UNIT 3 Inherited Change, Gene Technology, Selection and Evolution

Recommended Prior Knowledge Students should have covered sections E and F, Cell and nuclear division and Genetic control, in the AS syllabus.

Context This Unit builds on AS work on cell division and genetics. It covers material which will be developed further if students study Option 4, and also (to a lesser extent) Options 2 and 3.

Outline The mechanism and significance of meiosis is dealt with, and leads in to a study of genetics, including dihybrid crosses. The Unit then looks at some aspects of genetic engineering. Natural selection is discussed, including its role in evolution and speciation.
Reinforcement and formative assessment It is recommended that, towards the end of the time allocated to the unit, time be taken to permit reinforcement of the learning that has occurred. There are many ways in which this might be done, ranging from revision lessons, through overview homework, through research project and into preparation of essays, presentations, posters or other material.

- This topic, with so much current material appearing on the Internet lends itself to students researching e.g. dihybrid crosses or examples of the effects of the environment on the genotype to produce the observed phenotype. Small groups of two or three students should be encouraged to work together for an hour or two of lesson time, plus homework for a week or two. They should prepare a visual presentation of a topic to their peers. This could be in the form of a poster, a video, a PowerPoint presentation, an OHP illustrated talk, a short video clip or whatever seems appropriate. Some students will wish to draw their own diagrams, and others to download them from the net, and others to photocopy them from paper sources – all these approaches should be encouraged.
- The terms involved in this unit need to be very clearly understood and it may be useful to have card sets with terms on one set and meanings on another set and to use these regularly to reinforce their meaning.
- Formative assessment could take the form of student self-marked minitests, taking just 10 or 15 minutes for students to do and then mark for themselves, perhaps using questions from the Learn CIE Test Centre – discussing the correct answers as a whole class.
- At the end of the unit, there should be a much larger formative assessment test, using appropriate past-examination and similar style questions, taking a lesson to do, and a lesson to provide feedback after marking by the teacher.

Sequence of teaching and learning

- Some teachers prefer to teach it in the order it is presented, on the basis that the meiosis and chromosomes are more familiar and can act as a basis for understanding of variation. Also practical work is limited so more use is made of models and diagrams.
- The topic P on Selection and Evolution could be separated from topic O by another unit, however some Teachers find that the two topics help the understanding of each other making it easier for students to understand when they are taught together.
- Please evaluate these various approaches, and choose the sequence of topics that seems most appropriate for your students.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
O(a)	describe, with the aid of diagrams, the behaviour of chromosomes during meiosis, and the associated behaviour of the nuclear envelope, cell membrane and centrioles (names of the main stages are expected, but not the sub-divisions of prophase) **Learning Activity** Pupils should participate in: -reviewing knowledge of mitosis leading to a glossary of terms, annotated diagram of a chromosome and clear distinction between mitosis and meiosis. (pupils should make sure they can spell these carefully!). -using pipe cleaners model a body cell nucleus before division. DNA replication resulting in copies of each strand of DNA. Using the pipe cleaners, show how these copies are separated during mitosis. -discussing how meiosis results in half the chromosome number, using the pipe cleaners model the behaviour of the chromosomes. -making a series of clear annotated diagrams to illustrate the behaviour of chromosomes during meiosis. -discussing in groups the stages illustrated by micrographs and diagrams.	Set students a quiz relating to mitosis, chromosomes and cell division. Alternatively, give out a set of cards with terms on them (e.g. chromosome, chromatid, gene, allele) and second set with definitions; ask students to match them up. Use question and answer to help students to recall that meiosis is a type of nuclear division which halves chromosome number. Use pipe cleaners or coloured yarns (see AS Unit 1) to demonstrate the behaviour of chromosomes during meiosis. Use different colours to represent the different chromosomes, with homologous chromosomes being the same colour. Show students a 'cell' with four chromosomes (two homologous pairs) and ask them: how can the cell divide in such as way that each daughter cell gets just one copy of each homologous pair? (You may need to tell them that there are two divisions during this process.) Through discussion and demonstration, help them to understand the behaviour of chromosomes during the first and second divisions of meiosis. (You could, if you prefer, avoid mentioning crossing over at this stage.) Set students work based around micrographs, diagrams, and animations to consolidate their understanding.	http://www.biologymad.com/CellDivision/CellDivision.htm Good for revision of cell cycle and mitosis www.biology.arizona.edu/cell_bio/tutorials/meiosis/page3.html A meiosis animation, in 3D. www.biologyinmotion.com/cell-ivision/index.html	*Biology A2* Biozone, cover meiosis well on page 102. Model answers to questions are provided in a separate student book and on CD.

