OCR
Oxford Cambridge and RSA

Cambridge **TECHNICALS LEVEL 3**

APPLIED SCIENCE

Cambridge TECHNICALS 2016

Unit 5 – Genetics
DELIVERY GUIDE

Version 2

ocr.org.uk/science

CONTENTS

INTRODUCTION

This Delivery Guide has been developed to provide practitioners with a variety of creative and practical ideas to support the delivery of this qualification. The Guide is a collection of lesson ideas with associated activities, which you may find helpful as you plan your lessons.

OCR has collaborated with current practitioners to ensure that the ideas put forward in this Delivery Guide are practical, realistic and dynamic. The Guide is structured by learning outcome so you can see how each activity helps you cover the requirements of this unit.

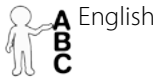
We appreciate that practitioners are knowledgeable in relation to what works for them and their learners. Therefore, the resources we have produced should not restrict or impact on practitioners' creativity to deliver excellent learning opportunities.

Whether you are an experienced practitioner or new to the sector, we hope you find something in this guide which will help you to deliver excellent learning opportunities.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk.

OPPORTUNITIES FOR ENGLISH AND MATHS SKILLS DEVELOPMENT AND WORK EXPERIENCE

We believe that being able to make good progress in English and maths is essential to learners in both of these contexts and on a range of learning programmes. To help you enable your learners to progress in these subjects, we have signposted opportunities for English and maths skills practice within this resource. We've also identified any potential work experience opportunities within the activities. These suggestions are for guidance only. They are not designed to replace your own subject knowledge and expertise in deciding what is most appropriate for your learners.



English

Maths


Work

Please note

The activities suggested in this Delivery Guide **MUST NOT** be used for assessment purposes. The timings for the suggested activities in this Delivery Guide **DO NOT** relate to the Guided Learning Hours (GLHs) for each unit.

Assessment guidance can be found within the Unit document available from http://www.ocr.org.uk/. The latest version of this Delivery Guide can be downloaded from the OCR website.

UNIT AIM

Genetics is the study of inheritance. We now know that in all organisms, genes control the characteristics that are passed on from generation to generation. Advances in DNA technologies have demonstrated the potential of this work in several areas of science, including our understanding of disease and screening for inherited conditions, epidemiology and disease control, forensic science and historical and archaeological investigations.

This unit looks at how characteristics are inherited using the long-established techniques of crossing plants and animals, and in humans, by looking at the inheritance of certain characteristics and clinical conditions.

By studying this unit, you will be able to apply techniques used in genetics crosses using mathematical techniques to determine probability of inheritance by producing genetic chromosome maps using data from crosses. You will understand how geneticists are now able to produce detailed chromosome maps using the science of genomics.

Unit 5 Genetics	
LO1	Understand the importance of meiosis
LO2	Be able to apply techniques used in genetics crosses
LO3	Understand the techniques of DNA mapping and genomics
LO4	Understand the impact of an innovation in an application of genomics

To find out more about this qualification, go to: http://www.ocr.org.uk/qualifications/vocational-education-and-skills/cambridge-technicals-applied-science-level-3-certificate-extended-certificate-foundation-diploma-diploma-extended-diploma-05847-05849-05879-05874-2016-suite/

Cambridge TECHNICALS 2016

2016 Suite

- **New suite for first teaching September 2016**
- **Externally assessed content**
- **Eligible for Key Stage 5 performance points from 2018**
- **Designed to meet the DfE technical guidance**

RELATED ACTIVITIES

The Suggested Activities in this Delivery Guide listed below have also been related to other Cambridge Technicals in Applied Science units/Learning Outcomes (LOs). This could help with delivery planning and enable learners to cover multiple parts of units.

This unit (Unit 5)	Title of suggested activity	Other units/LOs	
LO1	The principles of meiosis Explaining the process of meiosis	Unit 1 Science fundamentals	LO3 Understand cell organisation and structures
		Unit 8 Cell biology	LO3 Understand the cell cycle and the importance of mitosis
LO2	Dihybrid crosses	Unit 19 Crop production and soil science	LO1 Understand how common crops are grown for commercial production in the UK
LO3	DNA sequencing – a historical perspective DNA electrophoresis Genetic profiling – principles	Unit 1 Science fundamentals	LO3 Understand cell organisation and structures
		Unit 2 Laboratory techniques	LO2 Be able to separate, identify and quantify the amount of substances present in a mixture
LO4	How is information from the Human Genome Project used?	Unit 11 Drug development	LO1 Understand the principles of drug discovery and development processes
		Unit 18 Microbiology	LO4 Understand the action of antimicrobials on microorganisms
	Case study on an application of genomics	Unit 20 Conservation of biodiversity	LO4 Be able to investigate the efficacy of practical measures to conserve biodiversity

