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## GCE A LEVEL – BIOLOGY UNIT 4 QUESTION PACK

1075 (Legacy BY5) · New spec Unit 4 Topic 6 · A2 unit, first sat 2017, 90 marks, 2h paper

# REVISE

.wales

## BIOLOGY – UNIT 4 · DNA REPLICATION & PROTEIN SYNTHESIS

### 4.4 Variation and evolution – DNA replication (Meselson–Stahl) and protein synthesis (transcription, translation)

*Semi-conservative DNA replication as demonstrated by Meselson and Stahl using  $^{15}\text{N}$  /  $^{14}\text{N}$ , transcription of mRNA from a DNA template, translation at the ribosome with tRNA / codon-anticodon pairing, and how point mutations in coding regions alter the polypeptide product (with applied examples including RNA-virus transcription).*

#### LEGACY 2008 SPECIFICATION

#### Estimated time for entire question pack: ~1 h 36 min

*Derived from the legacy BY5 papers' pace of ~1.6 min/mark, padded for long-prose answers (60 marks over 5 questions).*

*You are advised to **not** attempt to complete all of this in one sitting.*

#### ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC BY5 papers (2008 modular spec, 2011–2017) that maps onto new-spec A2 Unit 4 Topic 6 (4.4). Questions are ordered by source paper date.

#### INSTRUCTIONS

Use black ink or black ball-point pen. Show all working – quality of written communication will affect marks. A calculator is allowed. Diagrams included in answers must be fully annotated.

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Q	Source	Max	Mark	Q	Source	Max	Mark
1	BY5 Jun 11 Q5	10		4	BY5 Jun 14 Q2	6	
2	BY5 Jun 11 Q6	12		5	BY5 Jun 16 Q4	21	
3	BY5 Jun 12 Q6	11					
						<b>Total</b>	<b>60</b>

# DNA Replication & Protein Synthesis – what the new spec asks

WJEC GCE A Level Biology (from 2015) · Unit 4: Variation, Inheritance & Options · Topic 4.4.

## Meselson–Stahl

- *E. coli* grown in  $^{15}\text{N}$  then transferred to  $^{14}\text{N}$ .
- After 1 generation: single intermediate-density band.
- After 2 generations: equal light and intermediate bands  $\Rightarrow$  semi-conservative.

## DNA replication

- Helicase unwinds; single-strand binding proteins stabilise.
- DNA polymerase III extends  $5' \rightarrow 3'$  using free dNTPs.
- Leading strand continuous; lagging strand in Okazaki fragments + ligase.

## Transcription

- RNA polymerase binds the promoter, separates strands.
- Reads template  $3' \rightarrow 5'$ ; synthesises mRNA  $5' \rightarrow 3'$ .
- Introns spliced; cap and polyA tail added in eukaryotes.

## Translation

- mRNA threads through ribosome small subunit.
- tRNA anticodon pairs with mRNA codon; amino acid added to chain.
- Stop codon  $\rightarrow$  release factor; polypeptide released and folded.

## Genetic code

- Triplet code (64 codons), degenerate (multiple codons per AA).
- Universal across nearly all organisms.
- AUG = start (methionine); UAA, UAG, UGA = stop.

## Mutations & protein effect

- Missense  $\rightarrow$  one AA changed; folding / activity may be altered.
- Nonsense  $\rightarrow$  premature stop; truncated non-functional protein.
- Frameshift  $\rightarrow$  entirely new downstream AA sequence.

# DNA Replication & Protein Synthesis in one page

Quick-reference notes – revisit before each question.

## Meselson–Stahl

*E. coli* in  $^{15}\text{N}$  then  $^{14}\text{N}$ .

Density gradient ultracentrifugation.

1 gen: intermediate band; 2 gen: 1:1

light + intermediate  $\Rightarrow$  semi-conservative.

## Replication mechanics

Helicase unwinds.

DNA polymerase III,  $5' \rightarrow 3'$ .

Leading continuous; lagging in Okazaki fragments + ligase.