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O(b) (c)	explain how meiosis and fertilisation can lead to variation; explain the terms *locus, allele, dominant, recessive, homozygous, heterozygous, phenotype* and *genotype* **Learning Activity** Pupils should participate in: -reviewing knowledge of variation to write a glossary of terms continuous, discontinuous. -researching to match up the terms locus, allele, dominant, recessive, homozygous, heterozygous, phenotype and genotype to their meanings. Draw diagrams of homologous chromosomes to annotate locus and allele and using examples draw homologous chromosomes with homozygous alleles, heterozygous alleles and the effect on the phenotype. -modelling using the pipe cleaners to show how meiosis results in variation in the gametes and drawing annotated diagrams to explain variation in meiosis. -modelling using pipe cleaners the various combinations which can occur in the gametes of a heterozygous parent. -modelling using the pipe cleaners how two heterozygous parents give rise to the 9:3:3:1 ratio. -using symbols drawing a genetic diagram and using a Punnet square to obtain the genotypes of the offspring	Use the pipecleaners (wrap coloured thread around them to represent different alleles of two genes on different chromosomes) to show students how, in a cell that is heterozygous at two loci, gametes with different genotypes will be produced depending on the orientation of the bivalents during metaphase 1. (Be meticulous in the correct use of the terms 'gene' and 'allele'.) Use suitable symbols for the alleles involved, and show students how the genotype of the parent cell is written (e.g. AaBb, not ABab). Make sure that they understand that the resulting gametes contain one copy of each gene (e.g. genotypes could be AB, Ab and so on, not AA). Ask them: if both parents had this heterozygous genotype, and if any one of the male gametes could fuse with any of the female gametes, what possible genotypes could there be in the offspring? Introduce the idea of using a Punnet square to help to work out these different combinations. Then demonstrate crossing over, and again help them to understand how this can lead to even more variation in the gamete genotypes. (Better to sort out a dihybrid cross without linkage first – worth emphasising that linkage is NOT required.)Students should already know the listed terms. Throughout	*http://www.biozone.co.uk/biolinks/GENETICS.html#Inheritance* *However the links given from this web page need to be carefully selected as some are not careful in their use of gene and alleles and some still use the term incomplete dominance.*	*Biological Nomenclature*, published by the Institute of Biology, provides definitions for many of the terms used in genetics. It can be ordered through the IoB web site. *Biology A2* Biozone, covers sources of genetic variation on page 96 and crossing over in detail on page 103 – 104. Model answers to questions are provided in a separate student book and on CD.

	and the phenotypic 9:3:3:1 ratio. - modelling what happens when crossing over occurs during meiosis so this is causes more variation in the gametes and then the offspring.	this work, use the terms correctly, checking that the students do understand their precise meanings.	http://saints.css.edu/bio/schroeder/meiosis.html Has animation to show meiosis and effects of crossing over.	

