IB · HL · Biology

3 hours 19 questions

Structured Questions

DNA Replication

DNA Replication / Electrophoresis & PCR / Electrophoresis & PCR: Applications / Mechanism of DNA Replication (HL)

Easy (8 questions)	/59
Medium (6 questions)	/64
Hard (5 questions)	/37
Total Marks	**/160**

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Easy Questions

1 (a) State the purpose of DNA replication.

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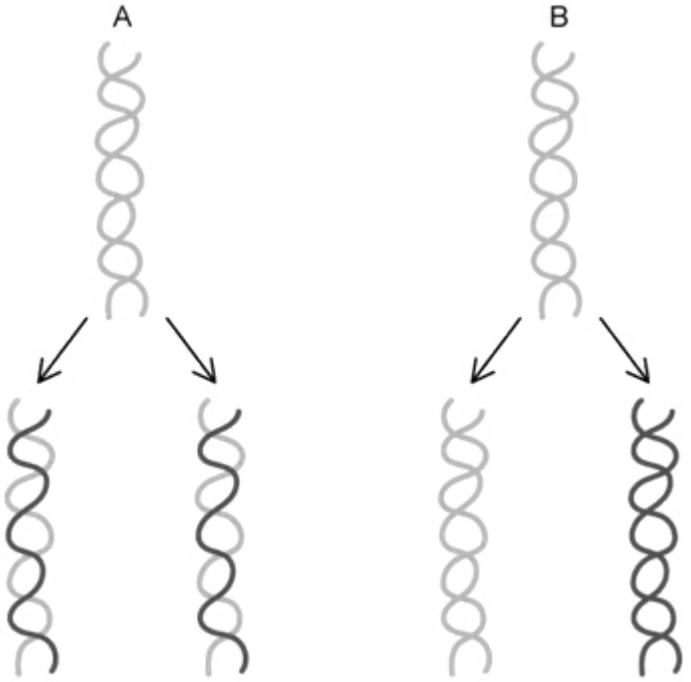
(1 mark)

(b) The diagrams below show two models of DNA replication.



State, with a reason, which diagram, **A** or **B,** is correct.

.....

.....

(2 marks)

(c) Identify **two** enzymes that are involved with the process of DNA replication.

.....

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(2 marks)

(d) Calculate the fraction of a cell's **original** DNA that will be present after 3 full cycles of DNA replication.

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(2 marks)

2 (a) Both DNA and RNA contain pentose sugars in their sugar-phosphate backbones.

Define the term **pentose** in reference to sugar molecules.

.....

(1 mark)

(b) During DNA replication the new bases are added to the new strand by the enzyme DNA polymerase in the 5' to 3' direction.

Use your knowledge of enzymes to explain why it would **not** be possible for DNA polymerase to add the new bases in the 3' to 5' direction.

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(2 marks)

(c) When bases are bonded to the new DNA strands during replication they undergo a condensation reaction.

Describe the events that occur during a condensation reaction.

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(2 marks)

(d) In a length of DNA 1 000 nucleotides long there are 382 guanine nucleotides in one of the strands.

Explain why it is not possible to calculate the number of guanine nucleotides in the opposite strand from the information provided.

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(2 marks)

3 (a) Describe how the structure of a tRNA molecule contributes to the accuracy of the translation.

(3 marks)

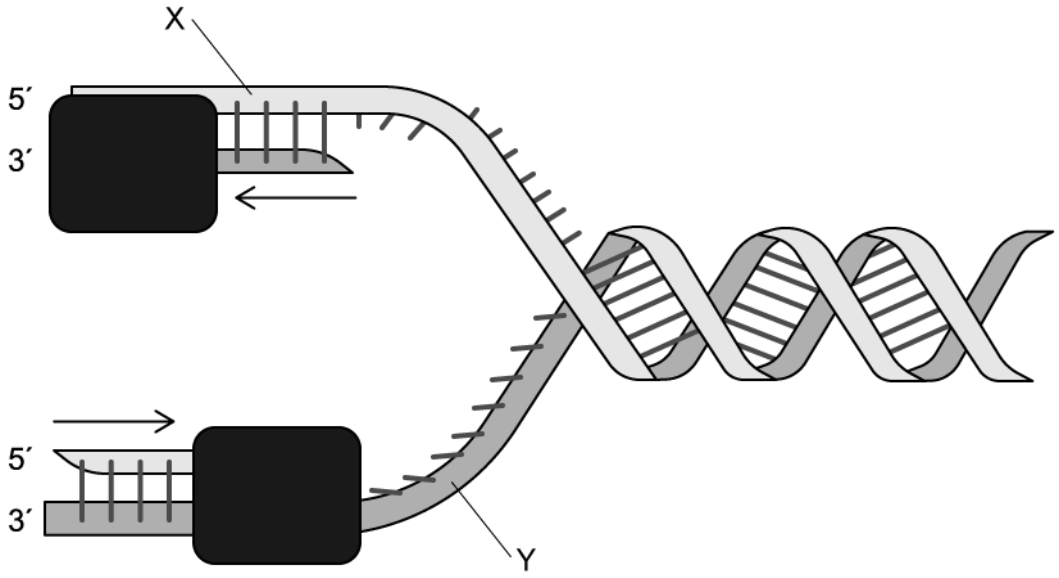
(b) Draw a labelled diagram of two nucleotides bonded together within the same DNA strand.

