

Structured Questions: Paper 2

# 3.4 Genetic Modification & Biotechnology

3.4.1 Electrophoresis & PCR / 3.4.2 DNA Profiling / 3.4.3 Genetic Modification / 3.4.4 Cloning / 3.4.5 Skills: Genetic Modification & Biotechnology

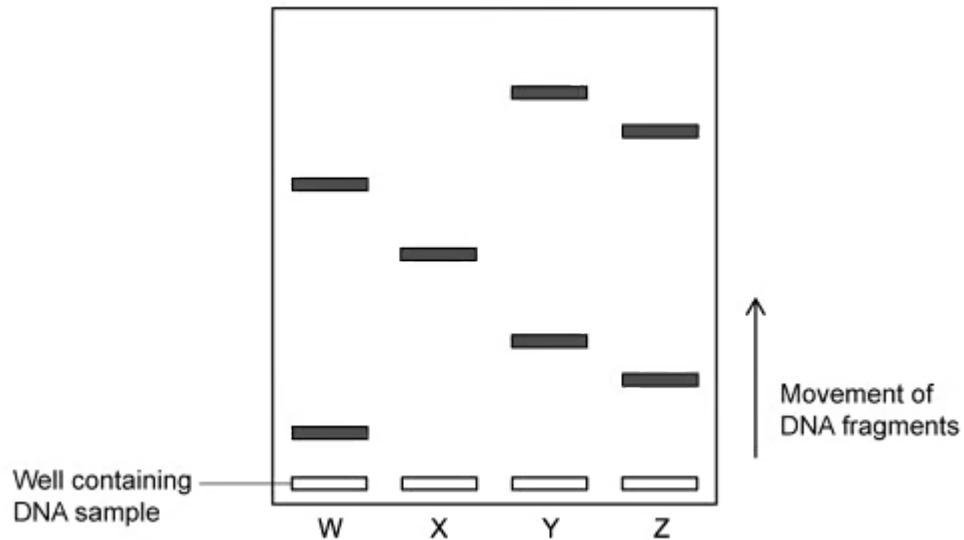
Easy (5 questions)	/40
Medium (5 questions)	/50
Hard (5 questions)	/60
<b>Total Marks</b>	<b>/150</b>

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# Easy Questions

- 1 (a) In the electrophoretogram, the DNA has moved from the negative cathode to the positive anode.



State the property of DNA which results in movement from cathode to anode.

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(1 mark)

- (b) State **two** uses of gel electrophoresis.

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.....  
(2 marks)

- (c) In some situations, gel electrophoresis cannot be carried out as the DNA samples are not collected in a large enough quantity.

Identify the process used to amplify the DNA in order to supply enough DNA for electrophoresis to be successful.

**(1 mark)**

**(d)** The stages of electrophoresis can be seen below.

Complete the table below by adding a number to the column to show the correct sequence of events in the process. The first one has been done for you.

A sample of DNA is collected from an individual	1
Samples of DNA fragments are loaded into wells in the agarose gel using a micropipette	
An enzyme is used to create fragments of the DNA in the sample	
An electrical current is applied to the tank	

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**(2 marks)**

2 (a) The molecules named below are all required during the process of PCR.

Draw a line between the boxes to show the function for each of the molecules named.

Free nucleotides	To mark the start of the sequence to be copied
Primer	An enzyme required to build the new DNA fragments
Taq polymerase	The building blocks required to build the new DNA fragments

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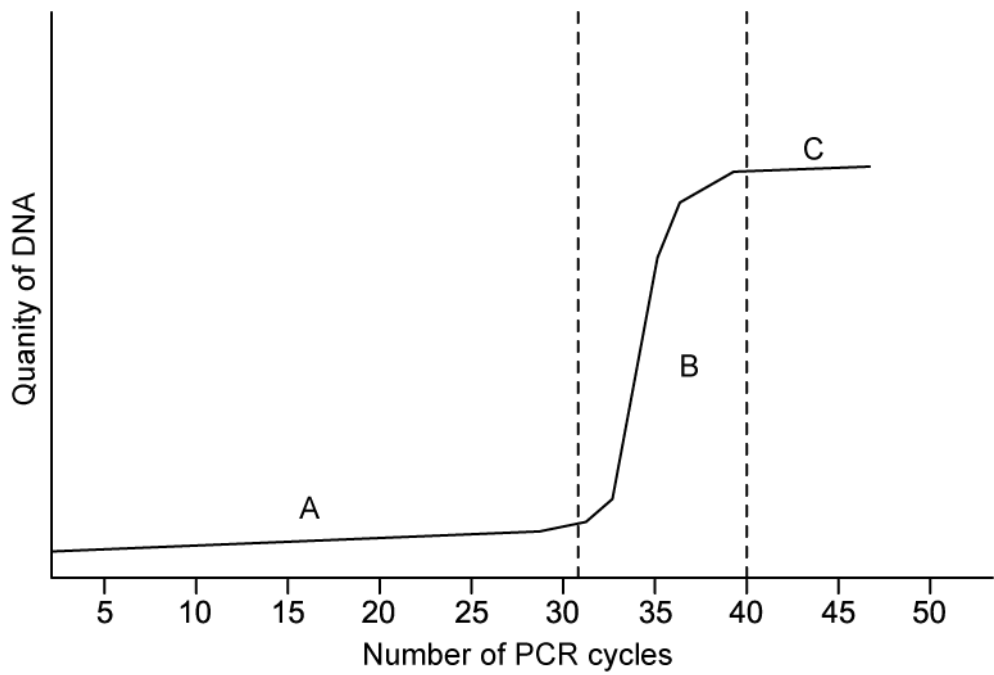
**(3 marks)**

(b) State the property of Taq polymerase that makes it suitable for use in PCR.