## Transcription

RNA polymerase opens DNA at promoter.

Reads template  $3' \rightarrow 5'$ .

mRNA cap + tail (eukaryotic); introns spliced out.

## Translation

mRNA threads ribosome small subunit.

tRNA anticodon pairs codon – peptide bond forms in P/A sites.

Stop codon  $\rightarrow$  release factor  $\rightarrow$  polypeptide free.

## Genetic code

Triplet; 64 codons; degenerate.

Start AUG (Met); stops UAA, UAG, UGA.

Near-universal.

## Mutation effects

Silent: same AA.

Missense: different AA.

Nonsense: stop codon  $\rightarrow$  truncated.

Frameshift: downstream reading frame wrong.

## RNA viruses

Some viruses (Ebola) have RNA genomes.

Use RNA-dependent RNA polymerase.

Mutation rate high  $\Rightarrow$  rapid evolution.

## Why semi-conservative

Each daughter DNA = 1 parental + 1 new strand.

Preserves sequence fidelity.

5. Meselson and Stahl investigated whether DNA replicated in a conservative or semiconservative way.

(a) What is meant by the term semiconservative replication? [2]

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(b) The bacterium *Escherichia coli* (E.coli) was cultured in a nutrient broth, containing the heavy isotope as a source of nitrogen  $^{15}\text{N}$  instead of the normal  $^{14}\text{N}$ . After several generations all of the DNA in all of the bacteria contained the heavy isotope  $^{15}\text{N}$ . They were then washed and transferred to a  $^{14}\text{N}$  medium and allowed to replicate. After each generation, bacteria were removed and ruptured to release the DNA. The DNA was then placed in a medium and spun in a centrifuge. The position of the DNA in the medium was then determined.

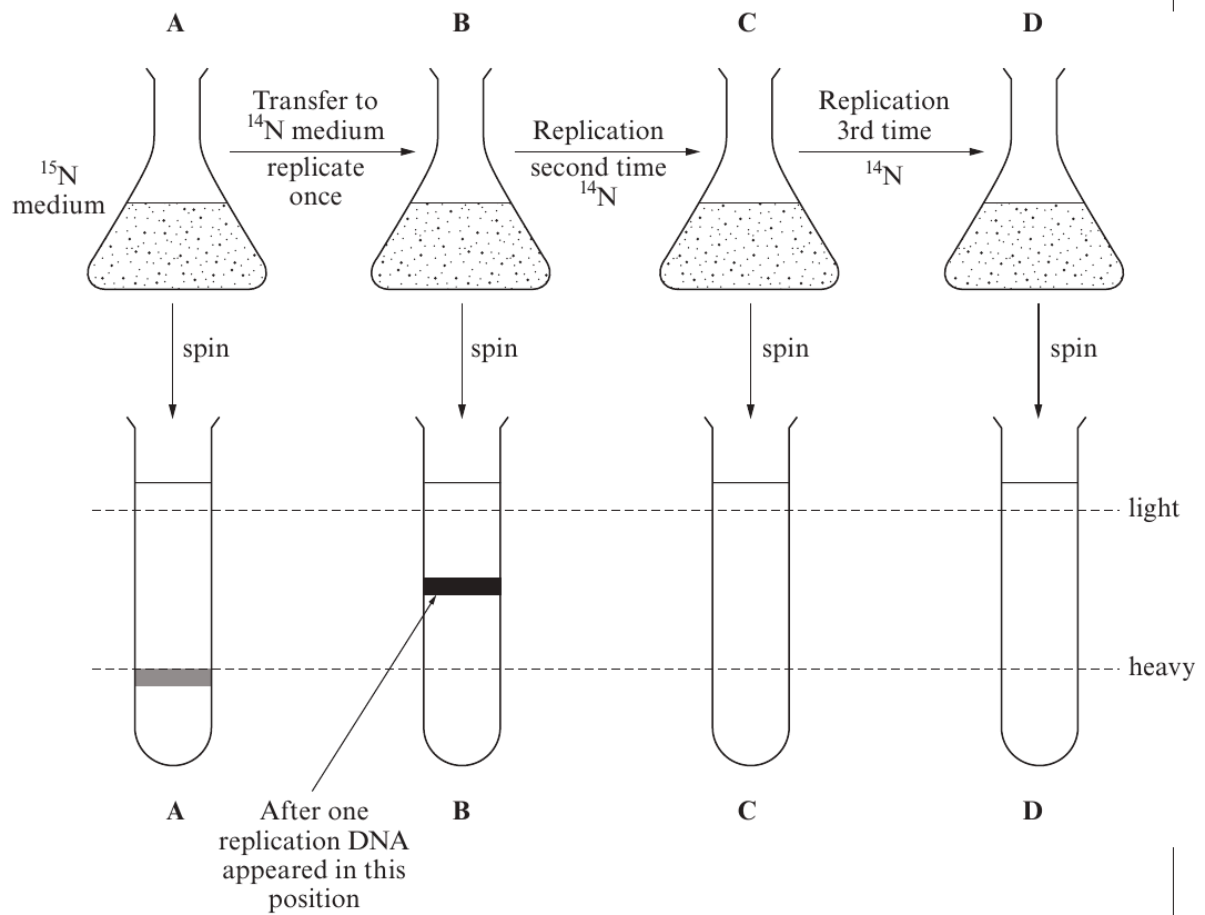
(i) Name the part of the DNA molecule which contained the  $^{15}\text{N}$ . [1]