(5 marks)

(c) Outline the three stages of polymerase chain reaction (PCR).

(7 marks)

4 (a) The diagram below shows the process of DNA replication.



Identify which strand of **X** and **Y** is the leading and lagging strand of the original DNA molecule.

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(2 marks)

(b) DNA replicates in a semi-conservative way.

Define the term 'semi-conservative' with regards to DNA replication.

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(1 mark)

(c) One of the enzymes involved with DNA replication is DNA primase.

Describe the role of DNA primase during DNA replication.

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(2 marks)

(d) DNA replication can only occur in the 5' to 3' direction in the new strand.

State the reason for this.

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(1 mark)

5 (a) A crime was committed and the DNA profiles of the victim and a drop of blood found at the crime scene were constructed. These were compared to the DNA profiles of three possible suspects, as seen in the diagram below.

Identify the suspect that most likely committed the crime.

.....

(1 mark)

(b) Variable number tandem repeats (VNTRs) are short, non-coding regions of DNA that can be used in DNA profiling.

Explain the use of VNTRs in DNA profiling.

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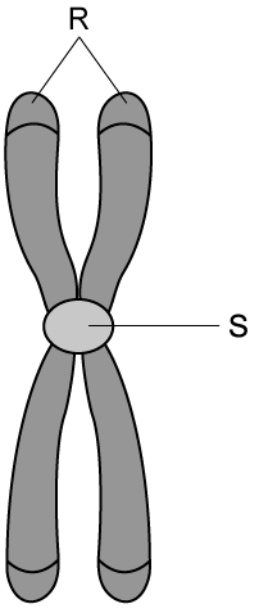
(2 marks)

(c) The diagram below represents the structure of a chromosome.



Label parts **R** and **S** of the chromosome.

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(2 marks)

(d) **R** and **S** from the chromosome at part c) represents non-coding regions of DNA.

State the function of **R** and **S** in a chromosome.

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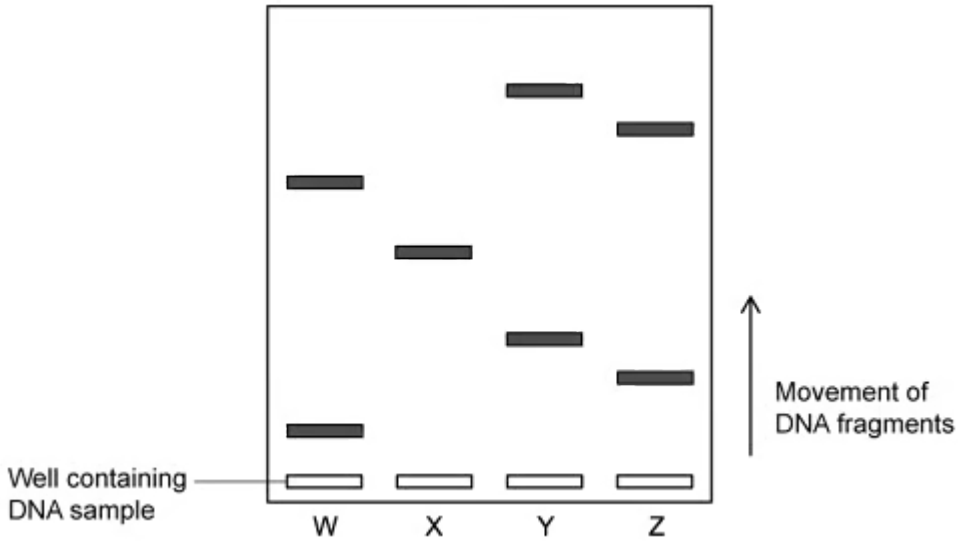
(2 marks)

6 (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.

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(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	

(2 marks)

7 (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.

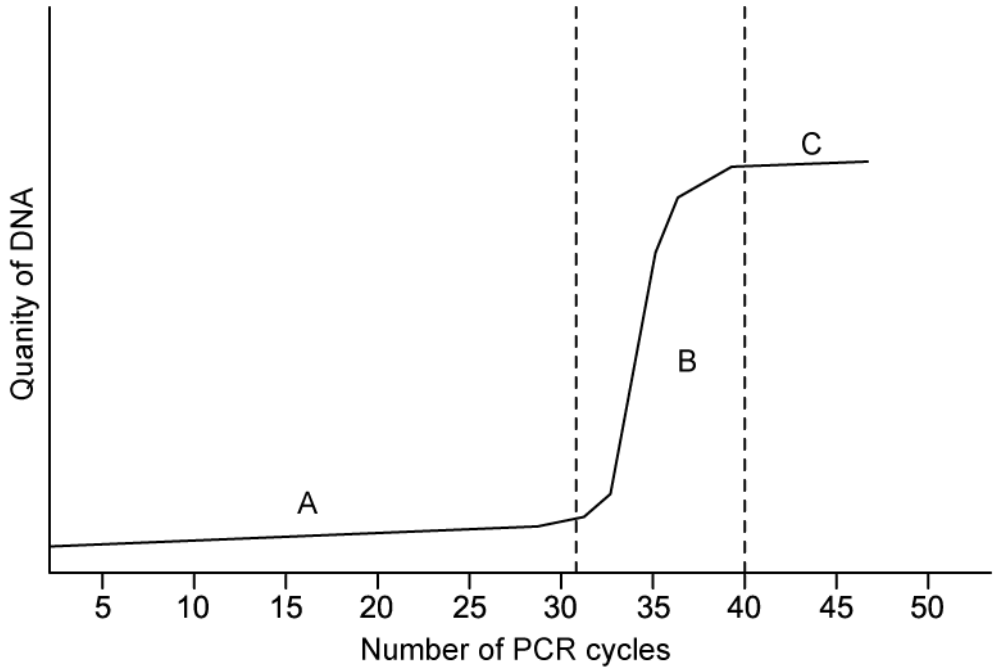
Free nucleotides	To mark the start of the sequence to be copied
Primer	An enzyme required to build the new DNA fragments
Taq polymerase	The building blocks required to build the new DNA fragments

