A2 Biology Syllabus 9700
Unit 4: Applications of Biology

Recommended Prior Knowledge
Students should have a good understanding of the AS content and Units 1, 2 and 3 of the A2 content. As will be seen from the following suggested ideas for a scheme of work, there are many areas where students should review their learning and make links to the applications sections.

Context
This Unit provides students with the opportunity to consider developments in biology and to gain an insight into how knowledge and understanding of biological facts, principles and concepts can be applied to develop new techniques that are beneficial in the everyday world. A good proportion of Unit 4 includes topics that are very much considered to be 'mainstream' biology. Also it has been a number of years since many of the techniques described in the Unit were considered to be 'cutting edge'. The terms 'core' and 'applications' could probably now be described to students as 'a good foundation' for appreciating 'how biology is used to benefit the world'.

Outline
There are five main topics in this unit, but these should not be taught in isolation as there are many cross references to the rest of the AS and A2 syllabus as well as many links between the five topics e.g. gene technology and biotechnology, gene technology and crop plants.

Q Biodiversity and conservation
- Classification
- Conservation issues

R Gene technology
- Gene technology for insulin production
- Markers for genetic engineering
- Benefits and hazards of gene technology
- DNA sequencing and genetic fingerprinting
- Cystic fibrosis
- Genetic screening and genetic counselling

S Biotechnology
- Industrial applications of microorganisms
- Batch and continuous culture
- Penicillin as an antibiotic
- Immobilisation of enzymes
- Monoclonal antibodies

T Crop plants
- Crop plant reproduction
- Crop adaptations
- Methods to improve crops

U Aspects of human reproduction
- Gametogenesis
- Roles of hormones in the menstrual cycle
- Controlling human reproduction

This is a Unit where students may want to engage in discussion and debate and they are likely to benefit enormously from group and class discussion. They should be encouraged to take an active role in their learning and be guided to think about the main points and arguments and listen considerately to the views of others. As questions may be set in different and new contexts it is important that the students are made aware of general concepts and principles and are encouraged to apply these to different case studies or situations.

Some teachers prefer to teach these sections in the order that they are presented in the syllabus, on the basis that students can follow easily the learning outcomes from a copy of the syllabus and then be encouraged to think about the cross links. Some of the learning outcomes may be covered as an extension to topics in the previous three Units, or should be considered as a ‘group’ that could be taught as one topic at this stage, for example, control of blood glucose, gene technology to produce human insulin and testing for glucose using biosensors. The advantage of covering the five sections together at the end of the course is that it gives students the opportunity to apply their knowledge and understanding of biology to environmental, industrial, agricultural and medical areas. Please evaluate these various approaches, and choose the sequence of topics that seems most appropriate for your students.

Use the practical opportunities within this Unit to develop strategies to help prepare students for Paper 5. Students will need to develop their skills relating to Assessment Objectives in Group C (Experimental skills and investigations), including data analysis and the design and evaluation of their own investigations. Students will also have opportunities to practise the use of statistical methods – both descriptive statistics and statistical tests. Try to ensure that each student works alone and under time pressure on some occasions.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
Q	(b) discuss the meaning of the term biodiversity; (a) outline the five-kingdom classification to illustrate the diversity of organisms (cross reference to Syllabus Section A (c) and A (g), a knowledge of phyla within the kingdoms is not required); (c) discuss the reasons for the need to maintain biodiversity;	Students should have a good understanding of the similarities and differences between plant and animal cells at the light microscope and electron microscope level and differences between eukaryotes and prokaryotes (sections A, Cell structure). They should understand the concept of the interdependence of organisms (section K, Ecology) and the need to maintain gene pools and gene diversity for the survival of species (section P, Selection and evolution). Where possible, in class discussion and question and answer sessions, take the opportunity of revising these sections. A brainstorming session with students of what they think is meant by the term biodiversity should help them see that a simple definition may be difficult. Ensure that the session and follow-up discussion enables them to consider: • diversity of ecosystems in a region • the number of species in each ecosystem • the genetic diversity within populations of each species • biodiversity at a local, national and global level When considering the five-kingdom classification, ensure that students realise that, although the kingdom Prokaryotae contains prokaryotes, there is no kingdom Eukaryotae – the term eukaryotic encompasses the four remaining kingdoms, Protoctista, Fungi, Plantae and Animalia. The main features of viruses should be considered to show the difficulty of classification (will help with S(d) and link back to AS work on viruses as pathogens). At this stage, a background outline of taxonomic classification (confined to kingdom, phylum, class, order, family, genus and species), will help students to understand these terms when they come across them in their research. Asking students why the term *species* can be considered to be the only natural classification group will prompt them to recall the definition of *species* that they have learned.	A web search using ‘define: biodiversity’ will lead students to a range of definitions to consider http://www.iucn.org/iyb/about/?gclid=CJ7n2a2576QCFQsGbAodI3nz1A a good introduction to biodiversity http://www.eoearth.org/topics/view/49480/ articles on biodiversity http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/artmay98/classif.html a good homework assignment to read about uncertainties in classification http://www.biologymad.com/master.html?http://www.biologymad.com/Classification/classification.htm basic notes on classification http://www.nationalgeographic.com/xpeditions/lessons/08/g68/preserve.html lesson plan ‘Why Preserve Biodiversity?’ http://www.davidsuzuki.org/search/?q=biodiversity&x=0&y=0 discussions about issues concerning biodiversity http://wwf.panda.org/about_our_earth/biodiversi

In their research of the meaning of biodiversity, students are likely to come across the reasons to maintain biodiversity and class discussion should encourage them to think widely and elicit ideas across many areas of biology, including

- maintenance of gene pools
- preservation of genetic diversity
- applications of the use of gene technology
- current uses of living organisms
- new uses (e.g. plants in the tropical rainforest for medicines) discovery of new species (some of which may have uses in the future
- aesthetic and spiritual benefits, of the uses of living organisms and the aesthetic value of animals e.g. dolphins to help autistic children, the awe of the vast range of living organisms, their attractive or unusual appearances and different methods of survival

Link back to work done on ecosystems and food webs, discuss and consider how removal of one species affects the survival of the other organisms in an ecosystem, including humans.

Class activities

1. Research definitions of biodiversity and produce a summary of what is meant by diversity, for example with bullet points or a spider diagram to cover the different aspects of biodiversity.
2. In groups, research one kingdom and agree the main identifying features. Produce a summary to illustrate these, with pictures or drawings of organisms which show the features. Present the information to, and make copies for, the others in the class.
3. Discuss whether viruses can be considered organisms.
4. List reasons for the need to maintain biodiversity, organising the list into different categories e.g. genetic, future uses, current uses, spiritual / aesthetic, etc.

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discussion about biodiversity and the reas
to maintain biodiversity

http://www.kew.org/science-conservation/kew-biodiversity/index.htm
plant biodiversity: up-to-date information and short video clips

AS and A Level Biology (Chapter 20) provides a definition of biodiversity (p.298) and summarises very clearly the five kingdom classification (pp. 293-298). There is a short section on the reasons for maintaining biodiversity (p. 298), which should be used as a starting point.

Bio Factsheet 34: *Species diversity*
Some parts relevant to the learning outcome.

