6. Nucleic Acids and Protein Synthesis

6.1 Structure of Nucleic Acids and Replication of DNA

Paper 2

Question Paper

1 During transcription, base pairing occurs between nucleotides.

Fig. 3.1 is a diagram to show complementary base pairing between a DNA nucleotide and an RNA nucleotide.

Only the base pair is shown in molecular detail.

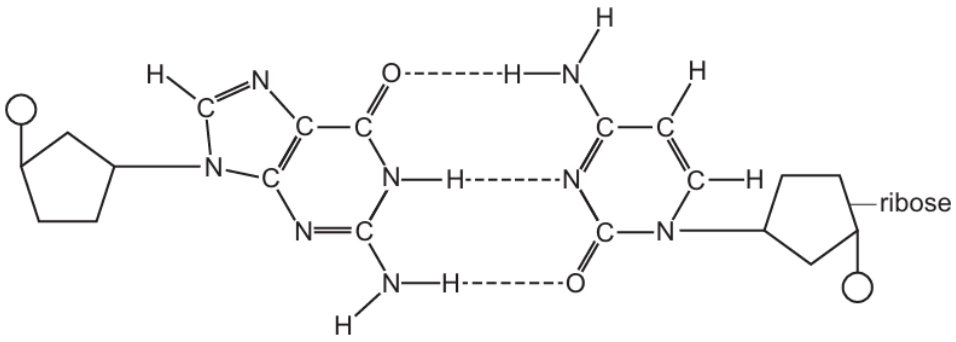


Fig. 3.1

(a) Explain why Fig. 3.1 does **not** include any phosphodiester bonds.

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..... [1]

(b) Identify **and** describe the DNA-RNA nucleotide pair shown in Fig. 3.1.

You may add labels and annotations to Fig. 3.1 if you wish.

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..... [4]

2 Nucleotide and nucleoside analogues are therapeutic drugs that have a similar structure to nucleotides or nucleosides of RNA and DNA.

A nucleoside is composed of a nitrogenous organic base (base) and a pentose sugar.

(a) The names of the bases present in RNA and DNA nucleotides can be abbreviated using a single letter. These are shown in Table 5.1.

Complete Table. 5.1 by stating:

- the name of each base
- whether the base is a purine **or** pyrimidine
- whether the base is present
  - **only** in an RNA molecule (write **RNA** in the table)
  - **only** in a DNA molecule (write **DNA** in the table)
  - in RNA **and** in DNA molecules (write the word **both** in the table).

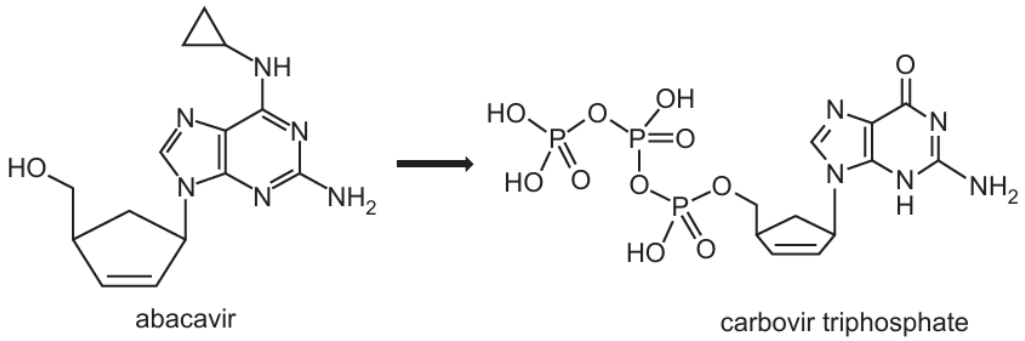
Table 5.1

base	name of base	purine or pyrimidine	present in RNA, DNA, or both
A			
C			
G			
T			
U			

[4]

(b) Abacavir is an analogue drug used in the treatment of some viral diseases. It enters a cell infected by a virus and is metabolised to the analogue carbovir triphosphate.

Fig. 5.1 shows the molecular structure of abacavir and carbovir triphosphate.



abacavir carbovir triphosphate

Fig. 5.1

Carbovir triphosphate can be inserted into an elongating polynucleotide chain instead of a nucleotide. This interferes with the action of DNA polymerase during the synthesis of viral DNA.

(i) With reference to Fig. 5.1, explain whether carbovir triphosphate will replace a purine or a pyrimidine nucleotide in the elongating polynucleotide chain.