(3 marks)

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

(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.

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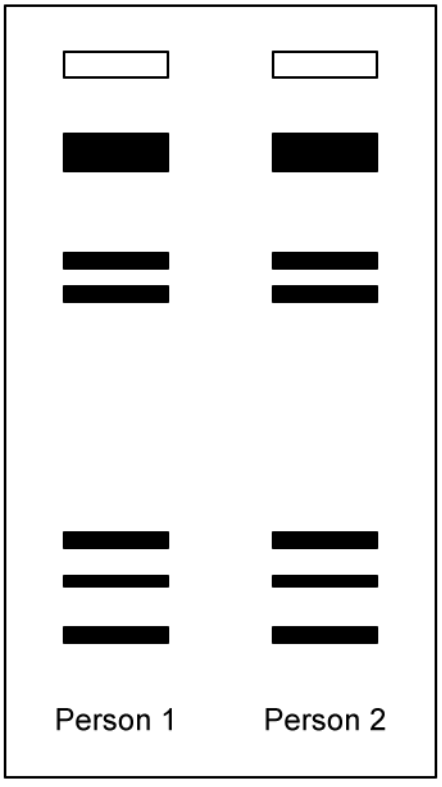
(1 mark)

(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.

.....

(1 mark)

8 (a) During electrophoresis, molecules travel through an agarose gel.

State **two** properties of the molecules that determine how far through the gel they can travel.

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(2 marks)

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

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(3 marks)

Medium Questions

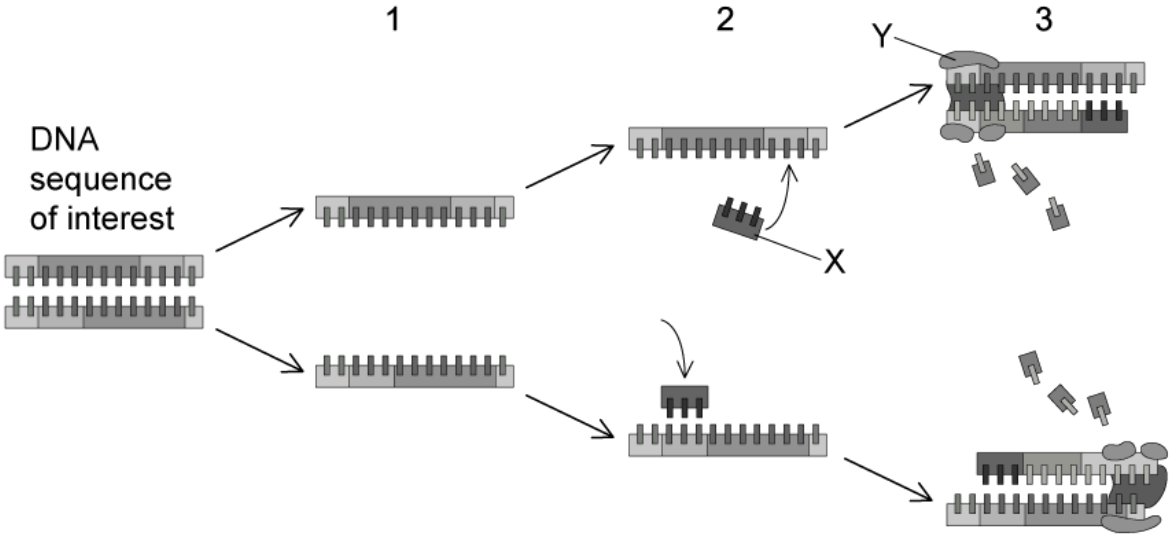
1 (a) Describe the structural features of a DNA molecule.

(4 marks)

(b) Describe the process of semi-conservative replication of DNA in eukaryotes. In your answer, include details of any molecules, bonds or enzymes involved.

(8 marks)

2 (a) The diagram below shows one cycle of the polymerase chain reaction (PCR).



Outline the events that are taking place during stage 1 in the diagram.

(3 marks)

(b) Molecule **X** in the diagram shown in part (a) is a DNA primer.

State the role of a DNA primer in PCR.

(1 mark)

(c) Stage 3 in PCR involves an enzyme.

Explain how the enzyme is suitable for its role in PCR.

(2 marks)

(d) State **two** applications of PCR.