Bio Factsheet 91: *Taxonomy and classification*
More information than required but has a summary of the five kingdoms.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
Q	(d) describe the reasons why one named species has become endangered, and use this information in the context of other endangered species; (e) discuss methods of protecting endangered species, including the roles of zoos, botanic gardens, conserved areas (national parks) and seed banks;	Students should be encouraged to consider a range of different organisms that are on the endangered list. A verbal question and answer exercise to classify some of the organisms on the list into their kingdom would provide the opportunity to review knowledge gained from learning outcomes (a) (b) and (c). By concentrating on one named species in activity 5, students should gain sufficient understanding to be able to apply the principles and concepts to new organisms introduced to them in the examination. Discuss the main features of the different methods used to protect endangered species and ensure that students can apply their knowledge and understanding to new situations. If possible, organise a visit to a national part, nature reserve, zoo or botanic garden so that students have an opportunity to see the work that is being done locally or nationally. **Class activities** 1. Research and define what is meant by the term *endangered*. 2. List the criteria used to classify an organism as endangered. 3. Research and define what is meant by the term *conservation*. 4. Produce a written summary of the different methods employed to protect endangered species, stating also the advantages and disadvantages of each. 5. Choose a specific organism that is considered to be endangered and present to the class the reasons for the organism being endangered. Include the species name if the organism is known by an additional name. This exercise could be done in pairs using a local / national example and a global example. Add to the list produced for activity 2, if necessary. 6. Following presentations, group work to discuss the best method for protecting the organisms. 7. Research local, national and international efforts to protect endangered species.	http://www.iucn.org/knowledge/tools/ conservation tools – web page from the International Union for Conservation of Nature http://www.iucnredlist.org/ for checking the status of different species http://www.worldwildlife.org/endangered/ and http://www.endangeredspecie.com/ information about protecting endangered species http://www.kew.org/science-conservation/index.htm plant conservation projects http://www.zsl.org/conservation/ click the places on the world map to read more about conservation projects and details about the organism at risk http://www.petermaas.nl/extinct/index.html the extinction website http://www.eoearth.org/topics/view/49513/ articles on conservation biology http://www.bbsrc.ac.uk/society/schools/secondary/extinct.aspx plant survival game http://www.satavic.org/biodiversity.htm global centres of biodiversity

8. With reference to genetic improvement and the maintenance of the gene pool, research landraces of crop plants or rare breeds of livestock.
9. Research examples of wild relatives of crop plants.
10. Explain what is meant by global centres of biodiversity.

http://www.jic.ac.uk/corporate/about/pu
s/substainable.pdf
sustainable agriculture and maintaining biodiversity of crops – notes about genetic modification of crops

AS and A Level Biology (Chapter 20, pp.298-302) covers these learning outcomes by using examples and includes SAQs for students to consider.

The following sheets all contain information that have links to these learning outcomes (students need to be selective):
Bio Factsheet 27: *Biological effect of deforestation*

Bio Factsheet 65: *Conservation*

Bio Factsheet 197: *Biology of coral reef ecosystems*

Bio Factsheet 203: *Climate change and ecological decoupling*

Bio Factsheet 208: *Captive breeding and the role of zoos*

Bio Factsheet 170: *Answering Exam Questions: Classification and Keys*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
R	(a) describe the steps involved in the production of bacteria capable of synthesising human insulin: • identifying the human insulin gene • isolating mRNA and making cDNA using reverse transcriptase • cloning the DNA using DNA polymerase • inserting the DNA into a plasmid vector using restriction enzymes and DNA ligase • inserting the plasmid vector into the host bacterium • identifying the genetically modified bacteria using antibiotic resistance genes • cloning the bacteria and harvesting the human insulin;	Before teaching this learning outcome ensure that students have knowledge and an understanding of the following: • prokaryotic structure • plasmids - small circular DNA molecules containing a few genes, such as those for antibiotic resistance • what is meant by a gene • (many) genes code for the production of proteins • transcription and translation • what is meant by an antibiotic Much of this will be AS revision and knowledge can be gauged by verbal question and answer and/or activities such as matching definitions to terms and placing in sequence cards with statements of the main steps in protein synthesis. In order for students to understand why mRNA is used in the genetic engineering procedure for insulin production, explain how eukaryotic DNA contains introns and exons and that the mRNA produced has had the introns removed. Explain also that bacteria cannot transcribe and translate eukaryotic genes (because they cannot remove introns). Although students will have covered insulin in their A2 course, they need now to consider the production and medical use of insulin for people with diabetes mellitus. Review the importance of insulin and its control of blood sugar. It is worth students having an overview of the entire process before proceeding to student activities that provide more details. They should understand that the desired product is a protein that can be obtained in large(r) volumes by using a host organism, often a bacterium. The desired gene needs to be obtained, either by removing it directly from the original organism or by synthesising it. A mechanism needs to be used to get the desired gene, coding for the protein product, into the host. Often this is achieved using a vector. Check that they understand the term *vector* (previously	http://www.littletree.com.au/dna.htm shows how human insulin is produced. http://www.abpischools.org.uk/res/coResourceImport/modules/hormones/en-flash/geneticeng.cfm simple step-by-step and overview –IGCSE level http://www.learner.org/interactives/dna/engineering.html information about genetic engineering includes insulin http://www.endocrineweb.com/conditions/diabetes/diabetes-what-insulin straightforward account of diabetes and the need for commercial insulin http://www.2aida.org/aida/index.shtml simulation where variables which affect diabetics can be changed to show changes in blood glucose level http://www.medicinenet.com/insulin/article.htm medication and drugs for diabetes http://www.iddtinternational.org/?page_id=61 human versus animal insulin, as well as additional reading for interested students http://learn.genetics.utah.edu/ plenty to choose from – information that is easy to read and understand, ranging from a revision of DNA structure and protein synthesis,

	used at AS to describe the role of the *Anopheles* mosquito in malaria). The term *recombinant* should also be considered. There are many definitions, but in this context students need to understand that novel DNA is formed by joining together DNA/genes from different sources, hence the terms *recombinant* DNA, *recombinant* plasmid, *recombinant* host Also remind students that the process is carried out on a larger scale than one desired gene being placed into one host, as they will continually see in textbook diagrams. This will lead to an explanation of cloning (gene cloning to produce many copies of the desired gene before being incorporated into plasmids; gene cloning as plasmids and the host cell replicates; bacterial cloning as bacteria replicate to give identical daughter cells). Depending on the group the outline discussion may lead into a follow-up discussion as to the benefits of using bacteria as hosts. However, this could wait until the end of the topic as it will make links with other sections. Include: simple nutritional requirements; able to obtain large volumes of product by fermentation (link to Section S), which also requires less space; can be cultured anywhere in the world; high population growth rate increasing product yield; fewer ethical problems and moral / religious dilemmas (see also learning outcome (f)). Some teachers prefer to include the use of antibiotic resistance markers to enable screening (for the desired recombinant bacteria) as it occurs in the process. Others leave this as an add-on at the end once students have a good grasp of the steps involved.	leading to biotechnological applications http://www.wiley.com/college/fob/quiz/quiz03_29.html construction of recombinant DNA - animation http://www.wellcome.ac.uk/Education-resources/Teaching-and-education/Big-Picture/All-issues/Epidemics/WTD028128.htm excellent images of *E. coli* http://www.biology.arizona.edu/molecular_bio/problem_sets/Recombinant_DNA_Technology/recombinant_dna.html a good site with much information and mini-tutorials that can be used to help learning ***AS and A Level Biology*** (Chapter 17, pp.237-239) gives a clear step-by-step account of the production of human insulin and in Chapter 21, pp.304-305, explains how genetically modified bacteria can be identified. There is a short section about the advantages of human insulin on p. 237, and again on pp.275-276, and p.303 has an SAQ about the topic. ***Bio Factsheet 13:*** *Genetic engineering*
(b) explain the advantages of treating diabetics with human insulin produced by gene technology;	The large scale production of insulin will lead on to discussion about the advantages of treating people with diabetes with human insulin produced by gene technology. Students may need to be told that insulin is otherwise obtained from slaughtered pigs and cattle by extracting insulin from their pancreases and that some people with diabetes are only able to use this type of insulin.	

