

● Before You Read

In 1953, James Watson and Francis Crick discovered the structure of DNA. But they were not the first people to ask, “How is genetic information passed from one generation to the next?” Watson and Crick’s work was possible because of the work of other scientists. On the lines below, identify a task that is possible only because of the work of many people. Then read the section to learn more about how scientists discovered that DNA is the genetic code.

MAIN Idea

The discovery that DNA is the genetic code involved many experiments.

What You’ll Learn


- the basic structure of DNA
- the structure of a eukaryotic chromosome

● Read to Learn

Discovery of the Genetic Material

Mendel’s laws of inheritance became well known to scientists in the early 1900s. Scientists knew that genes were carried on chromosomes. They also knew that chromosomes were made of DNA and protein. For many years, scientists tried to determine which of these two molecules—DNA or protein—carried the genetic information of a cell.

What are smooth and rough bacteria?

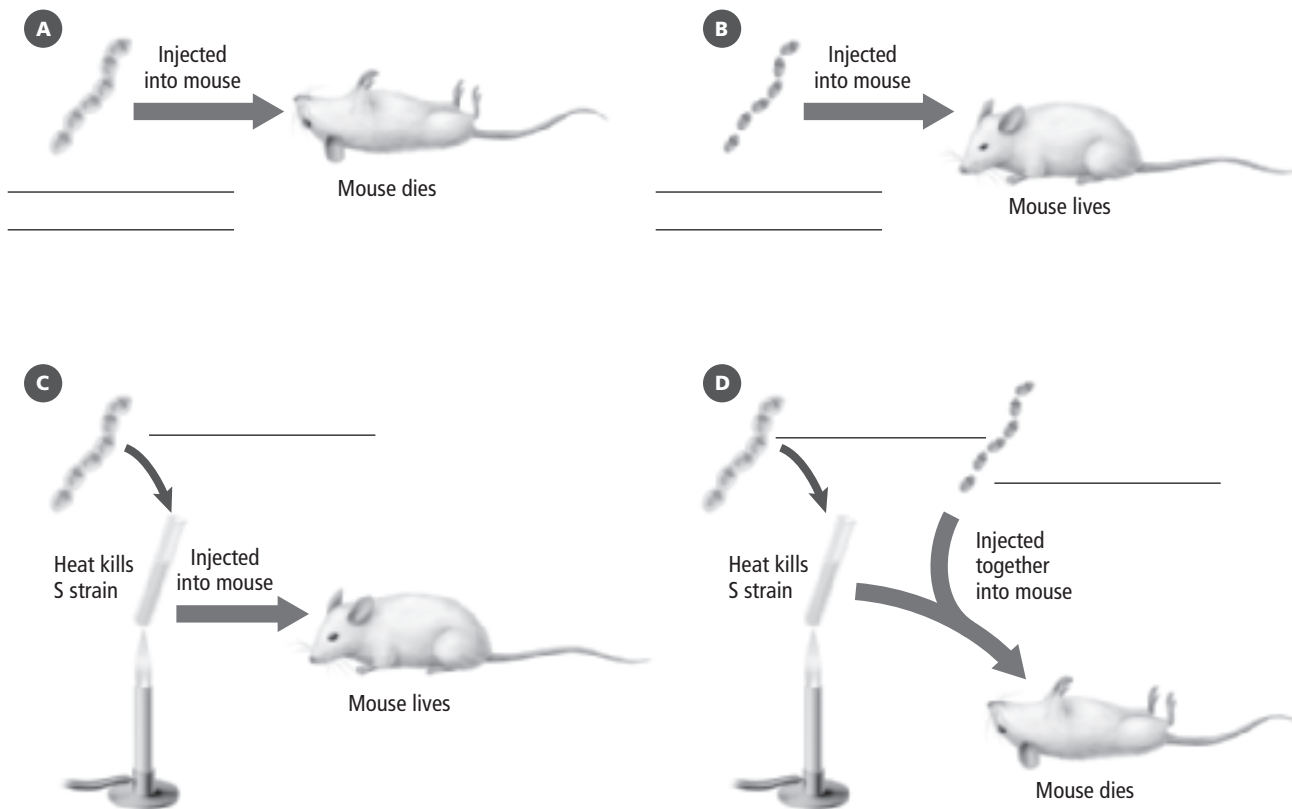
In 1928, Frederick Griffith conducted an experiment that led to the discovery of DNA as the genetic material. Griffith studied two strains of *Streptococcus pneumoniae*. One strain had a sugar coat and caused pneumonia. It was called smooth (S) because colonies of bacteria appear smooth. Another strain did not have a sugar coat and did not cause pneumonia. It was called rough (R) because its colonies have rough edges. Follow along with Griffith’s study described on the next page. 