KEY TERMS

Explanations of the key terms used within this unit, in the context of this unit	
Key term	**Explanation**
Allele	One form of a gene; e.g. tall and dwarf are the alleles for the height of a pea plant. More than two alleles can exist for any specific gene, but only two of them will be found within any individual.
Carrier	In a single gene disorder controlled by a recessive allele, a heterozygous individual, in which the condition will not appear in the phenotype, but will be 'carried' to the next generation.
Chromosome	A thread-like structure found in the nucleus of cells that is composed of DNA coiled around associated proteins. Chromosomes carry genetic information in the form of genes.
Crossover	The exchange of genetic material between adjacent chromatids of a homologous pair of chromosomes during Prophase I of meiosis. After crossing over, the sister chromatids of each chromosome will no longer be identical.
Dihybrid inheritance	The inheritance pattern of two different characteristics.
DNA	Deoxyribonucleic acid, a polymer made from repeating units called nucleotides.
Dominant	In a heterozygous combination, the allele that is expressed in the phenotype.
Epistasis	Where two or more genes at different loci interact. This interaction could produce a new phenotype, cause one allele to mask the effects of another/others, or one allele to modify the effects of another/others.
Gamete	A reproductive cell: an ovum (female) or sperm (male) in animals; an ovule (female) or pollen grain (male) in plants.
Gene	The unit of heredity comprising a linear sequence of nucleotides in a chromosome.
Genome	The total genetic information/material in an organism. The definition is often confined to chromosomal DNA, but should also include extra-chromosomal DNA, e.g. in mitochondria and plasmids.
Genomics	The study of the genomes of organisms.
Heterozygous	An individual that contains different alleles at the gene pair on homologous chromosomes; e.g. Dd.
Homozygous	An individual that contains only one type of allele at the gene pair on homologous chromosomes; e.g. DD is homozygous dominant and dd is homozygous recessive.
Meiosis	A reduction division in which chromosome number is halved.
Monohybrid inheritance	The inheritance pattern of a single characteristic.
Nucleotide	The repeating unit that makes up a nucleic acid, comprised of a nitrogenous base, a five-carbon sugar (deoxyribose or ribose) and a phosphate group.
Punnett square	A diagram used to illustrate or predict the outcome of a genetic cross. It was first devised and used by Reginald Crundall Punnett, one of the founders of the science of genetics and the first Professor of Genetics at the University of Cambridge in the early part of the twentieth century.
Recessive	In a heterozygous combination, the allele that is not expressed in the phenotype.

MISCONCEPTIONS

Some common misconceptions and guidance on how they could be overcome		
What is the misconception?	**How can this be overcome?**	**Resources which could help**
The factors influencing genetic variation	The three factors influencing genetic variation should be reinforced. Ultimately, mutation is the origin of genetic variation. Sexual reproduction and meiosis contribute to genetic variation. Crossing over and independent assortment should be discussed.	Sources of variation Griffiths, A.J.F., Miller, J.H., Suzuki, D.T. et al. (2000) *An Introduction to Genetic Analysis.* Seventh edition. New York: W.H. Freeman. http://www.ncbi.nlm.nih.gov/books/NBK22012/ A description of the sources of genetic variation.
Distinguishing between incomplete dominance and codominance	Learners may not appreciate that the differences relate to the degree of dominance. Use the examples of incomplete dominance, e.g. the snapdragon flower, *Antirrhinum*; and codominance, e.g. blood groups, roan coat colour in cattle.	Extensions of Mendelian Genetic Principles Academia.edu http://www.academia.edu/4716862/Extensions_of_Mendelian_Genetic_Principles_Chapter_4_Palomino_Horse_Incomplete_dominance_2_Multiple_Genes_One_Phenotype An in-depth look at incomplete dominance and codominance.
The differences between DNA sequencing and genetic profiling	Learners often confuse DNA sequencing with techniques that look at only part of the genome; for instance, genetic profiling.	Reinforcement of the differences through teaching.
Genetic profiling statistics	Learners appreciate that the product rule of probabilities is applied across the loci involved when calculating probabilities of forensic matches between DNA profiles, but do not always realise that the allele frequencies for each STR locus must be taken into consideration.	What are the 13 core CODIS loci? The Biology Project, University of Arizona http://www.biology.arizona.edu/human_bio/activities/blackett2/str_codis.html An excellent explanation of how the frequency of a genetic profile is worked out, albeit with just 13 loci.
The Human Genome Project	It is important to understand that genomics is not just about creating detailed maps of chromosomes. It is also about understanding the structure and function of genomes and understanding the role different genes and other regions of the genome play in the growth and development of an organism. While learners' studies of genetics tend to focus on just single genes, it is really important to realise that diseases caused by single genes are very rare; most are caused by several or many genes.	Human Genome Project and the Sanger Institute The Wellcome Trust Sanger Institute http://www.sanger.ac.uk/about/who-we-are/sanger-institute/history-sanger-institute/human-genome-project-and-sanger-institute Explains the role the Sanger Institute played in the Human Genome Project. Human Genome Project US Department of Energy http://web.ornl.gov/sci/techresources/Human_Genome/index.shtml Sets out the goals of the Human Genome Project.