Class activities

1. Label a diagram of a plasmid-containing *Escherichia coli* bacterium.
2. After obtaining an overview of the main stages in the production of insulin by genetic engineering, use a set of cards with a single step on each to try and put in to an order and learn the process in more detail. Then work in pairs to compare sequences and then in small groups to verify the correct order.
3. In small groups, model the main steps in the production of human insulin. Each group can demonstrate and describe their model to the rest of the class.
4. Using the sequenced set of cards for guidance, label and annotate diagrams to produce a flow chart for the production of human insulin by genetic engineering.
5. Produce a summary table of the names of the enzymes involved and the reactions they catalyse.
6. Consolidate leaning by matching up terms to definitions.
7. Research the benefits of using genetically engineered insulin rather than insulin from the pancreases of slaughtered animals. This information can be presented in a table of explained differences. Include ideas based on:
    - supply and demand
    - rejection
    - side effects
    - disease risk from contaminants
    - production costs
    - ethics
    - religion
8. Suggest reasons why some people with diabetes are still treated with insulin taken from pigs.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
R	(c) explain why promoters need to be transferred along with desired genes in gene technology;	Students may, through extension or background work, have gained an idea of promoters when studying protein synthesis at AS. They need to understand that a promoter is a nucleotide sequence along the DNA where RNA polymerase attaches to initiate transcription. The promoter allows the RNA polymerase to recognise which of the DNA strands is the template. Within the sequence is the transcription start point – the first nucleotide of the gene to be transcribed. In this way, the promoter can be said to control the expression of a gene. Having grasped the concept of promoters, ask students to suggest why a promoter needs to be transferred with the desired gene in gene technology. In their research, students may note that there are differences between bacteria and eukaryotes. In bacteria, the RNA polymerase recognises and binds directly to the promoter but in eukaryotes the binding is enabled by transcription factors which bind first.	http://www.web-books.com/MoBio/Free/Ch4C1.htm promoters of *E. coli* and eukaryotes the use of antibiotic resistance marker genes: http://www.gmo-compass.org/eng/safety/human_health/126.position_efsa_antibiotic_resistance_markers.html (links to other sites) and http://www.medicalnewstoday.com/articles/31227.php http://www.conncoll.edu/ccacad/zimmer/GFP-ww/GFP-1.htm green fluorescent protein –links to other sites
	(d) explain why and how genes for enzymes that produce fluorescent or easily stained substances are now used instead of antibiotic resistance genes as markers in gene technology;	Students could be given information about genes, which code for enzymes that produce fluorescent or easily stained substances and asked where these would be used in gene technology, then move on to discuss why these would have advantages over antibiotic resistance genes being used. **Class activities** 1. Make notes to explain what a promoter is, and to describe the role of a promoter. 2. Explain why a promoter needs to be transferred in gene technology and state the step in the overall procedure where this would occur. 3. Discuss in groups the problems that the use of antibiotic resistance genes might create. 4. Research one example, to present to the class, where genes for enzymes that produce fluorescent or easily stained substances are now used as markers.	http://www.scholarpedia.org/article/Fluorescent_proteins much detailed information, useful background reading, and links to other sites http://www.microscopyu.com/articles/livecellimaging/fpintro.html and http://micro.magnet.fsu.edu/primer/techniques/fluorescence/fluorescentproteins/fluorescentproteinshome.html fluorescent proteins linked to microscopy ***AS and A Level Biology*** (Chapter 21, p. 305) explains the use of promoters in gene technology and gives a balanced view about the use of antibiotic resistance markers. Green fluorescent proteins are introduced.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
R	(e) describe the benefits and hazards of gene technology, with reference to specific examples;. (f) discuss the social and ethical implications of gene technology;	Broaden the discussion and debate to other examples, besides insulin, 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 card carrying a statement which: clearly agrees e.g. “There is nothing wrong with genetic engineering – it’s another beneficial scientific technique”, clearly disagrees, e.g. “Genetic engineering is wrong; we should not mess with nature like this” or has a mixed approach, e.g. “I think it’s OK to use for th production of useful medicines, but not to make crops grow better”. Ask students to sort them into groups of ‘agree’, ‘don’t agree ‘and ‘unsure’, or stick up the statements around the room and get students to place ticks or crosses by each statement. Use the activity as the basis of a debate where students need to suggest benefits and hazards of gene technology, and consider social and ethical implications when they justify their views. It is important that students understand the difference between the terms *social* and *ethical*. Following the debate, some of the arguments used by students could be revisited, and students asked to state whether this was a social or ethical implication. social = related to human society e.g. interdependence, mutual relationships, cooperation for all to benefit ethics = set of agreed standards, determine what is acceptable, followed by a group of individuals, regulated behaviour **Class activities** 1. Research and give definitions of the terms *social* and *ethical.* 2. Sort a list of benefits and hazards into social or ethical implications and then organise into written notes. 3. Group work: each to choose a different type of gene technology to research (plant, animal, microbial: e.g. pest resistance in tobacco plants, human genes in pigs for xenotransplantation, production of HGH) and present, followed by class discussion to consider benefits and hazards.	http://www.wellcome.ac.uk/Education-resources/Teaching-and-education/Big-Picture/index.htm resources including ‘Big Picture' 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 http://www.i-sis.org.uk/GE-ethics.php Institute of Science in Society – list and links to many different articles http://www.beep.ac.uk Bioethics Education Project ***AS and A Level Biology*** (Chapter 21, pp.239-242) discusses these learning outcomes in details and gives a number of examples. There is no specific section on social implications of gene technology. ***Bio Factsheet 13:*** *Genetic engineering* Includes a brief discussion on ethical issues. ***Bio Factsheet 106:*** *Ethical issues in A-level Biology*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
R	(g) outline the principles of electrophoresis as used in: • genetic fingerprinting • DNA sequencing;	Before students can outline the main principles of electrophoresis, they need to understand the concepts and principles involved in the two techniques. For genetic fingerprinting (now commonly called DNA profiling), the topic can be confusing in that a number of different terms have been used for repeating sequences. To avoid confusion, use the term variable number tandem repeats (VNTRs) when describing sections of DNA with repeating nucleotide sequences, but mention to students that they may come across the other terms. Ensure students understand that • a particular VNTR occurs at a specific locus • for a particular VNTR different individuals can have a different number of repeats and so the DNA section will be of differing lengths • selected VNTRs, known to be very variable in different individuals, can be used as markers • from a DNA sample, polymerase chain reaction is carried out to amplify the quantity of each VNTR marker in the sample • the chances that two individuals (except for identical twins) have exactly matching DNA profiles (genetic fingerprints) for these selected markers is virtually 0. Show students an electrophoresis kit or photographs of a kit, explaining that an electric field is applied to samples that are placed at one end in the gel. Ask students to use their knowledge of DNA structure to explain why the samples will move towards the positive electrode. Then build up the idea that within the sample, the shorter VNTR sections are a smaller size than the longer sections; that they will be less impeded by the gel used; hence shorter VNTRs will move a further distance in the same time than the longer VNTRs. Work through an example e.g. using radioactive probes, to show how bands are obtained that can be analysed. The same principles of electrophoresis will apply for gene sequencing and, as with genetic fingerprinting, details of the	Searching for ‘Genetic fingerprinting’, ‘DNA profiling’, ‘DNA forensics’ will return many website results – check first for suitability before recommendation to students. http://www.life.uiuc.edu/molbio/geldigest/electro.html#run this takes students through an electrophoresis process using pictures and notes. http://www.koshlandscience.org/exhibitdna/crim01.jsp# interactive activity about DNA profiling (genetic fingerprinting) http://www.pbs.org/wgbh/nova/sheppard/analyze.html DNA electrophoresis and profiling (fingerprinting) exercise to identify a culprit. http://www.biotechnologyonline.gov.au/human/dnaprofile.html (uses the term STRs) simple explanation and followed by an interactive activity http://www-saps.plantsci.cam.ac.uk/worksheets/scotland/dna.htm gel electrophoresis of DNA activity. http://www.web-books.com/MoBio/Free/Chap9.htm techniques including DNA cloning, gel electrophoresis and DNA sequencing

preparation of the sample are not required, only sufficient to enable understanding of how electrophoresis is an appropriate technique to use. Using a detailed description, such as Fig. 21.5 in ***AS and A Level Biology***, work through an example with students, asking them verbally to summarise each step and then, by question and answer, get them to recall the principles of electrophoresis as applied to gene sequencing. Students should understand that the fragments of DNA result from the presence of dideoxynucleotides that lack the essential 3' OH (hydroxyl) group: there is chain termination as a result of one of these nucleotides binding instead of a normal deoxyribonucleotide. When they are integrated into the chain, the addition of further nucleotides is prevented. Main stages:

- denaturing of DNA into single strands
- binding of primer (radioactive or fluorescent label for detection)
- divide into four groups
- to each, add DNA polymerase, all four DNA nucleotides and a very small (e.g. 1%) proportion of one of ddATP, ddGTP, ddCTP or ddTTP
- polymerisation occurs, giving a series of strands of different lengths depending on where a dideoxynucleotide was added

Class activities

1. From a detailed account of the technique of genetic fingerprinting, produce an outline using bullet points.
2. List the main principles behind the use of electrophoresis in genetic fingerprinting.
3. Use kits to carry out gel electrophoresis of DNA or use simulations and web-based activities.
4. Carry out analyses of different results of genetic fingerprints or make up own worksheet containing simulated results e.g. from a crime scene or paternity suit, to swop within class for another student to analyse.
5. List the uses of genetic fingerprinting.
6. Assess the social and ethical implications of genetic fingerprinting.
7. Repeat activities 1., 2., 5. and 6. for gene sequencing.

http://www.ornl.gov/sci/techresources/H
Genome/elsi/forensics.shtml
DNA forensics

http://www.ncbe.reading.ac.uk/NCBE/MATERIALS/menu.html
NCBE can provide teaching kits for DNA and biotechnology. SAPS and NCBE work collaboratively

AS and A Level Biology (Chapter 21, pp.305-308) - a clear account at an appropriate level.