Mark the Text

Identify People As you read this section, underline the name of each scientist introduced. Highlight the sentences that explain each person’s contribution to understanding DNA.

Reading Check

1. **Contrast** Name two ways that rough bacteria differ from smooth bacteria.



Picture This

2. Label Write the name of each strain of bacteria (*S* for smooth, *R* for rough) in each of the experiments shown.

Reading Check

3. State what Avery found.

How were bacteria transformed?

When Griffith injected live *S* strain into a mouse, the mouse died. When Griffith injected live *R* strain into a mouse, the mouse did not die. These results are shown above in Parts A and B.

Next, Griffith heated and killed the *S* strain. When injected, the dead *S* strain no longer killed the mouse. This step is shown in Part C above.

Next, Griffith mixed the heat-killed *S* strain with the live *R* strain. As shown in Part D above, when he injected the mixture into a mouse, something unexpected happened—the mouse died. Griffith studied live bacteria from the dead mouse. The smooth trait was visible. He concluded that the live *R* strain had changed into live *S* strain.

How was the transforming factor identified?

In 1931, Oswald Avery, along with other scientists, identified the molecule that transformed the *R* strain into *S* strain. Avery tested DNA, protein, and lipids from heat-killed *S* strain. He found that only DNA was able to change *R* strain into *S* strain.

Who proved that DNA was the genetic material?

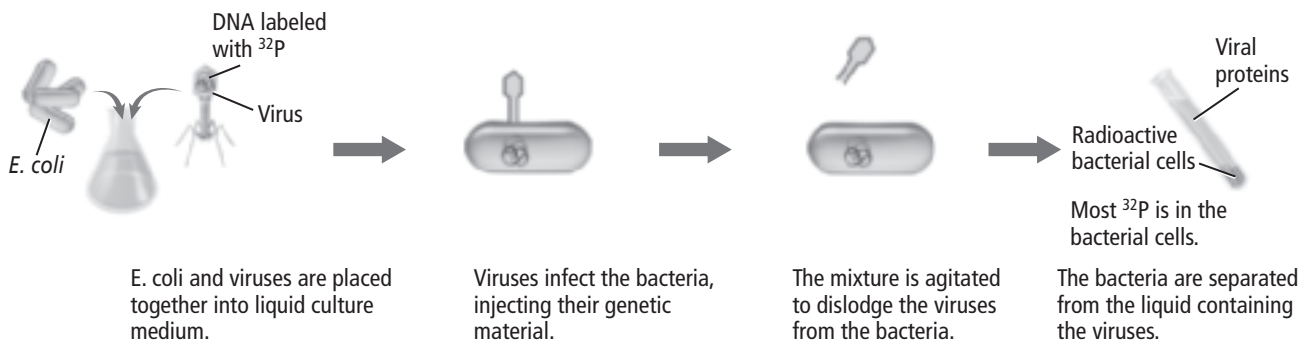
In spite of Avery's result, many scientists still questioned whether proteins or DNA were the genetic material. In 1952, Alfred Hershey and Martha Chase published results of an experiment proving that DNA was the genetic material. Hershey and Chase did an experiment with bacteriophages (bak TIHR ee uh fayjz), a type of virus that infects bacteria. The bacteriophages were made of DNA and protein. They reproduce by attaching to and injecting their genetic material into a living bacterial cell. ✓

Hershey and Chase used radioactive phosphorus (^{32}P) to label the DNA of one set of bacteriophages. They used radioactive sulfur (^{35}S) to label the protein of a second set of bacteriophages.

As shown in the figure below, Hershey and Chase mixed bacteria with viruses from the two groups. The viruses injected their genetic material into the bacteria. The viruses were separated from the bacteria.

Group 1

Viruses are grown in medium containing ^{32}P to label DNA.



Group 2

Viruses are grown in medium containing ^{35}S to label protein.



What did the viruses inject into bacteria?

Hershey and Chase found that both sets of viruses had replicated inside the bacterial cells. But only the labeled DNA had entered the bacterial cells. The labeled protein remained outside the bacterial cells. This experiment provided evidence that DNA, not protein, was the genetic material.