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**(1 mark)**

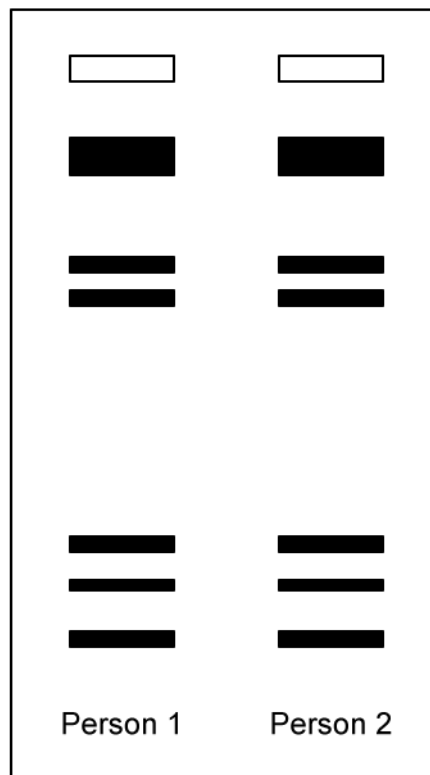
(c) The graph shows how the quantity of DNA increases over several cycles of PCR



Identify the stage of the graph where replication is exponential.

(1 mark)

(d) The electrophoretogram shows a pattern produced from the DNA of two people.

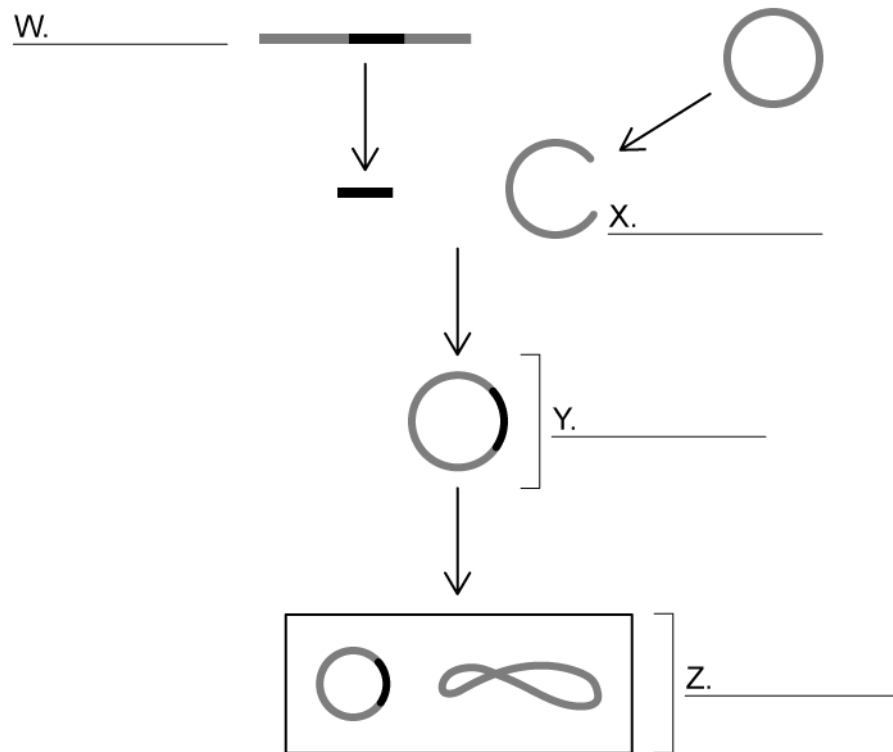


State how the electrophoretogram shows that the two people are identical twins.

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**(1 mark)**

3 (a) The diagram shows the process of genetic modification used to produce multiple copies of a required gene.



Label the diagram using the words provided.

**Recombinant DNA    Transgenic organism    Plasmid**

**Desired gene**

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**(4 marks)**

(b) Identify the vector used in this genetic modification process.

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**(1 mark)**

- (c) Gene transfer between organisms is possible due to the universal nature of the genetic code.