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(ii) With reference to Fig. 5.1 **and** the action of DNA polymerase, suggest why the conversion of abacavir to carbovir triphosphate increases the chance of the analogue being added to the viral polynucleotide chain.

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(iii) Suggest **and** explain how carbovir triphosphate interferes with the action of DNA polymerase **and** how this may prevent the synthesis of viral DNA.

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..... [4]

3 The gene for the enzyme catalase is on chromosome 11 in humans.

(b) Two enzymes, DNA polymerase and DNA ligase, are involved in the replication of DNA.

Fig. 4.1 shows the replication of part of human chromosome 11 by DNA polymerase. The arrows show the direction of synthesis of the new polynucleotides by DNA polymerase.

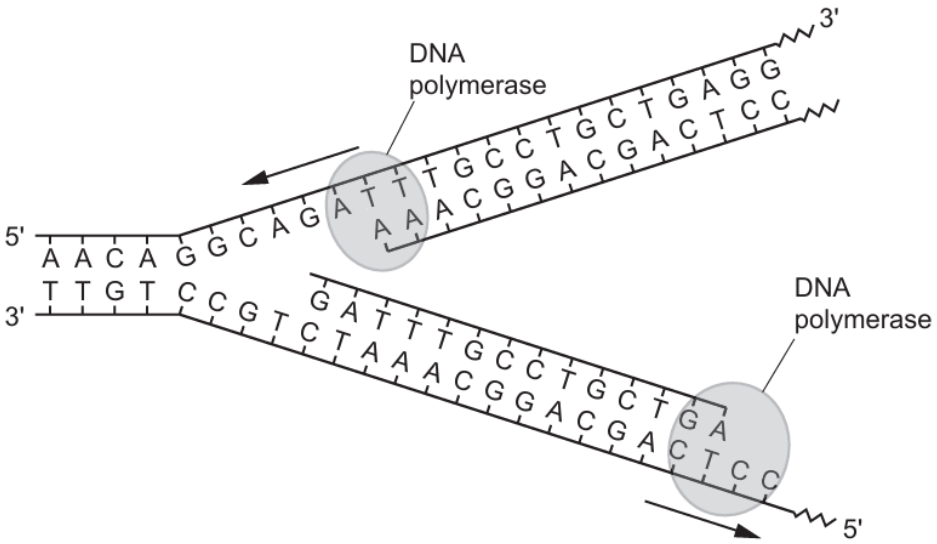


Fig. 4.1

(i) Describe the roles of DNA polymerase and DNA ligase in the replication of DNA.

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4 **(a)** **(i)** State the name of the phase of the mitotic cell cycle during which DNA replication occurs.

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(ii) During research, scientists can use modified nucleotides to prevent elongation of a polynucleotide chain during DNA replication.

Fig. 6.1 shows the structure of a DNA nucleotide found in the nucleus of a cell.

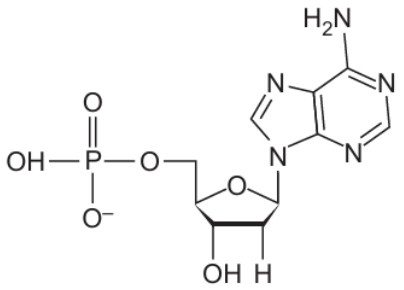


Fig. 6.1

Fig. 6.2 shows the structure of a modified nucleotide.

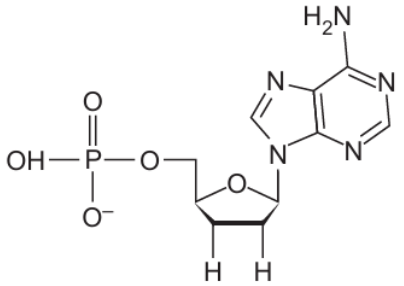


Fig. 6.2

Suggest how the structure of the modified nucleotide prevents DNA polymerase joining it to another nucleotide.

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..... [2]

5 Cotransporter proteins are membrane proteins found in companion cells of phloem tissue.

Messenger RNA (mRNA) is the molecule in cells that carries genetic information in the DNA that codes for cotransporter proteins to the sites of protein synthesis in the cytoplasm.

(a) Complete Table 6.1 to compare the structure of a molecule of mRNA with the structure of a molecule of DNA.

