# Nucleotides & Nucleic Acids

## Model Answers 1

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|---|---|
| Level | A Level |
| Subject | Biology |
| Exam Board | OCR |
| Module | Foundations in Biology |
| Topic | Nucleotides & Nucleic Acids |
| Booklet | Model Answers 1 |

**Time allowed:** **62 minutes**

**Score:** **/46**

**Percentage:** **/100**

**Grade Boundaries:**

| A* | A | B | C | D | E |
|---|---|---|---|---|---|
| >69% | 56% | 50% | 42% | 34% | 26% |

## Question 1

Fig. 24 shows a DNA nucleotide.

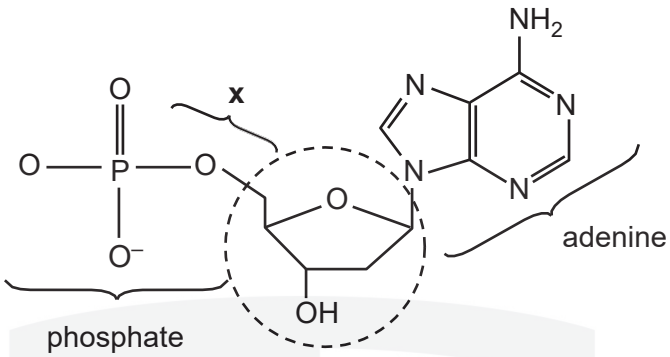



**Fig. 24**

**(a) (i)** Name the circled component in Fig. 24. **[1]**

deoxyribose

Note the question refers to DNA

**(ii)** Name the bond labelled **x** in Fig. 24. **[1]**

phosphodiester

**(b)** Identify two similarities and two differences between the DNA nucleotide shown in Fig. 24 and a molecule of ATP. **[4]**

Similarities

- Pentose sugars
- A base called adenine
- Phosphodiester bonds
- -OH / hydroxyl group on carbon 3
- Phosphate group

Differences

- ATP has two additional phosphates
- Deoxyribose is replaced by ribose
- ATP has –OH on carbon 2 or the sugar is ribose

It's important to realise that ATP and the nucleotide have a lot in common **[Total: 6]**

## Question 2

Semi-conservative replication describes the process by which DNA is replicated in all living organisms.

**(a) (i)** Explain the meaning of the phrase *semi-conservative replication*. **[1]**

- The DNA made as a result of semi conservative contains one old/original strand and one new strand.

The strong advice here is to avoid the word 'half' at all costs. Examiners will not allow it!

In this context 'conservative' means to conserve or to keep, so the DNA created 'keeps' an original strand.

**(ii)** DNA ligase is one enzyme involved in the replication of DNA.

State **two** other enzymes involved and describe their functions. **[4]**

- DNA helicase
- Splits the two strands apart by breaking the hydrogen bonds between the bases
- DNA polymerase
- Aligns the complementary base pairs between the nucleotides

DNA gyrase also gains a mark here, this enzyme uncoils the DNA

**(b)** In 1958, Matthew Meselson and Franklin Stahl carried out an experiment that provided evidence to support the hypothesis of semi-conservative replication of DNA.

Meselson and Stahl grew *E. coli* bacteria in a growth medium that contained only the heavy isotope of nitrogen $^{15}N$. They transferred the bacteria to a growth medium that had the light $^{14}N$ isotope and allowed the bacteria to undergo cell division.

After each division, the DNA from some of the bacteria was extracted from the culture and centrifuged to separate it. Fig. 25 shows the bands of DNA in the centrifuge tubes after a specific number of divisions.