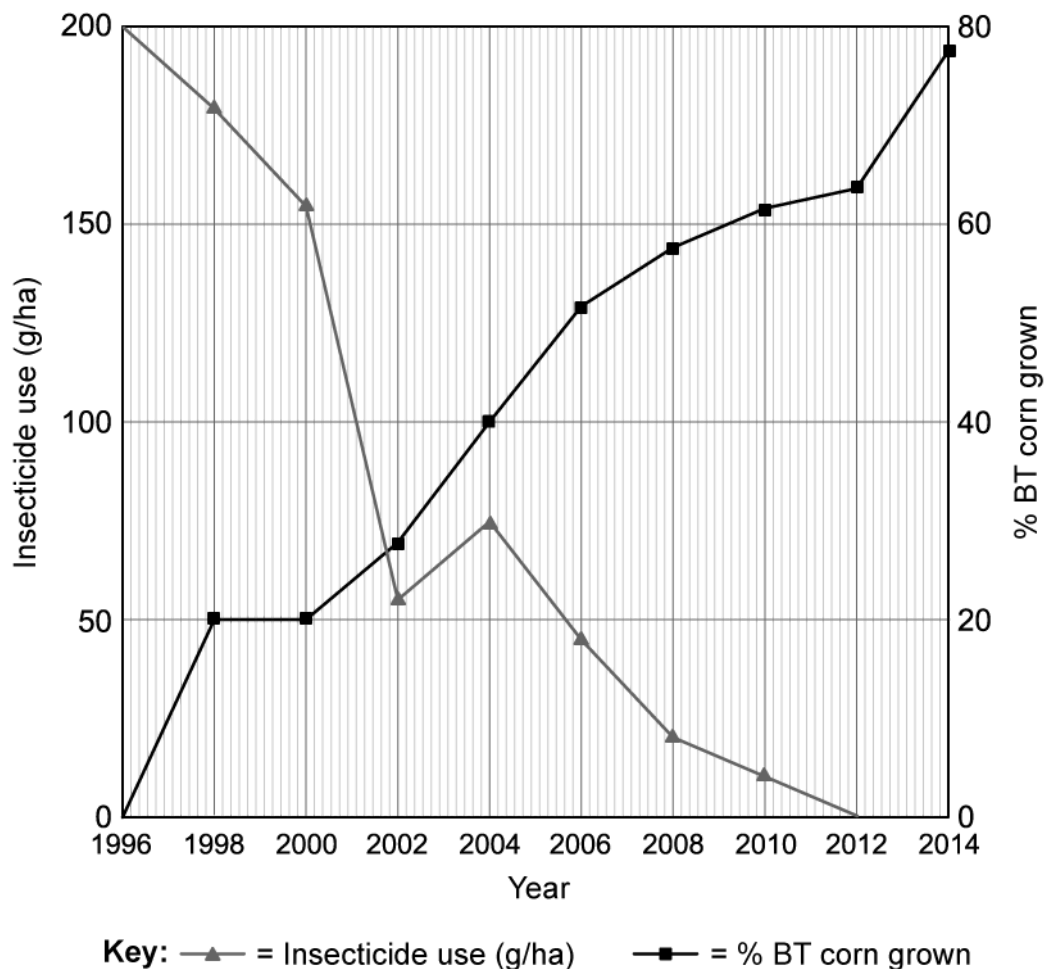
State what is meant by the term '**universal**'.

(1 mark)

- (d) Identify the enzyme used in recombinant DNA technology to cut out a desired gene at a specific base sequence resulting in the formation of sticky ends.

(1 mark)

- (e) Crops can be genetically modified to include the BT toxin, a natural pesticide produced by a bacterium, *Bacillus thuringiensis*. The graph shows the changes in pesticide application in response to changes in the quantity of BT modified crops grown in the U.S.





Describe the effect that the increasing use of BT crops has on pesticide application.

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**(1 mark)**

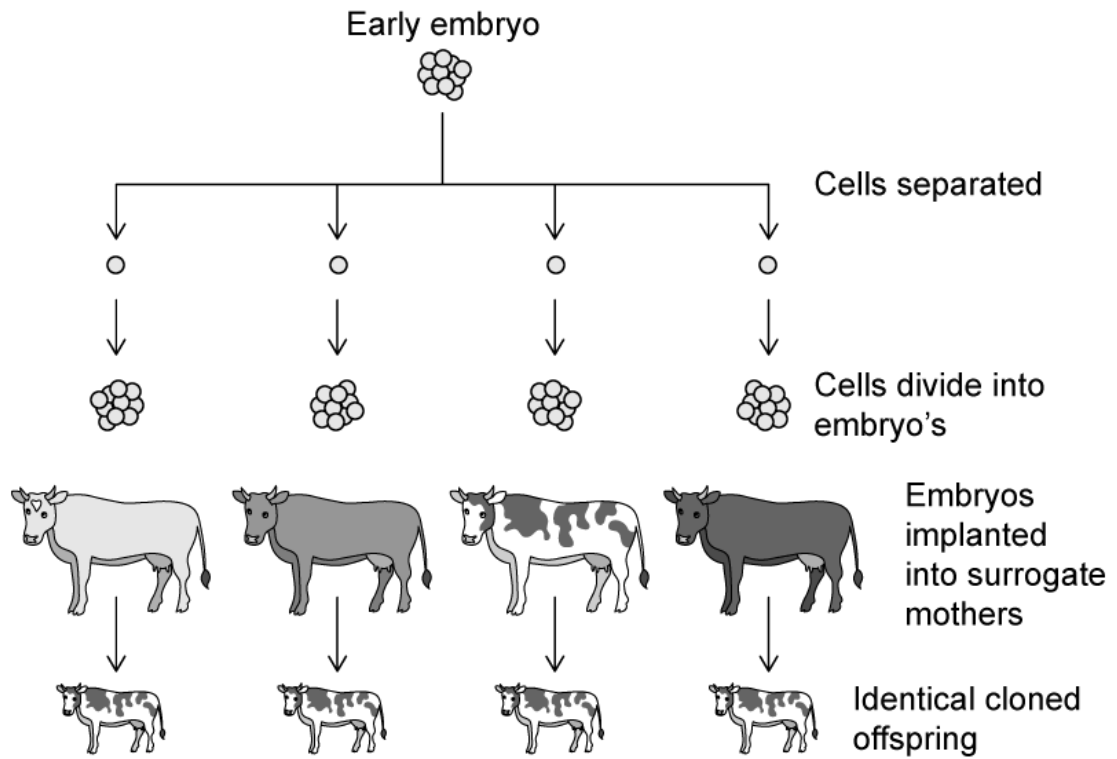
- (f)** BT toxin has a negative impact on many types of insects, including those which do not feed on the crops such as bees, flies, beetles and butterflies.