Reading Check

4. Identify What two molecules make up a bacteriophage?

Picture This

5. Identify Circle the bacterial cells that have radioactive material inside of them.

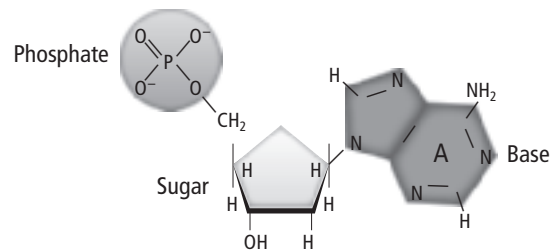
Picture This

6. Identify Is the nucleotide in the picture a DNA nucleotide or an RNA nucleotide? How can you tell?

DNA Structure

DNA is made of nucleotides. In the 1920s, biochemist P.A. Levene showed that each DNA nucleotide contains the sugar deoxyribose (dee ahk sih RI bos), a phosphate group, and one of four nitrogenous bases—adenine (A dun een), guanine (GWAH neen), cytosine (SI tuh seen), or thymine (THI meen).

RNA also is made of nucleotides. Each RNA nucleotide contains the sugar ribose, a phosphate, and one of four nitrogenous bases—adenine, guanine, cytosine, and uracil (YOO ruh sihl). The figure below shows the structure of a nucleotide.



Adenine (A) and guanine (G) are double-ringed bases, which are called purine bases. Thymine (T), cytosine (C), and uracil (U) are single-ringed bases, which are called pyrimidine bases.

Erwin Chargaff discovered that the amount of guanine is almost equal to the amount of cytosine, and the amount of adenine is almost equal to the amount of thymine for the DNA of any given species. This finding is known as Chargaff's rule: $C = G$ and $T = A$.

Who identified the structure of DNA?

After the Hershey-Chase experiment, most scientists thought that DNA was the genetic material. But they still did not know how nucleotides were arranged in a DNA molecule or why DNA followed Chargaff's rule.

Four scientists helped solve the structure of DNA: British scientists Rosalind Franklin, Maurice Wilkins, and Francis Crick and American scientist James Watson.

What did Franklin's picture show?

Franklin worked for Wilkins at King's College in London, England. She took a picture of DNA using X-ray diffraction, a technique that involved aiming X rays at DNA. Franklin's picture, called Photo 51, showed that DNA was a **double helix**, with two strands of nucleotides twisted around each other like a twisted ladder.

Reading Check

7. Identify What technique did Franklin use to take a picture of DNA?

What did Watson and Crick propose?

Watson and Crick saw Franklin's X-ray diffraction picture. They used Franklin's picture and data as well as other mathematical data to determine the specific structure of the DNA double helix.

Watson and Crick built a model of DNA with two outside strands made of deoxyribose alternating with phosphate. The bases were on the inside of the molecule—cytosine paired with guanine, thymine paired with adenine. ✓

What is the structure of DNA?

Imagine DNA as a twisted ladder. The rails of the ladder are made of alternating deoxyribose and phosphates. The pairs of bases (cytosine—guanine or thymine—adenine) form the rungs. The rungs are always the same width because a purine base always binds to a pyrimidine base.

Now imagine two pencils lying side by side with the point of one pencil next to the eraser of the other. Like these pencils, the two strands of the sugar-phosphate chain of a DNA double helix run in opposite directions. The ends of the sugar-phosphate strands are named 5' (read "five-prime") and 3' (read "three-prime"). One strand runs 5' to 3'. The other strand runs 3' to 5'.

When was the structure of DNA announced?

In 1953, Watson and Crick published a letter in the journal *Nature* suggesting the structure for DNA and a hypothesized method of copying the molecule. In the same issue, Wilkins and Franklin published separate articles that supported Watson and Crick's structure. Scientists had solved some mysteries. However, they still did not know how DNA worked as a genetic code.

Chromosome Structure

The DNA molecule in prokaryotes is contained in the cytoplasm. The DNA forms a ring with its associated proteins.

DNA in eukaryotes is organized into chromosomes. Human chromosomes vary in length from 51 million to 245 million base pairs. The DNA fits into the nucleus of a eukaryotic cell by coiling around a group of beadlike proteins called histones.

Nucleosomes are DNA that are tightly coiled around the histones. Nucleosomes are twisted together into chromatin fibers, which supercoil into a chromosome. ✓

✓ Reading Check

8. Identify how the DNA bases pair.

✓ Reading Check

9. Define What is a nucleosome made of?
