IB · DP · Biology

2 hours 15 questions

Structured Questions: Paper 2

2.5 Nucleic Acids: Structure & DNA Replication

2.5.1 DNA & RNA Structure / 2.5.2 DNA Replication / 2.5.3 Skills: DNA Replication

Easy (5 questions)	/37
Medium (5 questions)	/43
Hard (5 questions)	/43
Total Marks	**/123**

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Easy Questions

1 (a) Describe the main role of DNA.

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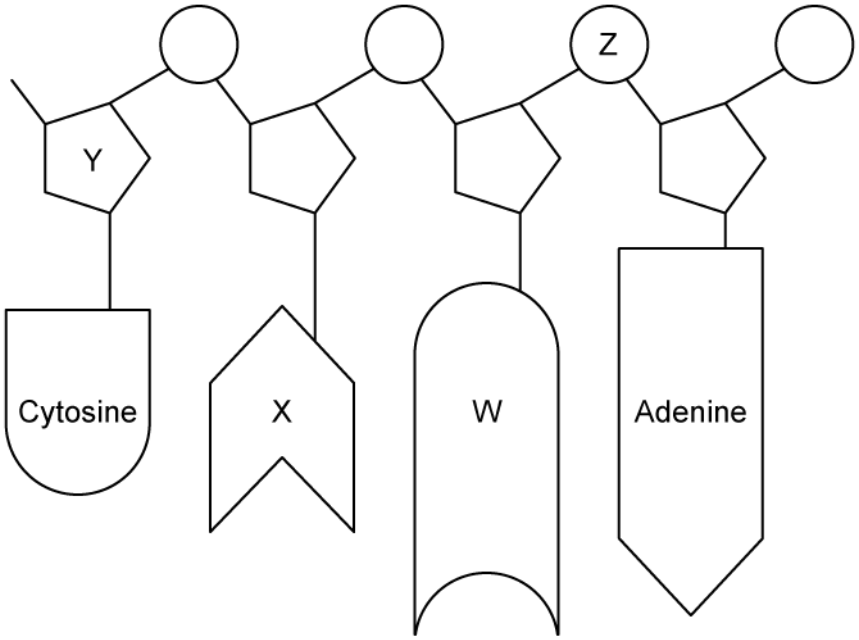
(2 marks)

(b) The image below shows a representation of several nucleotides in a molecule of DNA.



Identify the structures marked **Y** and **Z**.

.....

.....

(2 marks)

(c) Identify the nitrogenous bases in part b) marked **X** and **W**.

.....

.....

(2 marks)

(d) DNA and RNA are referred to as polynucleotides.

State the meaning of the prefix '**poly'** in the term **polynucleotide**.

.....

(1 mark)

2 (a) In a section of DNA 17 % of the nucleotides were found to contain cytosine.

Calculate the percentage of thymine in this section of DNA.

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(2 marks)

(b) State **one** reason why the calculation from part a) could not be performed for a piece of RNA.

