CHAPTER PREVIEW

Main Ideas

In this chapter, you will learn the basic structure of nucleic acids—DNA and RNA. You will also discover how DNA undergoes transcription to form RNA, and how the RNA then undergoes translation to form a protein.

Reading Strategies

Outlining Information Before you read this chapter, make a chart with the headings DNA and RNA. As you read this chapter, list the components of each nucleic acid and where the components are located in the cell.

Sequencing Events After you read this chapter, make a flowchart of all the steps involved in the formation, or synthesis, of a protein.

Journal Activity

Biology and Your World The deciphering of the genetic code is one of the most remarkable scientific achievements of the twentieth century. How do you think you would feel if you were a member of the team that "cracked" this code? Write about your feelings in a journal.

7–1 DNA

Guide For Reading

- What contributions did various scientists make to the idea that DNA carries the genetic code?
- What is the structure and function of DNA?
- How does DNA replicate?

By now, it should be clear that living cells are able to do some remarkable things. We might go so far as to say that cells "know" a great deal about the business of life: how to produce ATP, how to build cilia and centrioles, how to produce enzymes and membranes. It is as though cells are preinstructed by a code, or programmed, about what to do and how to do it.

A program, or code, in living cells must be able to duplicate itself quickly and accurately and must also have a means of being decoded and put into effect. In this chapter, we begin to learn about the nature of the cellular program—what biologists know and don't know about the ways in which the program is constructed, duplicated, and carried out.

The Genetic Code

Biologists call the program of the cell the **genetic code.** The word genetic refers to anything that relates to heredity. The genetic code, therefore, is the way in which cells store the program that they seem to pass from one generation of an organism to the next generation.

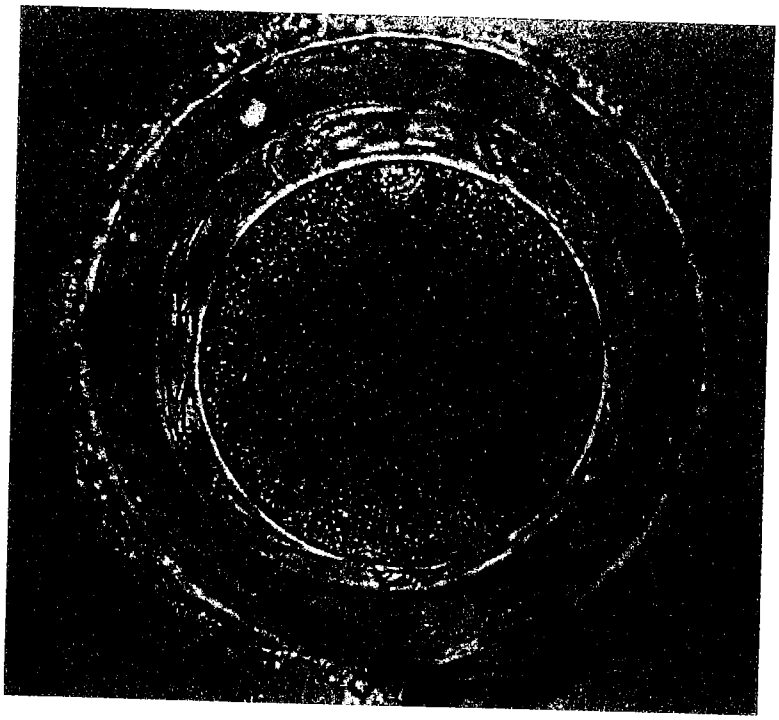


Figure 7–1 *The entire genetic program needed to produce a human is contained in a single fertilized egg cell such as this.*

The Structure of DNA

Even if DNA was shown to be the crucial molecule for the passing on of genetic information, a question of overwhelming importance remained. How could a molecule such as DNA store information and duplicate itself easily—two significant tasks? Let's take a look at the structure of DNA to see if that explains how it accomplishes these tasks.