SUGGESTED ACTIVITIES

LO No:	1		
LO Title:	**Understand the importance of meiosis**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
The principles of meiosis	A discussion of the principles of meiosis, i.e. the requirements of a reduction division in gamete production, should be established before beginning any genetics proper. This may be a recap from a Level 2 biology or science course. While learners may be conversant with the principles, they are unlikely to know the stages of meiosis. Introduce this with an animation in conjunction with a set of diagrams (use of the old nomenclature for the events of Prophase I is not recommended). The outcome of meiosis is that the four daughter cells produced will each have one chromosome from each homologous pair. Meiosis Sadava et al. (2010) *Life: The Science of Biology*. Ninth edition. Sinauer Associates http://www.sumanasinc.com/webcontent/animations/content/meiosis.html Animation of meiosis. Animation: How Meiosis Works McKinley, M. and O'Loughlin, V.D. (2006) *Human Anatomy*. McGraw-Hill Global Education http://highered.mheducation.com/sites/0072495855/student_view0/chapter28/animation__how_meiosis_works.html Animation of meiosis. The developing individual: Meiosis, growth and development (3.1.2) OCR http://www.ocr.org.uk/qualifications/as-a-level-gce-biology-b-advancing-biology-h022-h422-from-2015/delivery-guide/module-bb03-module-3-cell-division-development-and-disease-control/delivery-guide-bbdg013-the-developing-individual-meiosis-growth-and-development-312 OCR AS/A Level resources that include a meiosis animation.	1 hour	Unit 1 LO3 Unit 8 LO3

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Explaining the process of meiosis	Learners frequently affirm that they understand the process, but subsequently have difficulty in explaining it in detail. Animating the process will facilitate greater understanding. Individual learners should use poppet beads or pipe cleaners to construct 'chromosomes', given an instruction to demonstrate this (to peers or the tutor) in a cell of 2n = 4 or 3n = 6, for example. They could then progress to producing more formal animations, using a series of annotated diagrams, or a computer animation. An alternative might be to photograph poppet bead 'movements' during the process. This will be extended in future activities. The cell cycle, mitosis and meiosis University of Leicester – Virtual Genetics Education Centre http://www2.le.ac.uk/departments/genetics/vgec/schoolscolleges/topics/cellcycle-mitosis-meiosis An excellent website covering a range of genetics topics and links to resources.	1 hour	Unit 1 LO3 Unit 8 LO3
How does crossing over lead to genetic variation?	Learners will now look at the impact of crossing over during Prophase I of meiosis. For a pair of homologous chromosomes (paired up, with replicated DNA), learners could be asked to illustrate the exchange of genetic material before and after crossing over. They could use coloured poppet beads (which again, could be photographed), diagrams or produce a computer animation to illustrate the process. They should appreciate that the four gametes produced by meiosis will not carry forward genetic material unchanged from its maternal or paternal origin. Chapter 11: Sexual reproduction and meiosis Raven et al. (2008) *Biology*. Eighth edition. McGraw-Hill http://highered.mheducation.com/sites/9834092339/student_view0/chapter11/meiosis_with_crossing_over.html An animation of meiosis and crossing over. Nature of crossing-over Griffiths, A.J.F., Miller, J.H., Suzuki, D.T. et al. (2000) *An Introduction to Genetic Analysis*. Seventh edition. New York: W.H. Freeman. http://www.ncbi.nlm.nih.gov/books/NBK21900/ A more detailed account of meiosis and crossing over.	2 hours	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Segregation and independent assortment of genes	From the previous activity, learners will appreciate the principle of segregation of alleles during the formation of gametes (and then randomly uniting at fertilisation). The principle of independent assortment is fundamental to an understanding of genetics and dihybrid inheritance. Learners should appreciate that in gamete formation, the assortment of single chromosomes from each homologous pair into the gametes is random, so for instance, all the maternal chromosomes would not be separated into one cell, with paternal chromosomes into another. The assortment would be random for each chromosome. Again, the process is best demonstrated actively, with learners illustrating the process and some permutations with their poppet bead chromosomes, diagrams or computer animation. Principle of independent assortment Nature http://www.nature.com/scitable/definition/principle-of-independent-assortment-law-of-independent-302 A description of independent assortment. Chapter 11: Sexual reproduction and meiosis Raven et al. (2008) *Biology*. Eighth edition. McGraw-Hill http://highered.mheducation.com/sites/9834092339/student_view0/chapter11/random_orientation_of_chromosomes_during_meiosis.html A very good animation illustrating independent assortment.	1 hour	