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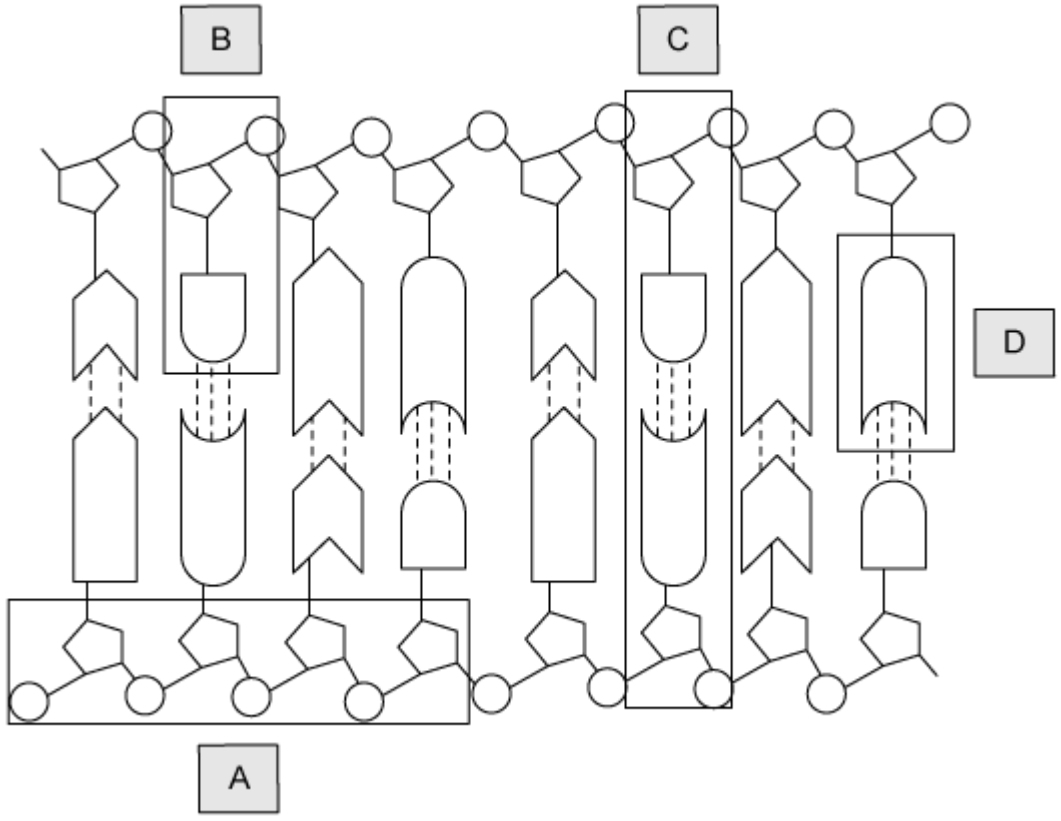
(1 mark)

(c) The diagram below shows a representation of part of a DNA molecule.



Identify the structures labelled **A, B,** and **D**.

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.....

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(3 marks)

(d) Identify **one** type of bond found within the structure labelled **C** in the diagram at part c).

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(1 mark)

3 (a) State the purpose of DNA replication.

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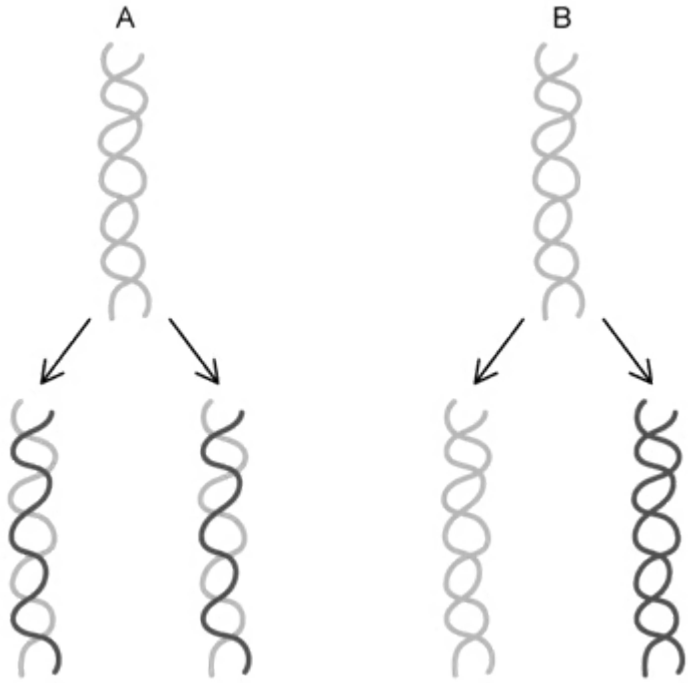
(1 mark)

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



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

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(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)