Bio Factsheet 67: *Modern techniques in Biology: Genetics*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
R	(h) describe the causes and outline the symptoms of cystic fibrosis (CF) as an example of a recessive genetic condition (reference should be made to CFTR protein). Issues related to CF will need to be handled with sensitivity); (i) describe the progress towards successful gene therapy for CF; (j) discuss the roles of genetic screening for genetic conditions and the need for genetic counselling;	Students need to use knowledge of protein structure (section B, Biological molecules), membrane proteins and transport mechanisms across membranes (section D, Cell membranes and transport), genetic crosses and mutations (section O, Inherited change). This topic needs careful handling. As an introduction, it may be of interest to students to note that some genetic conditions are more common in certain groups, as a result of common ancestry (and hence sharing similar genetic make-up). For example, cystic fibrosis is most common in Caucasians, sickle cell anaemia is common in West and East African, African-American and Mediterranean populations, Tay Sachs is more likely to occur in people of eastern and central European (Ashkenazi) or French Canadian ancestry. After an initial discussion with students to introduce the topic and deal with any issues that arise, the topic then lends itself to individual and small-group study using information sheets, text books and web-based research. Use whole group discussion at intervals to check understanding, pool information and discuss the difficulties of living with CF. Revisit section R (a) to compare with gene therapy, which uses some of the same techniques. Ask students to name some of the conditions for which genetic screening is available and ask them to suggest the benefits and difficulties that could be faced. Explain what is meant by genetic counselling and encourage students to debate the issue as different parties, e.g. parents of a child with CF, a couple, both of whom are carriers of CF, who wants to start a family, an insurance company representative, an employer, etc.	http://www.nlm.nih.gov/medlineplus/cysticfibrosis.html information about CF – also excellent for providing a wealth of web links to various other sites for information. http://ghr.nlm.nih.gov/gene/CFTR detailed information about the CFTR protein and links to other sites http://www.ygyh.org/cf/whatisit.htm facts about CF http://cystic-fibrosis-symptom.com/symptoms.htm site that has much information including symptoms of CF and genetic testing http://resources.schoolscience.co.uk/BBSRC/casestudies/cystic.pdf worksheets on CF http://learn.genetics.utah.edu/content/health/ngs/ information about genetic screening of new borns – links to an activity and additional material http://www.hdfoundation.org/html/hdsatest.php guidelines for testing for Huntington's disease http://www.merck.com/mmhe/sec22/ch256/ch256b.html information about genetic screening

Class activities

1. Draw a diagram of a normal CFTR protein within the cell surface membrane and annotate to show chloride movement out, followed by the osmotic movement of water.
2. Give an outline of the main symptoms of CF.
2. Explain how poorly or non-functioning CFTR proteins can lead to thick mucus and explain how this leads to some of the symptoms seen in people with CF.
3. Explain how different mutations within the CF gene can lead to different CFTR proteins with different levels of functioning (and hence people with different severity of condition).
4. Practise genetic crosses involving the inheritance of the recessive CF allele and draw genetic diagrams from case studies.
5. In groups research and summarise progress towards successful gene therapy (could give presentations to the rest of the class). Give an outline of the different methods employed to deliver the normal allele.
6. In groups research and discuss the use of genetic screening for genetic conditions and why genetic counselling is needed - from class discussion produce a summary diagram showing uses for specific conditions, benefits and consequences, and the ethical and social issues which arise.

AS and A Level Biology (Chapter 21, p 313) provides a comprehensive coverage these learning outcomes.

Bio Factsheet 134: *Cystic Fibrosis*

The following all include CF:
Bio Factsheet 110: *Genetic Disease in Humans*
Bio Factsheet 51: *Gene therapy*
Includes cystic fibrosis
Bio Factsheet 215: *Genetic Testing and Screening*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
S	(a) outline the use of microorganisms in the extraction of heavy metals from low grade ores;	Begin this section with a brainstorming or question and answer session to obtain a definition of biotechnology. Revise the different microorganism types and ask students for examples of where microorganisms are used in biotechnology. Move on to discussing the difficulties in extracting metal from ores and how microorganisms can be used for this process. **Class activities** 1. Produce a summary diagram of the extraction of copper or uranium or gold from low grade ores, annotating to show the involvement of microorganisms and the main stages in the process. 2. List the advantages of using microorganisms in the extraction of heavy metals from low grade ores. 3. Explain why the production of sulphuric acid during metal extraction is a potential problem. 4. List the features of microorganisms such as *Acidithiobacillus ferrooxidans* that make them suited to heavy metal extraction.	http://www.bioteach.ubc.ca/Bioengineering/Microbialmining/ provides clear notes and pictures of processes. http://www.molecular-plant-biotechnology.info/use-of-microbes-in-industry-and-agriculture/extraction-of-metals.htm information about extraction of metals ***AS and A Level Biology*** (Chapter 22, pp.314-316) has a summary diagram and relevant information for the learning outcome.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
S	(b) explain what is meant by the terms *batch culture* and *continuous culture*; (c) compare the advantages and disadvantages of batch and continuous culture with reference to the production of secondary metabolites (e.g. penicillin), enzymes (e.g. protease) and biomass (e.g. mycoprotein);	It is possible that students may not know about mycoprotein, a meat substitute made from the fungus *Fusarium venenatum* (formerly *F. graminearum*). Show students packets of the product or images of packets and explain that the product is made from the fungal hyphae of the growing organism, a good alternative source of protein for vegetarians with a similar texture to meat and able to take up a variety of flavours to resemble beef or chicken, for example. Also refer students back to the term *metabolism* and explain to them what is meant by a *metabolite, primary metabolite* and *secondary metabolite*. In order to get students used to the idea of identifying the correct conditions for the required type of population growth, practicals involving yeast population growth could be carried out. Students could be asked to design and carry out their own investigation by altering one variable required for growth, such as temperature, type of substrate, pH etc. However, ensure that students do not get the unicellular fungus, yeast confused with the filamentous fungus involved in mycoprotein production, *Fusarium*. By referring back to bacterial growth on nutrient agar or fungal growth on rotting fruit, students should be able to identify the requirements needed for microorganisms to grow in culture on a small scale. Ask them to suggest how this could be scaled up to a commercial scale and identify some of the problems that need to be overcome, such as contamination, control of conditions, obtaining oxygen (for aerobic organisms). Introduce the two types of culture, and explain that there are many variations on the basic theme before describing the fed-batch system (for penicillin production) and before students carry out activities. Link the fermentation type, batch or continuous, to the product required and the pattern of population growth (show students graphs of population growth curves):	An image websearch, for '*Penicillium chrysogenu*m' and '' reveals many beautiful images http://www.biotopics.co.uk/microbes/penici.html a batch fermenter and penicillin production and additional details about antibiotics http://www.dcu.ie/~oshead/BE401/lectures/pres438453849e9b7.pdf more detailed but readable account of penicillin production, including some historical aspects http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Contin/working.htm batch and continuous information and a graph to show effects of changing inlet substrate flow. Useful for more able students to investigate. http://www.mycoprotein.org/ a site devoted to mycoprotein http://www.biotopics.co.uk/edexcel/biotechnol/myco.html clear coverage of mycoprotein production Check websites of enzyme producers, e.g.: http://www.mapsenzymes.com/Making_of_Enzymes.asp ***AS and A Level Biology*** (Chapter 22, pp.316-320) covers the learning outcomes, with SAQs. ***Bio Factsheet 33:*** *Fermentation made simple* ***Bio Factsheet 176:*** *Penicillin production and use*

