UNIT 3 Enzymes and Genetic Control

Timing This unit comprises approximately 20% of the learning material in AS Biology, and about 10% of the learning material in a complete Biology A Level learning programme.

Recommended Prior Knowledge Students will need to have studied Units 1 and 2 before beginning this Unit

Context An understanding of enzyme function will be required in order to understand how DNA controls cell function. DNA and protein synthesis will be revisited if students continue to A2 level.

Outline This Unit builds on knowledge of protein structure from Unit 2, in describing and explaining enzyme activity. There are many opportunities for practical work, and this provides an excellent opportunity for students to develop their practical skills, including their ability to plan and evaluate investigations. DNA and protein synthesis leads on from work in Unit 2 on molecules. There are good opportunities within this Unit for students to develop their practical skills relating to Assessment Objectives in Group C (Experimental skills and investigations) including the design and evaluation of their own investigations. Try to ensure that each student works alone and under time pressure on some occasions, as this will help to prepare for the practical examination(s).
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Reinforcement and formative assessment It is recommended that, towards the end of the time allocated to the unit, time be taken to permit reinforcement of the learning that has occurred. This might take the form of structured revision and questions, perhaps making use of online question banks such as http://www.learncie.org.uk/ or http://exam.net/public/misc/pub_home.asp .

Formative assessment could take the form of student self-marked minitests, taking just 10 or 15 minutes for students to do and then mark for themselves, perhaps using questions from the banks above – discussing the correct answers as a whole class. At the end of the unit, there should be a much larger formative assessment test, using appropriate past-examination and similar style questions, taking a lesson to do, and a lesson to provide feedback after marking by the teacher.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
C(a) (b)	explain that enzymes are globular proteins that catalyse metabolic reactions; explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex, lowering of activation energy and enzyme specificity **Learning activities** – use paper cut out models, simulations, and whole class discussion to develop understanding of mode of action of enzymes, and the importance of complementary shape and fit – give a brief written description and annotated 'boulder analogy' graph to make the point that although the energy content of substrate and products is not changed, the reaction pathway follows a lower energy course	Use questioning to check students' knowledge of enzymes; it is likely that some will associate them only with digestion, and it is important to correct this mistake at an early stage. Revise the meaning of the term 'catalyst'. Ensure that students understand that there are many types of catalyst other than enzymes. Students will have already covered protein structure in Unit 2, so it should be a relatively small step forward to explain enzyme structure, including the active site. Emphasise the crucial role of the R groups of amino acids at this site in binding with the substrate.	http://www.bbc.co.uk/education/asguru/biology/02biologicalmolecules/01proteins/11enzymes/index.shtml Descriptions and explanations of how enzymes work, including a simple animation	All AS and A level texts cover this topic thoroughly.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
C(c)	follow the course of an enzyme-catalysed reaction by measuring rates of formation of products or rates of disappearance of substrate **Learning activities** – use yeast suspension as a source of catalyse, and measure the rate of release of oxygen (product) from hydrogen peroxide – most easily by collecting over water. – Use amylase (or diastase) to break down starch, finding the time taken to remove all the starch – discuss as a whole class, and then make a brief written explanation, in terms of initial rate of reaction, why measuring the rate of formation of products is a more reliable measure of rate of enzyme reaction that rate of disappearance of substrate	This practical work should illustrate the change in the rate of product formation, or substrate disappearance, as an enzyme-catalysed reaction runs its course. Students who have studied chemistry will almost certainly be familiar with the way in which other reactions, such as the production of carbon dioxide by the action of hydrochloric acid on marble chips, proceed and this will help them here. Catalase is a good enzyme for this investigation, as the product (oxygen) of the reaction can be collected over water and its volume measured at regular time intervals. There are several possible methods of measuring the rate of oxygen production, for example measuring the rate of loss of mass in the reaction vessel (stand it on the pan of an electronic balance) or using a gas syringe or manometer to measure the change in volume of oxygen with time. Students should be able to explain the initial steep release of product, which then flattens out, in terms of the behaviour of the enzyme and substrate. Students may also follow the disappearance of starch. If, so they need reminding that they are using iodine solution to show the loss of starch from	http://www.seps.org/cvoracle/faq/catalase.html useful background information http://www.science-projects.com/catalasekinetics.htm source of potential methods and analyses http://www.enzymes.co.uk/questions1.htm interesting questions and explanatory material	Apparatus that could be adapted for this investigation is shown in *Practical Advanced Biology*, King et al. *Comprehensive Practical Biology*, Siddiqui has several protocols that could be used here. *Advanced Biology principles and applications. Study Guide* Clegg and Mackean also has a number of suitable protocols to follow. The theory behind it is explained in *Biology*, Jones, Fosbery, Taylor and Gregory.