Suggest why there may be opposition to the use of BT corn by some.

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**(1 mark)**

4 (a) Identify the cloning process shown in the image.



(1 mark)

(b) Complete the table by placing a (✓) or an (X) in the correct column to identify which methods of cloning are natural and which are artificial.

	Natural cloning	Artificial cloning
Parthenogenesis		
Somatic cell transfer		
Bulbs		
Rhizomes		
Cuttings		

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(5 marks)

(c) The cells of the early embryo are described as being pluripotent.

Define the term **pluripotent**.

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(1 mark)

**5 (a)** *One mark is available for clarity of communication throughout this question.*

Outline some of the concerns that people may have over the use of genetically modified crops in agriculture.

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**(4 marks)**

**(b)** Describe some of the potential benefits of genetic modification of crops.

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**(5 marks)**

**(c)** Outline the process used to determine paternity using electrophoretograms produced in gel electrophoresis.

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**(3 marks)**

# Medium Questions

1 (a) State **two** features that allow nucleic acids or proteins to be separated by gel electrophoresis.

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(2 marks)

(b) During gel electrophoresis of a sample of DNA fragments,

- (i) Identify which electrode the DNA would move towards. Justify your answer.
- (ii) State which component of DNA gives it its charge.

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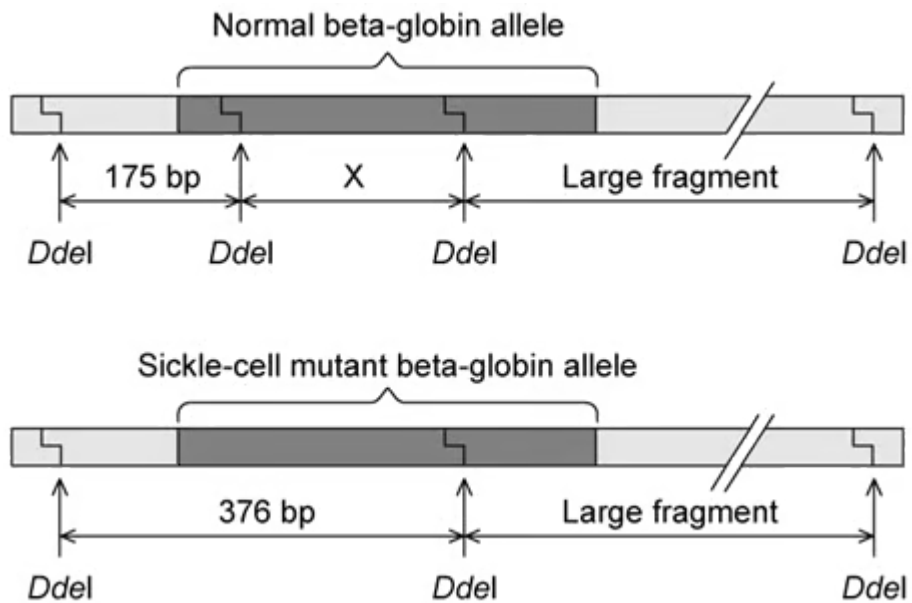
(3 marks)

(c) State which class of enzymes can be used to cleave DNA into fragments prior to gel electrophoresis.

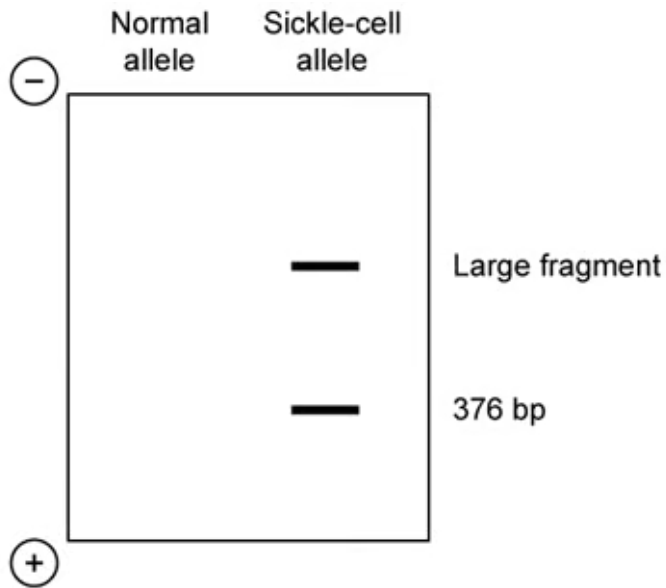
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(1 mark)

(d) Restriction enzymes and gel electrophoresis can be used in genetic screening, to identify genes associated with a disease. The mutation of the Beta-globin gene which gives rise to sickle-cell anaemia removes a recognition site of the restriction enzyme *DdeI* as shown in the diagram below. The lengths of some fragments are shown in base pairs (bp).



- (i) Deduce the size of **fragment X**.
- (ii) *Ddel* digested DNA from an individual who was a carrier for the sickle-cell beta-globin gene was analysed with gel electrophoresis as shown below. Draw and label the DNA fragments that would result from a normal individual.