- continuous – mainly for primary metabolites from synthesis and growth (e.g. the biomass of *Fusarium* for mycoprotein), where nutrients are continually added for growth, and waste and product removed at the same rate as nutrients added
- batch / fed-batch – mainly for secondary metabolites (e.g. penicillin) and enzymes

Class activities

1. Explain what is meant by (i) batch culture (ii) fed-batch culture and (ii) continuous culture.
2. Label a diagram of a typical batch fermenter, annotating with the function of each part. Suggest how the fermenter could be converted to carry out continuous culture
3. Construct a table comparing batch and continuous culture, to include advantages and disadvantages of each.
4. Produce a bullet-point or spider diagram summary for penicillin, mycoprotein and protease production, including, for example: type of culture; name and type of organism involved (inoculum); how type of culture links to products required (e.g. refer to growth phases) nutrients; fermenter conditions (e.g. oxygen, temperature, pH); downstream/ post-fermentation processing.
5. Use graphs showing production of penicillin and organism biomass to develop skills in data extraction and interpretation.
6. As background interest, research the suggested health benefits of mycoprotein.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
S	(d) describe, for penicillin as an example of an antibiotic: • the mode of action on bacteria and why it does not affect viruses • causes and effects of antibiotic resistance;	Antibiotics occur in sections: I, Infectious disease; P, Selection and evolution; and R, Gene technology. Students should be familiar with the main features of antibiotics, antibiotic resistance and penicillin production. Here they need to study the mechanism of action of penicillin and consider the way in which bacteria can be resistant to the antibiotic. Explain that there are a number of closely related antibiotics that belong to the penicillin group, which itself belongs to a group known as the beta lactams. If not already done at AS, students could culture bacteria such as *Bacillus subtilis* with different concentrations of antibiotic-pregnated discs. Review with students the structure of bacteria cell walls. They should understand that: the strength of the cell wall is only complete when the peptidoglycan chains have peptide cross links between them; formation of the links is catalysed by transpeptidase enzymes (glycoprotein peptidases). Help students to suggest how enzymes such as penicillin can act to inhibit transpeptidases. Ask for suggestions as to how bacteria could 'inactivate' penicillin - this should lead to: enzyme (beta lactamase, formerly penicillinase) hydrolysis; enzymes are proteins; genes code for proteins; mutations lead to new proteins – hence antibiotic resistance. From work done on HIV, students will know that antibiotics do not affect viruses - provide an outline of viral structure for activity 5. **Class activities** 1. Explain the difference between *bacteriostatic* and *bactericidal* antibiotics, identifying to which of the two type penicillin belongs. 2. Research the mode of action of penicillin and produce a bullet point summary of the main points. 3. Explain why penicillin is only active against growing bacteria that are laying down new cell wall components. 4. Use knowledge of mutation, gene expression and enzyme action to explain how some bacteria are resistant to penicillin. 5. Explain why viruses are not affected by penicillin and suggest why penicillin does not harm human cells.	http://www.biology.ed.ac.uk/research/groups/beacon/microbes/penicill.htm mode of action of penicillin, plus information on other antibiotics and antibiotic resistance http://www.antibioticresistance.org.uk/ basic information http://www.bbsrc.ac.uk/web/FILES/Resources/antibiotics.pdf general information as well as a summary of mechanism of action – good for students to update their knowledge http://pathmicro.med.sc.edu/fox/antibiotics1.htm details about beta lactams http://www.textbookofbacteriology.net/kt_toc.html plenty of useful information, worth the time to read the various sections linked to penicillin and antibiotics ***AS and A Level Biology*** (Chapter 22, pp.319-320) has information at an appropriate level about the mode of action of bacteria and about penicillin resistance.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
S	(e) immobilise an enzyme in alginate and compare the ease of recovering the enzyme and ease of purification of the product compared to the same enzyme that has not been immobilised;	This learning outcome is best taught by engaging students in a relevant practical activity. Revise the relevant learning outcomes in Enzymes (Section C) and Biological molecules (Section B) and, at some point, make reference to commercial production where immobilised enzymes are ideal to use in continuous culture systems. Protocols such as 'Better milk for cats' where students can appreciate an everyday application, will stimulate interest. In addition, this protocol involves the use of dipsticks containing glucose oxidase (learning outcome (f)). Whichever practical is chosen, use this as a basis for developing evaluation and design skills for Paper 5 e.g. changing the independent variable, controlling other variables, considering variables that cannot be controlled, measurement of dependent variable, replicates, presentation of results, etc. Demonstrate the same enzymatic reaction using the enzyme free in solution. Ask students to suggest the advantages of immobilising the enzyme rather than using it free (not immobilised). **Class activities** 1. Carry out a practical to make and use immobilised enzyme. 2. Design a practical to investigate the difference between immobilised and free enzyme, or the effect of changing a variable on the activity of immobilised enzyme (see above). 3. Summarise the advantages of using immobilised enzyme rather than using the same enzyme that is not immobilised. 4. Interpret graphical and tabulated data (e.g. changing temperature, pH, substrate concentration, inhibitor presence), to compare immobilised enzyme with non-immobilised enzyme. 4. Research one example where immobilised enzyme is used in industry to highlight the advantages of using immobilised enzyme rather than enzyme that is not immobilised.	http://www.rpi.edu/dept/chem-eng/Biotech-Environ/IMMOB/Immob.htm introduction to immobilisation and different methods. Plus good links to bioreactors. http://www.lsbu.ac.uk/biology/enztech/ very good book online for enzymes and immobilised enzymes – students need to be selective http://www.scienceinschool.org/repository/docs/issue10_catmilk.pdf protocol using immobilised lactase in alginate beads ***AS and A Level Biology*** (Chapter 22, pp.320-321) clearly explains a practical using immobilised lactose and milk and discusses the advantages of using immobilised enzyme.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
S	(f) explain the principles of operation of dip sticks containing glucose oxidase and peroxidase enzymes, and biosensors that can be used for quantitative measurement of glucose;	There are many different commercial products available for glucose detection and measurement. Students should be able to use the principles of operation to apply to a design that they may not have come across. The quantitative measurement of glucose for people with diabetes will link back to work done on insulin in section N (Regulation and control) and insulin production in section R (Gene technology). The commercial production of glucose biosensors is a fast developing field and students should be made aware of recent developments in this area, such as implantable devices and devices that can control and regulate insulin doses. If not already used in the immobilised enzyme practical, show students how a dipstick is used to detect glucose before explaining the principles behind their operation. Students will need to recall that enzymes are specific so that a reaction catalysed by glucose oxidase will confirm the presence of glucose. They should know the oxidation of glucose produces gluconic acid (some text books state gluconolactone, an intermediate) and hydrogen peroxide, and that peroxidases are used for the peroxide to react with a chemical (chromogen) that produces a coloured product. Some dipsticks produce a range of different colours or different intensities of colour to match to a glucose concentration. Give students an outline of the operation of the biosensor. Incorporate question and answer where there are links to AS: • partially permeable membrane only allows glucose to diffuse through (from the blood sample) • specific binding to immobilised glucose oxidase (on a biological recognition layer) allows a reaction to occur • method to detect reaction e.g. use of electrodes to detect: a decrease in oxygen; increase in hydrogen peroxide; production of gluconic acid • transducers convert the change into an electrical current which can be amplified and produce a digital reading	A web search for glucose biosensors and glucose oxidase dipsticks will enable students to see the range of products that are available. Many sites contain complex information beyond the requirements of the syllabus. http://www.southernbiological.com/Products/Kits&Equipment/SpecialLabFieldEquipt/G10_36.htm one of many websites explaining dipsticks containing glucose oxidase enzyme ***AS and A Level Biology*** (Chapter 22, pp.321-322) has a section on dipsticks and biosensors. ***Bio Factsheet 167:*** *Biosensors*

- the reading is proportional to the reaction so is proportional to the concentration of glucose

Students should be able to answer questions based on one of the very many different designs once they know the principles of operation.

A class discussion about the advantages of dipsticks and portable devices should alert students to the problems that people with diabetes had in the days before glucose biosensors.