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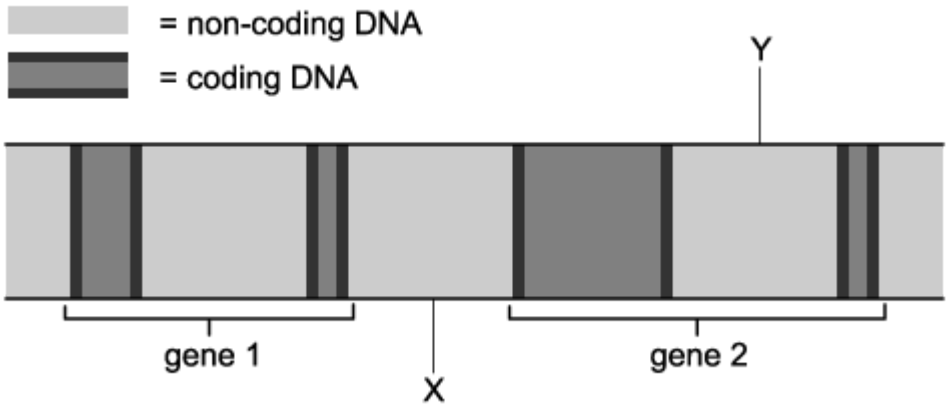
(2 marks)

3 (a) The diagram below illustrates a small section of a DNA molecule from the nucleus of a eukaryotic cell.



State the structures labelled **X** and **Y**.

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(2 marks)

(b) A repetitive sequence of DNA occurs at the ends of eukaryotic chromosomes, called a telomere.

Explain the role of a telomere.

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(2 marks)

(c) Most of the DNA in an organism is contained within the nucleus. Some of this DNA is unique, whilst some is made up of highly repetitive sequences.

Contrast unique and highly repetitive sequences of DNA

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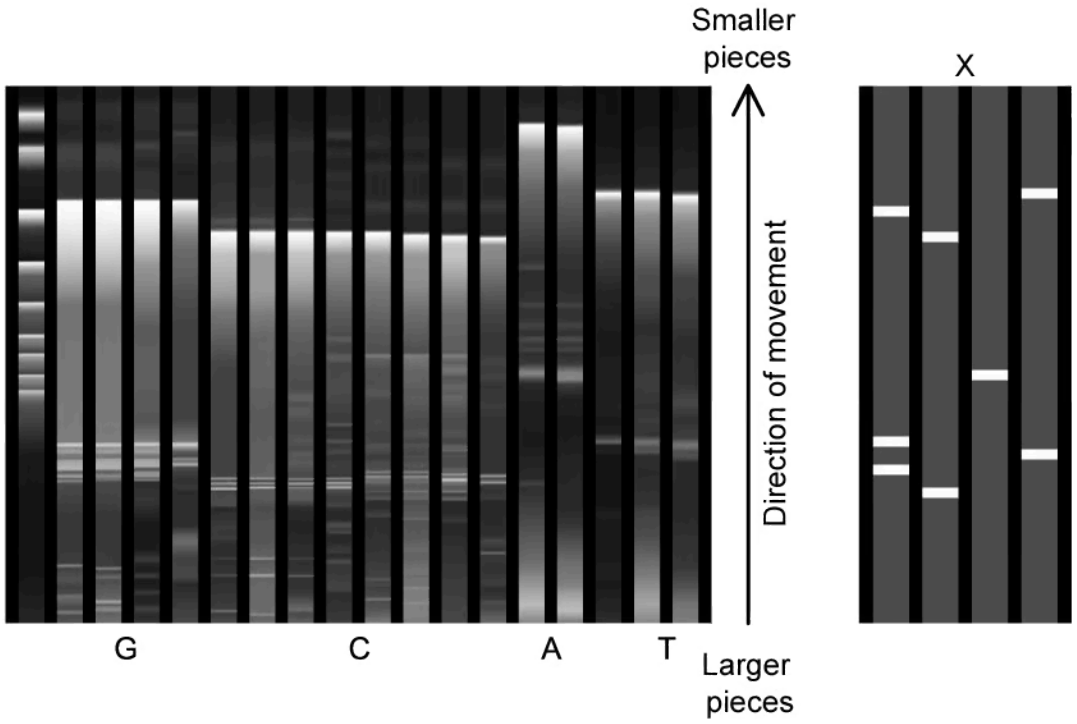
(3 marks)

(d) DNA was originally thought of as a protein. In the 1950s, Alfred Hershey and Martha Chase showed that DNA is a factor of heredity responsible for carrying genetic information from one generation to another.

Describe their experiment.

(3 marks)

4 (a) The chain termination process can be used to identify the sequence of base pairs.



Use the image above to identify the order of bases, starting with the smallest, in the block of DNA labelled X, on the right.

