A2 Biology Syllabus 9700
Unit 3: Inherited Change, Selection and Evolution

Recommended Prior Knowledge
Students should have a good knowledge and understanding of cell and nuclear division. They should be familiar with the term *meiosis* and understand that this is a reduction division. They should be able to describe the structure of DNA and the events occurring in DNA replication, in transcription and in translation. They should show an understanding of the genetic code and know what is meant by the term *gene expression*.

Context
This Unit builds on AS work, especially section E, Cell and Nuclear division, and section F, Genetic control. It also develops work already covered on sickle cell anaemia. It should be taught prior to Unit 4 as it has many links with material covered in Applications of Biology, especially in Section Q, Biodiversity and Conservation, and Section R, Gene technology. Each of the other sections has an overlap with Unit 3: Section S, biotechnology (causes and effects of antibiotic resistance), Section T, Crop Plants (crop improvement by genetic modification) and Section U, Human Reproduction (gametogenesis).

Outline
The mechanism and significance of meiosis is dealt with, and leads into a study of genetics, including dihybrid crosses. Natural selection is discussed, including its role in evolution and speciation. 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 match these regularly to reinforce their meaning and consolidate student learning.

O Inherited Change
- Passage of information from parent to offspring
- Nature of genes and alleles and their role in determining the phenotype
- Monohybrid and dihybrid crosses

P Selection and Evolution
- Natural and Artificial Selection

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, and that terms such as *allele*, *genotype* and *phenotype* will already be understood when they are used in Section P. Most teachers find that the two sections taught together help the understanding of each other, therefore making it easier for students. Please evaluate various approaches and choose the sequence of topics that seems most appropriate.

There are fewer opportunities within this unit for students to develop implementing and manipulative practical skills, but there are a number of topics in this Unit that can be used to develop skills in planning, analysis, evaluation and making conclusions (assessed in Paper 5). During the unit, each student should be given some opportunity to work alone and under time pressure in preparation for Paper 5.

AO	Learning outcomes	Suggested Teaching activities	Learning 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);	Students will be reminded of features of mitosis in the 2nd meiotic stage, so it may be less confusing for them to tackle meiosis first and then review mitosis at the end. Alternatively, test knowledge of mitosis first. Show students diagrams or photographs of an ordered haploid chromosome set, e.g. human sperm and egg. By question and answer, review the terms *homologous chromosome*, *haploid*, d*iploid*, and recall that fertilisation restores the diploid number. Students should think about how diploid cells form gametes (discuss different examples), helping them to recall that meiosis is a type of nuclear division which halves chromosome number. Make comparisons between a chromosome and its homologue: *gene* and *allele* should be discussed to confirm understanding: be meticulous in the correct use of these two terms. Give students pipe cleaners, thread or wool to demonstrate the behaviour of 4 chromosomes (i.e. 8 pipe cleaners) during meiosis. Talk students through activity 2, encouraging them to suggest 'what happens next' or explain why each stage occurs. If possible, use a darker and lighter version of the same colour for each pair to represent similar but not identical chromosomes and use two different colours for each homologous pair. At the appropriate point explain independent assortment. The concept of chiasmata formation and crossing over should be introduced (for outcome (c)). As students work through the stages and understand the behaviour of chromosomes, ask students to make comparisons with mitosis, or discuss the comparisons with the group at the end. Explain how reduction division separates the two alleles of a gene (as genes are located on chromosomes). This can be modelled on a homologous pair using sticky labels wrapped round: marked '***A***' on each chromatid of one chromosome and and '***a***' on each	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 http://www.biologyinmotion.com/cell_division/index.html interactive quiz on meiosis and mitosis http://www.sumanasinc.com/webcontent/animations/content/meiosis.html nice animation of meiosis http://members.cox.net/amgough/Fanconi-genetics-genetics-primer.htm#Overview%20Resources lots of useful information, includes a nice diagram of human haploid sperm and egg genome ***AS and A Level Biology*** (Chapter 17, pp. 222-224) has annotated diagrams, photomicrographs and written descriptions and explanations of meiosis. Pp.221-222 is a useful introduction, reviewing some of the AS course. ***Bio Factsheet 50:*** *Sources of genetic variation* This has the stages of meiosis and links it to genetic variation, so the sheet will be useful for a number of learning outcomes in this section.

chromatid of the homologous chromosome (to be reviewed when tackling monohybrid crosses). Introduce the term *heterozygote* (and the alternative, *homozygote*), for outcome (c).

