in the laboratory will require an extensive and demonstrable understanding of genetics.	Solve mono- and dihybrid problems. Analysis of the expected and observed patterns of inheritance.
P6	DNA Techniques	You are now ready to start working with DNA and your first task is to extract it from a suitable source.	Practical work. extraction of DNA from plant materials and/ or cheek cells.
P7	Applications of Genetic Engineering	You have been asked to research current uses of genetically engineered products and procedures and prepare a presentation.	Presentation.
M4, D3	Genetic Engineering Process	Before you can start manipulating DNA you need to familiarise yourself with the techniques involved. This includes digestion of DNA by restriction endonucleases, its separation by electrophoresis, and insertion into the host organism.	Description using diagrams or other appropriate means how a named genetically modified organism is produced.

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 the BTEC Applied Science suite of qualifications:

Level 2	Level 3
The Living Body	Physiology of Human Body Systems
Biotechnology Procedures and Applications	Physiology of Human Regulation and Reproduction
	Biochemistry and Biochemical Techniques
	Microbiological Techniques

Essential resources

Access to normal school or college laboratory facilities is expected. This should include all usual glassware, water baths, pipettes, microscopes etc. Models of DNA and RNA will help learners to understand the three dimensional structure of these molecules. Resources for the aseptic handling and disposal of bacteria will also be necessary. The laboratory should have bench surfaces suitable for topical sterilisation. Use of laminar flow cabinets is desirable but not essential. Pre-irradiated plastic petri dishes and pipettes, autoclave, media, microbiological loops, spreaders, culture bottles etc will all be required. Micropipettes and autoclavable tips are recommended. An incubator will be required for incubation of bacteria and *Drosophila*.

Since most of the DNA manipulation techniques are either designed to be performed using basic equipment or come in kit form, they have relatively few essential requirements. Micropipettes are useful, although simple forms are provided with many kits, and quantitative observation (desirable, though not essential; qualitative is acceptable), for example of β-galactosidase induction, requires a colorimeter.

Learners are expected to have access to a library containing Level 3 biology texts, as well as journals and newspapers in paper or electronic form. They should also have access to the internet.

Employer engagement and vocational contexts

Where possible, learners should visit a molecular biology laboratory in either an academic or 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

Adds J, Larkcom E and Miller R – *Genetics, Evolution and Biodiversity (Nelson Advanced Science: Biology Series)* (Nelson Thornes Ltd, 2004) ISBN 9780748774920

Adds J, Larkcom E and Miller R – *Molecules and Cells (Nelson Advanced Science: Biology Series)* (Nelson Thornes Ltd, 2003) ISBN 9780748774845

Giddings G, Jones N and Karp A – *The Essentials of Genetics* (Hodder Murray, 2001) ISBN 97807195861l8

Journals

Biological Science Review

New Scientist

Scientific American

Websites

www.abpischools.org.uk	Association of the British Pharmaceutical Industry
www.biologylab.awlonline.com/	Biology simulations and exercises
www.dnai.org/index	DNA interactive
www.dnalc.org/ddnalc/resources/animations	Gene Almanac DNA animations
www.dnalc.org/ddnalc/resources/shockwave/dnadetectives	DNA detective
www.ncbe.reading.ac.uk/menu	National Centre for Biotechnology Education
www.ncbe.reading.ac.uk/ncbe/protocols/PRACBIOTECH/PDF/onion.pdf	Method for extraction of DNA from onions
www.rothamsted.ac.uk/notebook/courses/guide/	Beginner's guide to molecular biology
www.thetech.org/genetics/zoomIn/index.html	DNA interactive
www.vcell.ndsu.nodak.edu/~christjo/vcell/animationSite/index	Virtual Cell animations

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 nucleic acids, eukaryotic cells and genetic engineering [IE2] planning and carrying out investigations in the laboratory [IE4] analysing information to produce an explanation of the behaviour of chromosomes and inheritance ratios
Creative thinkers	[CT2] asking questions and conducting research to extend thinking on nucleic acids and eukaryotic cells
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	[EP3] proposing practical ways forward when conducting experiments.

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 correlation between observed and predicted inheritance patterns [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 – Find and select information	
Select and use a variety of sources of information independently for a complex task	researching information on genetic engineering
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	producing an investigative report
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	carrying out chi-squared calculations
Select and apply a range of skills to find solutions	carrying out a practical investigation to record the stages of cell division
Draw conclusions and provide mathematical justifications	drawing conclusions from calculations and evaluating practical investigations
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	taking part in a group discussion about genetic engineering carrying out a presentation of their experiment to carry out DNA techniques
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	reading about the commercial, social and ethical concerns over genetic engineering
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing a report following laboratory experiments.