Table 6.1

feature	**mRNA**	**DNA**
names of four bases		
name of pentose sugar present		
number of strands		

[3]

6 Human cytomegalovirus (HCMV) is a common virus affecting humans. In people with a fully functioning immune system, infection by HCMV usually causes no, or only mild, symptoms.

Fig. 2.1**A** is a diagram of a section through HCMV. In Fig. 2.1**B**, only the outer part of HCMV is sectioned.

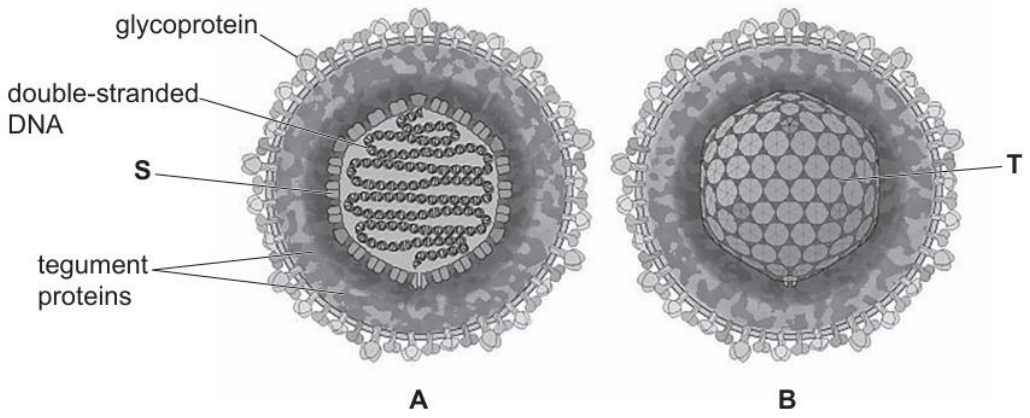


Fig. 2.1

The viral DNA shown in Fig. 2.1 contains genes that code for proteins important in viral replication and viral structure, including viral DNA polymerase and proteins known as tegument proteins.

Viruses can only replicate in host cells as they need to use processes and contents of the host cell. Complete viral particles that are released from the host cell are known as virions.

(c) Suggest the role of viral DNA polymerase within the host cell.

..... [1]

7 Carbonic anhydrase is a globular protein found in red blood cells.

(b) A protein such as carbonic anhydrase is coded for by a gene. A gene forms part of a DNA molecule.

Fig. 3.1 is a diagram of a small section of a DNA molecule.

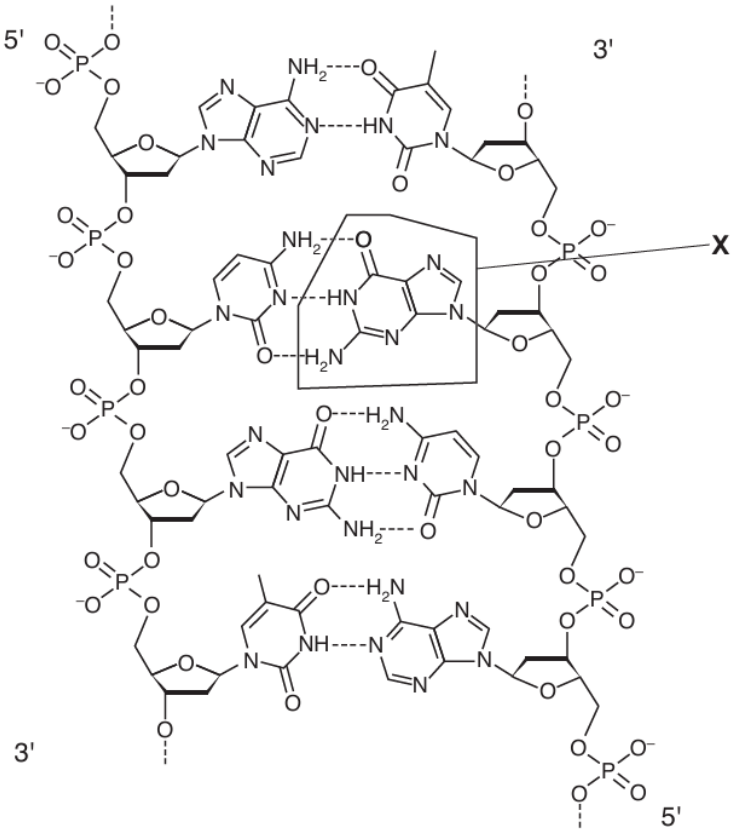


Fig. 3.1

(i) Identify the base **X and** state the evidence in Fig. 3.1 that supports this identification.

base **X** .....

evidence from Fig. 3.1 .....