Class activities

1. List the similarities and differences between homologous chromosomes.
2. Use prepared slides, photomicrographs, diagrams and animations to consolidate understanding.
3. Using 4 (+4) pipe cleaners, model a cell nucleus before division, showing DNA replication resulting in 2 identical chromatids for each chromosome. Continue modelling the stages of meiosis, to show the behaviour of 4 chromosomes (i.e. 8 pipe cleaners – 2 homologous pairs).
4. As a class exercise, make a series of annotated posters, using the pipe cleaners, to illustrate the behaviour of chromosomes during meiosis. Then draw a series of annotated diagrams to use as learning notes.
5. Match a set of cards with terms to a second set with definitions.
6. Construct a table of differences between mitosis and meiosis, ensuring precise spelling of the two terms.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
O	(b) explain how meiosis and fertilisation can lead to variation; (c) explain the terms *locus, allele, dominant, recessive, codominant, homozygous, heterozygous, phenotype* and *genotype*;	Ask students to work out how many different types of gamete could be formed with two homologous pairs assorting independently at metaphase 1 of meiosis. Lead up to the idea of 2^n different combinations, with n as the haploid number. A student with a handy calculator could work out the 2^{23} number for humans. Use pipe cleaners (wrap labels round them with '***A***' s marked on one homologue and '***a***'s on the other, to represent different alleles of a gene: repeat for the other pair using '***B***'s and '***b***'s), to show how, in a cell that is heterozygous for both genes involved (different loci, on non-homologous chromosomes), gametes with different	http://www.biozone.co.uk/biolinks/GENETICS.html#Inheritance gives links to other useful sites – select carefully as some sites are not as precise in their use of *gene* and *allele* and some use the term *incomplete dominance* http://www.biology.arizona.edu/vocabulary/mendelian_genetics/mendelian_genetics.html definitions

genotypes will be produced depending on the orientation of the bivalents at metaphase 1. Show students how the parental genotype is written (e.g. ***AaBb***, not ***ABab***). Ensure they understand that the resulting gametes contain one copy of each gene (e.g. genotypes ***AB***, ***Ab*** etc, not ***AA***). This will be reviewed when they tackle dihybrid crosses. Explain / revise and use the terms *locus and loci, heterozygous / heterozygote*, *homozygous / homozygote* and *genotype*.

Then demonstrate crossing over to show how this can lead to even more variation in the gamete genotypes. Students should be able to suggest that the longer the chromosome pair, the greater the number of possible crossovers. Mention that if the genes are on the same chromosome, they are said to be linked: explain that problems will only be set on unlinked genes.

Class activities

1. Draw annotated diagrams, using colours or shading, to show how two adjacent cells (haploid number 2) can produce 4 genetically different gametes by independent assortment.
2. Explain what is meant by independent assortment.
3. Using the symbols ***A*** and ***a*** for the alleles of a gene located on one homologous pair, and ***B*** and **b** for the other homologous pair, draw diagrams to show how independent assortment leads to genetic variation.
4. Give a definition of crossing over, and, using colours and annotations draw diagrams to explain the definition.
5. Outline how fertilisation leads to increased genetic variation.
6. Write definitions for the terms listed in learning outcome (c) and draw diagrams of homologous chromosomes to annotate locus and allele and, using examples, draw homologous chromosomes with different genotypes (homozygous alleles, heterozygous alleles, codominant alleles), indicating the phenotype.
7. Modelling using pipe cleaners to consolidate learning of independent assortment and crossing.

http://www.genome.gov/glossary/index.cfm?id=8
a talking glossary of genetics terms!

http://www.contexo.info/DNA_Basics/Meiosis.htm
includes a short animation of crossing over
http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter28/animation__how_meiosis_works.html
animation with a quiz

AS and A Level Biology provides some helpful definitions in the Glossary, beginning on p.399. Chapter 17, p.225 has very clear information about alleles and genotypes, including some SAQs.