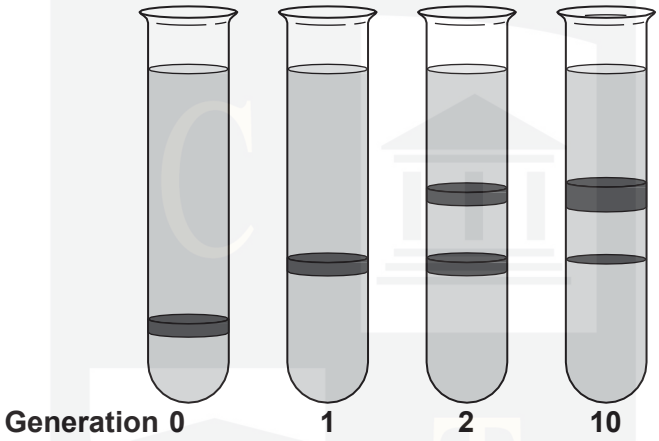
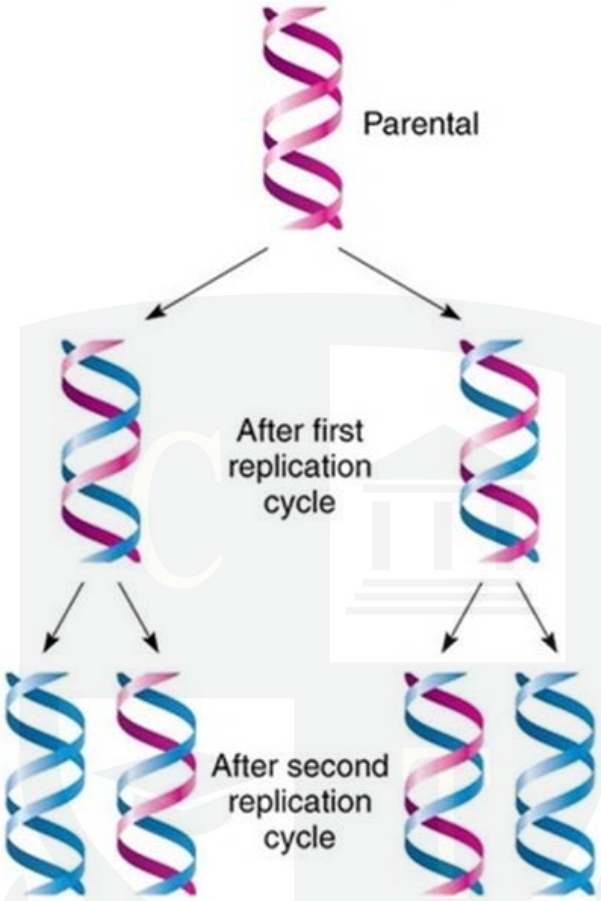



**Fig. 25**

The tube labelled **Generation 0** in Fig. 25 shows a single band of DNA containing bases that contain only the heavy isotope of nitrogen $^{15}N$.

Explain how the results from the other generations provide evidence to support the hypothesis that DNA replication is semi-conservative. **[2]**

- The DNA in generation 1 contains $N^{14}$ and $N^{15}$
- The DNA in generation 2 contains only light DNA with $N^{14}$
- So the light DNA in generation 1 must have acted as a template for the light DNA in 2
- The band of light DNA in the tube from generation 10 gets progressively thicker as more is made from light DNA




**[Total: 7]**

## Question 3

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.

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

**(i)** Calculate the number of Kb in the DNA of the fruit fly.
Show your working. Give your answer to the nearest whole number. **[2]**

164,706

5.6cm is 56mm

56mm is 56,000μm

So how many 0.34 μm are there in 56,000 μm?

56,000 ÷ 0.34 = 164,705.88 or

164,706 to the nearest whole number

**(ii)** The DNA of the fruit fly was analysed and 22% of the bases were adenine.

What % of the bases were guanine? Show your working. **[2]**

28%

22% are adenine, so by complementary base pairing 22% must be thymine.

44% of bases are A and T so 56% of bases must be guanine and cytosine.

By complementary base pairing 28% will be guanine.

(b) A DNA molecule contains polynucleotide strands.

(i) Individual nucleotides are joined together to make a polynucleotide strand.

What type of chemical reaction takes place when two nucleotides in a single polynucleotide strand are joined together?

condensation reaction **[1]**

**(ii)** Name the chemical released when the bond is formed between the two nucleotides.

water **[1]**

**(iii)** A DNA molecule contains two polynucleotide chains.

Describe how these two chains are held together. **[3]**

- The chains are held intact by phosphodiester bonds
- The strands are held together by hydrogen bonds
- Complementary base pairing, purine with pyrimidine or A with T and G with C
- 3 bonds between G and C, 2 bonds between A and T

Here's a good example of exam technique. You know about phosphodiester bonds, but are they relevant to this answer? Well just in case, include them in your answer because if they are not relevant the examiner will just ignore it. You will not lose a mark, however it is relevant in this case and would get you a mark.

**[Total: 9]**

## Question 4

DNA is arguably the most important molecule in the whole of biology.