		the reaction mixture. Samples have to be taken at regular intervals and tested with iodine solution. It is more difficult to produce quantitative results using this method, but it can be done using a colorimeter.		

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
C(d)	investigate and explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzyme-catalysed reactions, and explain these effects **Learning activities** – Planning and carrying out an investigation into the effect of temperature on rate of an enzyme catalysed reaction (with control of other variables) e.g. the yeast catalase experiment introduced in C(c) – Carrying out an investigation into the effect of pH on rate of an enzyme catalysed reaction (with control of other variables) e.g. protease (trypsin) digesting protein in exposed film – Contribute to question and answer / whole class discussion followed by written explanation and drawing of annotated graphs showing the key impact of; o rate of collisions (e.g. at low temperatures, in relation to concentration of enzyme and substrate (at low substrate	Before beginning this work, it is worth explaining that what should ideally be measured is the **initial** rate of enzyme activity. Measuring time taken for complete removal of substrate can sometimes lead to confusion, and is completely unsuitable if you are trying to measure the effect of substrate concentration (it gives seemingly 'contradictory' results, because with more substrate it actually takes longer for it all to disappear, even though the rate of reaction is faster!). This is a good opportunity to improve students' skills of planning an investigation in which several variables need to be controlled. You could perhaps discuss with the whole group the design of one experiment which is then carried out by the whole class, and later allow groups, pairs or individuals to plan and carry out their own investigations. Students often confuse the experiment where they follow the course of an enzyme-catalysed reaction with the effect of increasing substrate concentration on the rate of a reaction. This is probably because the curves are the same shape.	http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/menu.html Introduction to pdf downloads. Some downloadable booklets with a wide range of enzyme-based practical activities. For example, http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/juice.html links to several downloads for several fruit juice based practicals. http://www-saps.plantsci.cam.ac.uk/worksheets/ssheets/ssheet14.htm An interesting experiment using phosphatase, as well as ideas for students to design their own investigations. http://www.biology4all.com/resources_library/1.asp A protocol for an investigation using immobilised invertase	*Practical Advanced Biology*, King et al, has protocols, background information and questions covering several enzyme practicals, as well as numerous ideas for individual planning. *Comprehensive Practical Biology*, Siddiqui, also has protocols for these investigations as does *Advanced Biology principles and applications. Study Guide* Clegg and Mackean *Biofactsheet 43: Factors affecting enzyme activity*

		concentrations o hydrogen bonding, tertiary structure, shape of active site and complementary fit of substrate (e.g. at high temperatures and in relation to pH		The examplar practical lesson on the CIE Teacher Support website at http://teachers.cie.org.uk	