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[3]

8 **(b)** Semi-conservative replication of DNA occurs during interphase, before mitosis begins.

Write the correct term in the spaces provided to complete each of statements **A** to **D**.

A The DNA double helix unwinds and is separated into two template strands when ..... bonds holding the two strands together are broken.

B One of the template strands of DNA is copied in fragments. The enzyme ..... is required to join the fragments together to form a continuous strand of DNA.

C Complementary DNA nucleotides are added to the template strands, catalysed by the enzyme ..... .

D ..... are regions of repeating nucleotide sequences at the ends of chromosomes that allow the continued replication of DNA, without the loss of genes.

[4]

9 The causative organism of measles is *Morbillivirus*. Young children who have not been vaccinated for measles are at highest risk of becoming ill and of developing complications associated with the disease.

(a) The genetic material of *Morbillivirus* is a strand of RNA.

Statements **A**, **B** and **C** relate to the structure of RNA.

State the correct term or terms to match each of statements **A** to **C**.

A The names of the two purines and two pyrimidines in RNA.

purines .....

.....

pyrimidines .....

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B The type of covalent bond between RNA nucleotides.

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C The pentose sugar of the RNA nucleotide.

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[4]

10 **(a)** Fig. 4.1 is a drawing made by a student of a plant cell, showing one of the stages of mitosis.



Fig. 4.1

(ii) The chromosomes are composed of DNA.

Describe the structure of a monomer of a DNA molecule.

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..... [2]

11 In most plants, sucrose is the main sugar that is transported from sources to sinks.

(b) Fig. 5.1 shows part of one pathway that is used in plant cells to synthesise sucrose. The enzyme sucrose synthase catalyses the transfer of glucose from UDPG (uridine diphosphate glucose) to fructose.

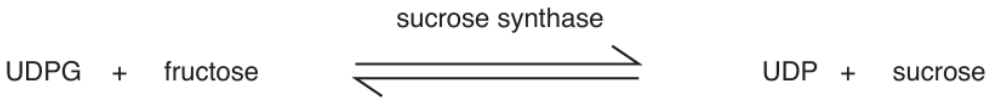


Fig. 5.1

The structure of UDPG is shown in Fig. 5.2.

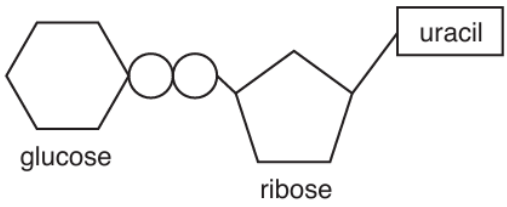


Fig. 5.2

(ii) Explain why UDP can be described as a phosphorylated nucleotide.

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..... [2]