For definitions of all the terms in learning outcome (c), see the 'Definitions' section, beginning on p.35 of the ***2012 Cambridge International A & AS Level Biology Syllabus, code 9700***.

Bio Factsheet 156: *Dominant and Recessive Alleles*
This factsheet contains information that is useful also for learning outcome (d)

Bio Factsheet 45: *Gene expression*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
O	(d) use genetic diagrams to solve problems involving monohybrid …. crosses, including those involving sex linkage, codominance and multiple alleles (but not involving autosomal linkage or epistasis); (e) use genetic diagrams to solve problems involving test crosses;	As geneticists continue researching, some human genetic traits used as examples in schools and colleges may turn out to be more complex than at first thought. Point this out to those students who may want work out patterns of inheritance in the family. Depending on the progress of the class, there are two approaches: (i) deal with all the theory of learning outcome (d) (not dihybrid crosses) before allowing students to work on a (mixed difficulty) set of problems at their own pace or (ii) have a set of problems prepared for each type of cross and let students practise these as they are taught. *Monohybrid cross and test cross* Using a visual (photographs/drawings), simple example (e.g. purple and white flowers in pea plants), remind students how to set out a genetic diagram correctly, beginning with homozygous parental genotypes and working through to the F_2 generation. Go back to the example of gamete formation that was demonstrated with the pipe cleaners. Insist that circles are drawn around the gametes, that the cross is written out fully, the gamete genotypes are clear, and the phenotype of each genotype of the offspring is stated. Ask students to explain why they can be certain of the genotype if a pea plant has white flowers. This should lead on to test crosses to explain how they could determine the homozygous dominant genotype from the heterozygous genotype. Note that the term *backcross* is no longer used. Give them one problem to work on themselves and check how they have laid out the cross. *Codominance* Describe an example of codominance. Ensure that students always show such alleles as superscripts. Many examples involve a 'colour' gene, so ensure that they know that ***C*** indicates the gene (and not 'C' for codominance). Note that the term *incomplete dominance* is no longer used. Go through the different ratios obtained and ask students to explain why no test cross is required.	http://learn.genetics.utah.edu/content/begin/traits/ nice introduction - links to other areas within the site, including *ABO* blood grouping http://www.dnaftb.org within the section *Classical Genetics* there are examples of genetics crosses illustrated with animations to help explanations. http://www.biology.arizona.edu/mendelian_genetics/mendelian_genetics.html some problems for students to try http://faculty.baruch.cuny.edu/jwahlert/bio1003/genetics.html some nice explanations of maize/corn genetics plus some general genetics problems (includes chi-squared) http://www.utilitypoultry.co.uk/sexlinkage.shtml to stimulate the more able this looks at sex determination and sex linked characteristics in chickens. http://www.pc.maricopa.edu/Biology/rcotter/BIO%20181/Lab/181Labpdf/10MendelianGenetics.pdf there is a list of human genetic traits in this assignment that students will find interesting – some of the examples (e.g. tongue rolling) may well be found in the future to be more complex than is known now. Also note that students should not be asked to taste substances.

Multiple alleles
Use the inheritance of human blood groups (ABO system) to illustrate multiple alleles, as students should now be feeling confident with dominance, recessiveness and codominance.

Sex linkage
Shows students how the X and Y chromosomes are largely non-homologous so they can understand why, in problems involving sex linkage, there will only be one allele represented in the male genotype. 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 symbol and how a dash by the Y symbol (Y^-) shows that the allele is not present. Set a simple monohybrid cross problem, involving sex linkage, and help them to draw correct genetic diagrams to show this cross. Remind them that not all problems that indicate numbers of individuals of each sex, or state 'female crossed with male', will be sex linked. Support students as they work on genetic crosses.

