WJEC EDUQAS A-LEVEL BIOLOGY · COMPONENT 2

BIOLOGY



EXAM QUESTION PACK

2.7 APPLICATION OF REPRODUCTION AND GENETICS

SCORE	PERCENTAGE
/53	%

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1. In April 2003 one of the most significant scientific breakthroughs of modern times was announced. After years of painstaking research carried out by thousands of dedicated scientists across the world, the complete genetic code of a human being – their genome – could now be made freely available on-line.

The Human Genome Project, as this work was known, was the largest international collaboration ever undertaken in biology with British scientists leading the global race to read the human genome using a technique called sequencing.

To bring the predicted benefits of genomics to NHS patients the 100 000 Genomes Project was launched in late 2012 and by 2017 had sequenced the genomes of 100 000 NHS patients. The project focussed on patients with a rare disease and their families, and on patients with cancer.

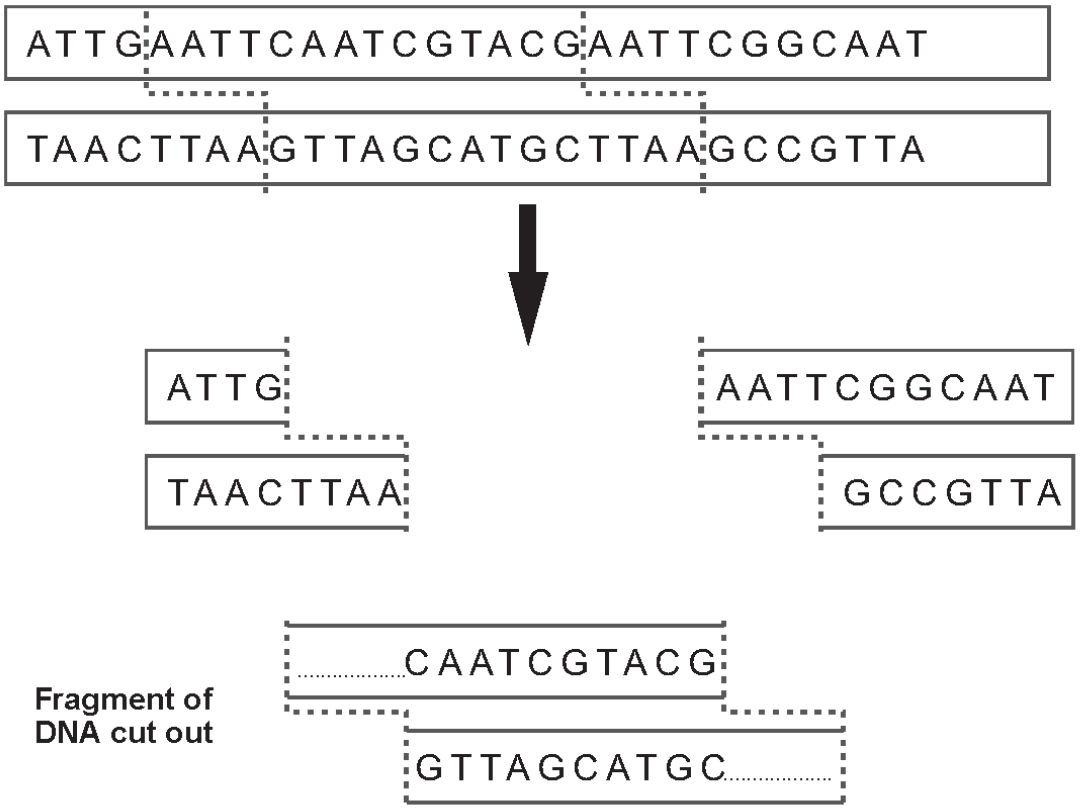
Scenario:

> It is 2025 and Sharon has a painful skin infection that she just can't get rid of. Her doctor would like to prescribe an antibiotic called phenyloxacillin, since it is especially effective against the bacteria *(Staphylococcus aureus)* that are causing the infection. However, her doctor knows that in a small number of cases phenyloxacillin can cause serious liver damage so suggests a genome test. She tells Sharon that there is a law giving people the right not to disclose the results of genetic tests to insurers.