As you will recall from Chapter 4, DNA is a polymer formed from units called **nucleotides**. Each nucleotide is a molecule made up of three basic parts: a 5-carbon sugar called deoxyribose (dee-ahks-ee-RIGH-bohz), a phosphate group, and a nitrogenous, or nitrogen-containing, base.

DNA contains four nitrogenous bases. Two of the nitrogenous bases, **adenine** (AD-uh-neen) and **guanine** (GWAH-neen), belong to a group of compounds known as purines (PYOOR-eenz). The remaining two, **cytosine** (SIGHT-oh-seen) and **thymine** (THIGH-meen), are known as pyrimidines (pih-RIHM-uh-deenz).

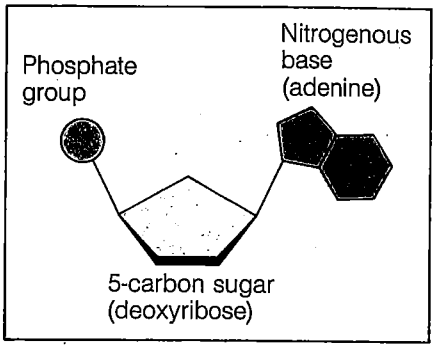
Individual nucleotides are joined together to form a long chain. Notice in Figure 7–10 on page 143 that the sugars and phosphate groups form the backbone of the chain, and the nitrogenous bases stick out from the chain.

X-RAY EVIDENCE In the early 1950s, the British scientist Rosalind Franklin turned her attention to the DNA molecule. She purified a large amount of DNA and then stretched the DNA fibers in a thin glass tube so that most of the strands were parallel. Then she aimed a narrow X-ray beam on them and recorded the pattern on film. When X-rays pass through matter, they are scattered, or diffracted. This X-ray scattering produces a pattern that provides important clues to the structure of many molecules.

Franklin worked hard to prepare better and better samples until the X-ray patterns became clear. The result of her work is

Figure 7–5 *Radioactive isotopes are used not only to follow the pathway of certain materials, but also to detect the presence of some types of cancer. This photograph shows how a radioactive isotope becomes more concentrated in a cancerous part of the body, in this case in bone, than in a healthy part of the body. The cancerous part appears in red.*

Figure 7–6 *DNA is a polymer formed from units called nucleotides. A nucleotide is composed of three basic parts: a phosphate group, a 5-carbon sugar, and a nitrogenous base. What is DNA's 5-carbon sugar called?*



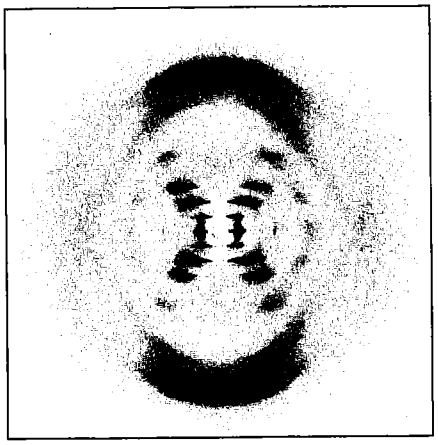


Figure 7–7 *This X-ray diffraction photograph of DNA was taken by Rosalind Franklin in the early 1950s. The X-shaped pattern in the center indicates that the structure of DNA is helical.*

the X-ray pattern shown in Figure 7–7. This pattern does not prove anything in itself, but it does provide some very important clues about the structure of DNA. One important clue is that the fibers that make up DNA are twisted, like the strands of a rope. This is shown by the small X near the center of the pattern. The other important clue is that large groups of molecules in the fiber are spaced out at regular intervals along the length of the fiber.

Taken alone, neither of these facts was enough to determine the structure of DNA. The X-ray pattern was like a fingerprint or a scrap of cloth at the scene of a crime. Crucial evidence, perhaps, but it would only make sense when put into a larger picture by a clever detective—or an inventive scientist!