4 (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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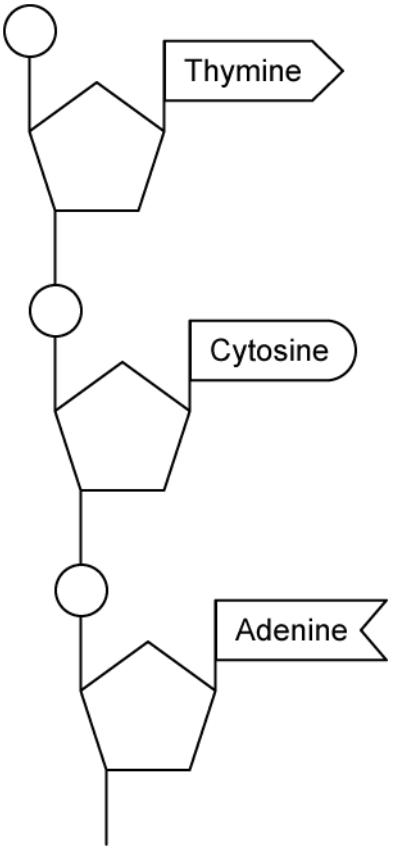
(2 marks)

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

Draw on and annotate the diagram below to show the correct structure of double-stranded DNA.



(4 marks)

(b) Compare and contrast the structures of DNA and RNA.

(5 marks)

Medium Questions

1 (a) The 3D shape of DNA is know as a double helix.

State whether it is possible for a strand of RNA to form a double helix.

.....

(1 mark)

(b) State how the two strands of the DNA molecule held together.

.....

(1 mark)

(c) State the part of a DNA molecule that contains nitrogen.

.....

(1 mark)

(d) Molecular modeling helped scientists determine the structure of DNA. Identify the two scientists credited with discovering the structure of DNA and explain why their model convinced other scientists.

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(2 marks)

2 (a) Using appropriate shapes to represent chemical structures, draw **and** label a single RNA nucleotide.

(2 marks)

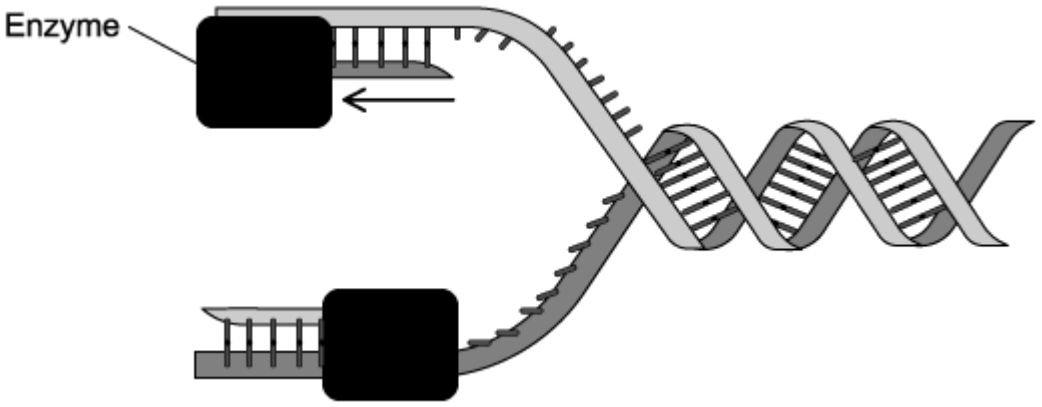
(b) A section of DNA was found to contain the following percentages of bases, as shown in the table below.

	%			
	Adenine	**Cytosine**	**Guanine**	**Thymine**
Sense strand	15			27
Antisense strand		23		

Use your knowledge of DNA structure to complete the table by filling in the missing boxes.

(2 marks)

(c) The diagram below shows DNA replication.



Identify the enzyme shown in the diagram and describe its function.

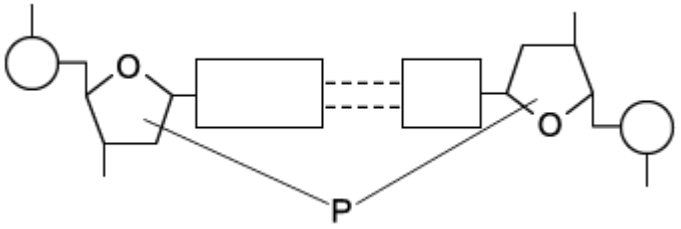
(3 marks)

(d) Indicate with a tick or ticks (✓) in the table below the chemical group(s) that appear(s) at the two ends of a single strand of DNA.

	Deoxyribose sugar	Phosphate
3' (3-prime) end		
5' (5-prime) end		

(1 mark)

3 (a) The diagram below shows a base pair within a molecule of DNA.