SUGGESTED ACTIVITIES

LO No:	2		
LO Title:	**Be able to apply techniques used in genetics crosses**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Monohybrid crosses	Monohybrid crosses will be familiar to many learners. The topic could be approached using a historical perspective, but is best approached in context. It is becoming increasingly clear that most human traits once thought of as demonstrating single gene inheritance, e.g. attached and detached ear lobes, are now known to involve more than one gene, so monohybrid inheritance is perhaps best demonstrated, initially, through the inheritance of a single gene disorder, e.g. cystic fibrosis. The principle of segregation should be reinforced, and the use of Punnett squares to illustrate genetic crosses may need to be demonstrated. Learners should work through, and demonstrate understanding of, a number of genetic crosses, i.e. • homozygous dominant x homozygous recessive • heterozygous x heterozygous • heterozygous x homozygous recessive. Learners should be able to demonstrate predicted ratios and probabilities, and appreciate that these are more likely to be met/approached in large population sizes than in families in human genetics. Learners could produce a number of displays to illustrate the crosses. Patterns of inheritance University of Leicester – Virtual Genetics Education Centre http://www2.le.ac.uk/departments/genetics/vgec/schoolscolleges/topics/inheritancepatterns A good introduction to Mendelian inheritance. Mendelian Genetics The University of Arizona – The Biology Project http://www.biology.arizona.edu/Mendelian_genetics/mendelian_genetics.html A good introduction to mono- and dihybrid inheritance. BTEC Applied Science: Harry Potter Genetics Fiendishlyclever https://www.tes.com/teaching-resource/btec-applied-science-harry-potter-genetics-6109054 A fun introduction to monohybrid crosses.	2 hours	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Incomplete dominance and codominance	The snapdragon flower, *Antirrhinum majus*, is a good example of incomplete dominance. The principle should be described, then learners should have the opportunity to demonstrate crosses when given specific examples. Additional examples include the 4 o'clock plant, *Mirabilis jalapa*, and the Andalusian breed of chicken. Learners could produce a number of displays to illustrate the crosses. Instances where dominance is incomplete should be distinguished from those of codominance. A good example to use is A, B, O blood groups. This should be explained, initially, by a simple illustration of type of glycolipid on the cell surface of red blood cells. Learners, again, should work through and could present displays of the principles involved. Incomplete dominance (1:2:1) ExpertsMind http://www.expertsmind.com/questions/incomplete-dominance-121-30117047.aspx Three examples of incomplete dominance. Extensions of Mendelian Genetic Principles Academia.edu http://www.academia.edu/4716862/Extensions_of_Mendelian_Genetic_Principles_Chapter_4_Palomino_Horse_Incomplete_dominance_2_Multiple_Genes_One_Phenotype A more in-depth look at incomplete dominance and codominance.	2 hours	
What is the relationship between phenotype and genotype at a molecular level?	Learners do not always consider the relationship between genotypes and phenotypes at physiological, molecular or biochemical levels, but this provides a good way of not only understanding the concept of 'dominant' and 'recessive', but also codominance and incomplete dominance. One place to start is with the gene involved in cystic fibrosis (CFTR) on Chromosome 7. It should be readily apparent why the heterozygote is 'normal'. Proceed to other contexts such as characteristics of pea plants. Reid, J.B. and Ross, J.J. (2011) Mendel's Genes: Toward a Full Molecular Characterization. *Genetics* 189, 3-10. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3176118/ The function of the genes in Mendel's crosses.	1 hour	
How are genes inherited on the sex chromosomes?	Learners should appreciate that for genes on the sex chromosomes, inheritance patterns will differ in males and females. In this activity, the onus should be on learners to demonstrate an understanding of genetics by illustrating some human genetic crosses that are sex-linked. Examples include red-green colour blindness, haemophilia, and Duchenne muscular dystrophy. Learners should trace and be able to explain the pattern of inheritance of some of these characteristics through family trees. Sex Linkage The Genetic Science Learning Center at The University of Utah http://learn.genetics.utah.edu/content/pigeons/sexlinkage/ An overview of sex linkage, including in birds, where females are the heterogametic sex.	1 hour	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Dihybrid crosses	Learners have already looked at independent assortment in Learning Outcome 1, and this will be reinforced when considering the inheritance of two genes. With a short demonstration of the principles, learners should be able to illustrate their own crosses. Mendelian Genetics The University of Arizona – The Biology Project http://www.biology.arizona.edu/Mendelian_genetics/mendelian_genetics.html A good introduction to mono- and dihybrid inheritance. This could be supported by learners carrying out some genetics crosses. Use *Drosophila melanogaster* or rapid cycling brassicas, *Brassica rapa*. In the latter, yellow-green and rosette mutants will give a 9:3:3:1 ratio in the F_2 generation. 'Fast Plants' - Rapid-Cycling Brassica Kits Student Sheet 1 - Planting instructions for rapid-cycling brassicas Student Sheet 2 - Growing and caring for rapid-cycling brassicas Practical activities for teaching genetics Science & Plants for Schools http://www.saps.org.uk/secondary/teaching-resources/126-rapid-cycling-brassica-kits http://www.saps.org.uk/secondary/teaching-resources/229-student-sheet-1-planting-instructions-for-rapid-cycling-brassicas#sthash.WzRA0iWd.dpuf http://www.saps.org.uk/secondary/teaching-resources/230-student-sheet-2-growing-and-caring-for-rapid-cycling-brassicas#sthash.MJMLa5zA.dpuf http://www.saps.org.uk/saps-associates/browse-q-and-a/471-can-you-suggest-some-practical-activities-for-teaching-qapplications-of-genetics Practical activities in genetics using rapid cycling brassicas. Having carried out crosses, or using secondary data, learners should use the chi-squared test to compare expected (9:3:3:1) and observed progeny in a cross. It is important that they show understanding of statistical significance of differences in data, and probabilities of (any apparent) differences having occurred by chance. Chi-squared tests University of Maryland, Mathbench Biology Modules http://mathbench.umd.edu/modules-au/statistical-tests_chisquare_intro/page15.htm A good introduction to chi-squared tests.	2 hours	Unit 19 LO1