.....

(ii) If they wanted to show the relative position of DNA from different samples of bacteria, suggest **two** variables which would need to be controlled in the centrifugation process. [2]

1. ....
2. ....

(c) The diagram represents the results which they obtained.



(i) Explain why the results in tubes **A** and **B** support semiconservative replication. [3]

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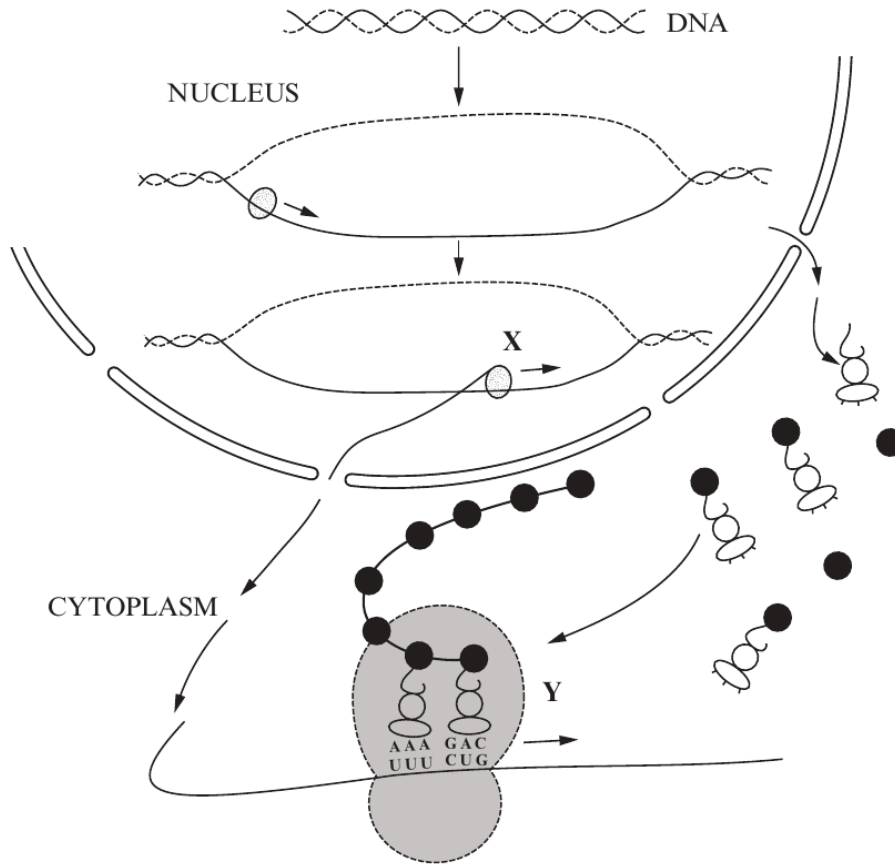
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(ii) Complete diagrams **C** and **D** to show the pattern and relative proportions of DNA you would expect. [2]

(Total 10 marks)

6. The diagram represents stages of protein synthesis.



(a) (i) Give the name of the processes taking place at X and Y. [2]

X .....

