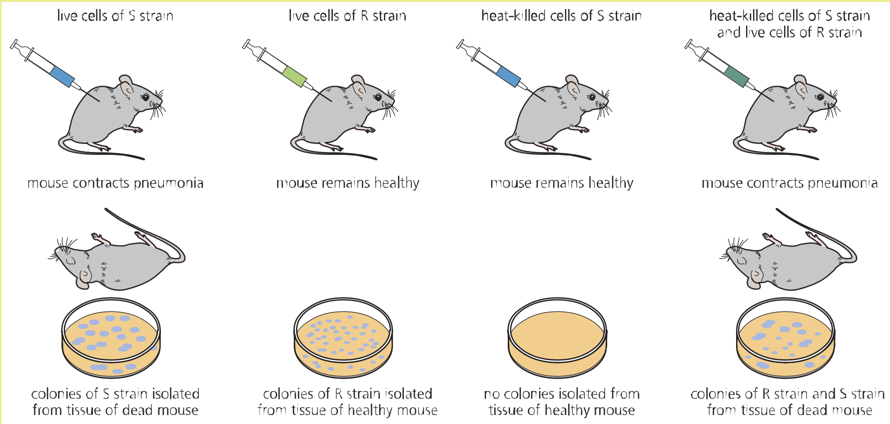
Figure 4 to see this. This is a fairly strong bond and is not easily broken. The second is the hydrogen bond between bases in a base pair, as shown in Figure 8(a). Although hydrogen bonds are relatively weak, a single molecule of DNA might be several thousand nucleotides long. Thousands of hydrogen bonds ensure that the two polynucleotide strands are held firmly together.

Experiments showing that DNA is the genetic material

Scientists were not easily convinced that DNA is the genetic material. It might be a surprise to hear that, for the first half of the twentieth century, most scientists believed that proteins held the genetic code. They thought the components of DNA seemed much too simple! Let's look at some experiments that changed their minds.

In the first experiment, a bacterium called *Streptococcus pneumoniae* was used. It causes pneumonia in humans and other mammals. The bacterium is rod-shaped and has two strains. On agar plates, colonies of the **S strain** bacterial cells produce an outer polysaccharide coat and appear smooth. Colonies of the mutant **R strain** bacterial cells lack the polysaccharide coat and appear rough.

A team of scientists injected mice with different combinations of these two strains of the bacterium. Figure 9 shows the results.



▲ **Figure 9** The effect of injecting mice with different combinations of the S strain and R strain of *Streptococcus pneumoniae*.

1 Which strain of the *S. pneumoniae* caused the mice to die? Use Figure 9 to explain your answer.

2 Suggest why this scientist used mice in his experiment.

Heat-killed S strain on its own did not cause mice to die, yet mixed with R strain it did. The first team of scientists concluded that the genetic information of the heat-killed S strain was able to get into the live cells of the R strain and transform them into S-type cells. They did not know the chemical nature of this transforming agent.

Some time later, another team of scientists set up an experiment to try to find the nature of the transforming agent. They treated heat-killed samples of the S strain of *S. pneumoniae* with different enzymes. Each enzyme broke down specific molecules within the bacteria. The scientists then mixed each of the extracts from these S-strain cells with a different culture of the R strain, and looked at the type of colony that grew on an agar plate. Table 2 shows their results.

3 This research team suspected that three types of molecule found in cells might be the transforming agent. Name these types of molecule.

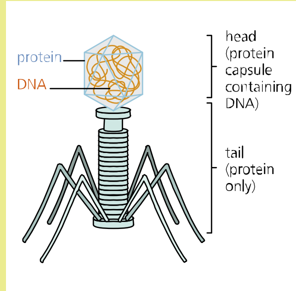
Table 2 The effect of incubation with different enzymes on the ability of the S strain of *S. pneumoniae* to transform the R strain.

Experiment	Enzyme used to treat heat-killed cells of S strain of S. pneumoniae	Appearance of R-strain colonies growing on agar plate
1	Protease	Smooth
2	Ribonuclease	Smooth
3	Deoxyribonuclease	Rough

4 The team concluded that DNA was the transforming agent. Use the data in Table 2 to explain why.

Most scientists remained unconvinced, and these results were largely ignored for many years. The results were criticised for several reasons. These included:

- some contaminating protein could have been left in the protease preparation.
- DNA might be only part of a pathway that proteins used for transformation.

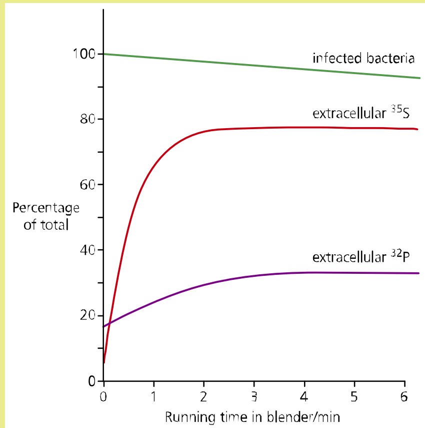


▲ **Figure 10** T2 bacteriophages are viruses

It took a Nobel Prize-winning experiment to convince scientists around the world that DNA was the genetic material. This experiment used a **bacteriophage**. This is a virus that infects and kills bacteria. The virus was the T2 bacteriophage. This bacteriophage infects *Escherichia coli*, a bacterium which commonly grows in the gut of humans. Figure 10 shows a single T2 bacteriophage. Notice its simple structure: it has an outer protein capsule surrounding a molecule of DNA. When a T2 bacteriophage infects an *E. coli* bacterium, it multiplies to produce large numbers of bacteriophages that burst the bacterial cell and are released.

5 Suggest one advantage of using T2 bacteriophages in this experiment.

Protein contains sulphur, which DNA does not. DNA contains phosphorus, which proteins do not. Each of these elements has a radioactive isotope, ^{32}P and ^{35}S. The team of scientists grew some T2 bacteriophage in the presence of ^{32}P, which labels their DNA, and some in the presence of ^{35}S, which labels their proteins. After infecting a culture of *E. coli* with these labelled bacteriophages, the team put samples of the culture in a blender. This removed the bacteriophages from the surface of the bacteria. They then looked to see where the radioactive elements were found. Figure 11 shows their results.



▲ **Figure 11** The location of radioactivity after removing the T2 bacteriophage from the surface of infected *E. coli* cells.

6 Where does Figure 11 show that most of the DNA was found? Where was most of the protein found?

7 The team went on to show that new bacteriophages released by bursting *E. coli* cells were labelled only with ^{32}P. Why did this finally convince scientists that DNA is the genetic material?