12 Fig. 6.1 shows the formation of a polypeptide during translation in a eukaryotic cell.

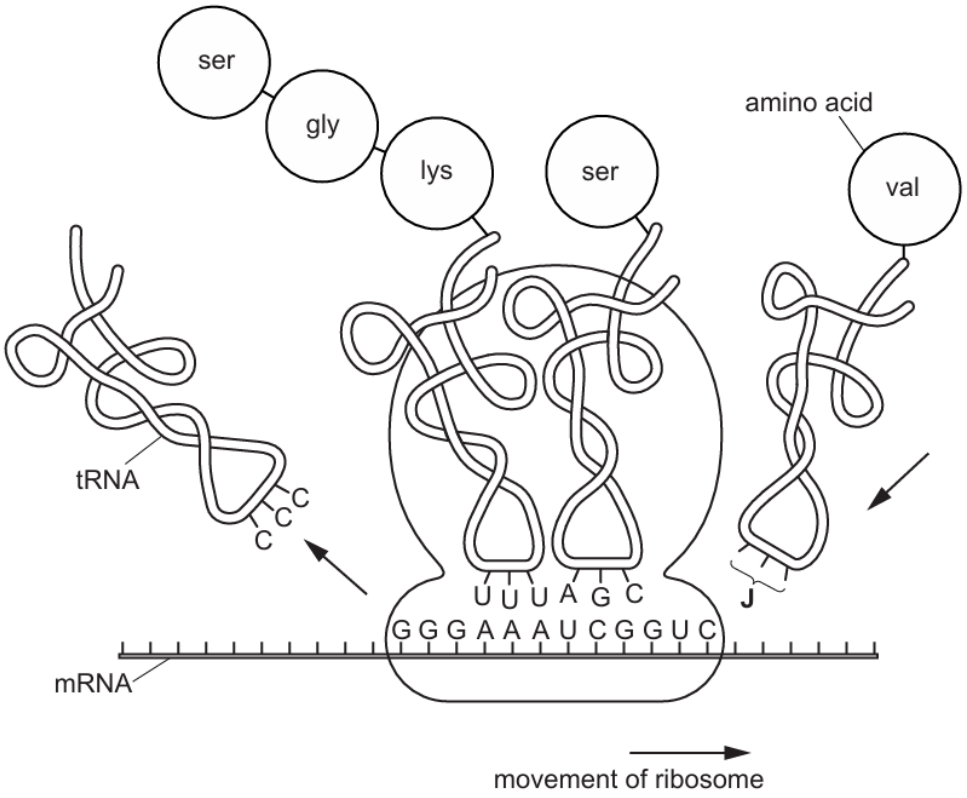


Fig. 6.1

(a) Name the purine bases shown in Fig. 6.1.

..... [1]

13 **(a)** Outline the role of DNA polymerase in the replication of DNA.

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..... [3]

14 Carbohydrates, proteins and nucleic acids are types of biological molecule. Within each type, there are examples of molecules that can be described as polymers.

(c) Polymerisation of DNA nucleotides occurs during the semi-conservative replication of a molecule of DNA during interphase.

Describe the semi-conservative replication of DNA.

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..... [5]

15 **(a)** The DNA in the nucleus is known as nuclear DNA.

(i) In the cells of the grasshopper, *Chorthippus brunneus*, 20% of the nucleotides in nuclear DNA contain thymine.

Calculate the percentage of nucleotides in the nuclear DNA of *C. brunneus* that contain guanine **and** explain your answer in terms of the structure of DNA.

percentage .....

explanation .....

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..... [3]

16 In 1953, James Watson and Francis Crick published details about the structure of DNA. They used experimental results from other scientists to help them work out the structure and then built a model of a section of a DNA molecule, using pieces of wire and metal, with clamp stands to hold the model in place. This is shown in Fig. 2.1.