Y .....

(ii) On the diagram label the following structures using clear lines and the letters given. [8]

- M = messenger RNA
- N = nuclear pore
- O = RNA polymerase
- P = codon
- Q = ribosome
- R = transfer RNA
- S = three hydrogen bonds between complementary bases
- T = template/sense strand of DNA

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- (b) Transfer RNA (tRNA) molecules are very specific and will only carry one type of amino acid depending on three unpaired nitrogenous bases on the molecule (the anticodon). The table shows the type of tRNA molecules which combine with certain amino acids.

<i>Amino acid</i>	<i>anticodon</i>
glycine	CCU
cysteine	ACA
arginine	GCA
alanine	CGU

Using the information given, state the nucleotide sequence on the **DNA molecule** which codes for the following polypeptide. [2]

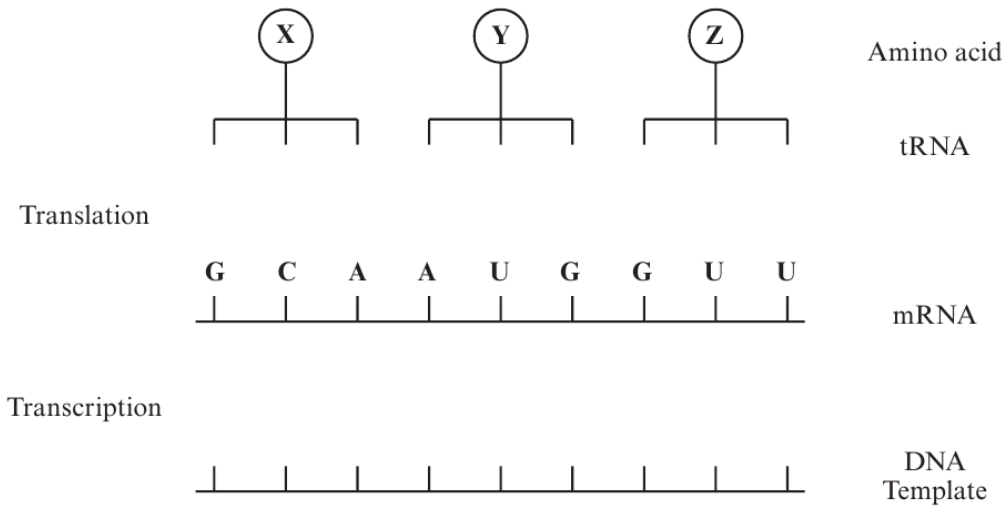
glycine-cysteine-arginine-alanine.

.....

**(Total 12 marks)**

6. (a) Name the enzyme involved in the transcription stage of protein synthesis. [1]

(b) The diagram shows some molecules involved in protein synthesis.

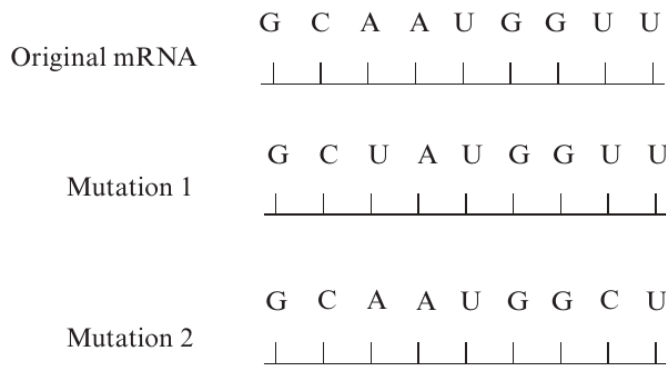


Complete the diagram to show

- (i) the bases on the template DNA strand from which the mRNA was transcribed; [1]
- (ii) the bases forming the anticodons of the tRNA molecules. [1]



- (c) The diagram below shows the effects of two different mutations of the DNA on the base sequence of the mRNA.  
The table shows the mRNA codons for three amino acids.