Explain what is meant by 'sequencing' the human genome and describe the type of data that might be made available on-line.
Explain how the extra information provided by the '100 000 Genomes Project' might be used in medicine, and describe how the scenario above illustrates one possible beneficial application and an ethical dilemma of genome sequencing. [9 QER]

2.

(a) Restriction enzymes are essential tools of genetic engineering. A restriction enzyme cuts the double-stranded DNA molecule at its specific **recognition site**. The diagram below shows how one such enzyme would cut out a DNA fragment.



(i) Draw in the bases which are missing from the ends of the fragment of DNA which has been cut out. [1]

(ii) Explain why the parts completed in (i) are known as 'sticky ends'. [1]

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(iii) A number of different restriction enzymes are now available, some of which are shown in the table below:

Enzyme	Source	Recognition site
***Eco*RI**	*Escherichia coli* RY 13	GAATTC
***Bam*HI**	*Bacillus amyloliquefaciens* H	GGATCC
***Hind*III**	*Haemophilus influenzae* Rd	AAGCTT

Name the enzyme used in the example above. [1]

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(b) In recombinant DNA technology, the piece of DNA which has been cut out is inserted into a plasmid which has been cut open using the same enzyme.

(i) Define the term 'plasmid'. [1]

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(ii) Why is it important to use the same enzyme? [1]

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(iii) Name the type of enzyme used to join the cut fragment into the plasmid. [1]

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(c) Restriction enzymes are also used to cut up DNA during DNA fingerprinting/profiling. Labelled DNA probes are then used to identify the positions of the fragments on an electrophoresis gel. The fragments used are sections cut from introns rather than exons.

Explain why introns are more useful for genetic fingerprinting than exons. [2]

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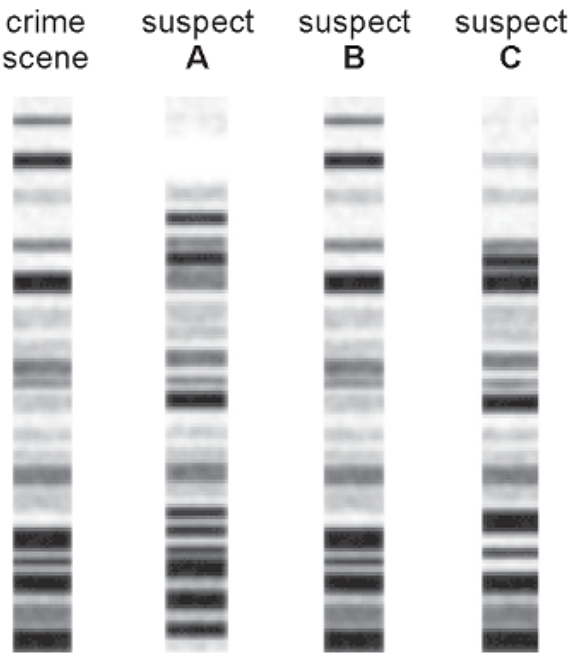
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(d) DNA profiles of a sample of DNA taken from a crime scene and samples prepared from blood of three suspects are shown below.

DNA samples from:



Give **two** features of the DNA profiles which would lead to the identification of suspect **B** as being present at the scene of the crime. [1]

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(e) (i) DNA at crime scenes is often found in very small quantities. Polymerase Chain Reaction (PCR) is a technique that enables the analysis of these small samples of DNA. State how PCR makes this possible. [1]

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(ii) The enzyme used in the technique has an important function during interphase in both mitosis and meiosis.

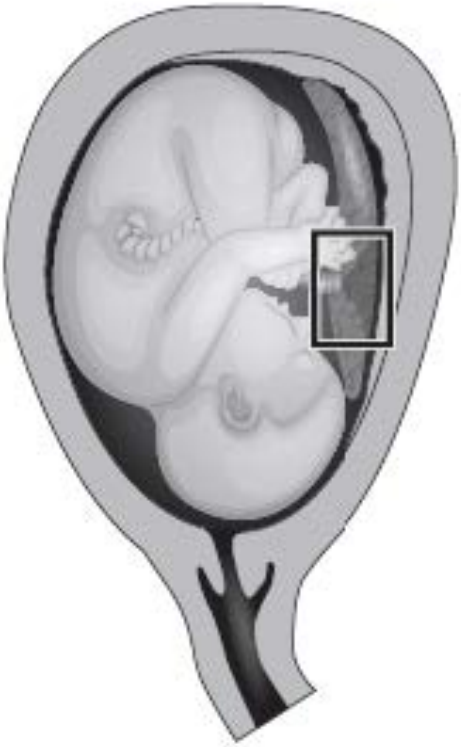
Name: [2]