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O(d)	Use genetic diagrams to solve problems involving monohybrid and dihybrid crosses **Learning Activity** Pupils should participate in: -using genetic diagrams to show a monohybrid cross -using genetic diagrams to show dihybrid crosses -marking each others diagrams for accuracy. -discussing good and poor genetic diagrams -discussing how to spot monohybrid, dihybrid and crossing over from information provided.	Remind students how to set out a genetic diagram correctly to show a monohybrid cross between two heterozygous organisms. Take them back to the example of gamete formation that was demonstrated with the pipecleaners, and ask someone in the class to try to build up a genetic diagram on the board to show this cross. Encourage them to draw circles around the gametes and always to write out the cross fully. (Students often fail to make the gamete genotypes clear, and also do not always state the phenotype of each genotype of the offspring.) Set students a range of problems of increasing difficulty, and support them as they work on these.	http://www.dnaftb.org Within the section *Classical Genetics* there are examples of genetics crosses illustrated with animations to help explanations.	The booklet *Biological Nomenclature* published by the Institute of Biology, explains how a genetic cross should be shown. (It can be ordered from the IoB web site.) *Biology A2* Biozone, provides lots of examples of both monohybrid and dihybrid crosses on pages 122 – 129. Model answers to questions are provided in a separate student book and on CD.
O(d)	use genetic diagrams to solve problems involving sex linkage, (but not involving autosomal linkage or epistasis) **Learning Activity** Pupils should participate in: -modelling using pipe cleaners the X and Y chromosomes and the red/green colour blindness gene to show the formation of the gametes by meiosis -modelling various crosses between parents with and without the colourblindness allele -discussing how to draw a genetic diagram showing sex linkage -solving different problems involving sex linkage	Shows students how the X and Y chromosomes carry different genes and are largely non-homologous. Use an example of a sex-linked trait (for example red-green colour blindness) and ask them to write down the possible genotypes for this characteristic . Explain to them how to show the allele symbols as superscripts above the X or Y symbol. Set a simple monohybrid cross problem, involving sex linkage, and help them to draw correct genetic diagrams to show this cross. Provide more problems for them.	http://www.utilitypoultry.co.uk/sexlinkage.shtml To stimulate the more able this looks at sex determination and sex linked characteristics in chickens.	*Biofactsheet 97: A guide to sex linkage* *Biology A2* Biozone, gives a good explanation on pages 132 – 133. Model answers to questions are provided in a separate student book and on CD.

O(d)	use genetic diagrams to solve problems involving codominance and multiple alleles **Learning Activity** Pupils should participate in: -modelling using pipe cleaners the formation of the gametes by meiosis for an example of codominance in a monohybrid and the resulting offspring after crossing -modelling using pipe cleaners a dihybrid cross involving codominance -drawing genetic diagrams to show the results of various crosses showing codominance and noting the resulting ratios of phenotypes -modelling using pipe cleaners the effect of multiple alleles as shown in blood groups -drawing genetic diagrams involving multiple alleles to show the resulting phenotypes and genotypes.	Describe an example of codominance, and give students problems involving first monohybrid and then dihybrid crosses involving codominance. (Note that the term 'incomplete dominance' is no longer used.) Ensure that students always show such alleles as superscripts. Use the inheritance of human blood groups (ABO system) to illustrate multiple alleles.		*Biology A2* Biozone, provides examples of both incomplete and codominance on page 124. Model answers to questions are provided in a separate student book and on CD.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
O(e)	use genetic diagrams to solve problems using test crosses **Learning Activity** Pupils should participate in: -discussing the problem of finding out the genotype of a dominant phenotype -drawing genetic diagrams to show test crosses to solve various problems.	Provide students with a problem relating to a monohybrid cross and ask them to solve it - for example, how could you find out if a black rabbit had genotype Aa or AA? Help them to work out what they could do to determine whether an organism showing the dominant characteristic is homozygous or heterozygous. Set problems involving test crosses (both monohybrid and dihybrid). (Note that the term 'backcross' is no longer used.)		*Biofactsheet 23: Genetics made simple* *Biology A2* Biozone, covers test crosses on page 122. Model answers to questions are provided in a separate student book and on CD.
O(f)	use the chi-squared test to test the significance of differences between observed and expected results (the formula for the chi-squared test will be provided) **Learning Activity** Pupils should participate in: -studying the results of various dihybrid crosses and how to show that the results are statistically close enough to the 9:3:3:1 ratio using the chi-square test -practising using and interpreting chi-square tests to write a valid conclusion about the results of a genetic cross	Take students through an example of the use of the chi-squared test, using the results of a dihybrid cross which should result in a 9:3:3:1 phenotypic ratio in the offspring. Set them further problems and support them as they work.		The chi-squared test is explained in *Biology*. *Biofactsheet 79: the chi-squared test for goodness* of fit *The AS/A2 Biology Statistics CD-ROM from Curriculum Press allows students to carry out step by step calculations of chi-squared and other statistical tests.* *Biology A2* Biozone, gives a good explanation of using chi-squared tests on page 131. Model answers to questions are provided in a separate student book and on CD.
O(g) (i)	explain, with examples, how mutation may affect the phenotype; explain how a change in the nucleotide sequence in DNA may affect the amino acid	Explain the meaning of the term 'mutation', emphasising that it can involve either whole chromosomes or just one base in a gene. Describe an example of a chromosome	http://gslc.genetics.utah.edu/units/activities/wheatgerm A simple protocol for extracting DNA	*Biofactsheet 110: Genetic Disease in Humans* *Biology A2* Biozone, explains