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Developing an understanding of epistasis	Tutors may wish to progress to gene linkage after the statistical analyses, as this leads naturally to early techniques of gene mapping. Genes can be linked or sometimes show an interaction called epistasis, where two or more genes at different loci interact to produce a new phenotype, cause one allele to mask the effects of another/others, or cause one allele to modify the effects of another/others. Typically, if epistasis is involved, instead of a 9:3:3:1 ratio in a typical dihybrid cross, a modified Mendelian ratio is produced, e.g. a 9:7 ratio, 15:1 ratio, etc. This is best illustrated using examples, e.g. comb colour in chickens, kernel colour of wheat, flower colour in sweet peas, fruit colour of squashes, and learners should, when working through some dihybrid crosses, demonstrate that they can identify the type of interaction taking place. Several examples could be investigated by learners covering a range of different ratios. Inheritance Science Aid http://www.scienceaid.co.uk/biology/genetics/inheritance.html A basic introduction to the principles of epistasis (along with other principles of genetics). Gene interactions Phillip McClean, North Dakota State University https://www.ndsu.edu/pubweb/~mcclean/plsc431/mendel/mendel6.htm A good overview of gene interactions, with examples.	2 hours	
Developing an understanding of gene linkage	Ideas about gene linkage could be introduced through a historical perspective, e.g. the work of Bateson and Punnett with sweet peas, then learners should be introduced to other examples. As with epistasis, learners should be able to, when working through a range of dihybrid crosses, identify the type of interaction taking place. Linked Genes On The Same Chromosome Exhibit Distorted Mendelian Ratios Phillip McClean, North Dakota State University https://www.ndsu.edu/pubweb/~mcclean/plsc431/linkage/linkage1.htm A good introduction to gene linkage and use of the chi-squared test. Lobo, I. and Shaw, K. (2008) Discovery and types of genetic linkage. *Nature Education* 1(1):139 http://www.nature.com/scitable/topicpage/discovery-and-types-of-genetic-linkage-500 There is a series of articles on gene linkage on the Scitable website, http://www.nature.com/scitable. Some Genes Are Transmitted in Groups via the Phenomenon of Gene Linkage Nature http://www.nature.com/scitable/topicpage/Some-Genes-Are-Transmitted-to-Offspring-in-6524945 A excellent overview of gene linkage.	1 hour	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Constructing gene maps	Learners will be familiar with the principles of DNA recombination – the exchange of genetic material that occurs between homologous chromosomes during meiosis – from Learning Outcome 1. For this task, learners could produce a review on gene mapping, using some illustrations of the estimations to be carried out, and the limitations of the techniques, but beginning with a historical perspective of the events that led to the production of the first genetic maps. Alfred Sturtevant used measurements of recombination between genes to create the first genetic map. See: Genetic Linkage and Distances Boundless Biology https://www.boundless.com/biology/textbooks/boundless-biology-textbook/modern-understandings-of-inheritance-13/chromosomal-theory-and-genetic-linkage-97/genetic-linkage-and-distances-427-11654/ A basic introduction to genetic mapping. Lobo, I. and Shaw, K. (2008) Thomas Hunt Morgan, genetic recombination, and gene mapping. *Nature Education* 1(1):205 http://www.nature.com/scitable/topicpage/Thomas-Hunt-Morgan-Genetic-Recombination-and-Gene-496 An excellent introduction from a historical perspective. Learners should then appreciate: • that the amount of crossing over will be related to how close the genes are to each other on the chromosome. Genes that are relatively close together undergo fewer crossing over events than those farther apart, so fewer recombinant gametes are produced. For genes next to each other on a chromosome, crossover events will be rare. Genes may be so close together on a chromosome that they are always inherited as a single unit. • that from observed recombinant offspring in cross, it is possible to estimate the genetic distance on a chromosome between the genes in question. Learners could be taken though this procedure, and the numerical components involved (the percent of recombinants is the distance in centimorgans [cM]). In their review, learners should illustrate the logic using real or hypothetical recombination data from crosses to produce a simple genetic map of a chromosome. Clearly, this should be limited to a *small* number of genes.	4 hours	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Constructing gene maps (continued)	Recombination and Estimating the Distance Between Genes Philip McClean, North Dakota State University https://www.ndsu.edu/pubweb/~mcclean/plsc431/linkage/linkage2.htm A good introduction to gene mapping from recombinant data. Deriving Linkage Distance and Gene Order From Three-Point Crosses Philip McClean, North Dakota State University https://www.ndsu.edu/pubweb/~mcclean/plsc431/linkage/linkage3.htm Gene mapping from recombinant data. In the final part of the review, learners should describe the limitations of gene maps produced in this way, resulting from the possibility of further crossovers, leading to a discrepancy between distances in maps produced and actual progeny obtained in crosses, and other gene interactions. The advent of DNA sequencing techniques has transformed gene mapping.		