Class activities

1. Make bullet point notes to summarise the principles behind the use of dipsticks and biosensors to detect glucose. Include the equation for the reaction catalysed by glucose oxidase.
2. Draw diagram to show the main parts of a biosensor and annotate to show the principles of operation.
2. Compare the use of glucose dipsticks and glucose biosensors.
3. Explain the advantages of using dipsticks and biosensors to detect glucose rather than using the Benedict's tests.
4. Research the latest biosensors for the detection of glucose.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
S	(g) outline the hybridoma method for the production of a monoclonal antibody;	This enables students to review knowledge of section J, Immunity. A question and answer session should review prior knowledge so that students are clear about antigens, antibodies, specificity, B lymphocytes and plasma cells. They should recall, from section E, Cell and nuclear division, that cancer cells divide uncontrollably. Students should be able to work through the steps of the hybridoma method themselves, with guidance and follow-up assignments. Point out that the hybridoma cell formed contains the genetic material of both cells so that the desirable features of both cells become incorporated into the hybridoma. As with the other areas of biotechnology, developments continue at a rapid pace and students will be expected to use biological principles and concepts in new situations. From their knowledge of immunology, discuss with students why there has been a move to produce humanised antibody rather than mouse antibody.	http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/M/Monoclonals.html a clear description of production of monoclonal antibodies with related links. http://www.bio.davidson.edu/Courses/molbio/MolStudents/01rakarnik/mab.html detailed information about monoclonal antibodies http://www.nap.edu/openbook.php?record_id=9450&page=8 far more detail than is required, but will satisfy interested students who want to know more
	(h) evaluate the use of monoclonal antibodies compared to conventional methods for diagnosis and treatment of disease, and testing for pregnancy;	Students commonly confuse the hybridoma cell with the monoclonal antibody. Ensure they understand that: • a clone of hybridoma cells produces monoclonal antibody • the clone is a group of genetically identical cells formed from one original ‘ancestor’ cell • this cell was formed from the fusion of a specific plasma cell (B lymphocyte) and a myeloma cell • only one type of specific antibody is produced Students will need to be very clear about antibody structure and function in explaining the principles behind disease diagnosis and treatment using monoclonal antibodies. A good way of learning is by looking at a number of different examples, possible learning one of each in more detail and making comparisons to conventional methods. In their evaluation they could consider: cost; timing; ethics; convenience; practicality; whether diagnosis or treatment existed before; reliability; effectiveness; side effects, etc.	http://chemistry.about.com/od/chemistryfaqs/f/pregnancytest.htm how pregnancy tests work http://www.sumanasinc.com/webcontent/animations/content/pregtest.html pregnancy testing kit: animation http://www.hhmi.org/biointeractive/immunology/vlab.html virtual lab – disease diagnosis http://www.molecular-plant-biotechnology.info/hybridoma-and-monoclonal-antibodies-mabs/uses-of-monoclonal-antibodies.htm some uses of monoclonal antibody

Students would benefit from researching the many different commercial products available for pregnancy testing – the websites often have detail about how the test kit works and, although the basic scientific principles are the same, there will be differences in design. Students need to be able to apply their knowledge and understanding of this topic to new contexts.

Class activities

1. Produce an outline of the main stages in the production of monoclonal antibody. Within each main stage, describe the steps that occur, giving explanations or reasons for each step. This can be done as bullet points or in a table.
2. Annotate a series of drawings or diagrams outlining the main steps in monoclonal antibody production.
3. Using sets of cards, match definitions to terms.
4. Describe in detail the events that occur within the mouse from introduction of HCG antigen to harvesting of the plasma cells located in the mouse spleen (splenocytes).
5. Choose one type of pregnancy testing kit and explain the principles behind the design and use of the kit, using annotated diagrams to help.
6. Research one example of the use of monoclonal antibody in diagnosis of disease and one example for use in treatment of disease and compare this to conventional methods.
7. Following presentation of examples to the rest of the class and class discussion, agree and compile an evaluation of conventional methods of diagnosis and treatment compared to the use of monoclonal antibody.

http://www.mayoclinic.com/health/mono
antibody/CA00082
use of monoclonal antibody in cancer treatm

AS and A Level Biology (Chapter 22, pp.322-324) has an outline of the procedure for the hybridoma method and uses examples to discuss diagnosis and treatment of disease and testing for pregnancy.

