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Monday 9 January 2017 – Morning

LEVEL 2 CAMBRIDGE NATIONAL IN SCIENCE

R072/02/I How scientific ideas have developed

INSERT

Duration: 1 hour

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INSTRUCTIONS TO CANDIDATES

- This Insert contains the case study required to answer Question 1. Question 1 accounts for 25% of the total marks.

INFORMATION FOR CANDIDATES

- This document consists of **8** pages. Any blank pages are indicated.

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The story of DNA

Miescher discovers nuclein

The year 1869 was a landmark year in the discovery of DNA. This was the year in which Swiss scientist Friedrich Miescher found the substance we now know as DNA. Miescher was looking for proteins in the nuclei of white blood cells. He collected a large amount of used, blood-stained bandages from a local hospital. He separated the white blood cells from the blood and extracted some proteins from the nuclei of the white blood cells. He also collected a new substance which he called 'nuclein'.

Table 1 shows some differences he found between the elements present in proteins and in nuclein.

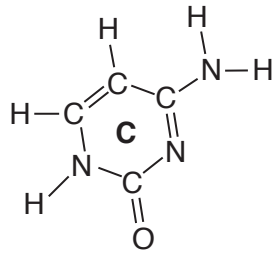
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Phosphorus
Proteins	✓	✓	✓	✓	✓	✗
Nuclein	✓	✓	✓	✓	✗	✓

Table 1

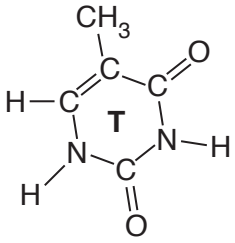
Miescher realized that he had discovered a new type of substance. He decided that there was a whole family of these substances. The term nuclein was later changed to DNA.

What is in DNA?

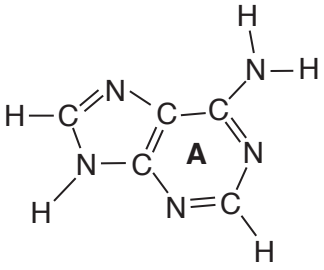
In the 20th Century, scientists worked out that DNA is a long chain. Each link in the chain was made of a common sugar called deoxyribose ($C_5H_{10}O_4$) and a phosphate group (phosphorus and oxygen). They also knew that DNA included four molecules called adenine, thymine, guanine and cytosine (usually abbreviated A, T, G and C). They called these molecules bases. The structure of these bases is shown in **Fig. 1**.



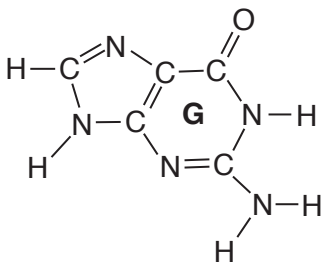
Cytosine



Thymine



Adenine



Guanine

Fig. 1

Scientists began to think that DNA were the instructions that the cells used to make proteins. However, it was difficult to see how only four bases could make a code for the twenty amino acids in a typical protein.

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Chargaff discovers some 'rules'

Erwin Chargaff found out more information about the structure of DNA. At the time, scientists thought that DNA was the same in all living things. Chargaff was not so sure. In 1950, he used newly-discovered paper chromatography to separate DNA from many different species. He then measured the percentage of each base (adenine, guanine, cytosine and thymine) in the DNA from each species. **Table 2** shows some of his results.

Species	Adenine (%)	Guanine (%)	Cytosine (%)	Thymine (%)
Octopus	32.2	17.6	17.6	32.6
Grasshopper	29.3	20.5	20.7	29.5
Chicken	28.0	22.0	21.6	28.4
Human	29.3	20.7	20.0	30.0

Table 2

He used his data to compare the percentages of each base in different species. Later scientists used his data as evidence for the idea that bases are paired.

Franklin's X-rays give clues to the structure of DNA

Watson and Crick used stick-and-ball models to try out their ideas about the possible structure of DNA. At the same time, a scientist called Rosalind Franklin was using X-ray diffraction to find evidence for the structure of the DNA in crystals of DNA. When a beam of X-rays hits a crystal of DNA, most of the X-rays go straight through, but some bounce off the solid particles. These rays can make complicated patterns on photographic film. By looking at the patterns, it is possible to work out how the particles in the crystal are arranged. Franklin's famous "photograph 51" revealed the structure of DNA to Watson and Crick in 1953. Photograph 51 showed a fuzzy 'X', as shown in **Fig. 2**.