SUGGESTED ACTIVITIES

LO No:	3		
LO Title:	**Understand the techniques of DNA mapping and genomics**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
DNA sequencing – a historical perspective	Tutors could begin by defining DNA sequencing and establishing the difference between this and techniques looking at only part of the genome, e.g. genetic profiling. They could direct learners to relevant sources so learners could obtain an overview of development of DNA sequencing techniques. These should include: • the Sanger sequencing method • the development of the polymerase chain reaction (PCR), enabling scientists to rapidly amplify DNA samples • the first fully-automated systems (developed by Applied Biosystems). • the advent of next-generation sequencing techniques (NGS, or high-throughput sequencing) – note that learners get an overview here, but it is suggested that they research this in more detail in the 'Advances in DNA sequencing' activity (see below). Learners could produce a timeline summarising these events, as a display or interactive web page. Sanger method of DNA sequencing; DNA Sequence Assembly; Polymerase chain reaction (PCR) HHMI Biointeractive http://www.hhmi.org/biointeractive/sanger-method-dna-sequencing http://www.hhmi.org/biointeractive/dna-sequence-assembly http://www.hhmi.org/biointeractive/polymerase-chain-reaction-pcr There are many animations available that illustrate the principles of DNA sequencing, but the Howard Hughes Medical Institute (HHMI) offers a series of animations pitched at a good, introductory level. Next generation sequencing Wellcome Genome Campus http://www.yourgenome.org/stories/next-generation-sequencing The 'Your Genome' site, with a series of excellent links to web pages on DNA sequencing. History of Genome Sequencing – The Sanger Method Roche Diagnostics Corporation. 454 Life Sciences http://454.com/downloads/news-events/history-of-genome-sequencing_FINAL.pdf Comprehensive overview of the history.	2 hours	Unit 1 LO3 Unit 2 LO2

Title of suggested activity	Suggested activities	Suggested timings	Also related to
DNA sequencing – a historical perspective (continued)	What is Next-Generation DNA Sequencing EMBL-EBI http://www.ebi.ac.uk/training/online/course/ebi-next-generation-sequencing-practical-course/what-you-will-learn/what-next-generation-dna- An overview of the techniques involved. Online Genomics Resources NHS Health Education England. Genomics Education Programme. https://www.genomicseducation.hee.nhs.uk/resources/online-genomics-resources Links to some helpful genomics resources.		
DNA electrophoresis	While learners are carrying out their research, this could be interspersed with some practical work that illustrates the principles, i.e. PCR and DNA electrophoresis. See: Investigating Plant Evolution: amplifying chloroplast DNA using PCR Science & Plants for Schools (SAPS) http://www.saps.org.uk/secondary/teaching-resources/119-investigating-plant-evolution-amplifying-dna-using-pcr Simple extraction of chloroplast DNA from plant tissue, its amplification by the PCR, and gel electrophoresis of the PCR product. The PCR and plant evolution National Centre for Biotechnology Education (NCBE) http://www.ncbe.reading.ac.uk/NCBE/MATERIALS/DNA/plantevomodule.html The materials for the extraction, amplification, and gel electrophoresis of chloroplast DNA samples.	4 hours	Unit 1 LO3 Unit 2 LO2