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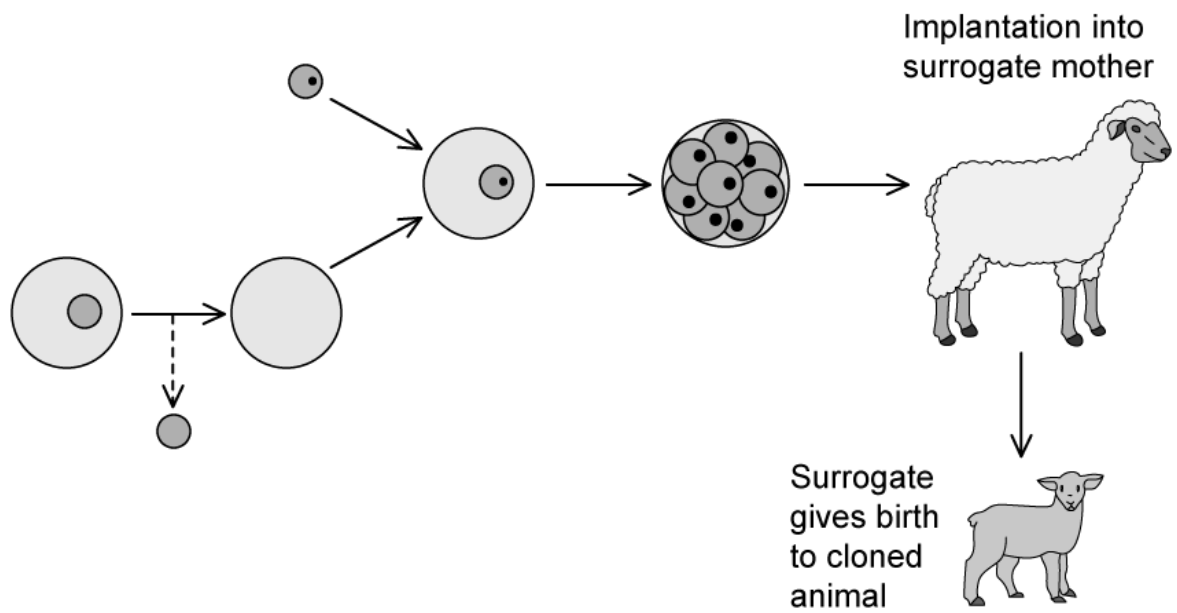
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(3 marks)

2 (a) Explain what is meant by the term, 'clones'.

(1 mark)

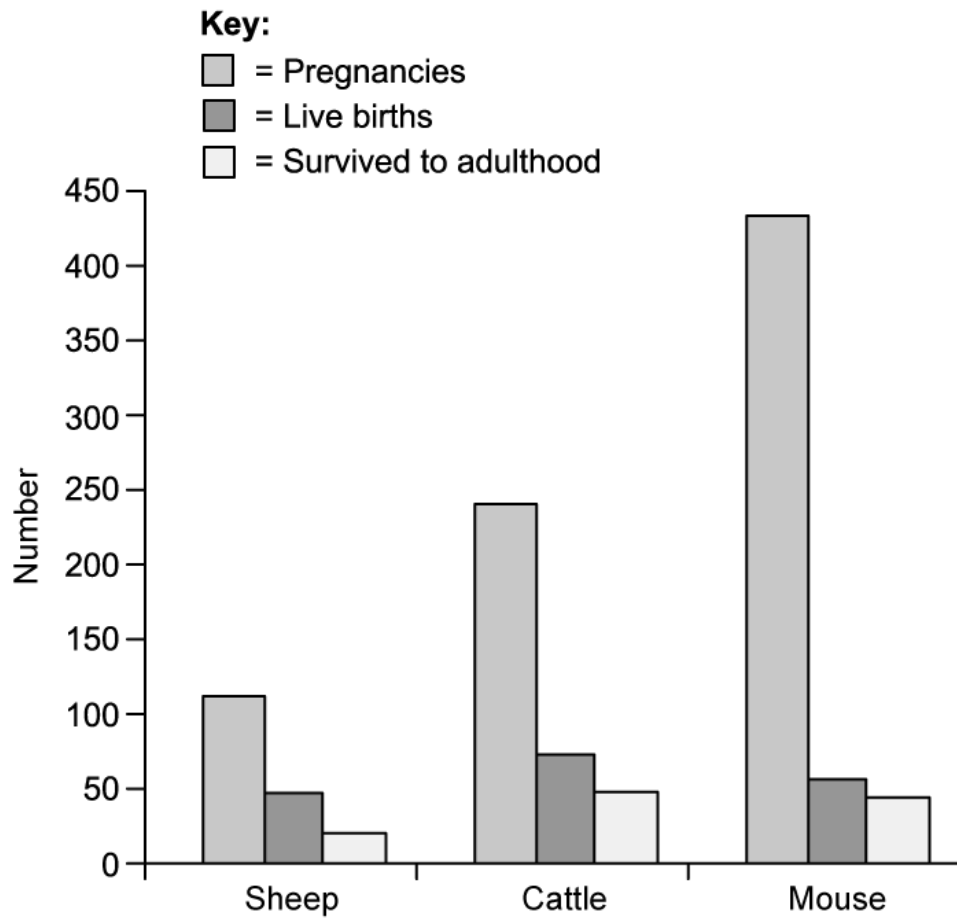
(b) The diagram below outlines the process of somatic cell nuclear transfer that was used to create Dolly the sheep. Describe each of the different steps that lead up to implantation.



(4 marks)

(c) The graph below shows the survival rates for different cloned animals.