Identify part **P** of this section of DNA

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(1 mark)

(b) Scientists sequenced the gene for a hormone, in order to understand more about why some individuals stop producing this hormone. The scientists determined that the gene consisted of 1 500 base pairs; 30% of the total bases were cytosine.

How many nucleotides of adenine and guanine were there in this sample of DNA?

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(2 marks)

(c) Describe the conventional numbering system for carbon atoms in a pentose sugar such as the ribose or deoxyribose sugars found in RNA and DNA. You may sketch a diagram to illustrate your answer.

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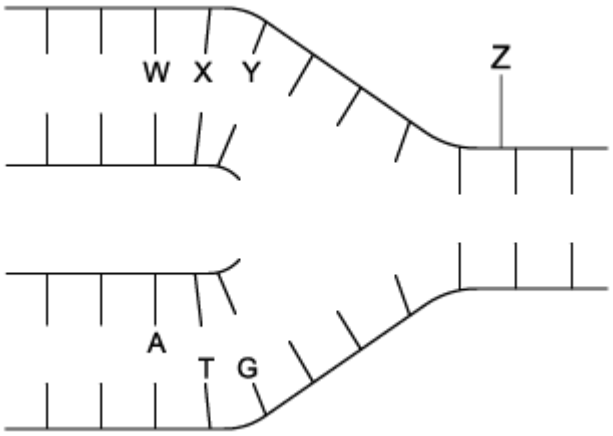
(3 marks)

4 (a) The diagram below shows the process of DNA replication. The horizontal lines represent the positions of bases.



Identify the parts of the DNA molecule represented by the labels **W, X, Y** and **Z**.

.....

.....

(2 marks)

(b) The table shows the percentage of different bases in the DNA of some organisms.

Organism	Percentage of each base			
	Adenine	Guanine	Cytosine	Thymine
Human	32.8	17.2	17.2	32.8
Caterpillar	33.1	16.9	16.9	33.1
Mouse		22.4		
Virus	24.7	24.1	18.5	32.7

Calculate the missing figures for mouse DNA and complete the table.

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.....

(2 marks)

(c) Humans and caterpillars have very similar percentages of each base in their DNA but are not the same class of organism.

Use your knowledge of DNA structure and function to explain how this is possible.

(3 marks)

(d) The DNA of the virus is different from that of the human, caterpillar and mouse. Some viruses contain single-stranded DNA that is not base-paired to a complementary strand. Use data from the table in question 4b) to show evidence for this difference.

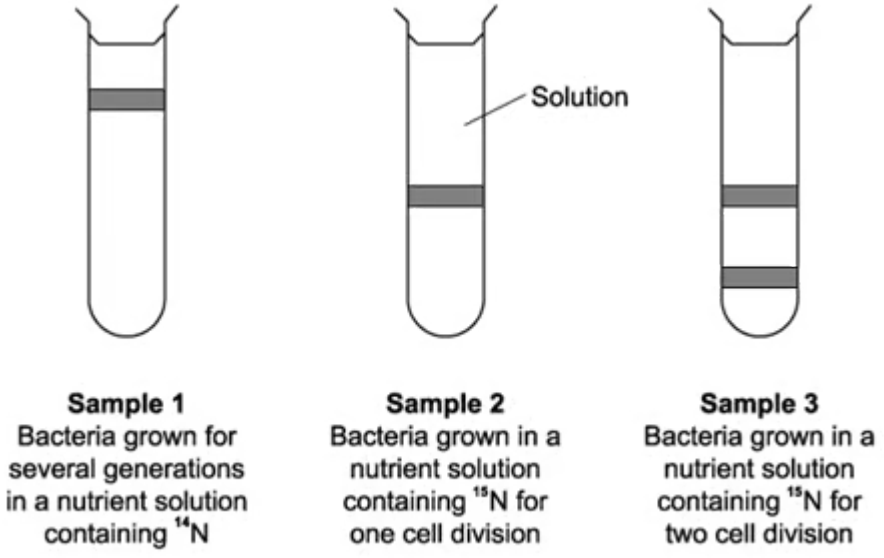
(2 marks)

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

Describe the structural features of a DNA molecule.