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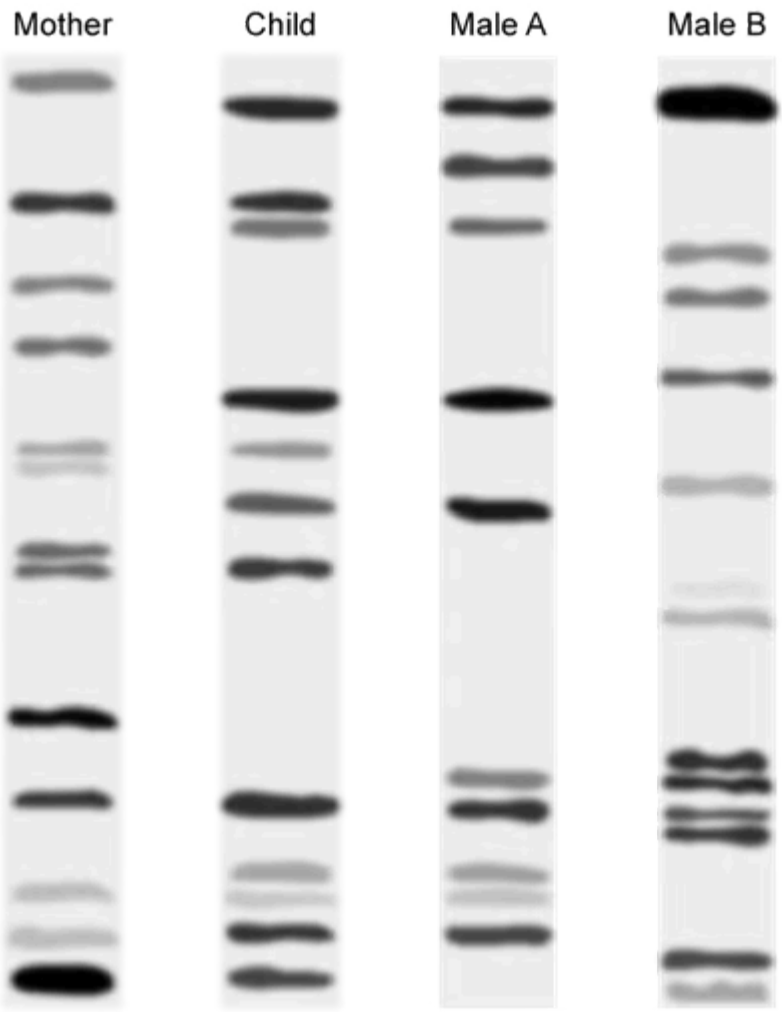
(1 mark)

(b) Results from a paternity test using gel electrophoresis are shown in the image below. DNA was isolated from a mother, her child and two potential fathers. Primers designed to amplify different satellite DNA regions were used and amplified alleles are shown in the results below.



Use the gel electrophoresis DNA profiles in the image above to determine which male is the child's father.

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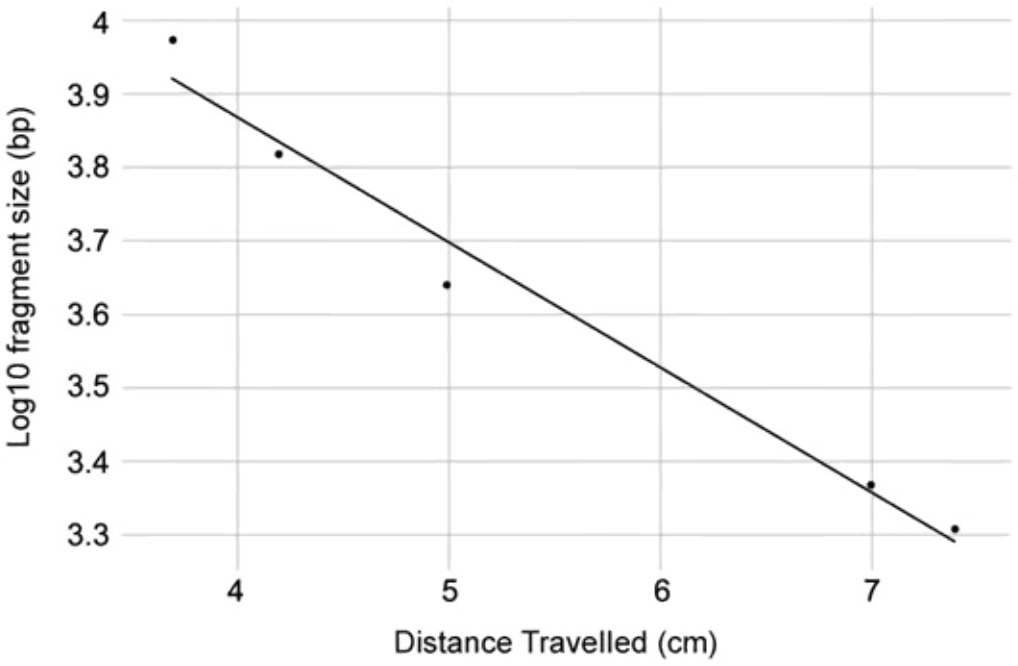
(1 mark)

(c) The DNA fragments separated in the gel electrophoresis in part (c) vary in size from 100 bp (base pairs) up to 5 000 bp. DNA fragments of known size were used to create the plot shown in the graph below.



Use the line of best fit on the graph to determine the base pair length for DNA fragments that travelled 5 cm on the gel electrophoresis plate. Give answers to the nearest whole number.

(2 marks)

(d) Outline the steps of DNA replication at a replication fork, describing the role of each of the enzymes involved.