- (i) Identify trends in the data.
- (ii) State why this data could not be used in isolation to assess the successfulness of animal cloning.

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**(3 marks)**

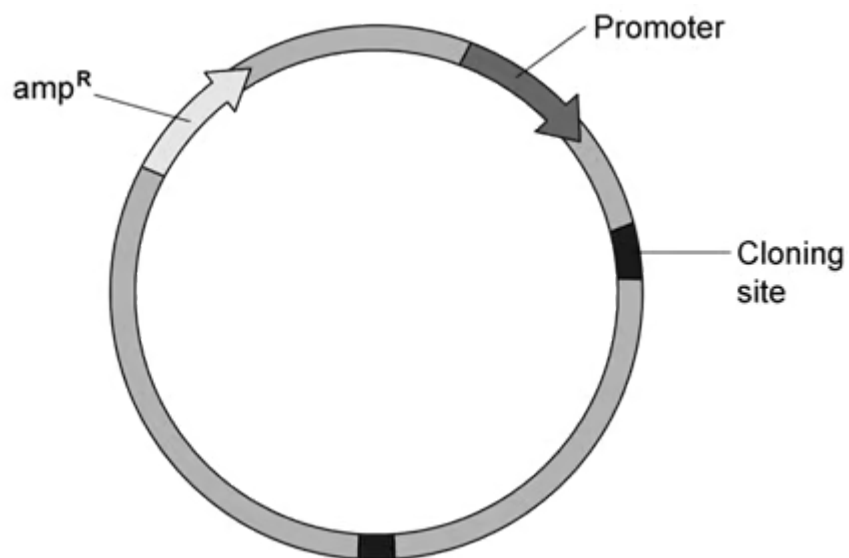
3 (a) Describe what a genetically modified “transgenic” organism is.

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(2 marks)

(b) A bacterial plasmid used for recombinant DNA technology is represented in the diagram below. The *amp<sup>R</sup>* gene encodes for antibiotic resistance.



Explain the usefulness of the *amp<sup>R</sup>* and promoter elements in recombinant DNA technology.

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(2 marks)

(c) Before the discovery of recombinant DNA technology, diabetics had to be treated with animal insulin obtained directly from animal pancreatic tissue which led to many complications and premature deaths.

Outline the key steps involved in the commercial production of human recombinant insulin.

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**(5 marks)**

4 (a) The table below shows historic annual mortality from different public health diseases.

Global mortality (millions)	2010	2017
Vitamin A deficiency	2.8	1.9
HIV/AIDS	1.8	0.9
Tuberculosis (TB)	1.4	1.6
Malaria	0.7	0.5

Genetic modification has assisted in the fight against four major human diseases. Calculate the disease which showed the largest percentage drop in global mortality in the period 2010 - 2017.

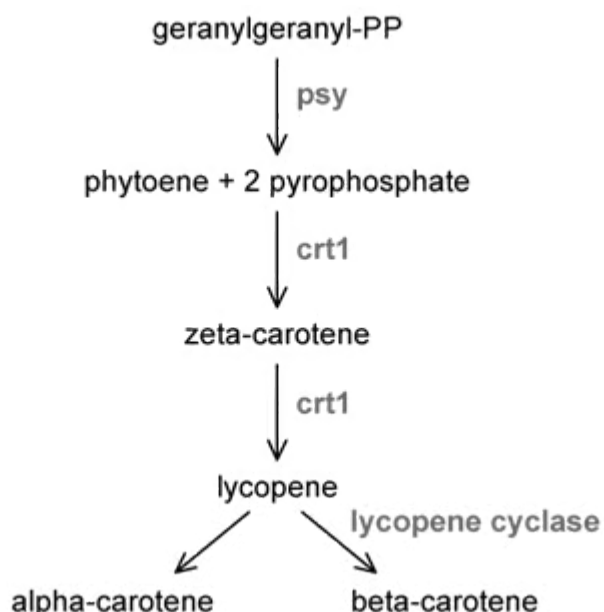
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(1 mark)

(b) Vitamin A deficiency is prevalent in many developing countries as a result of poor nutrition and is a common source of blindness. 'Golden Rice' is a variety of genetically modified rice developed to produce beta-carotene (pro-vitamin A). Golden rice was created by introducing rice with the following beta-carotene biosynthesis genes:

- *psy* (phytoene synthase) from wild daffodil (*Narcissus pseudonarcissus*)
- *crt1* (phytoene desaturase) from a soil bacterium (*Erwinia uredovora*)

The pathway for beta-carotene biosynthesis is shown below.



The table below shows the total amount of beta-carotene produced when different *psy* genes were inserted into 'Golden Rice'

Transgene source	Total beta-carotene (arbitrary units)
<i>Arabidopsis thaliana</i> (thale cress)	410
<i>Daucus carota</i> (wild carrot)	430
<i>Narcissus pseudonarcissus</i> (wild daffodil)	380
<i>Zea mays</i> (maize)	1 800
<i>Capsicum annuum</i> (cayenne pepper)	800

Originally, 'Golden rice' did not accumulate high levels of beta-carotene. Identify, with a reason, how it was improved.

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**(2 marks)**

**(c)** Discuss the risks and benefits associated with GM crops.

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**(6 marks)**

**5 (a)** *One mark is available for clarity of communication throughout this question.*

Archaeologists in Pompeii recently discovered the remains of seven human skeletons within a house that was buried under volcanic ash when Mount Vesuvius erupted during ancient Roman times in 79 AD. Researchers were interested to know if the skeletons were from related individuals, they isolated DNA from the skeletons and used it in the Polymerase Chain Reaction (PCR).