Class activities
1. Explain what is meant by *true* (or *pure*) *breeding*, *codominance*, *multiple alleles*, *sex-linked* and *test cross*.
2. State and explain the pattern of inheritance that indicates sex-linkage.
3. Solve problems, including:
   - constructing genetic diagrams to show results of crosses
   - performing test crosses
   - checking diagrams of other students for accuracy.
   - learning how to spot problems involving one or more of codominance, multiple alleles and sex linkage
   - being able to give ratios
   - being able to match genotypes to phenotypes
   - interpreting pedigree diagrams
4. To consolidate understanding of the link between the genetic cross outcomes and gamete formation and fertilisation, model (pipe cleaners) one each of the different types of genetic cross.

http://www.utilitypoultry.co.uk/sexlinkage.shtml
to stimulate the more able this looks at sex determination and sex linked characteristics in chickens.

http://www.nature.com/nature/journal/v423/n6942/fig_tab/423810a_F1.html
an excellent electron micrograph of a human X and Y chromosome

AS and A Level Biology (Chapter 17, pp. 225-231) has excellent explanations and uses some nice examples. SAQs are also included.

Biological Nomenclature (4th Edition) has recommendations for symbols to use. There are also definitions for many of the terms used in genetics.

Bio Factsheet 23: *Genetics made simple: I*
Includes information about monohybrid and dihybrid crosses.

Bio Factsheet 97: *A guide to sex linkage*

Bio Factsheet 93: *The ABO Blood Group System*

Bio Factsheet 183: *Variations from expected Mendelian Monohybrid Ratios*
Includes information about lethal genes.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
O	(d) continued use genetic diagrams to solve problems involving …dihybrid crosses;	Students need to be clear that the dihybrid crosses that they will be expected to deal with involve two genes located on separate non-homologous chromosomes (unlinked / separate linkage groups). If necessary, review the chromosome modelling of independent assortment. Work through a typical dihybrid cross, e.g. Mendel's pea plants, asking students to work out first the possible gametes involved in crossing the double heterozygotes. Explain how to construct a Punnett square and get students to work out the possible genotypes if any one of the male gametes could fuse with any of the female gametes. Remind them that genotypes should be clearly linked to the resulting phenotypes. Point out to students that the 9:3:3:1 ratio, still fits in with the 3:1 ratio learned for monohybrid crosses (each gene shows a 12:4 ratio). **Class activities** 1. Use symbols to draw a genetic diagram and use a Punnett square to obtain the genotypes of the offspring and the phenotypic 9:3:3:1 ratio. Draw out a test cross with the double heterozgote. 2. Solve problems involving dihybrid inheritance and test crosses, including some that involve more complex interpretation (e.g. codominance or sex linkage).	There will be many sites with 'dihybrid cross problems' – be selective and choose those most appropriate http://www.mendel-museum.com/eng/1online/experiment.htm explanations and animations from the Masaryk University Mendel Museum http://www.sumanasinc.com/webcontent/animations/content/independentassortment.html animation showing independent assortment and formation of genetically different gametes http://www.sumanasinc.com/webcontent/animations/content/mendel/mendel.html interactive animation involving monohybrid and dihybrid crosses. Remind students that in the F_1, they should only write the gamete types and genotype once in the genetic cross e.g. AA x aa produces only (A) and (a) gametes, not (A), (A), (a) and (a) gametes http://www.learnerstv.com/animation/animation.php?ani=2&cat=Biology Mendels pea plants – different traits ***AS and A Level Biology*** (Chapter 17, pp. 231-233) goes through an example very clearly and has some good explanations. The SAQs are relevant and should be attempted. ***Bio Factsheet 115:*** *Answering Examination Questions:Genetics*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
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);	Before explaining the chi-squared test to students, revise the various different ratios obtained with the different types of genetic cross. Make sure that students understand that these are theoretical ratios based on probability. With verbal question and answer, give them simple numbers to work with e.g. 40 offspring, how many of each if expecting a 3:1? Then approach from a different direction: e.g. in an F_2 generation there were 32 red, 26 pink and 10 white flowers – explain these results (or use a simpler 3:1 ratio idea). Students should come up with the idea of codominance, with a ratio approximating 1:2:1, the observed ratio being near enough to the expected for any differences to be simply due to chance effects. Move on from this and ask if they could be sure that the same explanation could be given for a 15 red, 20 pink, 13 white result. Some students may suggest that something else is occurring to make the result too far away from 1:2:1 to be a chance effect i.e. the differences between them are statistically significant. Take students through an example of the use of the chi-squared test, including an explanation of the use of a null hypothesis. Gauge the level of understanding of the group to choose whether the example uses the results of a monohybrid 3:1 or 1:1, or slightly harder 1:2:1, or move straight to a problem 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. **Class activities** 1. Using the results of a genetic cross, with a calculated chi-squared value: • state the critical value at a stated probability level • state where the chi-squared value fits in the range of probabilities • make a conclusion, referring to a null hypothesis and significance level	http://www.blc.arizona.edu/courses/mcb422/MendelStarFolder/merChiSquare.html for interested students who want more information about the chi-squared test ***AS and A Level Biology*** (Chapter 17, pp. 233-234) introduces the topic very clearly and works steadily through an example, showing students how to use the chi-squared value in the look-up table and how to interpret the result. P. 235 has a SAQ. The ***AS/A2 Biology Statistics*** CD-ROM, pub. Curriculum Press, allows students to carry out step by step calculations of chi-squared and other statistical tests. ***Bio Factsheet 79:*** *The chi-squared test for goodness of fit* Includes a worked example using a genetic crosses