(6 marks)

5 (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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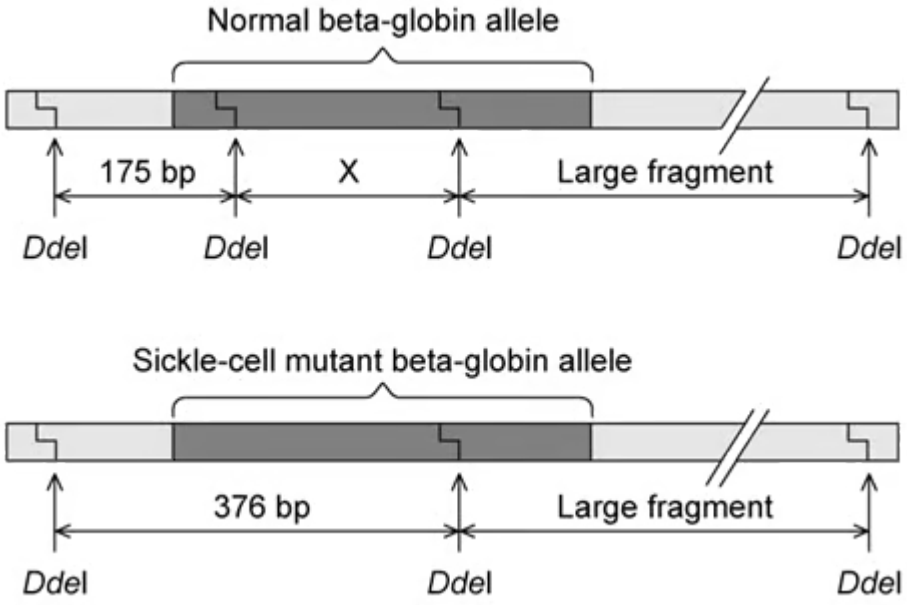
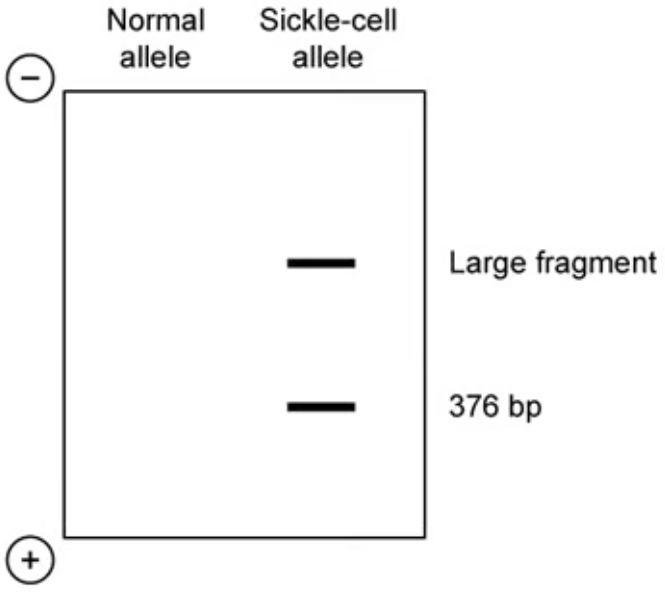
(1 mark)

(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 *Dde*I 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) *Dde*I 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.



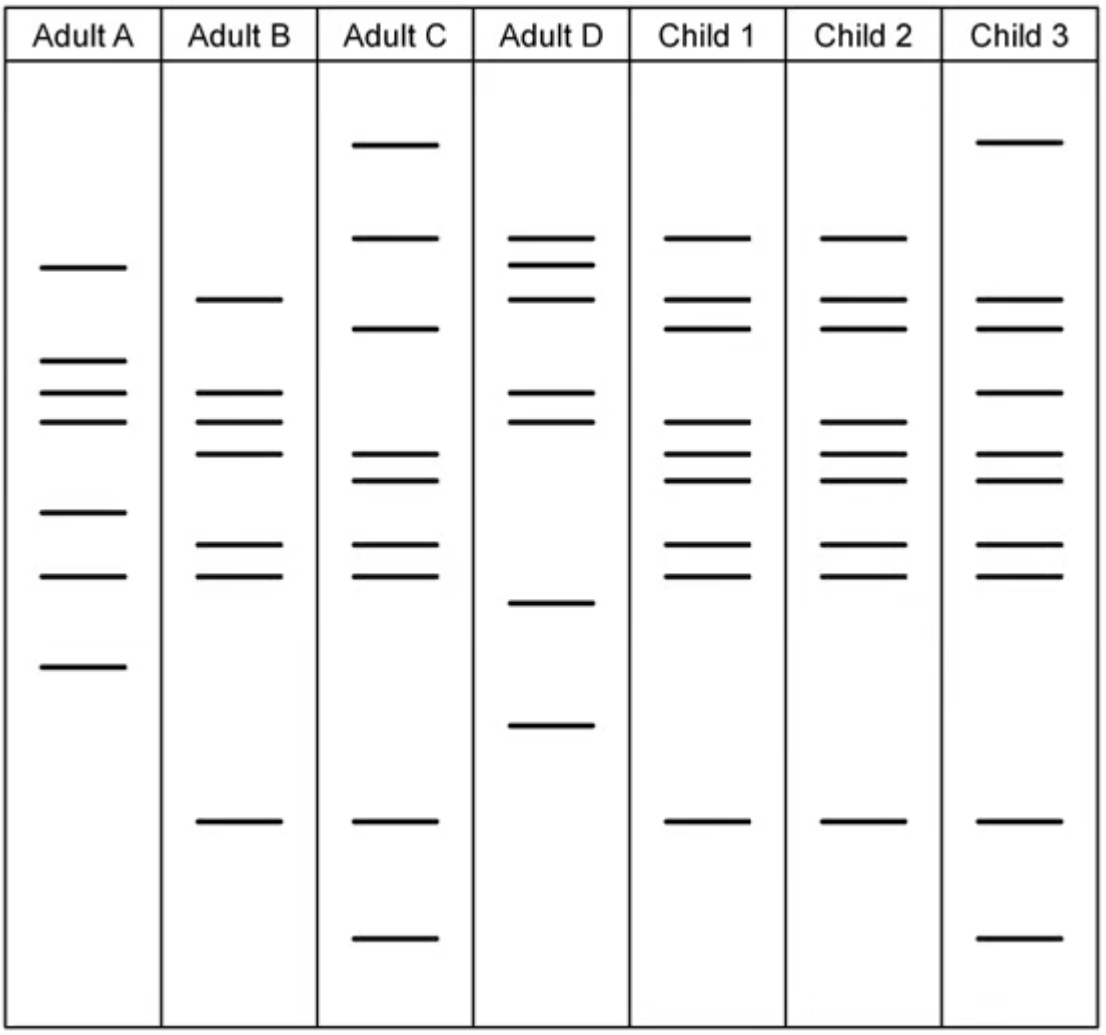
(3 marks)