Bio Factsheet 112: *Monoclonal Antibodies*

Bio Factsheet 219: *Monoclonal Antibodies: An update*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
T	(a) describe and explain the structural features of a named, wind pollinated plant; (b) compare the outcomes of self-pollination and cross-pollination in terms of genetic variation;	Students may need to review knowledge, or learn the main points of flowering plant reproduction before progressing to the details of this learning outcome. Depending on the level of knowledge, they may benefit from going through an example, emphasising general labelling and function of flower structure. They should also recall knowledge of meiosis from section E (Nuclear and cell division) and section O (Inherited change). Use local examples where possible so that students can observe details for themselves. They may need reminding of how pollen needs to germinate in order to fertilise the ovules to form the seed contained within the fruit. Discuss self-pollination and cross-pollination and ask students how meiosis will give rise to variation in pollen and embryo sacs. Students should see that there will be some variation with self-pollination and should be asked to suggest and explain why variation increases with cross-pollination between two flowers from different plants (of the same species). **Class activities** 1. Group discussion to produce diagrams to illustrate genetic variation as a result of self-pollination and cross-pollination; to include formation of haploid nuclei by meiosis, mitosis to form gametes, and fusion of gametes (male nucleus of pollen and female nucleus in ovule). 2. Complete gaps and add labels to worksheets on flowering plant structure and life cycle. 3. Carry out practical observation of wind-pollinated flowers, comparing to insect pollinated flowers. 4. Draw and label annotated drawings of named examples of wind-pollinated flowers, explaining how they are suited to pollination by wind. 5. Light microscope observation of pollen from wind-pollinated flowers (could make comparisons to insect-pollinated pollen). 6. From a set of photographs of drawings of flowers, identify whether they are wind or insect pollinated.	http://www.saburchill.com/chapters/chap0044.html wind pollinated flowers – links to plant reproduction and insect pollinated flowers on the same website http://www.daviddarling.info/encyclopedia/P/pollination.html a nice summary http://www.countrysideinfo.co.uk/flower.htm reminder to students of flower structure and plant reproduction http://www.nbii.gov/portal/server.pt/community/learn_about_pollination/872 wind and insect pollination and self- and cross-pollination ***AS and A Level Biology*** (Chapter 23, pp.327-330) goes through the features of cereal crops and provides adequate detail of pollination and fertilisation. ***Bio Factsheet 96:*** *Pollination* ***Bio Factsheet 117:*** *Fertilisation and Seed Production in Flowering Plants*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
T	(c) describe the structure of the fruit in maize and explain the function of the endosperm; (d) explain the significance of the grains of cereal crops in the human diet;	Students will already have come across maize in section T, Crop plants. Ensure that students have carried out sufficient research to know what maize is and what it looks like (note that is also called *corn*). As an introduction, start with a survey of the maize life cycle and identify each part of the mature plant and its role. Maize fruit are hard so may need to be softened in water before dissection: students could discuss why the fruits are hard and suggest advantages for this e.g. prevents enzyme activity in the seed. Students could develop skills of application of knowledge by referring back to work done in section N (Regulation and control) and, as a class exercise, suggest stages in the germination of the seed, including the role of gibberellin. Using class discussion and verbal question and answer, ensure that students know what is meant by *cereal crops* and *grains* and review knowledge of human diet. Ask students for examples of cereal crops (include local cereals and those important globally). The benefits of grains of cereal crops in the diet need to be weighed against some people's autoimmune reaction to gluten. **Class activities** 1. If available, study a whole maize plant, and / or a maize cob, before moving on to activity 2. 2. Dissect a maize fruit and then draw and label its structure. 3. Research the function of the endosperm in the maize fruit and make bullet point notes. 4. Research the benefits of including grains of cereal crops in the human diet, producing a spider diagram or other summary. 5. Explain how some people have to be selective in their diet with regard to the grains of cereal crops. 6. Review work done at AS and carry out biochemical tests to determine which biochemical are present in maize fruit.	'maize', 'maize fruit' , 'corn', 'corn fruit',' maize caryopsis' in Goggle images (or similar) will enable students to be completely familiar with the material that they are studying. The Wikipedia site has useful information and good background reading: fhttp://en.wikipedia.org/wiki/Maize http://www.nature.com/nrg/journal/v4/n5/fig_tab/nrg1064_F3.html photograph of stained section through maize fruit http://gos.sbc.edu/m/mcclintockfig3.html L.S. through maize kernel http://www.nationmaster.com/encyclopedia/Cereal general information on cereals. http://www.iita.org/maize the importance of maize in Africa http://www.vegsoc.org/info/cereals.html cereals in the diet, also stating whether gluten-free or not. ***AS and A Level Biology*** (Chapter 23, pp.327-330) goes through the features of cereal crops and provides adequate detail of pollination and fertilisation. ***Bio Factsheet 118:*** *Germination* Contains some relevant information.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
T	(e) explain how the anatomy and physiology of the leaves of C4 plants such as maize or sorghum are adapted for high rates of carbon fixation at high temperatures in terms of: • the high optimum temperatures of the enzymes involved • the spatial separation of initial carbon fixation from the light-dependent stage (biochemical details of the C4 pathway are not required);	Students need to be familiar with section: C, Enzymes; M, Photosynthesis; O, Inherited change; and P, Selection and evolution. If not covered previously, explain why the term *C3 plant* is used. Students will need to review knowledge of C3 photosynthesis in order to access C4 and need to be clear about photorespiration before considering the adaptations of the leaf cell structure. A review of knowledge of dicotyledonous leaf structure will enable them to compare with C4 maize leaf structure. Introduce the idea of photorespiration to students and describe, using diagrams, the structural and functional features of C4 plants, such as maize of sorghum, explaining that C4 plants are traditionally from hotter environments. Ask students to suggest how the features adapt the plants remove photorespiration. They could be given graphs of the rate of photosynthesis with changing temperature and asked to sketch in the graph for a C4 plant. This should stimulate the discussion of the effect of higher temperatures on C3 enzymes versus C4 enzymes. **Class activities** 1. Review C3 photosynthesis by completing worksheets with gaps or be rearranging cards describing stages. 2. Explain what is meant by photorespiration and how it affects plants. 3. Label and annotate a diagram of a section through the leaf of a C4 plant. 4. Produce a comparison table of C3 and C4 leaf structure. If possible the use of light microscopes and TS of the different leaves could be used for making annotated drawings to compare the leaves. 5. Summarise the adaptation of C4 plants to reduce photorespiration. 6. As extension work, consider the effects of global warming on the distribution of C4 plants.	http://www.icrisat.org/text/coolstuff/crops/gch2.html and http://www.icrisat.org/crop-sorghum.htm information about sorghum – from the home page students can learn more about this international crops research organisation http://maize.agron.iastate.edu/general.html information about maize(corn) from Iowa State University, illustrating the importance of maize in the agricultural world. http://en.wikipedia.org/wiki/Sorghum good introduction to sorghum. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/C/C4plants.html photorespiration ***AS and A Level Biology*** (Chapter 23, pp.331-332) uses both maize and sorghum to illustrate this learning outcome.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
T	(f) explain how sorghum is adapted to survive in arid environments; (g) explain how rice is adapted to grow with the roots submerged in water in terms of tolerance to ethanol and presence of aerenchyma;	Having covered adaptations to leaf structure and function for C4 photosynthesis, students will already have been reminded of adaptations for survival. Students should be prepared to describe an adaptation and link this to an explanation of how it provides the plant with an increased ability to survive in more extreme conditions. Check student understanding of the terms used in the learning outcome: *arid*; *submerged*; *tolerance* Help students to recall the work done on xerophytes in Section G, Transport, before they research sorghum's ability to grow in arid conditions. Similarly, check their knowledge of anaerobic respiration from section L, Energy and respiration, before research on rice. For all the crop plants studied, tabulated and graphical data can be collected from studies into improving yield by altering variables and can be converted into worksheets for students to develop analytical and evaluative skills. **Class activities** 1. Use a light microscope to observe aerenchyma in root and stem sections of prepared slides. 2. List and explain the features that make sorghum adapted to survive in arid conditions. 3. Explain why most plants cannot survive when their roots are submerged in water. 4. List and explain the features that make rice adapted to grow with roots that are submerged in water.	Refer also to websites in learning outcomes (c),(d) and (e). http://en.wikipedia.org/wiki/Rice full information about rice http://www.riceromp.com/teachers/lessonContent.cfm?pId=147 student information on structure and life cycle of rice http://www.homepage.steudle.uni-bayreuth.de/rice1.htm has photomicrographs of aerenchyma in roots of rice www.biologymad.com/resources/Crop%20Plants.pps a PowerPoint based on crop plants, with useful information on maize, rice and sorghum ***AS and A Level Biology*** (Chapter 23, pp.333-335) provides a comprehensive coverage of adaptations of sorghum and rice.

AO	Learning outcomes	Suggested Teaching activities	Learning resources
T	(h) outline the following examples of crop improvement by conventional breeding techniques: • hybridisation leading to polyploidy in wheat • inbreeding and hybridisation in producing vigorous, uniform maize;	Students will have the opportunity to use knowledge from section E, (Cell and nuclear division) to revise the idea of chromosome sets and ploidy, and section O (Inherited change), to be reminded of meiosis, homozygosity and heterozygosity. In addition, students need to be clear about the terms *inbreeding*, *polyploidy*, *hybridisation* and *vigour*. These can be discussed as they occur or as a separate exercise. Hybridisation leading to polyploidy in wheat can be introduced step by step, with verbal question and answer to check student understanding and showing examples to consolidate learning. For maize, discuss the difference between outbreeding and inbreeding and help students to understand why inbreeding is carried out. Provide students with examples In both cases, students should be able to describe the improvement to the crop.	http://en.wikipedia.org/wiki/Special:Search?search=wheat+polyploidy&fulltext=Search it uses Wikipedia and is the search page for wheat polyploidy – click on links. http://www.answers.com/topic/the-natural-history-of-wheat informative site about wheat http://www.kew.org/science/ecbot/papers/nesbitt2001wheat.pdf article about wheat evolution – has a table of the main wheat species http://www.pioneer.com/CMRoot/Pioneer/media_room/publications/documents/maize_hybrid.pdf maize hybrids
	(i) outline the following examples of crop improvement by genetic modification and include any associated detrimental effects on the environment or economy: • herbicide-resistant oil seed rape • insect-resistant maize and cotton • Vitamin A enhanced rice;	Ask students to name some examples of genetically modified crops (e.g. soya) and add to this list, so that students can see that there are many different reasons why genetic modification has become so widespread e.g. economic, increased yield, medical, aesthetic, spoilage prevention, flavour, etc. Students will need to use knowledge from section F, Genetic control and section R, gene technology when considering crop improvement by genetic engineering. Remind students of the main stages: identify and obtain the desired gene; use a method to introduce the gene into the host plant; screen for the successful recombinant host plant; production on a large scale. Students should gain an understanding of the main steps in the production of the three types of GM crop listed and should be clear about the benefits and detrimental effects. They should consider these from a local, national and global view. Presenting data of GM and non-GM yield and associated costs and gains, is an opportunity for students to analyse information and draw conclusions.	http://en.wikipedia.org/wiki/Golden_rice and http://www.irri.org/publications/annual/pdfs/ar2001/datta.pdf information on vitamin A and rice http://www.gmo-compass.org/eng/grocery_shopping/crops/24.genetically_modified_rice.html GM rice includes a section on Golden Rice http://www.goldenrice.org/ the Golden Rice website http://www.ornl.gov/sci/techresources/Human_

Discuss with students the fact that in some crop plants all improvement is by conventional means and in others it involves genetic modification and conventional means.

Class activities

1. Research and explain, in terms of crop plants, what is meant by the following terms: *hybridisation, polyploidy, inbreeding, vigorous*, *hybrid vigour.*
2. Complete diagrams showing hybridisation and polyploidy in wheat by adding labels stating whether the plant is fertile or sterile, labelling hybrids and stating the ploidy of the plant.
3. Explain why hybrid plants are infertile.
4. Investigate polyploidy and hybridisation in one named wild or domestic species of wheat, for example, spelt, wild Einkorn and durum wheat.
5. Make bullet point notes on inbreeding and hybridisation in maize, explaining the benefits of each to the farmer.
6. In groups, prepare annotated flow diagrams summarising one example of crop improvement from the list in the learning outcome (herbicide-resistant oil seed rape, insect-resistant maize and cotton, Vitamin A enhanced rice by genetic modification. Make copies of diagrams and present the information to the class.
7. For each of the listed examples state the benefits and the detrimental effects of GM crops.
8. As extension, research other examples of crop improvement by genetic modification.
9. Outline the advantages and disadvantages of crop improvement by conventional breeding techniques compared to genetic modification.