2. Practise the calculations involved in the chi-squared test and Interpret the results to write a valid conclusion about the nature of the genetic cross. Problems should be attempted where 1,2 and 3 degrees of freedom need to be used.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
O	(g) explain, with examples, how mutation may affect the phenotype; (i) explain how a change in the nucleotide sequence in DNA may affect the amino acid sequence in a protein and hence the phenotype of the organism;	Use questioning, or a quiz sheet of 20 multiple choice questions to be done in 5 minutes, to gauge AS knowledge of DNA structure, protein synthesis and protein structure, haemoglobin and oxygen transport. If necessary, revise this work with them. Explain the meaning of the term *mutation*, emphasising that it can involve either whole chromosomes, sections of chromosomes (i.e. many genes) or just changes within a gene. Describe an example of a chromosome mutation (e.g. non-disjunction leading to trisomy 21: Down syndrome). Use sickle cell anaemia to illustrate a mutation within a gene and, using the genetic code, get students to see how the amino acid sequence in the beta haemoglobin chain alters so that the tertiary structure is affected so drastically. Discuss how the consequences of changes in DNA nucleotide sequence can range from no effect (i.e. codon change still leads to the same amino acid being specified) to very profound effects (e.g. changed amino acid sequence causes loss of active site or tertiary structure, preventing normal protein function). Explain the effects of loss of enzyme functioning on the phenotype and give examples of changes in the structure of proteins altering phenotypes, such as in cystic fibrosis (covered later in Unit 4). **Class activities** 1. Research the term mutation and write a clear definition. 2. Explain the differences between chromosome and gene mutations. Give an example of a named chromosomal mutation (such as Down syndrome) and make notes and draw a series of annotated diagrams or construct a flow chart to show how a gene mutation can lead to symptoms of sickle cell anaemia.	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 http://www.s-cool.co.uk/alevel/biology/evolution/evolution-in-action.html#sickle-cell-anaemia antibiotic resistance and sickle cell anaemia http://genetics-education-partnership.mbt.washington.edu/class/activities/HS/sickle-bean.htm an activity to help understanding of sickle cell inheritance http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/M/Mutations.html detailed information, with examples ***AS and A Level Biology*** (Chapter 17, pp. 235-236) concentrates mainly on different types of gene mutation and includes sickle cell anaemia as an example. ***Bio Factsheet 94:*** *Gene Mutations*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
		3. Make notes about different types of gene mutation: base substitution, base additions (insertions), base deletions, additions and deletions leading to frameshifts. 4. Work through problems, covering the range of different types of mutation.	***Bio Factsheet 179:*** *Answering Exam Questions: Mutation* ***Bio Factsheet 110:*** *Genetic Disease in Humans* Has a short section on sickle cell anaemia