6 (a) 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.

(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.



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.

(7 marks)

Hard Questions

1 (a) Explain why only bases that are complementary to the bases on the template strand can be added to the new DNA strand during DNA replication.

(2 marks)

(b) Ultraviolet exposure can cause guanine to be oxidised to 8-oxyguanine, which is no longer complementary to cytosine. Instead, during replication, 8-oxyguanine can form bonds with adenine, resulting in a base pair.

Outline the possible consequences of this change.

(3 marks)

(c) In the absence of mutagens, the rate of mutations during DNA replication is very low, approximately 160 bases per cell cycle.

Given that the human genome contains 3.2 billion base pairs, calculate the percentage copying error rate of each cell cycle.

(1 mark)

(d) Discuss the formation of Okazaki fragments during the process of replication on the lagging strand of a DNA molecule.

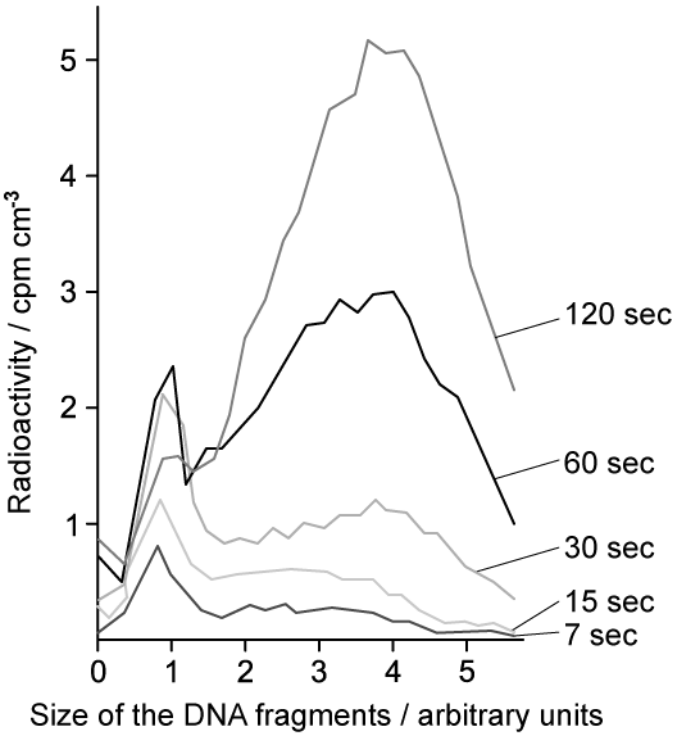
(5 marks)

2 (a) A group of scientists studied the replication of DNA in *Escherichia coli* bacteria.

During their investigation, radioactive nucleotides were added to DNA that was actively replicating in a short pulse of about 5 seconds. This allowed the radioactive nucleotides to be incorporated into the new DNA strands.

This was followed by a "chase" period, during which an abundance of unlabelled nucleotides was added to the DNA for different amounts of time, between 7 and 120 seconds. After the isolation and centrifugation of the DNA molecules, the results were obtained.

The graph below shows the results of their investigation.



Contrast the results obtained at a "chase" period of 7 seconds with those obtained at 120 seconds.

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(2 marks)

(b) Explain the results obtained at a "chase" period of 60 seconds.

(2 marks)

(c) Suggest a possible explanation for the low number of small fragments present at 120 seconds.

(1 mark)

(d) Sketch a line on the graph of the predicted results that could be obtained at a "chase" period of 150 seconds.