(4 marks)

(b) Meselson and Stahl grew bacteria for several generations in a solution containing light nitrogen (^{14}N) and obtained DNA from a sample of these bacteria (Sample **1**).They then transferred the bacteria to a solution containing heavy nitrogen (^{15}N). This step of the process was timed so that the bacteria were allowed to grow and divide twice. After each division, they obtained DNA from a sample of bacteria (Samples **2** and **3**).The DNA from each sample of bacteria was suspended in a solution in separate tubes which were then spun in a centrifuge at the same speed and duration. The diagram below shows Meselson and Stahl's results.



The table below shows the types of DNA molecule that could be present in samples **1** to **3**. Complete the table with a tick (✓) if the DNA molecule is present in the sample.

Sample	Type(s) of DNA molecule present in each sample		
	^{14}N ^{14}N 	^{15}N ^{15}N 	^{15}N ^{14}N 
1			
2			
3			

(3 marks)

(c) 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)

Hard Questions

1 (a) The ends of a DNA strand are referred to as the 3′ end and the 5′ end.

Describe the aspects of DNA structure that give rise to this naming system.

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(3 marks)

(b) Adenine/thymine and guanine/cytosine form hydrogen-bonds with each other in complementary base-pairing within the DNA double helix. These bases can also form bonds with other molecules in order to carry out their function.

(i) Suggest **one** other molecule that might form bonds with the bases in a DNA molecule.

[1]

(ii) State the role of the molecule identified in part i).

[1]

.....

.....

(2 marks)

(c) The structure of DNA has many characteristics that enable it to carry out its function.

(i) Identify **two** structural features that help DNA to carry out its function.

[2]

(ii) For each feature identified at part i), explain how it assists with DNA function.

[2]

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(4 marks)

2 (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.

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(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.

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(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)

3 (a) Even the smallest DNA molecules are very long.

- A kilobase (Kb) is a unit equivalent to 1000 base pairs of a DNA molecule.
- One Kb of double stranded DNA has a length of 0.34 μm.

The DNA in the nucleus of a cell from a fruit fly (*Drosophila*) is 5.6 cm long.

Calculate the number of Kb in the DNA of the fruit fly. Give your answer to the nearest whole number.

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(2 marks)

(b) The amount of DNA found in the nucleus of cells can vary amongst people, with each human chromosome containing between 5×10^4 and 26×10^4 Kb of DNA.

Suggest **one** reason why people might have different quantities of DNA to each other.

.....

(1 mark)

(c) Other than for use in replication, explain **one** advantage of DNA molecules having two strands.

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(1 mark)

4 (a) A section of DNA contains 1,200 base pairs.

- The number of guanine molecules on strand one was counted as 156.
- The number of cytosine molecules on strand one was counted as 209.
- The number of adenine molecules on strand two was counted as 264.

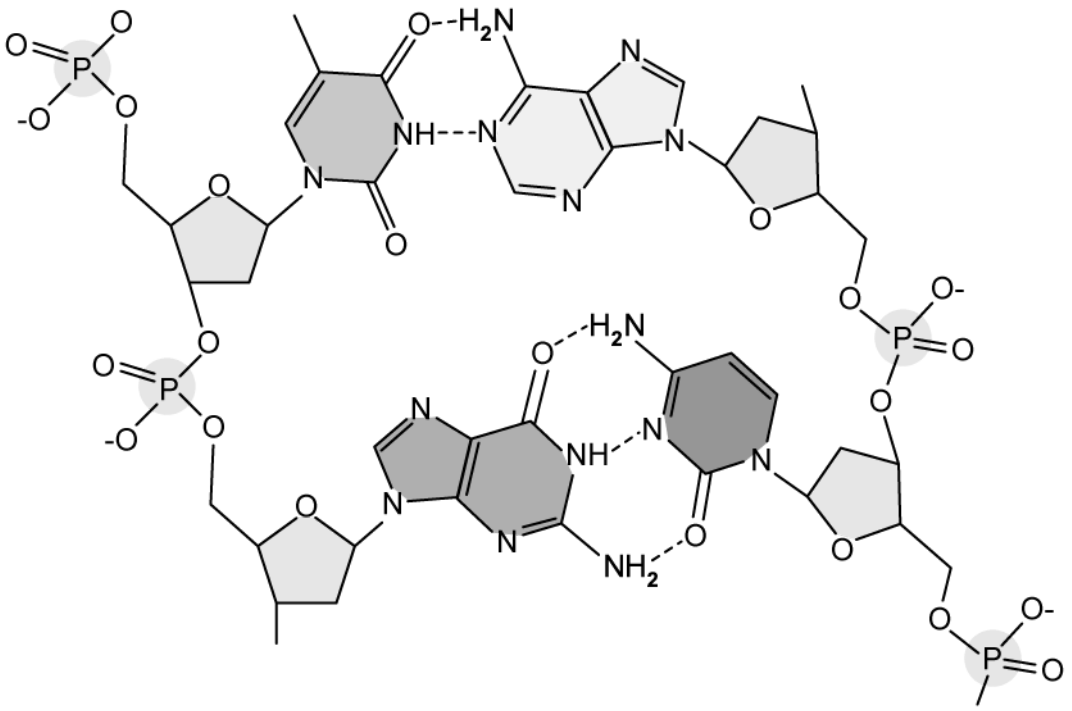
Complete the table below to include the total number of each base present in the section, and the % composition of each base.