Amino acid	mRNA codon
methionine	AUG
valine	GUC GUU
alanine	GCA GCC GCU

Use the information in the table to

- (i) Identify amino acid X in the diagram in part(b). [1]

- (ii) Explain how each mutation may affect the polypeptide for which this section of DNA is part of the code.

Mutation 1 [2]

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Mutation 2 [2]

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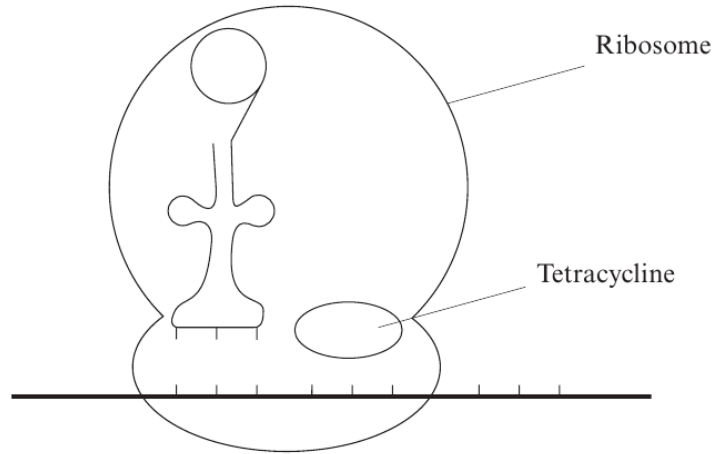
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- (d) Tetracycline is an antibiotic. The diagram below shows how tetracycline binds to bacterial ribosomes.



Explain how the tetracycline stops protein synthesis in bacteria.

[3]

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(Total 11 marks)

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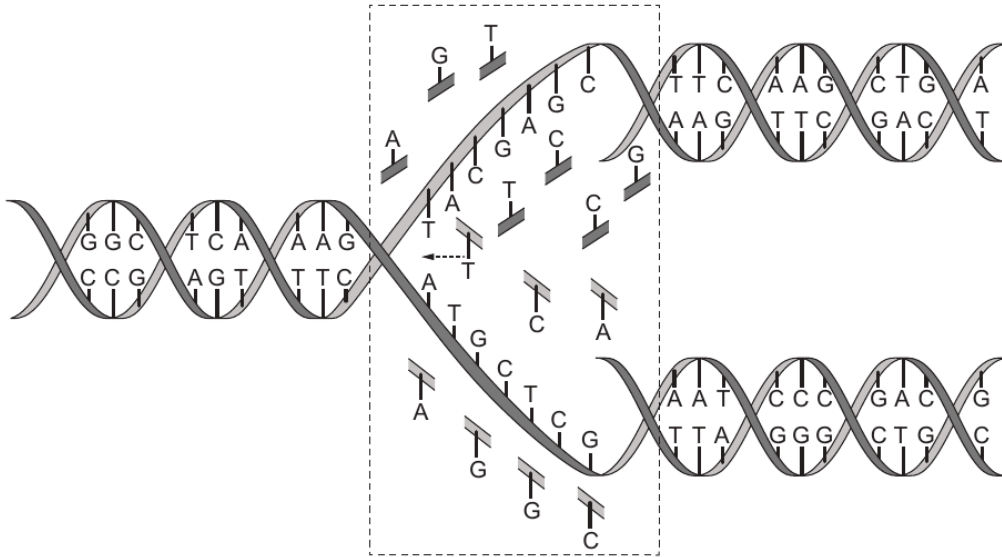
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2. The diagram below illustrates replication of DNA in cells.