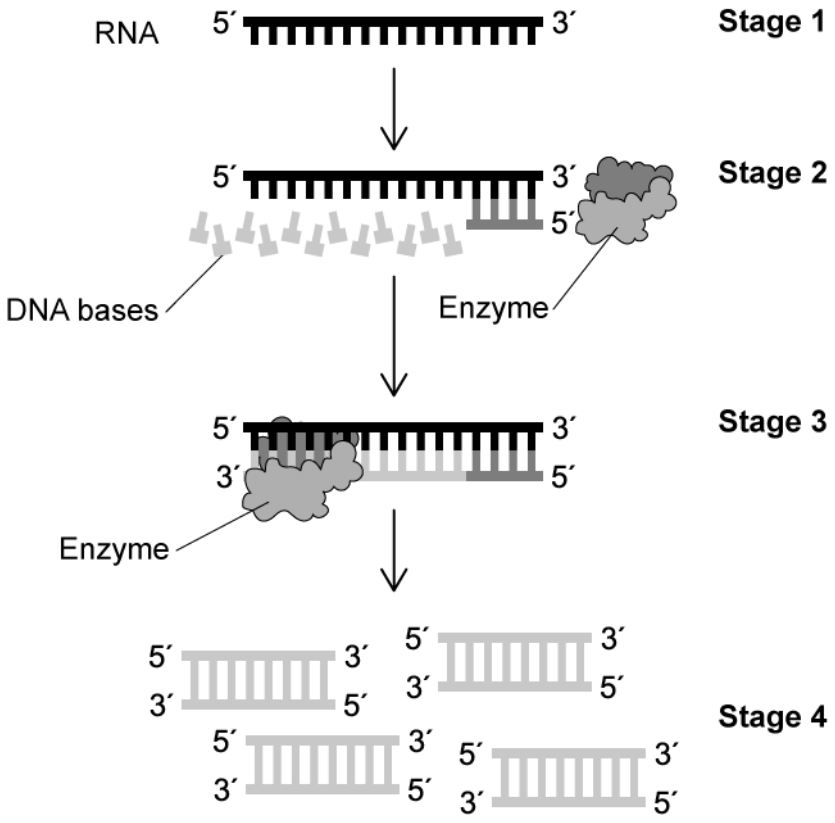
(2 marks)

3 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.

(3 marks)

4 (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.

(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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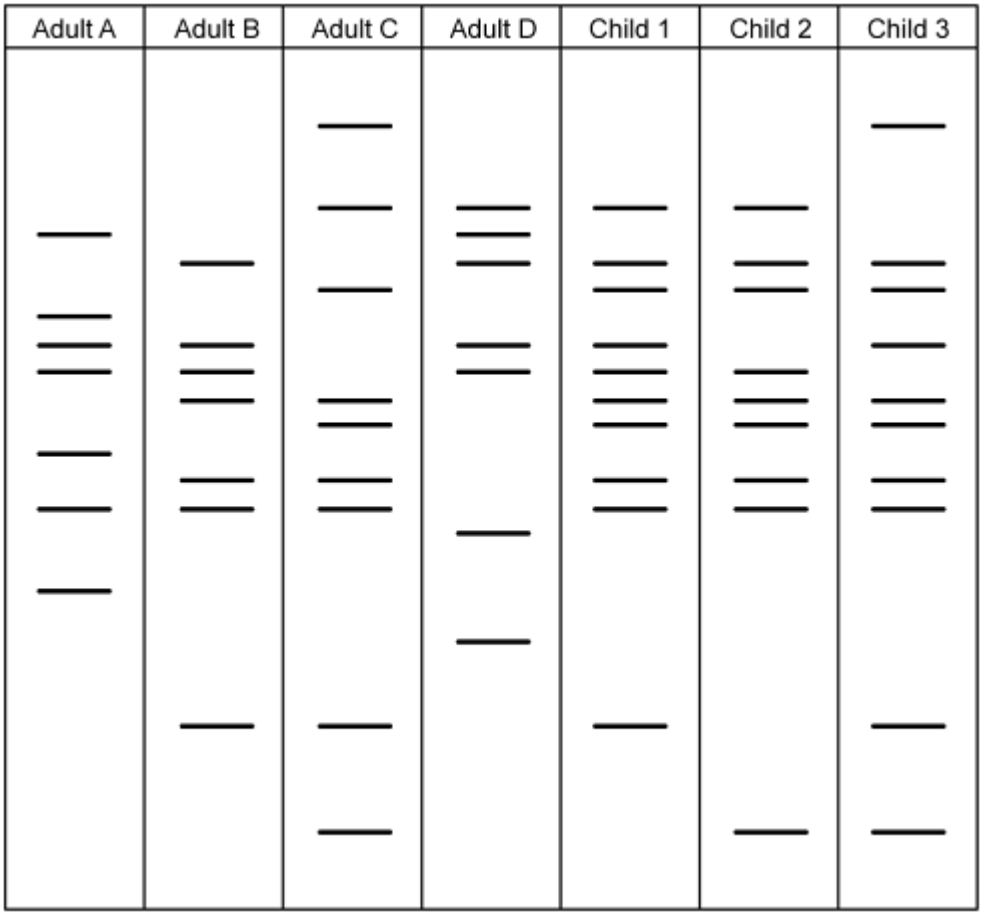
(2 marks)

(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.



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)

5 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.

(4 marks)