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Advances in DNA sequencing	Learners should be given an overview of NGS, and then directed to a series of resources that describes procedures and the implications and applications of these. What is Next-Generation DNA Sequencing EMBL-EBI http://www.ebi.ac.uk/training/online/course/ebi-next-generation-sequencing-practical-course/what-you-will-learn/what-next-generation-dna- An overview of the techniques involved. An Introduction to Next-Generation Sequencing Technology Illumina http://www.illumina.com/content/dam/illumina-marketing/documents/products/illumina_sequencing_introduction.pdf An excellent, more detailed overview of the techniques involved. Online Genomics Resources NHS Health Education England, Genomics Education Programme https://www.genomicseducation.hee.nhs.uk/resources Links to some helpful genomics resources.	2 hours	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Genetic profiling – principles	Tutors could give of a brief overview of the technique of genetic profiling. An engaging starting point could be ITV's 'Code of a Killer', a dramatisation of the work of Dr Alec Jeffreys. See: Code of a Killer ITV http://www.itv.com/presscentre/press-packs/code-killer The DVD is available from DVD outlets. Learners should then be directed towards references to produce an overview of the principles. This is particularly important as much information on the Internet is out of date, with current techniques being based on analysis of short, repeating sections of DNA – short tandem repeats (STRs). Are You Ready For The Biggest Change In Forensic DNA Technology In The UK Since 1995? DNA 17 http://dna17.co.uk/ The first minute of the video gives a helpful overview of the development of DNA profiling. Blackett Family DNA Activity 2: What is a Short Tandem Repeat Polymorphism (STR)? Methods of Analysis of STRs Collecting STR DNA profile data The Biology Project, University of Arizona http://www.biology.arizona.edu/human_bio/activities/blackett2/str_description.html http://www.biology.arizona.edu/human_bio/activities/blackett2/str_analysis.html http://www.biology.arizona.edu/human_bio/activities/blackett2/act_data1.html An excellent introduction to STRs and methods of analysis. These also link well with the next suggested activity. Information fact sheet for the introduction of new DNA-17 profiling chemistries for the National DNA Database (NDNAD) Home Office www.keyforensic.co.uk/docs/dna17-factsheet1.pdf A good overview of the introduction of the technique. DNA-17 Profiling The Crown Prosecution Service http://www.cps.gov.uk/legal/d_to_g/dna-17_profiling/ A good review of the technique, partial matches and risks.	2 hours	Unit 1 LO3 Unit 2 LO2

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Genetic profiling – principles (continued)	The National DNA Database The Parliamentary Office of Science and Technology (2006) http://www.parliament.uk/documents/post/postpn258.pdf A good review, though now out of date, of the National DNA Database (NDNAD). Learners may wish to locate the loci involved, and a helpful article is on the Promega website, one of the producers of DNA chemistries approved to generate profiles for the National DNA Database (NDNAD). Strategies for Concordance Testing Promega http://www.promega.co.uk/resources/profiles-in-dna/2010/strategies-for-concordance-testing/ An excellent overview of the 17 loci of the PowerPlex systems.		
Statistical consideration of genetic profiling 	The probability of a match between DNA profiles when analysing DNA from a crime scene with that of a suspect or DNA database, or to eliminate people from an enquiry, is critical in forensic science. The product rule of probabilities across the loci can be used, but learners must also take allele frequencies for each STR locus into consideration. The University of Arizona web pages illustrate the principles extremely well and should form the basis of learners' understanding of the principles. Learners should work through the web pages below to develop an understanding of the calculation of gene frequencies, and can then use data from the site to illustrate their calculations of probabilities based on combined profiles at several loci that they specify. Blackett Family DNA Activity 2: What are the 13 core CODIS loci? DNA Profile Frequency Calculations Genotype Probability at any STR Locus The Biology Project, University of Arizona http://www.biology.arizona.edu/human_bio/activities/blackett2/str_codis.html http://www.biology.arizona.edu/human_bio/activities/blackett2/act_probability1.html http://www.biology.arizona.edu/human_bio/activities/blackett2/str_frequency.html Excellent web pages on frequency/probability calculations of loci.	2 hours	

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Evaluation of genetic profiling techniques	DNA 17 offers improved discrimination between genetic profiles, but a number of factors potentially affect the reliability of the technique and the conclusions that can be drawn. These are grouped into: • Quality of DNA: degradation and interference of other chemicals generating at best partial matches • Sensitivity of techniques and contamination • Errors in amplification • Compatibility of different systems • Extent of NDNAD. Miscarriages of justice resulting from flawed DNA collection and analysis are becoming increasingly rare, but learners could research and present case studies of these miscarriages of justice, focusing on the scientific elements. Learners could develop an understanding of a range of possible flaws in genetic profiling techniques, then apply these to real-life crime cases (preferably) or fictitious scenarios they develop and describe. DNA-17 Profiling The Crown Prosecution Service http://www.cps.gov.uk/legal/d_to_g/dna-17_profiling/ A good review of the technique, partial matches and risks.  Several websites are available describing miscarriages of justice related to DNA evidence. The quality of the evidence and discussion varies and learners should be able to evaluate the reliability of these.	3 hours	