	sequence in a protein and hence the phenotype of the organism. **Learning Activity** Pupils should participate in: -researching the term mutation and writing a clear definition. -researching Down's syndrome and writing a summary of the condition and its cause. -reviewing their knowledge of DNA and protein synthesis, protein structure, haemoglobin and oxygen transport. -discussing the effect of a gene mutation such as that causing sickle-cell anaemia and drawing a series of diagrams to illustrate the effect of changing one base on the whole process of protein synthesis and the incorrect protein produced. This could be produced as poster or flow chart. -using this knowledge to investigate other examples of gene mutations	mutation (e.g. Down's syndrome). Use questioning, or a quiz sheet of 20 multiple choice questions to be done in 5 minutes, to find out how much students have remembered about DNA and protein synthesis and about protein structure, haemoglobin and oxygen transport (covered in the AS course). If necessary, revise this work with them. Use sickle cell anaemia to illustrate a mutation within a gene. Help them to bring together their knowledge of protein synthesis and protein structure to predict the effect that this will have on the amino acid sequence in the beta haemoglobin chain, and the subsequent effect on the shape and functioning of the haemoglobin molecule. Provide students with other (not necessarily 'real') examples of this kind of mutation, and help them to see why some mutations may have significant effects (especially if they result in a frame shift) while others have no effect at all.	http://www.dnaftb.org/dnaftb/27/concept/index.html Animation and information about mutation http://www.who.int/genomics/public/geneticdiseases/en/index2.html A really interesting site looking at gene mutations and human diseases	the effects of mutations on page 108 – 109 and explains the causes on pages 110 – 111. Model answers to questions are provided in a separate student book and on CD.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
O(h)	explain, with examples, how the environment may affect the phenotype **Learning Activity** Pupils should participate in: -researching different examples of the effect of the environment on a phenotype and presenting these using posters, powerpoint to the rest of the class. -summarising different examples of the effect of the environment on the phenotypes of organisms and linking this to the effect of variation	Ask students to think of examples where environment affects phenotype.	There are many examples on the web if environment effect on phenotype is used in a search engine like Google. However once again warn students that they need to be careful of the way the terms are used e.g. gene and allele.	*Biology A2* Biozone, provides various examples on pages 100 – 101. Model answers to questions are provided in a separate student book and on CD.
O(j)(k) (l)	outline the use of recombinant DNA technology in biotechnology, with reference to the synthesis of human insulin by bacteria and production of Factor VIII; outline the use of restriction enzymes for removing sections of DNA; describe the formation of recombinant DNA **Learning Activity** Pupils should participate in: -modelling the process of recombinant DNA technology using lengths of different coloured cord to represent the required gene, the DNA in the bacteria or hamster cells, the various enzymes involved and the protein produced -producing annotated flow chart to show the process of insulin production and Factor VIII production	If possible, use kits and/or protocols to do practical work involving DNA. Use the examples of insulin production by bacteria, and of Factor VIII by hamster cells, to explain the principles of genetic engineering.	http://www-saps.plantsci.cam.ac.uk/workshop_dna.htm Gives the details for a protocol for obtaining DNA from plant samples. http://www-saps.plantsci.cam.ac.uk/worksheets/scotland/dna.htm Gel electrophoresis of DNA activity.	Science and Plants for Schools, or SAPS, run workshops for teachers to introduce them to practical work using DNA. SAPS also supplies kits for carrying out these practicals. Contact the SAPS office in Cambridge for further information. SAPS@homerton.cam.ac.uk
O(m) (n)	explain the advantages of treating diabetes with human insulin produced by genetic engineering; describe the benefits and hazards of genetic	Help students to think of possible benefits of using genetically engineered insulin rather than insulin from the pancreases of slaughtered animals.	http://gslc.genetics.utah.edu./units/newborn A stimulating exercise that	*Teacher Resource Handbook on CD* Biozone, covers techniques and applications of genetic engineering.

