Chapter 7

Genetic Technologies

7.6 Genome Editing with CRISPR-Cas9

It's been called the biotechnology discovery of the century. But what exactly is CRISPR-Cas9? CRISPR-Cas9 is a powerful tool for genome editing. It allows scientists to add, remove, or change DNA at specific locations in the genome. The CRISPR-Cas9 system was developed in 2012 by Jennifer Doudna at the University of California, Berkeley and Emmanuelle Charpentier at the Max Planck Institute for Infection Biology in Berlin, Germany. The term "CRISPR" is short for Clustered Regularly Interspaced Short Palindromic Repeats. A CRISPR is a sequence of nucleotides in the DNA commonly found within prokaryotes, such as bacteria. The "Cas" is a CRISPR associated protein that works with the CRISPR sequence. In 2020, Doudna and Charpentier were awarded the Nobel Prize in Chemistry for their work.

FIGURE 7.11

Jennifer A. Doudna and Emmanuelle Charpentier have discovered one of gene technology's sharpest tools: the CRISPR/Cas9 genetic scissors.

CRISPR-Cas9 is a system used by some bacteria to defend themselves from viruses. When viruses attack, these bacteria save some of the virus's DNA in special "CRISPR arrays." If the viruses ever return, DNA from the CRISPR arrays is used to make RNA. This RNA locates matching DNA sequences in the attacking viruses. Then, the Cas9 enzyme cuts the DNA apart, destroying the virus.

The CRISPR-Cas9 genome editing tool works in a similar way. Scientists create "guide RNA" with the desired target sequence and attach it to the Cas9 protein. The RNA locates the matching DNA, and the Cas9 enzyme cuts it (Figure 7.12). Specific genes can then be added or removed from that precise location in the genome.

The CRISPR-Cas9 system is exciting because of its many potential uses. For example, many serious human diseases, including hemophilia and cystic fibrosis, are the result of a small number of faulty genes. CRISPR-Cas9 may allow scientists to cut out the faulty genes and replace them with normal, working versions. Genome editing could also lead to treatments for more genetically complex diseases, such as cancer.

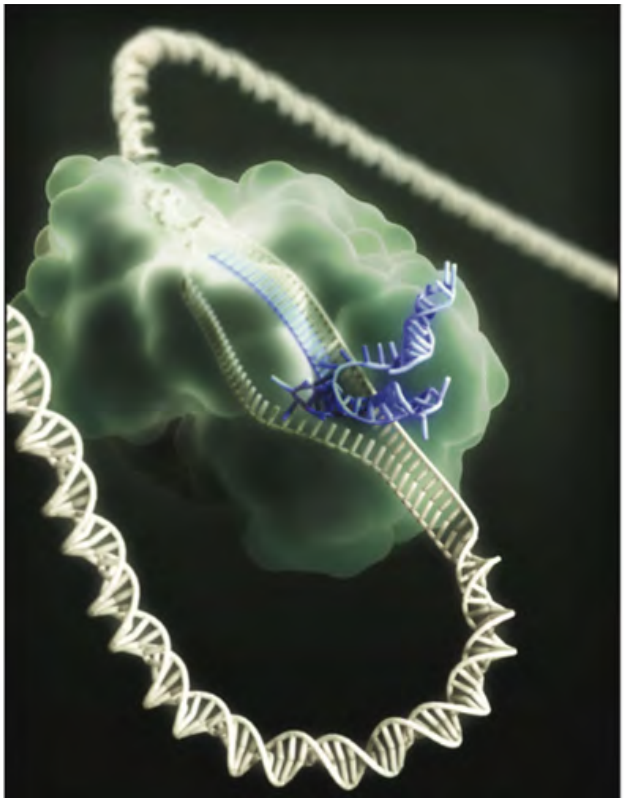

FIGURE 7.12

The CRISPR-Cas9 genome editing system includes a guide RNA (blue) that helps to locate a target in the DNA genome (white). The Cas9 enzyme (green) linked to the RNA then cuts the DNA at the appropriate spot.

Although CRISPR-Cas9 has yet to be used to treat human diseases, it has already been used to slow the growth of cancer in mice, to spread infertility in female mosquitoes, and to remove HIV, the virus that causes AIDS, from living organisms.

This powerful technology raises some ethical concerns, however. First, there are issues of safety. More research is needed to determine what could go wrong if CRISPR-Cas9 were to be used to treat human diseases. For example, in one experiment, the Cas9 enzyme cut the human genome at several unintended locations in addition to the target location. A second question is, what limits, if any, should be placed on editing the human genome?

Although most people agree that using a technology such as CRISPR-Cas9 to treat disease is reasonable, people disagree about whether other uses are ethical. For example, is it ethical to use genes to improve or "enhance" human traits? Many people also favor a ban on the use of genetic technologies in human eggs and sperm, where they would produce genetic changes that would then be passed from one generation to the next.

READING CHECK

Why is the CRISPR-Cas9 system useful as a tool to scientists?

CHECK YOUR ANSWER

The CRISPR-Cas9 system allows scientists to effectively manipulate DNA. It can be used to cut DNA at specific locations in the genome and then add or delete DNA sequences.

You can read more about CRISPR-Cas9 here:

https://medlineplus.gov/genetics/understanding/genomicresearch/genomeediting/