SUGGESTED ACTIVITIES

LO No:	4		
LO Title:	**Understand the impact of an innovation in an application of genomics**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
How is information from the Human Genome Project used?	A good place to start is for learners to begin by researching the Human Genome Project. There is a plethora of information on this project. This work has evolved into the science of genomics. It is important for learners to understand that genomics is not just about creating detailed maps of chromosomes. It is also about understanding the structure and function of genomes and understanding the role different genes and other regions of the genome play in the growth and development of an organism. Learners could go on to present information on the impact of any innovation in the field of genomics, but health implications are well-documented, and this activity could begin with a discussion of this, before learners work on an application in which they are interested. Learners should be introduced to a series of resources that will present the rationale, successes and potential of future developments. They should consider ethical, legal and social implications (ELSI). **General websites** Adams, J. (2008) DNA sequencing technologies. *Nature Education* 1(1):193 http://www.nature.com/scitable/topicpage/dna-sequencing-technologies-690# There is a series of articles on genomics on the Scitable website, http://www.nature.com/scitable. NHS Health Education England, Genomics Education Programme https://www.genomicseducation.hee.nhs.uk/ Programme to prrovide staff in the health and care system with the knowledge, skills and experience in genomic and precision medicine. The website has useful links to educational resources. Next-generation sequencing Wellcome Genome Campus http://www.yourgenome.org/stories/next-generation-sequencing The 'Your Genome' site, with a series of excellent links to web pages on DNA sequencing. BRAF: From Gene to Cancer Therapy Wellcome Genome Campus http://www.yourgenome.org/video/braf-from-gene-to-cancer-therapy-video A video on how DNA sequencing was used to identify that the gene BRAF is commonly mutated in malignant melanoma, and how this led to the development of a targeted drug against the mutation.	4 hours	Unit 11 LO1 Unit 18 LO4

Title of suggested activity	Suggested activities	Suggested timings	Also related to
How is information from the human genome used? (continued)	The Human Genome Project: Benefits Biology-Online http://www.biology-online.org/articles/human-genome-project/benefits.html Some applications of genomic research. Applications and issues of the Human Genome Project David Boehm http://www.ndsu.edu/pubweb/~mcclean/plsc431/students99/boehm.htm An account of the Human Genome Project written in 1999 before its completion. Human Genome Project US Department of Energy http://web.ornl.gov/sci/techresources/Human_Genome/index.shtml A general website with a series of helpful links. **Disease and healthcare** Genomes and Disease Nature Education http://www.nature.com/scitable/ebooks/genomes-and-disease-16569473/contents E-book published in 2010. Introducing Genomics in Healthcare Genomics Education Programme https://www.youtube.com/watch?v=KiQgrK3tge8 Vivienne Parry OBE introduces the fundamentals of genomics and its growing importance in healthcare. The 100,000 Genomes Project Genomics England http://www.genomicsengland.co.uk Genomics England was set up by the Department of Health to deliver the 100,000 Genomes Project. Initially the focus will be on rare disease, cancer and infectious disease. Genome campus will host UK NHS 100,000 genomes project Wellcome Trust Sanger Institute http://www.sanger.ac.uk/news/view/2014-08-01-genome-campus-will-host-uk-nhs-100-000-genomes-project Press release announcing £200 million funding for UK genomic research into cancer and rare disease.		

Title of suggested activity	Suggested activities	Suggested timings	Also related to
How is information from the human genome used? (continued)	Weinstock, G.M. and Peacock, S. (2014) Next-generation pathogen genomics. *Genome Biology*, 5, 28 http://www.genomebiology.com/content/pdf/s13059-014-0528-6.pdf An overview of pathogen genomics. Pathogen Genome Cluster Computing London School of Hygiene and Tropical Medicine http://pgcluster.lshtm.ac.uk/genomes.htm An overview of genomes of pathogenic bacteria Public Health Genomics Centers for Disease Control and Prevention http://www.cdc.gov/genomics/pathogen/index.htm An overview of genomes of pathogenic bacteria. **Cancer** The Cancer Genome Atlas National Cancer Institute http://cancergenome.nih.gov/ A portal leading to a wealth of information. Cancer Genome Project Wellcome Trust Sanger Institute http://www.sanger.ac.uk/science/groups/cancer-genome-project A link to research projects. COSMIC, Catalogue of Somatic Mutations in Cancer Wellcome Trust Sanger Institute. http://cancer.sanger.ac.uk/wgs Database of mutations leading to cancer. **Drug design and medicine** Welcome to the Centre for Therapeutic Target Validation Centre for Therapeutic Target Validation http://www.targetvalidation.org/ The importance of genomic research in informing drug design.  Where do you start when developing a new medicine? Wellcome Trust Sanger Institute http://www.sanger.ac.uk/news/view/2014-03-27-where-do-you-start-when-developing-a-new-medicine- Press release announcing scientific collaboration to use genomics and big data to drive drug discovery.		

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Case study of an application of genomics	A brief overview, with some examples of resources, could be given to learners before they embark on a case study of an application that takes their interest. These might include: **Classification, phylogeny and evolution** Identifying Species with DNA Barcoding Barcode of Life http://www.barcodeoflife.org/ An international initiative devoted to developing DNA barcoding as a global standard for the identification of biological species. Hands-on DNA: Training Resources UK Association for Science and Discovery Centres http://www.sciencecentres.org.uk/projects/handsondna/training_resources.html Links to two sets of resources produced for the Hands-on DNA: Exploring Evolution project. **Ecology and conservation** Inbreeding makes mountain gorillas genetically healthy BBC News http://www.bbc.com/earth/story/20150409-gorilla-genome-good-news Role of genome sequencing in work on endangered species.  The Micro B3 Project Micro B3 Consortium http://www.microb3.eu/ Genome sequencing in the role of organisms in the ocean community.	4 hours	Unit 20 LO4

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