Genome/elsi/gmfood.shtml
interesting information about GM foods, including benefits and controversies

AS and A Level Biology (Chapter 23, pp.335-340) has a comprehensive coverage of crop improvement by conventional methods and gives information about the production of Golden Rice.

Bio Factsheet 69: *Genetic engineering in agriculture*

Bio Factsheet 13: *Genetic engineering*
Has a short section on genetic improvement of crops.

Bio Factsheet 137: *GM Farm Scale Evaluation Trials*

Bio Factsheet 192: *Investigating weeds and crop yield*
Includes a comparison of GM and non GM crops

AO	Learning outcomes	Suggested Teaching activities	Learning resources
U	(a) describe the histology of mammalian ovary and testis; (b) outline gametogenesis in a male and female human as a process involving mitosis, growth, meiosis and maturation;	Students need to review knowledge of sections A, Cell structure and E, Cell and nuclear division. They should know the difference between mitosis and meiosis and have a clear understanding of *diploid* and *haploid*. Remind students of the structure of the male and female reproductive systems so that they know the location of the ovaries and testes. Students should become familiar with the histology of mammalian ovary and testis before moving on to the outline of gametogenesis. They need to return to the histology to ensure that they can make links to gametogenesis. Explain gametogenesis to students only in enough detail for them to be able to work on their own to consolidate understanding. Students should be encouraged to consider where cells are diploid and haploid and could include this information for humans on their diagrams. Extension work could use a case study for a different mammal, with a different diploid number, to review learning. **Class activities** 1. Students should use the light microscope and slides of ovary and testis and photomicrographs to observe histology and make annotated drawings. 2. Label diagrams of ovary and testis histology to show the stages of gametogenesis. 3. In small groups research spermatogenesis in a male human and oogenesis in a female human and then sort cards with separate stages of gametogenesis into the correct order. Confirm the correct sequence by class discussion and copy these using different colours to highlight where mitosis and meiosis occur. 4. Compare the similarities and differences between male and female gametogenesis.	A search of Google images for ovary and testis histology results in many excellent images. http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter28/animation__unique_features_of_meiosis.html animation reminding students of the features of meiosis http://wps.prenhall.com/esm_freeman_biosci_1/0,6452,501052-,00.html the links, each to a nice flash animation of oogenesis, spermatogenesis and a comparison of the two. http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter28/animation__spermatogenesis__quiz_1_.html spermatogenesis animation with quiz 1– links to quiz 2 Bioscope for testis histology. ***AS and A Level Biology*** (Chapter 24, pp.341-345) covers these learning outcomes at an appropriate level. ***Bio Factsheet 168:*** *Gamete Formation in Animals*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
U (c) (d) (e)	(c) explain the role of hormones in maintenance of the human menstrual cycle, and link this to changes in the ovary and uterus during the cycle;	Students need to review the work done on the endocrine system and hormones in section N, Regulation and control. As a class exercise, gradually build up the menstrual cycle, ensuring that each part is understood before progressing on to the next. Students need to know the different origins of the hormones, their role in control the cycle and the effects they have on the ovary and uterus. The importance of synchronising activities of the ovary and uterus should be discussed. Draw a long x-axis, marked up to 28 days and discuss how this can differ for longer / shorter menstrual cycles. Sketch diagrams of the physical / structural changes that occur within the uterus and ovary over this time to allow students to visualise what effects occur, before moving on to the control by hormones, emphasising the feedback mechanisms that occur to enable the cycle to be controlled. As with many text books, sketching separate graphs, e.g. above and below the original and keeping the sex hormones oestrogen and progesterone separate from the pituitary hormones, luteinising hormone and follicle stimulating hormone, may help some students visualise the mechanism more clearly as the complete cycle is built up. Use verbal question and answer to get students to interact and interpret what is going on. Discuss the role of gonadotrophin releasing hormone GnRH	'menstrual cycle graphs' images search on Google (or similar) produces many different charts http://www.biologymad.com/master.html?http://www.biologymad.com/Hormones/Hormones.htm notes on hormones http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter28/animation__positive_and_negative_feedback__quiz_1_.html positive and negative feedback http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter28/animation__maturation_of_the_follicle_and_oocyte.html maturation of the follicle and oocyte animation http://en.wikipedia.org/wiki/Reproductive_rights reproductive rights – useful for discussion.
	(d) outline the biological basis of the effect of oestrogen/progesterone contraceptive pills;	If learning outcome (e) is dealt with last, then move on to (d), concentrating only on ensuring that discussions and set task enable students to understand the biological basis of the contraceptive pill.	http://hcd2.bupa.co.uk/fact_sheets/html/hormonal_contraception.html general information about hormonal contraception
	(e) discuss and evaluate the biological, social and ethical implications of the use of contraception;	For (e), students need to be guided to discuss different views and evaluate evidence when considering the implications of the use of contraception. Check that they know of the various different methods of contraception available worldwide before breaking up into small group discussions. Details of each type of contraception are not required. Review their understanding of *biological*, *social* and *ethical*, pointing out that sometimes an implication may impinge	http://health.howstuffworks.com/sexual-health/female-reproductive-system covers much of the material for these learning outcomes, includes a good animation (ignore comment on timing of menstruation)

on another, for e.g. slows down population growth (could be considered a biological implication) could have social implications.

Class activities

1. Following class discussion, individually or in pairs, summarise the menstrual cycle and control by hormones using annotated graphs (use different colours for each hormone) and diagrams, and making bullet point notes.
2. Discuss the changes to the graph(s) for shorter / longer cycles and for pregnancy, and change which might result in infertility.
3. Describe specific examples within the cycle of positive and negative feedback mechanisms.
4. To consolidate learning, complete unlabelled diagrams and graphs showing the events in the menstrual cycle.
5. Research how the combined oral contraceptive pill prevents pregnancy and compare this with the progestin-only pill.
6. Work in small groups. Each group choose one from biological, social or ethical implications of the use of contraception to research, discuss and evaluate. Each group should present their ideas for a class discussion before individuals produce a summary.
7. As extension work (and a review of IGCSE), survey the different methods of birth control and classify them into groups, considering the biological explanations for each type of birth control.

Governmental and other organisations have placed much information on websites; many of these have up-to-date information, e.g. http://www.mybirthcontrol.ca/index.asp?C=467294048478936342 59 explains the choices available for hormonal contraceptive control on a daily, weekly, monthly, quarterly or yearly/longer basis.

AS and A Level Biology (Chapter 24, pp.346-349) basic details given, with good diagrams. It would be useful to add the role of GnRH and discuss feedback mechanisms. There is a useful SAQ about oral contraceptives that will help student understanding.

Bio Factsheet 57: *Oestrous cycles*

AO	Learning outcomes	Suggested Teaching activities	Learning resources
U	(f) outline the technique of in-vitro fertilisation (IVF) and discuss its ethical implications;	There are many variations of the IVF procedure but students are only required to provide an outline of the techniques, such as is described in ***AS and A Level Biology*** and understand the main principles involved so that they can apply this to new situations. In discussing the ethical implications, students need reminding that ethical implications need to be specific to IVF and general statements such as “it’s not natural” would have to be qualified. **Class activities** 1. Produce an annotated flow chart summarising the technique of IVF. 2. Participate in small group or class discussion and produce a bullet point summary of the ethical implications of IVF. 3. As extension work, carry out a brief survey of causes of infertility and of other treatments, such as artificial insemination.	http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/S/Sexual_Reproduction.html#ART very useful for IVF and other methods of assisted reproductive technology http://en.wikipedia.org/wiki/In_vitro_fertilization includes some good images ***AS and A Level Biology*** (Chapter 24, pp.349-352) discusses causes of infertility, IVF (described at an appropriate level) and other methods of assisted reproductive technology. ***Bio Factsheet 105:*** *Manipulation and control of reproduction* ***Bio Factsheet 195:*** *Biology of Infertility*