	Number of molecules present	**% composition**
Adenine		
Cytosine		
Guanine		
Thymine		

(4 marks)

(b) The image below shows a section of the skeletal formula of a DNA molecule.

Number the carbon atoms of all the pentose sugars shown in the image using the standard numbering format.



(2 marks)

(c) The DNA nucleotides are covalently bonded together in the sugar-phosphate backbone between the pentose sugar and the phosphate group, however, they are hydrogen bonded together between the bases.

Explain why both types of bonds are important for the functioning of DNA.

(2 marks)

(d) During DNA replication both DNA strands act as a template, whereas in transcription only one strand acts as a template.

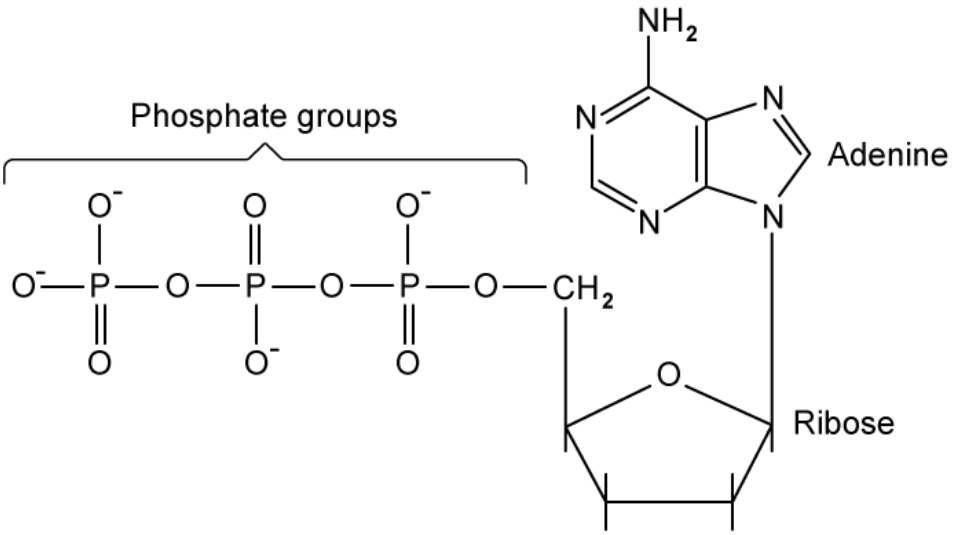
Outline what is meant by the word 'template' in this context.

(1 mark)

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

ATP is a source of energy used in cells and is produced from processes such as respiration.

The structure of ATP is shown in the diagram below.



Use the information in the diagram, as well as your own knowledge, to compare and contrast the structure of ATP with an adenine DNA nucleotide.

(4 marks)

(b) Explain how the structure of DNA allows replication.

(4 marks)

(c) Outline the steps in the experiment that Meselson and Stahl carried out to determine the semi-conservative nature of DNA replication.

(7 marks)