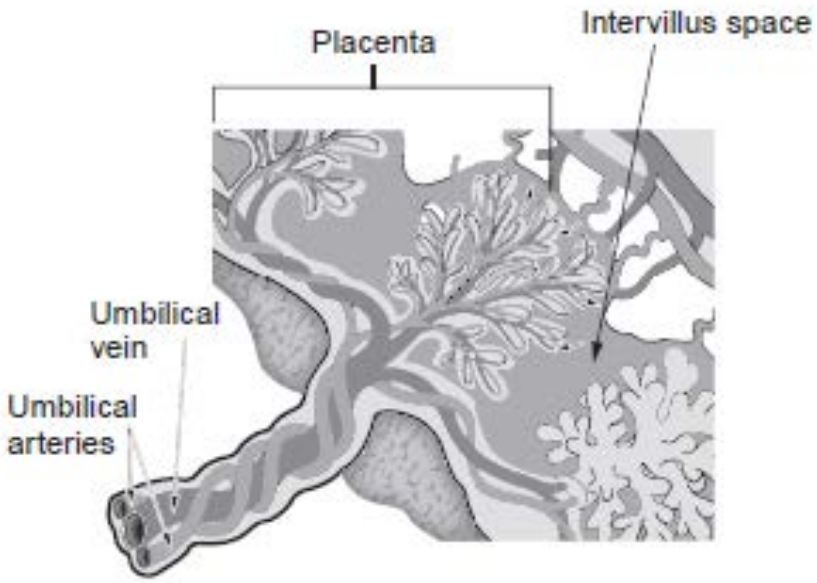
I. the enzyme used; .....

II. the enzyme's function in interphase. .....

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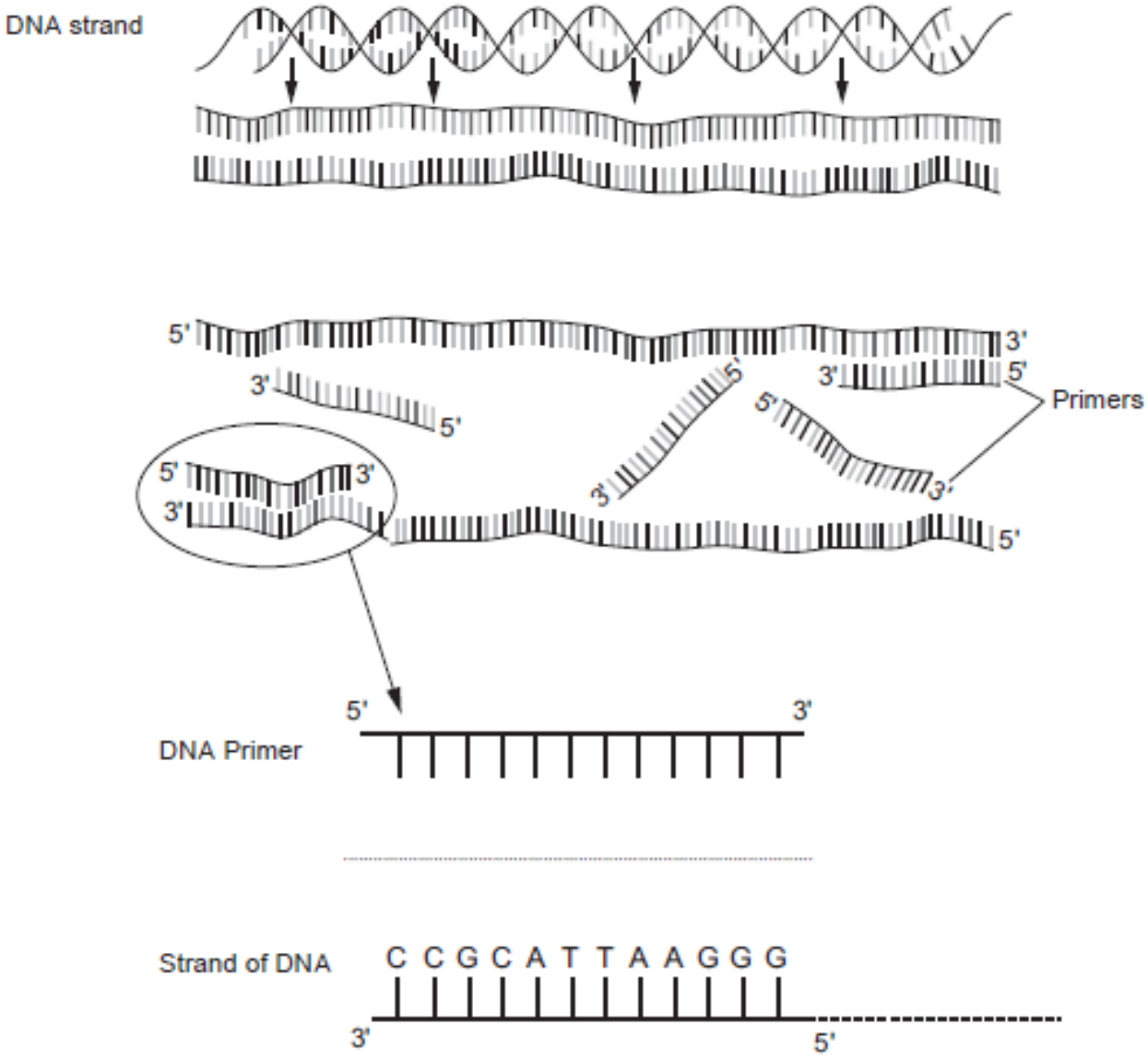
3. The diagram below shows the structure of a human placenta.