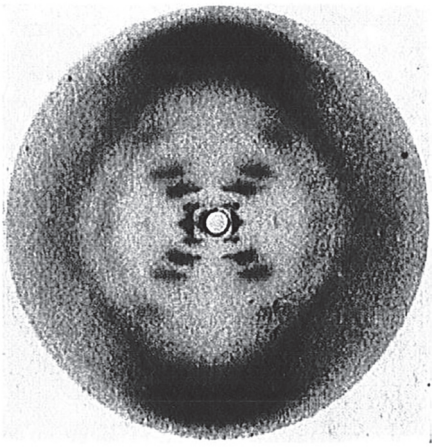

Fig. 2

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The marks on the photograph suggest that the DNA molecule was a helix. The positions of the marks give the size and angles of the helix shape. Franklin took many other photographs both before and after 'photograph 51'. Before she published her work, Watson and Crick were able to use data from her photographs to make a model of the whole structure. On the 21st of February 1953 they realised that pairs of bases could join together two strands of DNA. The sugar-phosphate backbones form a smooth double helix, like a twisted ladder. Each 'step' of the ladder is formed from two bases (as shown in **Fig. 3**).

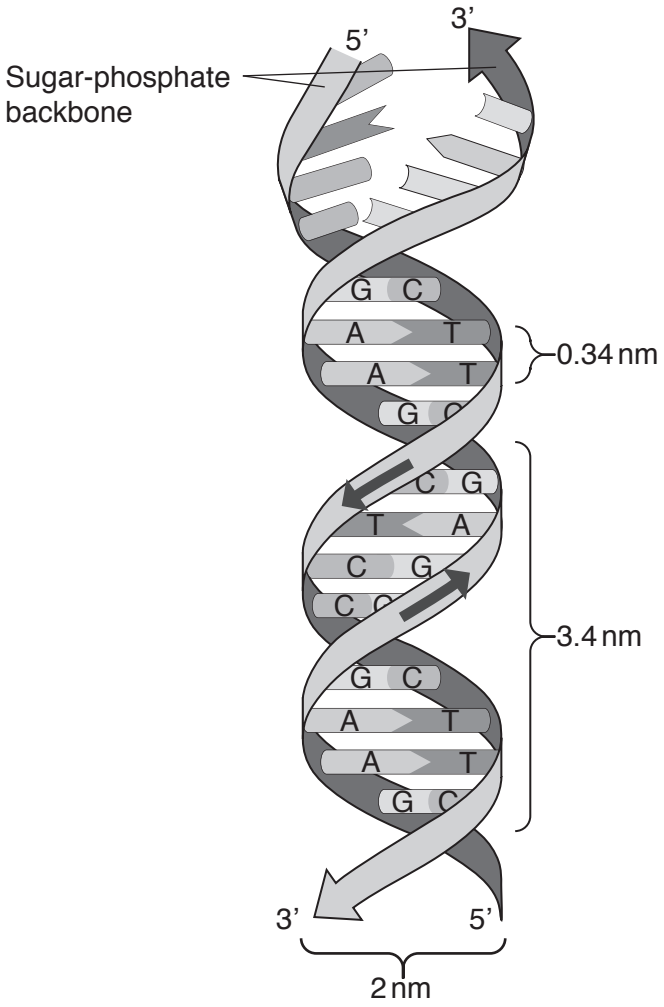

Fig. 3

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The DNA code

DNA is a code for making a protein in the cell. The order of the bases gives instructions for the order of the amino acids in the final protein. The simplest code would be if one base matched one amino acid, but there are 20 amino acids and only four bases. Even a pair of bases cannot make enough codes for 20 amino acids.

Three bases in DNA make a code for each amino acid. This is called a **triplet code**. Some amino acids have more than one triplet code which matches them. For example, in **Fig. 4**, CTC and CTA both match the amino acid Leu.

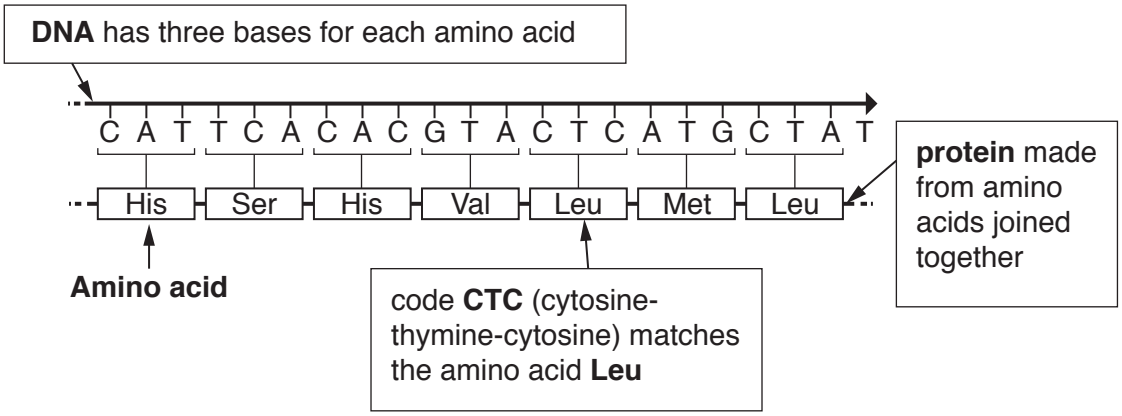

Fig. 4

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