PCR utilises multiple cycles of three simple steps, describe these steps and suggest why the researchers used PCR in their investigation.

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**(5 marks)**

**(b)** DNA profiling was carried out on the PCR products to identify if the skeletons came from related individuals. The results are seen in the image below.

Adult A	Adult B	Adult C	Adult D	Child 1	Child 2	Child 3
		—————				—————
—————		—————	=====	—————	—————	
=====	—————	—————	=====	=====	=====	=====
=====	=====	=====	=====	=====	=====	=====
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		—————				—————

It was determined that the three children were siblings and shared the same biological parents. Their mother is **Adult B**.

- (i) Predict which adult is the children’s father. Justify your answer.
- (ii) Suggest why the profiles for Child 1 and Child 2 are the same.

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(3 marks)

(c) Outline the method by which DNA profiling is undertaken and describe why it is a useful technique.

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**(7 marks)**



# Hard Questions

- 1 (a)** Human blood carries several proteins which are required in the mechanism of blood clotting. One of these proteins, factor VIII, is lacking in individuals with haemophilia.

A team of scientists has genetically engineered goats by introducing a gene allowing them to produce factor VIII in their milk. This milk can then be purified and the proteins can be used to treat haemophiliac patients.

Describe **two** methods by which the scientists could obtain the human gene coding for the factor VIII protein.

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**(4 marks)**

- (b)** Before carrying out PCR on the isolated gene sequence, the scientists modified the gene in two ways:

1. They attached a jellyfish gene which codes for a fluorescent protein to the start of the gene sequence.
2. They added a promotor region in front of the jellyfish gene.

After these modifications, the DNA sequence will be inserted into the nucleus of some body cells of a goat.

Suggest the purpose of attaching the jellyfish gene.

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**(2 marks)**

- (c) The promotor region provides a base sequence compatible with the active site of the enzyme RNA polymerase.

Suggest why the addition of the promotor region is required in the production of factor VIII.

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**(3 marks)**

- (d) One round of PCR takes approximately 75 seconds.

Calculate how many copies of DNA would be produced after a single fragment of DNA has been in the thermal cycler for 1.5 hours. Give your answer in standard form.

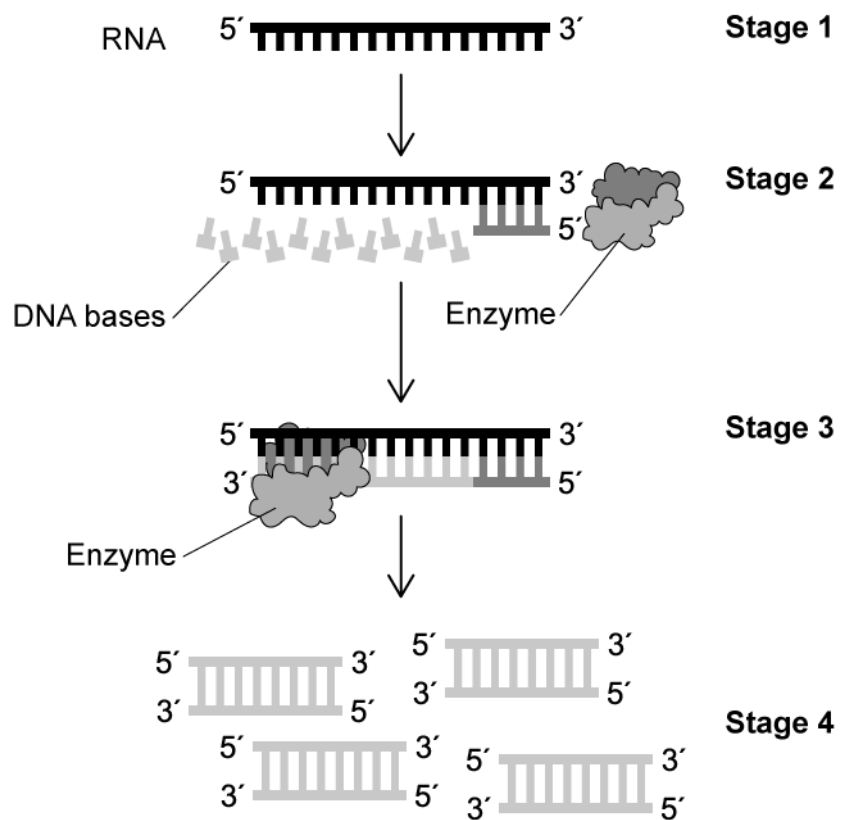
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**(3 marks)**

2 (a) The diagram below shows the processes involved in the amplification of a sample of viral RNA.



Compare and contrast the process in the image with the process used in the amplification of a fragment of DNA.

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(6 marks)

- (b)** The addition of RNAase enzyme occurs between stages **3** and **4** shown in the diagram from part **a**).

Suggest why this is a necessary part of the process.

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**(2 marks)**

- (c)** Seven skeletons were discovered in a house in Pompeii, three of which were children. It is believed they were inhabitants and workers within the house when Mount Vesuvius erupted in 79 AD.

Researchers were able to isolate very small amounts of DNA from these skeletons. The DNA obtained was used in the polymerase chain reaction (PCR). Genetic fingerprinting was then carried out on this DNA to identify the skeletons.

The image below shows some of the results of the genetic fingerprinting of the three children and four adults.