(a) During pregnancy, foetal cells die and release many different fragments of DNA into the mother's blood. A blood sample can be taken from the mother and foetal DNA fragments isolated and replicated (amplified) using the polymerase chain reaction (PCR). Many chromosomal abnormalities can be identified using this DNA, by a technique called non-invasive prenatal diagnosis.

Two different primers are needed in the polymerase chain reaction as shown in the diagram below.



(i) **On the diagram above complete** the nucleotide sequence of the DNA primer complementary to the strand of DNA. [1]

(ii) Explain why two different DNA primers are required. [1]

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(iii) A sample of blood from a pregnant woman is taken. Primers specific to a gene on chromosome 21 are used to replicate it. Primers specific to another gene on a different chromosome are used at the same time. These act as a control. Both primers have fluorescent markers attached.

Suggest why it is important to use primers which are specific to a certain gene on each chromosome. [1]

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(iv) After the PCR, the DNA fragments are separated using gel electrophoresis and the level of fluorescence for each gene is measured. The level of fluorescence corresponds to the quantity of that gene.
The quantity of both genes is expressed in the form of a ratio as shown below.

Quantity of gene from chromosome 21 : Quantity of gene from control chromosome.

Suggest why it is necessary to express the quantity of the genes as a ratio. [2]

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4. The techniques of recombinant DNA technology and micro-propagation are used to produce Genetically Modified Crops. The following summary is adapted from an account given on the Food Standards Agency's web site [www.food.gov.uk]

1. A plant with the desired characteristic is identified - e.g. resistance to the herbicide 'Roundup'.

2. The specific gene that produces this characteristic is found in the plant's DNA and cut out.

3. To get the gene into the cells of the plant being modified, the gene needs to be attached to a carrier. A piece of
bacterial DNA called a plasmid is joined to the gene to act as the carrier.

4. Once the gene is attached to the plasmid, a marker gene is also added to identify which plant cells take up the new
gene.

5. The 'gene package' is put in a bacterium, which multiplies, to create many copies of the 'gene package'.

6. A copy of the 'gene package' is dried onto a gold or tungsten particle - and fired into a piece of tissue from the plant being modified. The particle carries the 'gene package' into the plant's cells.