	engineering with reference to specific examples **Learning Activity** Pupils should participate in: -discussing the advantages of using genetically engineered insulin rather than insulin from the pancreases of slaughtered animals -discussing/debating other examples of genetic engineering and common opinions. Sorting out what they agree with and what they don't and providing logical arguments to support their ideas.	Broaden the discussion and debate to other examples of genetic engineering. Provide stimulus material such as newspaper articles, video clips, to start students thinking about the issues. Provide sets of 'statement cards' each carrying a statement such as "I think it OK to use genetic engineering for production of useful medicines, but not to make crops grow better'; 'Genetic engineering is wrong; we should not fiddle with nature like this' and ask students to sort them into groups with which they do and don't agree. Use these as the basis of a debate. Encourage students to justify their views with logical arguments.	students can carry out to help them to think about ethical and moral issues of testing newborn children for genetic defects www.wellcome.ac.uk/en/1/pinpubactedurespub.html 'Lab Notes' from the Wellcome Trust, available as downloadable pdfs; the series is available free to teachers and students and covers a variety of social and ethical issues arising from current biomedical research in genetics. http://www.bbsrc.ac.uk/ A summary of possible beneficial applications of genetic modification of animals. by typing in: benefits of cloning animals	

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
P(b)	explain why variation is important in selection **Learning Activity** Pupils should participate in: -reviewing knowledge of variation and its causes and summarising these in bullet points. -discussing how organisms with different genotypes and phenotypes may differ in their chances of survival or reproduction and summarising this information	Ask students: what causes the differences between organisms of the same species? Help them to outline the causes of variation. Using real or imaginary examples, discuss how organisms with different genotypes and phenotypes may differ in their chances of survival or reproduction.	*Biofactsheet 50: sources of genetic variation*	
P(c)	explain how all organisms can potentially overproduce **Learning Activity** Pupils should participate in: -investigating/researching population sizes and what controls population size -summarising the controls on population size, natural and artificial.	Use examples to illustrate the relative steadiness of population size, despite the large numbers of offspring produced.	http://www.sciencedaily.com/releases/2001/10/011019075032.htm Flour beetles population study. http://bru.gmprc.ksu.edu/proj/tribolium/ This is the flour beetle site and also includes genetics!	
P(d)(a)	explain, with examples, how environmental factors can act as stabilising or evolutionary forces of natural selection; explain how natural selection may bring about evolution **Learning Activity** Pupils should participate in: -discussing variation, overproduction and the effects of selection on allele frequency to predict how a change in environmental factors could lead to a change in allele frequency in a population. This is evolution.	Help students to pull together what they have learned about variation, overproduction and the effects of selection on allele frequency to predict how a change in environmental factors could lead to a change in allele frequency in a population. This is evolution. Students should also appreciate that, in most populations for most of the time, selection tends to maintain the status quo; this is called stabilising selection. Use examples, e.g. antibiotic resistance in bacteria, to illustrate these processes.	www.the-cohens.com/marc/HMS-Crew/camouflage.html A lab exercise simulating natural selection http://www.accessexcellence.org/AE/AEPC/WWC/1995/camouflage.html	*Practical Advanced Biology*, King et al, contains several investigations relating to variation, natural selection and evolution. *Biofactsheet 44: Evolution* *Biology A2* Biozone, covers this section well with specific reference on page 152. Model answers to questions are provided in a separate