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
C(e)	explain the effects of competitive and non-competitive inhibitors on the rate of enzyme activity **Learning activities** – investigate the effect of a non-competitive inhibitor (solutions of lead nitrate, copper sulphate or silver nitrate) on an enzyme-catalysed reaction (e.g. protease (trypsin) on exposed film or fruit oxidase enzymes and browning of fruit) – be involved in a question and answer / whole class discussion, leading to individual written explanations of the effect of competitive inhibitors (act at active site, reversible, overcome by high substrate concentrations, occupation of active site by inhibitor reduces collisions) and non-competitive inhibitors (act away from active site, may be reversible or irreversible, reduce maximum rate irrespective of substrate concentration, change the shape of the whole enzyme molecule including the active site so the substrate no longer fits)	Only an outline is required here. It is best to restrict discussion to reversible inhibitors that act either at the active site (competitive) or elsewhere (non-competitive). If the students carry out an investigation with an irreversible inhibitor then they should be made aware of this type of inhibition.	http://www-saps.plantsci.cam.ac.uk/worksheets/activ/prac2.htm A protocol for an interesting investigation into a non-competitive inhibitor (banana catechol oxidase and lead) To show that an inhibitor is competitive is difficult because students need to make up separate reaction mixtures with different concentrations of the substrate.	

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
F(a)	describe the structure of RNA and DNA and explain the importance of base pairing and hydrogen bonding **Learning activities** – label pre-existing diagrams of DNA to show nucleotides, phosphate, deoxyribose, sugar-phosphate backbone, adenine, thymine, cytosine, guanine, hydrogen bonds, base pairing between A and T, and between C and G – take a diagram of single strand of DNA and add to it appropriate drawings of nucleotides to create a second strand – question and answer / whole class discussion on the relative strength of the bonds that hold the sugar-phosphate backbone together compared to those that hold together the two strands of DNA – make a summary table of the similarities and differences between DNA and RNA – make a summary table of correctly matched pairs of pieces of information (e.g. thymine = base only found in DNA, thiamine = vitamin; adenine =	You may like to begin this topic with a discussion about exactly what DNA does, before embarking on its structure. Ask students to recall what they know of protein structure, and then explain that DNA encodes instructions for the sequence in which amino acids are linked together. Then consider the requirements for such a molecule - how the information might be carried, the need for stability, and the need to be able to replicate so that the information can be passed on to daughter cells. The history of the discovery and understanding of DNA makes fascinating reading. You might like to ask students to research this. Take care that during your teaching you do not accidentally cause confusion (e.g. between thymine and thiamine, or between adenine and adenosine - these are very common errors, or between nucleotides and amino acids – for example by stating that DNA is composed of amino acids – a very common wrong answer in examinations). It is a good idea **not** to tell students directly that they will find these things confusing. It is far better to give them access to the information	http://www.dnaftb.org This deals with many aspects of DNA and genetics. Within the section *Molecules of Genetics* are sections relevant to this Unit. http://www.bbc.co.uk/education/asguru/biology/04genesgenetics/index.shtml Clear descriptions of DNA and RNA structure, with animations. http://accessexcellence.org/AB/GG/ Images of RNA and DNA structure. http://gslc.genetics.utah.edu/units/activities/wheatgerm A simple protocol for extracting DNA.	All AS and A level text books cover these topics very thoroughly.

	base found in DNA and RNA, adenosine = the A in ATP; nucleotide = monomer / building block of DNA and RNA, amino acid = monomer / building block of protein)	correctly (e.g. from books), and ask them to write out correct meanings / matches		