7. The plant tissue is put into a selective growth medium so that only modified tissue develops into plants.

(a) Explain how different types of enzymes are used in stages 2 and 3 to produce the 'gene package'.

[4]

(b) (i) Explain the advantage to farmers of having crops resistant to 'Roundup'.

[3]

(ii) Explain why environmentalists might have legitimate objections to using GM crops resistant to 'Roundup'.

[2]

5.

Currently, a million tons of wild fish are harvested from the oceans annually. Of these, 80% are used to feed fish reared in farms.
Fish do not make their own omega-3 fatty acids, they get these by eating algae. For farmed fish to be as nutritious as wild fish, they need to be fed a diet rich in omega-3 fatty acids. Algae are hard to culture on a large scale, so wild fish provide a more convenient source.

Scientists have identified and spliced genes from algae that code for producing high levels of omega-3 fatty acids into *Camelina* plants. The genetically modified *Camelina* plants now produce seeds that contain 26% omega-3 fatty acids, so are useful for fish farm feed.

(a) Explain how named enzymes would be used to cut genes from algae and splice them into *Camelina* plants. [3]

(b) Explain why feeding genetically modified *Camelina* seed to farmed fish could benefit biodiversity. [1]

6.

A recently developed technique in genetic engineering is called CRISPR. In this technique guide RNA is made which attaches to complementary sequences on DNA.

Nucleic acid molecules are constructed from sub-units called nucleotides.

(a) Describe **three** ways in which a DNA molecule differs from an RNA molecule. [2]

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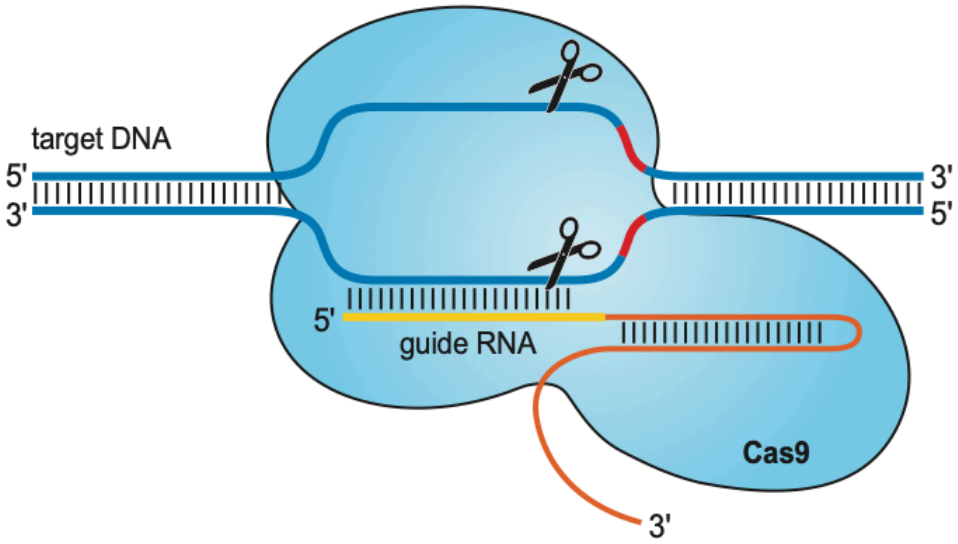
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The CRISPR technique can be used to remove a target gene.
In this technique:

- Guide RNA is made.
- The guide RNA and Cas9 endonuclease combine to form a CRISPR/Cas9 complex.
- The complex is then inserted into a cell.
- The guide RNA attaches to the target gene as shown in Figure 2.1.

Figure 2.1



(b) Cas9 enzyme is a restriction endonuclease. State what is meant by a restriction endonuclease. [2]

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Genetic engineers have discovered that by synthesising guide RNA with particular nucleotide sequences they can target any gene in any organism, if they know its nucleotide sequence. Using this technique it is possible to remove a target gene.

(c) Scientists have identified a gene that is essential for fertility in mosquitoes of the genus *Anopheles*.

Suggest how the CRISPR technique could be used to modify mosquito eggs to produce sterile adult mosquitoes. [3]

(d) Explain how releasing these sterilised mosquitoes into the wild might benefit humankind and suggest an ethical reason for not doing so. [3]

7.