	-researching antibiotic resistance in bacteria write a summary to show evolution. -Using beads model the effect on allele frequency in a population and the resulting change in phenotypes. This should lead to drawing graphs to show the effect of selection pressure on the allele frequency over time.	Encourage students to think about *genotypes* and *alleles* being selected for, rather than 'characteristics'. Students can model the way in which allele frequencies are affected by differential survival of two different genotypes. Use a large number of beads of two different colours; place them all in a large container to represent the two alleles of a gene in a population. Decide on a percentage survival rate for the double recessive genotype, say 60 %. Pick out pairs of beads at random, and discard 4 out of every ten pairs of recessive beads. When all beads have been used, replace the ones which 'survived' and do the same for the next generation. If numbers of each genotype are recorded in each generation, graphs can be drawn to show the effect of this selection pressure on allele frequency over time.	A different lab exercise, again simulating the effect of natural selection on camouflage. www.biologyinmotion.com/evol/ A fun, interactive simulation of natural selection and evolution.	student book and on CD.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
P(e)	describe the processes that affect allele frequencies in populations with reference to the global distribution of malaria and sickle cell anaemia **Learning Activity** Pupils should participate in: -whole class discussion/verbal questioning to review learning about malaria and link this to the processes that affect the allele frequency of sickle cell anaemia in the population resulting in the global distribution of malaria – bullet point the main points from the discussion.	Use question and answer to draw out what students remember from their AS course about malaria. Use sickle cell anaemia as an example to illustrate how one genotype may be 'fitter' than another when a particular environmental factor (infection with *Plasmodium*) is exerting a strong selection pressure.	www.genome.gov/Pages/Education/Kit/main.cfm?pageid=90 A downloadable activity, Genetic Variation in Populations, including a look at the distribution of malaria and sickle cell anaemia	*Biology A2* Biozone, cover heterozygous advantage of malaria and sickle cell anaemia on page 166. Model answers to questions are provided in a separate student book and on CD.
P(g)	describe one example of artificial selection **Learning Activity** Pupils should participate in: -researching an example of artificial selection in groups and presenting their information to the whole class	Use stimulus material as available to help students to learn about an example of artificial selection which is relevant to them. Students should appreciate that this selection must take place over several generations.	http://www.animaldata.co.uk/ayrshire.htm Records of milk production from 1989 to the present for Ayrshire cows in Britain, illustrating the effects of selection. There are other sets of statistics at this site.	*Biology A2* Biozone, provides good examples and coverage on pages 168 – 172. Model answers to questions are provided in a separate student book and on CD.
P(f)	explain the role of isolating mechanisms in the evolution of new species **Learning Activity** Pupils should participate in: -researching the meaning of the term ‘species’ and discussing in the whole class the various meanings -discussing how Darwin suggested that isolation of populations leads to speciation leading to use of	Discuss with the students the meaning of the term 'species', and the difficulties in defining this term to suit all situations. Use examples to illustrate how geographical isolation may lead to reproductive isolation, and hence possibly to speciation. Students should also be aware of other isolating mechanisms, such as breeding at different times of year, or polyploidy.	http://www.rit.edu/~rhrsbi/GalapagosPages/DarwinFinch.html Photographs of Darwin’s finches and information about them.	*Biology A2* Biozone, covers the evolution of new species very well, on pages 176 – 184. Model answers to questions are provided in a separate student book and on CD.

	drawings/photographs of Darwin’s finches to annotate to explain speciation by isolation. -discussing and bullet points of other isolating mechanisms			