When a cell divides an identical copy of its DNA is made in a process called DNA replication.

**(a)** Explain how pairing of nitrogenous bases allows identical copies of DNA to be made. **[3]**

- A pairs with T and G with C
- Hydrogen bonding is responsible for the pairing
- Purines pair with pyrimidines as they are different sizes

Bit vague and not sure what to include? Focus on 'pairing of nitrogenous bases'. Write as much know on this topic

**(b)** **(i)** Outline how the process of DNA replication is completed, following the pairing of nitrogenous bases. **[3]**

- DNA polymerase aligns the bases
- Sugar phosphate backbone is joined by DNA ligase
- This involves a condensation reaction

The lagging strand is built in sections as it's in the wrong direction, these are called Okazaki fragments.

**(ii)** Why is DNA replication described as semi-conservative? **[1]**

The new molecule has one old or original strand of DNA and one new

Avoid the word 'half' at all costs. Note the new DNA or DNA that's produced contains (or conserves) one old strand and one new.

**[Total: 7]**

## Question 5

**(a)** Fig. 5.1 shows part of a DNA molecule.

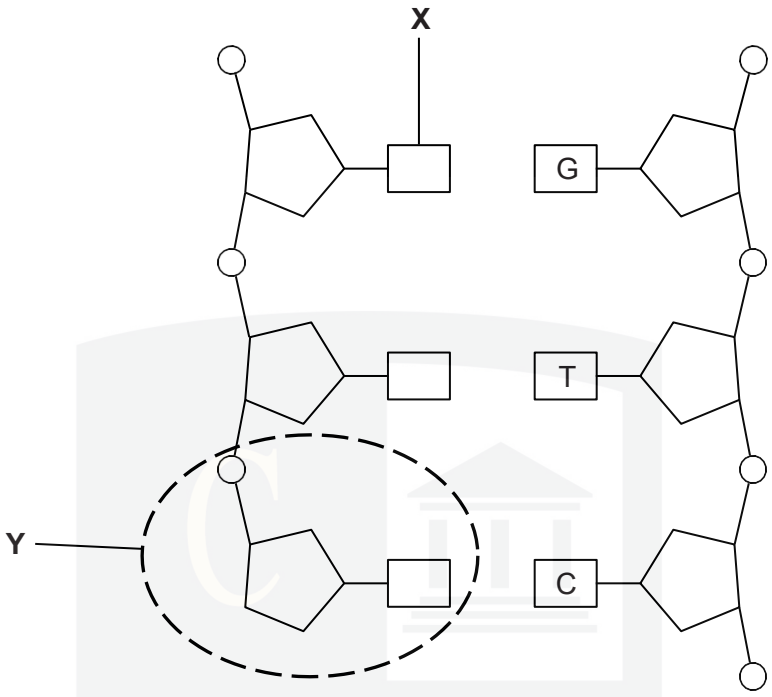



**Fig. 5.1**

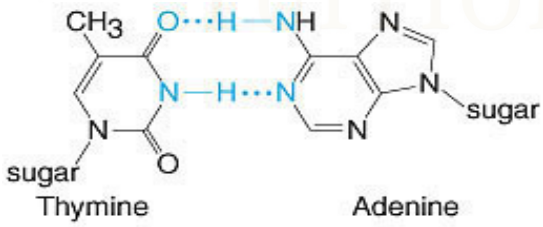
**(i)** Name the parts of the molecule represented by the letters **X** and **Y**. **[2]**

- X is cytosine
- Y is a nucleotide

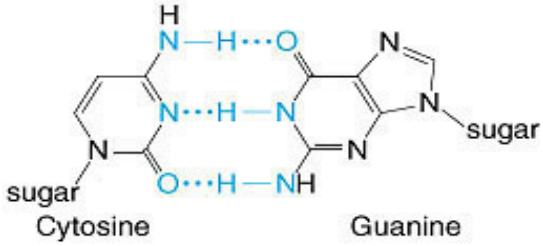
**(ii)** **Complete the diagram in Fig. 5.1** by drawing hydrogen bonds to connect the two strands.

*The hydrogen bonds should be drawn on Fig. 5.1.* **[2]**

- One line drawn between two bases
- Two lines drawn between A and T and three lines drawn G and C




T═A




C═G

**(iii)** Complete the following paragraph by using the most appropriate term(s).

A gene is a section of DNA that codes for the production of a polypeptide .