Plants, such as maize *(Zea sp.)*, can be genetically modified to provide resistance to insect pests. The bacterium, *Bacillus thuringiensis*, naturally produces a protein toxic to insects. The Bt gene that codes for this protein can be introduced into plant cells using a genetically engineered plasmid. One way of achieving this is to prepare a cDNA fragment containing the Bt gene and then incorporating it into a suitable plasmid.

Describe how a cDNA fragment containing the Bt gene can be prepared and the processes by which genetically engineered plasmids can be produced. Explain why there are concerns over the use of such a technique to increase resistance to insect pests in crop plants. [9 QER]

1.

Question	Marking details	Marks available					
		AO1	AO2	AO3	Total	Maths	Prac
1	**Indicative content** **Sequence and data:** • the order of nucleotides/bases in the DNA • Sanger sequencing • descriptions of methods used • data/information would give {loci/sequences} of individual genes • coding for specific amino acid/proteins • descriptions of introns and exons (correct context) **100 000 Genomes Project:** • Next Generation Sequencing/NGS • locate genes responsible for {rare genetic disorder/cancers}/mutated sequences • by comparing genomes of sufferers with {normal genome/large number of individuals} • Predisposition to disease/{diagnosis/ understanding causes} of diseases • developing treatments/gene therapy. • Use in prenatal diagnosis **Benefits and ethics:** • Sharon would find out if the drug would give her liver damage/benefit is matching drugs to genetic make up of patient/personalised medication • ethical dilemma is over rights of access to genomic information • {Misuse of genetic information} by Employers/insurers • Wider implications on family health • {Anxiety/distress} caused by knowledge • Social discrimination/OWTTE						
	7-9 marks Indicative content of this level must address all three parts: *The candidate constructs an articulate, integrated account, correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses scientific conventions and vocabulary appropriately and accurately.* **4-6 marks** Indicative content of this level addresses at least two parts. *The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate usually uses scientific conventions and vocabulary appropriately and accurately.* **1-3 marks** Indicative content addresses at least one part. *The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate has limited use of scientific conventions and vocabulary.* **0 marks** *The candidate does not make any attempt or give a relevant answer worthy of credit.*						
	Question 1 total	**4**	**5**	**0**	**9**	**0**	**0**

2.

Question			Marking details	Marks Available
2	*(a)*	(i)	AATT and TTAA;	1
		(ii)	they have unpaired bases / they have exposed bases / they are single stranded DNA sections;	1
		(iii)	EcoR1;	1
	(b)	(i)	{Ring of / circle of / loop of} DNA (found in bacteria); Accept {additional / extra} DNA qualified	1
		(ii)	so that the cut ends (of the fragment and the plasmid) are <u>complementary</u>;	1
		(iii)	Ligase;	1
	(c)		• Introns are {non-coding / blocks of repeated nucleotides} /exons code (for proteins); • so there is more variability / more unique to individual / {number of times that the blocks are repeated varies/ {STRs / VNTRs} vary / ORA for exons;	2
	(d)		Same position **and** thickness of bands;	1
	(e)	(i)	{Makes multiple copies / amplifies} DNA; NOT replicates unqualified	1
		(ii)	<u>DNA</u> polymerase; (DNA) <u>replication</u>;	2
			Question 2 Total	**[12]**

3.

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)		GGC GTA ATT CCC		1		1		
		(ii)		different nucleotide sequence at each end/one primer for each strand of DNA (1).			1	1		
		(iii)		Enables {specific/the gene} to be {amplified/to be copied/to be replicated} (1)			1	1		
		(iv)		Does not matter how {many cycles in PCR/initial quantity/number of copies made}(1) Ratio will be same (1)			2	2		

4.