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(a) (i) Describe the sequence of events shown within the dotted rectangle in the diagram above. [3]

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(ii) What is the role of DNA polymerase in the process? [1]

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(b) Explain why the process is referred to as 'semi conservative'.

[2]

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- (b) When Ebola viruses enter human cells one of their genes controls the production of a glycoprotein that is immediately released.

The gene which codes for this glycoprotein is changed after infecting cells. An extra adenine is inserted at position 1016.

The changed gene then controls the production of the second glycoprotein which forms part of the viral capsule.

Diagrams of the changed and original base sequences for the glycoproteins are shown below.

**Changed base sequence**

Nucleotide position number	1010	1015	1020	1025	
Changed nucleotide sequence	CUU	GUU	AUA	AAA	AAA AUA C
Changed amino acid sequence	Leu	Val			

**Original base sequence**

Nucleotide position number	1010	1015	1020	1025	
Original nucleotide sequence	CUU	GUU			
Original amino acid sequence	Leu	Val			

- (i) Use the table below to complete the **changed amino acid sequence in the diagram** above. [1]

		Second				
		U	C	A	G	
U		Phe	Ser	Tyr	Cys	U
		Phe	Ser	Tyr	Cys	C
		Leu	Ser	STOP	STOP	A
		Leu	Ser	STOP	Trp	G
C		Leu	Pro	His	Arg	U
		Leu	Pro	His	Arg	C
		Leu	Pro	Gln	Arg	A
		Leu	Pro	Gln	Arg	G
A		Ile	Thr	Asn	Ser	U
		Ile	Thr	Asn	Ser	C
		Ile	Thr	Lys	Arg	A
		Met	Thr	Lys	Arg	G
G		Val	Ala	Asp	Gly	U
		Val	Ala	Asp	Gly	C
		Val	Ala	Glu	Gly	A
		Val	Ala	Glu	Gly	G

- (ii) Complete the **original nucleotide sequence** in the diagram. [1]
- (iii) Use the table again to complete the **original amino acid sequence**. [1]

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(iv) Explain why the original glycoprotein is smaller than the changed glycoprotein. [2]

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.....

(c) On contact with the plasma membrane of human epithelial cells the capsule glycoprotein molecules form transmembrane proteins, which assist the virus in gaining entry to the cells.

Draw a labelled diagram of a typical cell membrane including a transmembrane protein. [2]

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(d) The Ebola virus capsid glycoprotein has been purified and injected into mice which then produce antibodies against the protein. The genes for these antibodies have been cut from mouse DNA and inserted into Tobacco Mosaic Virus (TMV) genes. By allowing these viruses to infect tobacco plants, genetically modified tobacco plants can be grown which produce antibodies against Ebola.

(i) Name the enzyme that would be used to cut the antibody producing gene from the mouse DNA. [1]

.....

(ii) Name the vector used to transfer the mouse gene. [1]

.....

(iii) Name the enzyme that would be used to insert the mouse gene into the vector. [1]

.....

(iv) Bacteria could be used instead of tobacco plants to produce the antibodies. What vector would be used in this case? [1]

.....

(v) Give **one** advantage of using bacteria instead of tobacco plants. [1]

.....

(e) The technology described in part (d) was used during the Ebola outbreak of 2014 to develop a drug called ZMapp. The drug was only used to treat two Americans who had been working as medics in Africa. Its use was controversial because the drug had not been tested on humans. At the time there were only a few doses of ZMapp available.

(i) Suggest a reason why the decision to use the drug was taken, even though it had not been tested. [1]

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(ii) Apart from the fact that drug had not been fully tested, give **one** reason why using the drug in the way described could be considered unethical. [1]

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## **END OF QUESTION PACK**

5 questions · 60 marks · ~1 h 36 min

Source: WJEC BY5 (2008 modular spec, 2011–2017)

Curated for WJEC Biology 2015 spec A2 Unit 4 – Topic 6 (4.4)

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