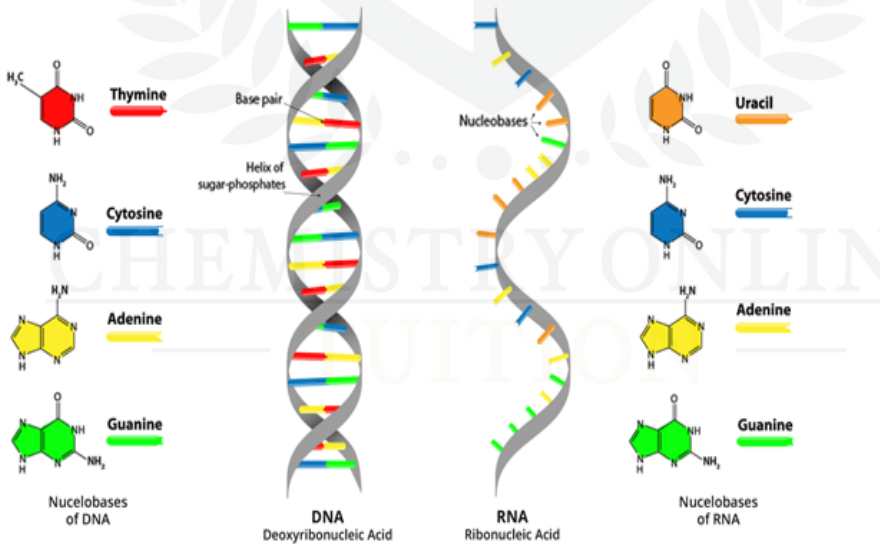
The molecule that copies a gene and carries the information to a ribosome

is called RNA. **[2]**

'**Protein**' was allowed instead of '**polypeptide**' in the mark scheme but strictly speaking it is wrong. Some proteins such as haemoglobin and antibodies have 4 polypeptide chains so a single gene cannot code for them.

**(iv)** State **two** ways in which a diagram of part of an RNA molecule would appear different from the DNA molecule shown in Fig. 5.1. **[2]**

- RNA would have a single strand
- RNA would have uracil instead of thymine



**(b)** DNA replication takes place during interphase of the cell cycle. It occurs by a semi-conservative mechanism.

**(i)** Explain why DNA replication is considered to be semi-conservative. **[2]**

- Semi conservative replication suggests that the DNA formed when it replicates, contains one old or original strand and one new strand.
- Each strand of DNA acts as a template for the other strand


**(ii)** Explain why complementary base-pairing is important in DNA replication. **[2]**

- Complementary base pairing means DNA can be replicated without error
- It reduces the chance of mutation
- It allows hydrogen bonds to be reformed between the bases

(c) In 1958, two scientists, Meselson and Stahl, conducted an investigation into DNA replication.

- Bacteria were grown in a food source that contained only the 'heavy' isotope of nitrogen, $^{15}N$. After many generations, the bacterial DNA contained only the 'heavy' form of nitrogen.
- Some of the bacteria were then transferred to another food source containing only the normal, 'lighter' form of nitrogen, $^{14}N$.
- DNA was extracted from the bacteria and centrifuged. (When a solution is centrifuged, the heavier, more dense molecules tend to settle nearer the bottom of the tube.)

Some of the results from the experiment are shown in Fig. 5.2.