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
F(b)	explain how DNA replicates semi-conservatively during interphase **Learning activities** – use computer simulations and whole class discussion / question and answer to build understanding of DNA replication – use photocopies / jigsaw puzzles of DNA diagrams and matching nucleotides to simulate DNA replication	If you have already covered mitosis, then you could begin this topic by reminding students of the necessity for chromosomes to divide before mitosis occurs. Try to ensure that they make connections between mitosis, chromosomes and DNA: each chromosome contains a DNA molecule. DNA replication results in two identical DNA molecules, one in each identical chromatid. Animations can be very helpful in aiding understanding of DNA replication. Students should understand the meaning of the term 'semi-conservative'. There is no need to go into details of any other possible methods of replication, nor of experiments such as those of Meselsohn and Stahl - though these could form the basis of interesting questions to test students' understanding.	http://www.bbc.co.uk/education/asguru/biology/04genesgenetics/02replicationmitosis/index.shtml Explanation and animations of DNA replication. http://www.accessexcellence.org/AB/GG/dna_replicating.html Diagram and notes on semi-conservative replication	All AS and A level text books cover these topics very thoroughly.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
F(c) (d) (f)	state that a gene is a sequence of nucleotides as part of a DNA molecule, which codes for a polypeptide; describe the way in which the nucleotide sequence codes for the amino acid sequence in a polypeptide; explain that, as enzymes are proteins, their synthesis is controlled by DNA **Learning activities** – whole class discussion / question and answer to build understanding of the triplet code – use a DNA dictionary to work out, from specific nucleotide base sequences, specific amino acid sequences, including normal and sickle-cell haemoglobin – make a flow diagram, linear sequential notes or annotated diagram showing that: DNA codes for the amino acid sequence in protein, which is the primary structure; primary structure determines where the protein chain spirals and folds (secondary and tertiary structure); secondary and tertiary structure determines the shape;	It is a good idea to give students an overview of the way in which DNA codes for protein structure, before going into the details of how this process occurs. The important point to get over here is that the sequence of nucleotides in part of a DNA molecule codes for the sequence of amino acids in a protein. You can also get them to think back to what they know about protein structure and function, and remind them how the function of a protein - including enzymes - depends on the sequence of amino acids within it. An error that frequently appears in answers to examination questions on this topic is confusion between nucleotides and amino acids. It is very important to reinforce the correct relationship between nucleotides and DNA / RNA, and between amino acids and protein. A learning methodology called 'error-free learning' shows that when students 'guess' or are given *incorrect* matches, it is the *incorrect* matches that they learn, so they must *never* be given incorrect matches as a learning tool (see also F(a)).	http://www.bbc.co.uk/education/asguru/biology/04genesgenetics/index.shtml has information about the nature of the genetic code http://www.kumc.edu/gec/ has links to lots of sites that have information about the human genome project, genetic code and many other related topics	All AS and A level text books cover these topics very thoroughly.

	and shape (e.g. of active site, specific channel or receptor site) determines the function			

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
F(e)	describe how the information on DNA is used to construct polypeptides, including the role of messenger RNA, transfer RNA and the ribosomes **Learning activities** – whole class discussion / oral question and answer, animations and reinforcement written questions to build understanding of the genetic code, the role of mRNA and transcription – revisit the DNA sequences met in F(c),(d)&(f), plus decode new DNA sequences, with only a mRNA codon dictionary, transcribing from DNA to mRNA, and then working out from the dictionary, the sequence of amino acids – whole class discussion / oral question and answer, animations and reinforcement written questions to build understanding of translation and the role of tRNA and ribosomes. – Use the DNA sequence for the first 6 amino acids in drawing a comprehensive whole page annotated diagram to show transcription and translation – the	It is very important to ensure that students understand the overall sequence of events here, before they get bogged down in the details of transcription and translation. Ensure that they understand the role of mRNA in carrying a copy of the information from DNA to the ribosome, and the role of tRNA in translating this information into the sequence of amino acids that are strung together. Incidentally, trans**C**ription comes before trans**L**ation alphabetically as well as in protein synthesis. Animations can be very helpful in describing how translation and transcription take place.	http://www.bbc.co.uk/education/asguru/biology/04genesgenetics/index.shtml good information on this topic, with excellent interactive animations aimed at AS level students http://www.pbs.org/wgbh/aso/tryit/dna/ the DNA workshop activity on protein synthesis places the student inside the cell. There are also links to other sites on, for example, Crick, Franklin and some relevant applied research.	*Biofactsheet 22: Protein synthesis I – nucleic acids* *Biofactsheet 49: Protein synthesis II – mechanisms* All AS and A level text books cover these topics very thoroughly.

	outlines of cell, nucleus and ribosome (not to scale) can be provided by the teacher			