AO	Learning outcomes	Suggested Teaching activities	Learning resources
O	(h) explain, with examples, how the environment may affect the phenotype	If total phenotypic variation of any one trait is described to students as being the sum of variation due to genetic effects and variation due to the environment, then students will be able to visualise (but no necessity to learn): $$Vp = Vg + Ve$$ A class discussion, with verbal question and answers, will stimulate ideas from students about this topic. Ask the students to list some examples that are clearly due only to genetic effects, such as blood groups, and where the contribution of the environment would be 0. Discuss the use of monozygotic twins, with the result that Vg = 0, to study the effects of the environment. Ask students to think of examples where environment affects phenotype. **Class activities** 1. Research different examples of the effect of the environment on a phenotype and present these using posters and / or PowerPoint to the rest of the class. 2. Produces a list of possible causes of variation due to the environment, giving examples.	There are many examples on the web if 'environment effect on phenotype' is used in a search engine like Google. However advise students that they need to be careful of the way the terms are used e.g. gene and allele. http://www.flowersbulbs.com/ql_hydrangea_color.htm the changing colour of hydrangeas three articles from the Nature publishing group: http://www.nature.com/scitable/topicpage/environmental-influences-on-gene-expression-536 environmental influences on gene expression – http://www.nature.com/scitable/topicpage/heritability-of-human-intelligence-iq-and-eugenics-796 twin studies and IQ http://www.nature.com/scitable/topicpage/phenotypic-range-of-gene-expression-environmental-influence-581 armadillos ***AS and A Level Biology*** (Chapter 17, p. 237) presents two examples to get students thinking in the right direction.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
P	(b) explain why variation is important in selection;	Remind students that organisms that are members of the same species have similar morphological, biochemical, behavioural, physiological and anatomical features (the idea is required at this stage and these terms do not have to be used, although if students begin their understanding of the term species here, it will help for Unit 4). Then ask students: what causes the *differences* between organisms of the same species? Having just covered learning outcome (h) in section O, they should have no problem recalling environmental causes of variation and suggesting the genetic causes of variation (meiosis, fertilisation and mutation covered in section O (b) and (g)). Using one or two real or imaginary examples, discuss how organisms with different genotypes and phenotypes may differ in their chances of survival or reproduction. **Class activities** 1. Research the meaning of the following terms: continuous variation, discontinuous variation, polygenic inheritance, 2. Outline the causes of genetic variation (and environmental variation if not already done in section O (h)). 3. Discuss in groups the difference between asexual and sexual reproduction in terms of variation and debate the advantages and disadvantages of both. 4. Research and describe examples of how organisms with different genotypes and phenotypes may differ in their chances of survival or reproduction.	http://darwiniana.org/evolution.htm links to other sites that students may be interested in as they progress through this section. There is a short piece on differential survival and reproduction in the Natural Selection section http://www.eoearth.org/article/Genetic_variation an article about genetic variation http://www.wellcometreeoflife.org/ 'Tree of Life' student and teacher resources, plenty of information, video and interactive exercises from the Wellcome Foundation – many parts useful for section P ***AS and A Level Biology*** (Chapter 18, pp. 244-245) covers the causes of variation at the start of the chapter on Selection and evolution. ***Bio Factsheet 50****: Sources of genetic variation*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
P	(c) explain how all organisms can potentially overproduce	Introduce the idea to students that organisms have high reproductive potential and an initial few individuals of any one species, in an ideal environment, will experience exponential or explosive population growth. Using examples, ask students to suggest what might be meant by ideal conditions. In this way, they should see that it is not possible to sustain ideal conditions and will be able to explain the controls on population size that exist. It would be beneficial if students understood the difference between abiotic and biotic limiting factors and density dependent and density independent factors. They are not required to provide definitions of density dependent and density independent factors. Use examples to illustrate the relative steadiness of population size, despite the large numbers of offspring produced. Ensure that students understand that the size of the population will not increase unless individuals survive to reproductive age. **Class activities** 1. For a named example, describe the conditions that were present that allowed explosive population growth and explain how the size of the population was eventually limited. 2. List factors that will control population size, explaining how each factor serves to limit population sizes. 3. From the list produced in activity 2, state whether the factor is biotic or abiotic, and whether it is density dependent or density independent. 4. Explain why most populations oscillate about a mean size.	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! http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Populations2.html detailed information about factors that control population size, with named examples helping to promote learning http://www.eoearth.org/article/Population_ecology article about population ecology with links to other short article ***AS and A Level Biology*** (Chapter 18, p. 245-247) explains this learning outcome clearly and includes some interesting examples.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
P	(a) explain how natural selection may bring about evolution;	Give students an outline of evolution, emphasising the general idea that life has evolved as well as introducing the importance of natural selection. Include in the discussion: • species have formed from pre-existing species (students may need to revise definitions of the term *species*) • mutation, variation, isolation and speciation are all important processes in evolution • natural selection is a mechanism by which evolution occurs From knowledge of learning outcome (c) students should be able to suggest reasons why, when there is overproduction of offspring, some individuals survive and others die (differential survival). By discussion and verbal question and answer, and using named examples, work through the meaning of selection pressure. Ask students for examples of selection pressures. Ensure they understand that: • individuals within a population show variation (different phenotypes and genotypes) • phenotypes, with their specific genotypes, that are better adapted to survive are selected for • and pass on their alleles to their offspring when they reproduce (differential reproduction) • so the frequency of the allele in the population increases Avoid, and discourage students from, using the term *survival of the fittest* – this is a misleading term as there can be many different phenotypes that are equally fit. At A2 students will be expected to show understanding of adaptation, relative fitness, differential survival and reproduction.Use examples to get students to predict how changes in environmental factors could lead to changes in allele frequency within a population. Help students to understand that a different set of selection pressures in a different environment will lead to different outcomes for the population and could eventually lead to the formation of new species (covered more fully in outcome (f).	http://www.pbs.org/wgbh/evolution/library/index.html links to resources http://www.eoearth.org/article/Evolution?topic=49508 a nice summary http://www.biologycorner.com/worksheets/peppermoth_paper.html assignment on the peppered moth http://www.accessexcellence.org/AE/AEPC/WWC/1995/camouflage.html 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. http://biology4.wustl.edu/cloverproject/Assets/White%20Clover%20Background%20for%20Teachers.pdf information about cyanogenesis in white clover http://evolution-textbook.org/content/free/notes/ch18_WN18D.html cyanogenesis in white clover – distribution map http://www.blackwellpublishing.com/ridley/a-z/Stabilizing_selection.asp birth weight in babies and stabilising selection:

Mention to students that most mutations are not beneficial so the frequency of the mutated allele in the population remains low. Get students to suggest what would happen if environmental factors change so that the mutation becomes beneficial. Once students appreciate the principles, they can consider how natural selection can affect the level of genetic variation for any one heritable trait and how the changing allele frequencies will result in evolution. Explain that in most cases the environment remains stable and so the same phenotype has a selective advantage in each generation – stabilising selection – selection usually removes the extremes of the phenotype (e.g. birth weight in human babies). Discuss the other 2 modes of selection: directional, where allele frequencies change in one direction (e.g. drug resistance in bacteria) and disruptive, where the extremes of the phenotype are favoured (e.g. size of male Pacific salmon).

Class activities

1. Research examples of natural selection and produce a summary table: example, different phenotypes, selection pressure, adaptation, and additional notes. Include at least one from the following list: warfarin resistance in rats; melanism in peppered moths; cyanogenic clover; antibiotic resistance in bacteria; resistance in insects to insecticides (for the last two examples, research a recent example)
2. Choose one example from the table of activity 1 and write a sequential account to explain how allele frequencies within a population can change.
3. Using beads model the effect on allele frequency in a population 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

data displayed as a graph

http://www.nature.com/nature/journal/v313/n5997/abs/313047a0.html
abstract of the article on disruptive selection: size of Pacific male salmon

http://www.bbsrc.ac.uk/society/schools/secondary/darwin-today-factsheets.aspx
Darwins ideas used in contemporary research

AS and A Level Biology (Chapter 18, pp. 246-251 and p.253) covers this topic at an appropriate level of detail for the examination. Examples are used to help understanding.

Practical Advanced Biology contains several investigations relating to variation, natural selection and evolution.

Bio Factsheet 44: Evolution

Bio Factsheet 142: *Modern Examples of Evolution in Action*

Bio Factsheet 191: *What have we learned from Darwin's finches?*

each genotype are recorded in each generation, graphs can be drawn to show the effect of this selection pressure on allele frequency over time.