BUILDING A MODEL OF DNA At the same time that Franklin and her colleague, Maurice Wilkins, were doing their research, two young scientists working in Cambridge, England, were also trying to determine the structure of DNA. One of the scientists was Francis Crick, a British physicist. The other was James Watson, a 25-year-old American biochemist.

Watson and Crick had been trying to solve the mystery of DNA structure by building three-dimensional models of the atomic groups in DNA. They twisted and stretched the models in various ways to see if any of the structures that formed made any sense. Watson and Crick had some interesting ideas, but nothing to test them against.

Then, during a visit to London, Watson was able to observe Franklin's remarkable X-ray pattern of DNA. At once Watson and Crick realized that there was something important in that pattern. They immediately set out to use the clues that Franklin had provided. Within weeks, Watson and Crick had figured out the structure of DNA.

Figure 7–8 *This photograph of Watson and Crick with one of their first models of DNA was taken in 1953.*

THE DOUBLE HELIX Working with these clues, Watson and Crick began, quite literally, to play with their models of the DNA fiber. What they needed to do was to twist their model into a shape that would account for Franklin's X-ray pattern. Before long, they developed a shape that seemed to make sense. They called this shape a helix because it was similar to a spiral, or the way in which the threads are arranged in a screw. Using Franklin's idea that there were probably two strands of DNA, Watson and Crick imagined that the strands were twisted around each other, forming a double helix.

Watson and Crick's model explained one more characteristic about DNA's structure. The nitrogenous bases on each of the strands of DNA are positioned exactly opposite each other. This positioning allows weak hydrogen bonds to form between the nitrogenous bases adenine (A) and thymine (T), and between cytosine (C) and guanine (G).

Another interesting piece of information that helped Watson and Crick to work out their model of DNA's structure was provided by Erwin Chargaff, an American biochemist.

Chargaff observed that in any sample of DNA, the number of adenine molecules was equal to the number of thymine molecules. The same was true for the number of cytosine and guanine molecules. Chargaff's observation enabled Watson and Crick to determine that adenine bonds only to thymine and cytosine bonds only to guanine. The two scientists further reasoned that the attraction of these bases for each other is very specific. The attraction between such bases is known as **base pairing**. Base pairing is the force that holds the two strands of the DNA double helix together. As you can see, Watson and Crick set out to solve one puzzle and found the answer to another puzzle!

In 1953, after making careful drawings of their model of DNA, Watson and Crick submitted their findings to a scientific journal. Their model, although speculative in some areas, was almost immediately accepted by scientists the world over. Why? Because, as we shall see, it contained a feature that explained a great mystery: how DNA could copy itself!

The importance of this work on DNA was acknowledged in 1962 by the awarding of the Nobel prize for medicine or physiology—the highest prize the international community can give for a scientific discovery—to its discoverers. Because Rosalind Franklin had died in 1958 and Nobel prizes are given only to living scientists, the prize was shared by Watson, Crick, and Franklin's associate, Maurice Wilkins.

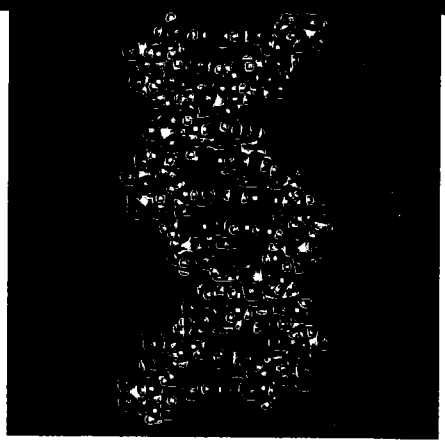


Figure 7–9 *In this computer-generated model of DNA, the paired nitrogenous bases form the rungs, and the connecting sugar-phosphate molecules form the side rails.*

Figure 7–10 *The two strands of DNA are held together by hydrogen bonds. Because of the total number of hydrogen bonds that each can form with the other, adenine can pair only with thymine and cytosine can pair only with guanine.*