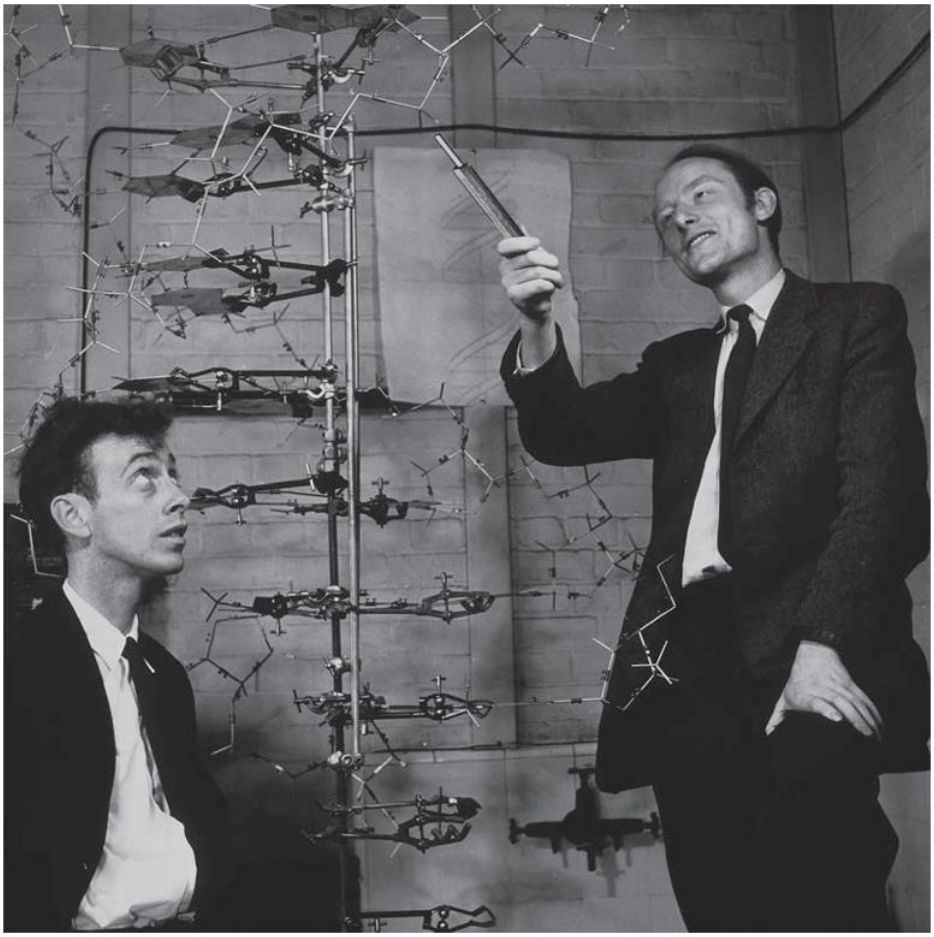


Fig. 2.1

(a) Watson and Crick used results from work carried out by Erwin Chargaff. He found that the proportions of the bases A, T, C and G were different in different species, but **within** each species:

- the proportion of A was equal to the proportion of T
- the proportion of G was equal to the proportion of C.

(i) Name the bases A, T, G and C.

A .....

T .....

G .....

C .....

[2]

(ii) Suggest **and** explain how Chargaff's findings helped Watson and Crick work out the structure of DNA.

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.....[3]

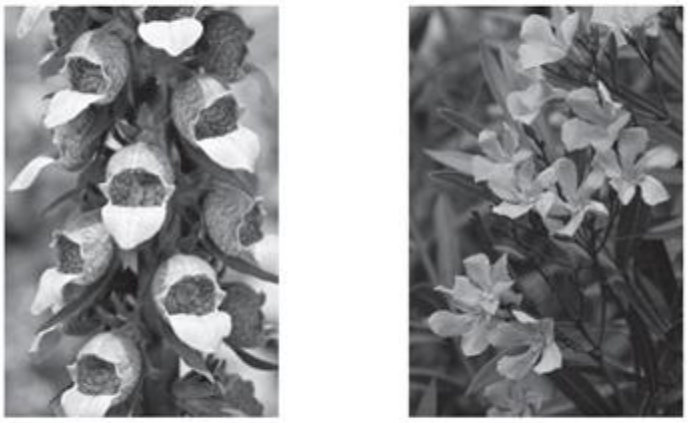
(b) Phoebus Levene isolated the nucleotides of DNA and identified the carbohydrate component of each nucleotide.

State the name of this carbohydrate component.

.....[1]

17 Woolly foxglove, *Digitalis lanata*, shown in Fig. 2.1**A**, and common oleander, *Nerium oleander*, shown in Fig. 2.1**B**, are plants grown for the attractive flowers that they produce.

Both plants are poisonous, as their leaves produce toxic organic compounds known as cardiac glycosides. Cardiac glycosides have a powerful effect on the action of cardiac muscle.



A B

Fig. 2.1

Cardiac glycosides have an effect on the movement of ions into and out of cardiac muscle cells. The outcome is an increased ability for the cells to contract.

(c) Investigations into the action of the cardiac glycoside oleandrin, extracted from *N. oleander*, have shown that it acts to prevent the correct functioning of Na/K-ATPase, a membrane transport protein.

Na/K-ATPase has a role as an enzyme **and** as a transport molecule.

- ATPase is an enzyme that catalyses the hydrolysis of ATP to ADP and inorganic phosphate.
- Energy released from this hydrolysis is used to transport sodium ions (Na^+) out of cardiac muscle cells and potassium ions (K^+) into the cells.

(i) Explain what is meant by the *hydrolysis of ATP*.

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..... [2]

18 DNA and RNA are nucleic acids.

(c) Nucleotides are structural components of nucleic acids. Each nucleotide consists of a pentose sugar, a phosphate group and a nitrogenous organic base.

Complete Table 5.1 to compare DNA nucleotides with RNA nucleotides as structural components of nucleic acids.

Table 5.1

feature	DNA nucleotides	RNA nucleotides
pentose sugar component		
purine bases		
pyrimidine bases		

[3]

19 **(c)** DNA and RNA both contain nucleotides with adenine.

Complete Table 5.1 to compare:

- a DNA nucleotide with adenine
- an RNA nucleotide with adenine
- ATP.

Table 5.1

feature	DNA nucleotide with adenine	RNA nucleotide with adenine	ATP
contains nitrogen (yes or no)			
contains a pyrimidine base (yes or no)			
number of phosphate groups			
name of the sugar component			

[5]