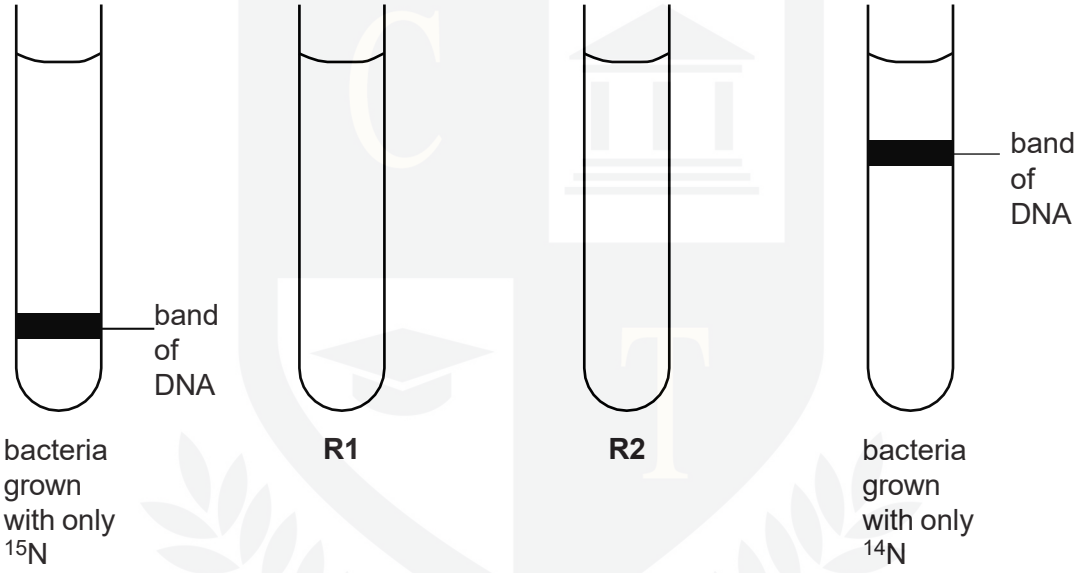
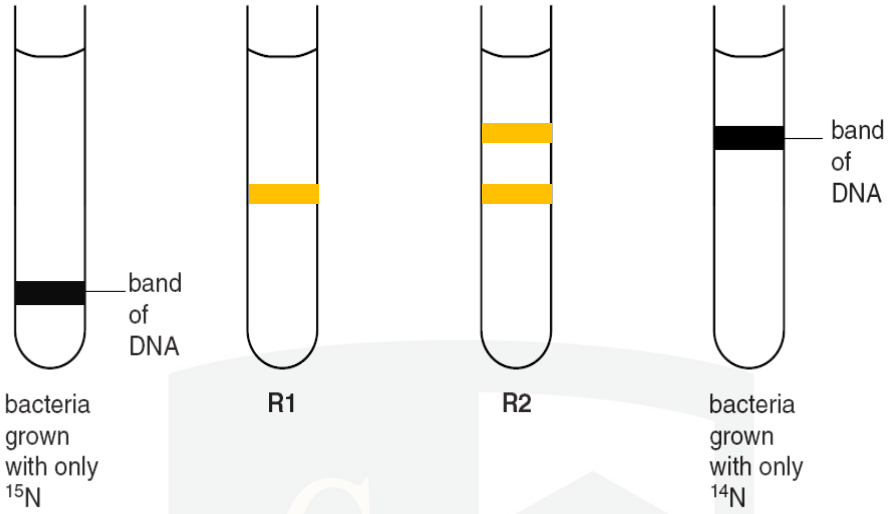



**Fig. 5.2**

**(i)** In Fig. 5.2, the tube labelled **R1** represents the results for DNA extracted from bacteria that had been **transferred** from the $^{15}N$ to the $^{14}N$ food source and left long enough for their DNA to replicate **once** only.

Draw **one** band on tube **R1** in the position you would expect the DNA to appear **after** centrifuging.

*Draw the band on Fig. 5.2.* **[1]**




- Band of DNA in between $^{15}$N and $^{14}$N

**(ii)** In Fig. 5.2, the tube labelled **R2** represents the results for DNA obtained from bacteria that had been **transferred** from the $^{15}$N to the $^{14}$N food source and left long enough for their DNA to replicate **twice**.

Draw **two** bands on tube **R2** in the positions you would expect the DNA to appear **after** centrifuging.

*Draw the bands on Fig. 5.2.* **[1]**

- Band of DNA in between $^{15}$N and $^{14}$N and at the same level as $^{14}$N

(d) The technique of centrifugation used by Meselson and Stahl involves:

- mixing the DNA sample with concentrated sugar solution
- placing the mixture of DNA and sugar solution in test-tubes
- spinning the test-tubes at a very high speed.

Suggest **three** precautions that Meselson and Stahl would have taken in order to ensure that the centrifugation part of their investigation produced valid results. **[3]**

- The tubes should have contained the same concentration of sugar
- The tubes should have contained the same volume of sugar solution
- Tubes should have been centrifuged at the same speed
- The tubes should have been spun for the same time

The techniques involved in centrifugation are included in the three bullet points. Each tube contains a concentration gradient of sucrose which becomes more dense towards the bottom of the tube. Heavier molecules such as the DNA with nitrogen 15 will settle further down the tube when they reach the sucrose concentration with the same density.

**[Total: 17]**