Adult A	Adult B	Adult C	Adult D	Child 1	Child 2	Child 3
		_____				_____
_____		_____	=====	_____	_____	
_____	_____		=====	_____	_____	_____
_____	_____	_____	=====	_____	_____	_____
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	_____	_____		_____		_____
		_____			_____	_____

Explain why the researchers used PCR in their investigation.

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**(2 marks)**

- (d)** It was determined that the three children were siblings and shared the same biological parents. Their mother is **Adult B**.

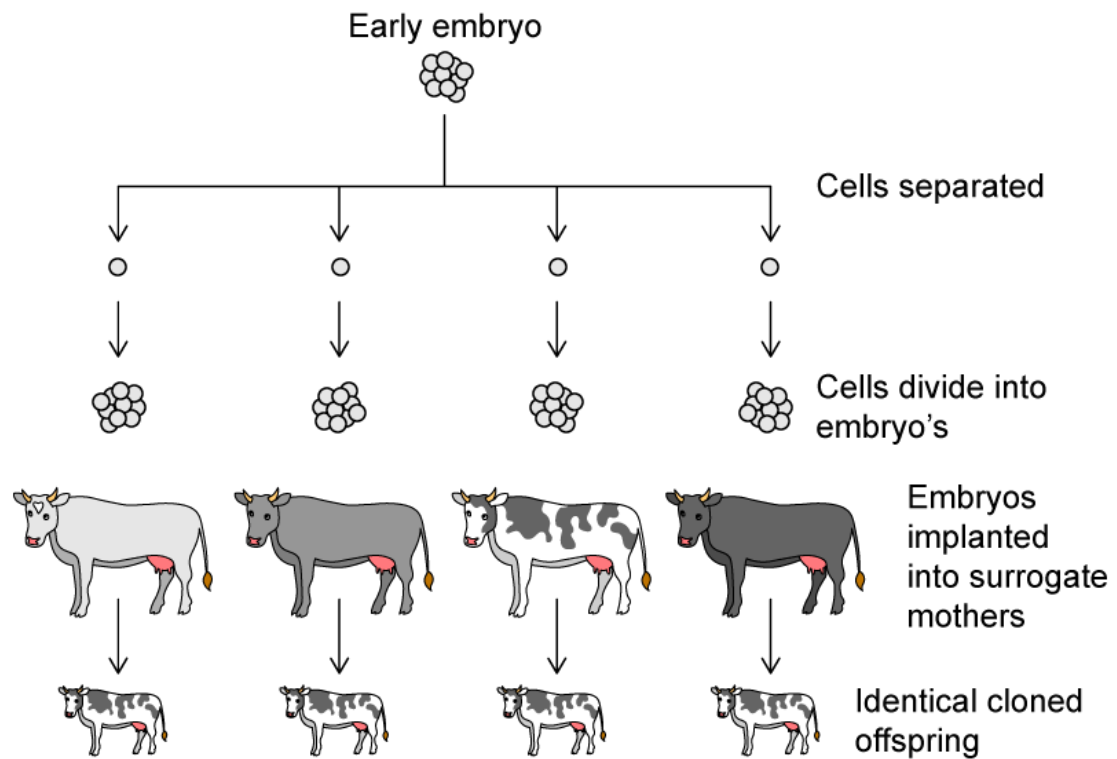
Identify, with a reason, which of the other adults was the children's father.

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**(2 marks)**

**3 (a)** Embryo splitting is a process which can be used to produce larger numbers of high quality cattle for farmers. The process can be seen below.



An embryo with more than 8 cells cannot be used in embryo cloning, suggest why.

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 .....  
 (2 marks)

**(b)** Clones produced in the process in part **a**) may show different phenotypes to each other.

Explain why.

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 .....  
 (2 marks)

**(c)** Describe three natural cloning methods used by plants and animals.

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**(3 marks)**

- 4 (a) An investigation was carried out to show the affect of different rooting powders on the growth of roots in cuttings taken from bean plants.

The results from the investigation are shown in the table.

SE refers to the standard error of the data, which is the spread of data around the calculated mean value.

Rooting hormone	Mean number of roots $\pm$ SE	Mean root length $\pm$ SE
1	5.86 $\pm$ 0.42	6.20 $\pm$ 0.14
2	4.41 $\pm$ 0.13	5.01 $\pm$ 0.03
3	4.27 $\pm$ 0.25	4.98 $\pm$ 0.27
Control	2.16 $\pm$ 0.005	2.65 $\pm$ 0.35

Suggest the conclusions that can be drawn from these results.

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(4 marks)

- (b) A company selling rooting powder 1 to gardeners made the following claim:

*With this rooting powder, your plant cuttings will grow more roots of a greater length than other rooting powders.*

Evaluate the validity of this claim.

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(3 marks)



(c) Outline a method that could have been used to determine how rooting powders affect the growth of roots in bean plants.

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**(6 marks)**

**5 (a)** *One mark is available for clarity of communication throughout this question.*

During PCR DNA is heated to 94 °C and DNA primers, nucleotides and thermostable enzymes are added to the mixture.

Explain the purpose of these steps.

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**(4 marks)**

**(b)** Scientists have proposed a method to genetically engineer mosquitos as a method of controlling disease spread by the insects.

Analyse the ethics surrounding the use of genetically engineered mosquitos as a public health tool.

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**(6 marks)**

**(c)** Discuss the use of cloning methods to produce genetically identical copies of organisms in agriculture.

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**(6 marks)**