Question			Marking details	Marks Available
4	(a)		Restriction {endonuclease/ enzymes} used to cut (out the desired gene); The same {endonuclease/ enzyme} is used to open the plasmids; Producing {complementary/ corresponding} 'sticky ends'; Ligase is used to {join/ splice/ attach/ adhere/ anneal} gene into plasmid;	4
	(b)	(i)	'Roundup' will not kill crop but it will kill {other plants / weeds}; Reducing competition in the field; Allowing increased yield;	3
		(ii)	There will be increased use of herbicide; a reduction in biodiversity/ may lead to {herbicide resistant weeds/ superweeds} bioaccumulation in food chain; OR Dispersal of pollen from crops engineered for herbicide resistance to {wild relatives/ weeds}; may lead to {herbicide resistant weeds/ superweeds}; OR Dispersal of pollen from crops engineered for herbicide resistance to other crops; May contaminate organic crops; OR (GM crop) produces a new protein; Unknown effects of eating new protein;	Max 2
			Question 5 Total	**[9]**

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5.

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	(a)			Any 3 from: {Restriction (endonuclease) enzyme/ named enzyme e.g. EcoR1} used to cut out {gene/ DNA} (1) Sticky ends/ or description of (1) Same restriction enzyme used to open DNA in {vector/ plasmid/ virus/ *Camelina*} (1) Ligase used to {insert / anneal / splice} gene into {vector/ plasmid/ viral/ *Camelina}*(1)	3			3		
	(b)			Less wild fish will be harvested (to feed farmed fish)			1	1		

6.

Question				Marking details	Marks Available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*			• Double stranded {not single/ RNA is single stranded}/ double helix vs {not double helix/ single stranded} • deoxyribose not ribose • thymine not uracil Accept letters • Longer molecule **2 marks for 3 correct** **1 mark for 2 correct**	2			2		
	(b)			It cuts DNA/ or description (1) Ignore reference to RNA At a specific (base) sequence(1)	2			2		
	(c)			Any **three** (×1) from: • Make guide RNA (with complementary sequence) of {target gene/ fertility gene} (1) • Insert {CRISPR/ Cas9} into {eggs/ cells} (1) NOT mosquitoes alone • and incubate/allow to {grow/mature} (1) • remove the gene that {makes them fertile/ affects meiosis} (1)		3		3		
	(d)			• Reference to reduced fertility in mosquitoes (1) • Less mosquitoes = less malaria (1) • Any **one** (×1) from Reference to right of humans to make another species extinct / Effect on {removal from food chain/ ecosystems/ biodiversity} Unknown effects of GM mosquitoes in the environment (1)		2	1	3		
				Question 6 total	**4**	**5**	**1**	**10**	**0**	**0**

7.

Question	Marking details	Marks available					
		AO1	AO2	AO3	Total	Maths	Prac
7	• **Extract** mRNA from the bacterium (which is synthesising the proteins). • Use **reverse transcriptase** to synthesise a {single strand of DNA/ cDNA} using the mRNA (as a template). • Use **DNA polymerase** to produce double stranded DNA. • **Sticky ends** are added to the end of each DNA strand of the DNA. • The DNA is copied many times using the **PCR.** • Plasmids from bacteria are isolated • **Restriction {endonuclease/ enzymes}** is used to open the plasmid (at a specific point) • producing **sticky ends complementary** to the DNA. • **DNA ligase** is used to bind the DNA into the plasmid. • **Antibiotic resistance genes / markers/ LacZ** are used to select bacteria containing the recombinant plasmids. Concerns: • dispersal of pollen from engineered crops to wild relatives/ contamination of organic crops • unknown effects of eating new protein which is toxic to insects/ health concerns from eating GM crop • a reduction in biodiversity e.g. beneficial insects killed/ affect on food chains • Could result in resistance to protein in insects/ selection pressure						
	7-9 marks Indicative content of this level is… Detailed explanation of all three areas in the indicative content. *The candidate constructs an articulate, integrated account, correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses scientific conventions and vocabulary appropriately and accurately.* **4-6 marks** Indicative content of this level is… Detailed explanation of 2 areas of the indicative content, or partial description of 3 areas. *The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate usually uses scientific conventions and vocabulary appropriately and accurately.* **1-3 marks** Indicative content of this level is… Good explanation of one area of the indicative content or partial description of 2/3 areas. *The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate has limited use of scientific conventions and vocabulary.* **0 marks** *The candidate does not make any attempt or give a relevant answer worthy of credit.*						
	Question7 total	**7**	**2**		**9**	**0**	**0**