4. Draw graphs to summarise the 'before', 'during' and 'after' phenotype frequency curves for the three different modes of selection, researching examples to describe.

AO	Learning outcome	Suggested Teaching activities	Learning resources
P	(e) describe the processes that affect allele frequencies in populations with reference to the global distribution of malaria and sickle cell anaemia;	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 and discuss how one genotype may be *fitter* than another when a particular environmental factor (infection with *Plasmodium*) is exerting a strong selection pressure. **Class activities** 1. Revise genetic crosses and draw out annotated crosses between two heterozygous individuals and a heterozygous individual crossed with an individual homozygous for the normal haemoglobin allele. 2. Using sickle cell anaemia as an example, describe and explain the differences observed in allele frequencies between areas that are free of malaria and areas where malaria is endemic.	http://sickle.bwh.harvard.edu/malaria_sickle.html fairly complex article but full of facts http://www.pbs.org/wgbh/evolution/library/01/2/l_012_02.html links to a short, informative on-line video showing the protective effect of sickle cell trait against malaria (natural selection and evolution are discussed). Not that the terms *gene* and *allele* are not used precisely ***AS and A Level Biology*** (Chapter 18, pp. 251-252) covers this learning outcome at an appropriate level.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
P	(f) explain the role of isolating mechanisms in the evolution of new species	Discuss again with the students the meaning of the term *species*, and the difficulties in defining this term to suit all situations. Use examples to illustrate the different ways that reproductive isolation may come about and hence possibly lead to speciation. Polyploidy is discussed in Crop Plants (Section T) in Unit 4. **Class activities** 1. Define the terms *gene pool*, *reproductive isolation*, *speciation*, *allopatric speciation*, *sympatric speciation*, *polyploidy*, *autopolyploid*, *allopolyploid*. 2. Research and describe examples of allopatric and sympatric speciation. 3. Discuss in groups how Darwin, using Darwin's finches as an example, suggested that isolation of populations leads to speciation. Use drawings / photographs of Darwin's finches to annotate to explain speciation by isolation. 4. Research Darwin's mockingbirds, explaining how the observations made of these birds are believed to have had a major influence on Darwin in his development of the concept of natural selection.	http://people.rit.edu/rhrsbi/GalapagosPages/DarwinFinch.html photographs of Darwin's finches and information about them. http://www98.homepage.villanova.edu/robert.curry/Nesomimus/index.html information about Darwin's mockingbirds ***AS and A Level Biology*** (Chapter 18, p. 253-256) provides a comprehensive coverage of isolating mechanisms. There is an introduction designed to help students understand what is meant by a species, before they move on to the idea of speciation and isolating mechanisms. ***Bio Factsheet 92:*** *Isolation Mechanisms*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
P	(g) describe one example of artificial selection	Use stimulus material to help students to learn about an example of artificial selection that is relevant to them. Students should appreciate that this selection must take place over several generations. Discuss also the differences between selecting for a qualitative feature (e.g. presence or absence of horns) and a quantitative feature (e.g. milk production). The former can be done over a few generations whereas the latter takes much longer. Ask students to suggest how this might relate to the number of genes and alleles involved. **Class activities** 1. Make notes about the steps involved in artificial selection, including: • choice of character(s) to improve • selection of individuals showing feature(s) • breeding • assessment of offspring looking for those showing improvement • making crosses for next generation • repeating the procedure. 2. Research an example of artificial selection in groups and present the information to the whole class. 3. State the similarities and differences between artificial and natural selection. 4. Explain why artificial selection is not the same as genetic engineering. 5. Using data for a continuously varying character (e.g.milk production in cows) carry out a statistical comparison, using the t-test, for different generations in an artificial selection programme.	http://www.embryoplus.com/cattle_ayrshire.html history of the Ayrshire breed of cattle http://www.teachersdomain.org/resource/viewtext_printer_friendly/8150 a lesson plan based on artificial and natural selection in cows – links to other resources http://www.petermaas.nl/extinct/articles/selectivebreeding.htm an interesting site explaining how selective breeding is being used to breed animals similar to the wild ancestors originally used ***Bio Factsheet 187****: Selective Breeding of Cattle*