Manipulating the Genome

6.4

In the early 1970s, American researchers Stanley Cohen and Herbert Boyer performed a series of experiments that resulted in a way to select, recombine, and introduce new genes into bacteria. Although this was important scientific work, the commercial value of the experiments was uncertain at the time.

Today, the genetic engineering techniques developed by Cohen and Boyer are used to insert genes from one organism into another. Bacteria can be manipulated to produce insulin for people with diabetes, botanists can modify crops to make them herbicide resistant, and genetic researchers can study the role of individual genes by inserting them into other organisms that normally do not carry that gene. Mammals, birds, fish, insects, worms, plants, fungi, and bacteria have all been manipulated genetically for a variety of purposes, including research into how the human body functions and how disease arises.

The Tools of Genetic Engineering

Two tools are used to cut out a gene from one organism and insert it into another: plasmids and restriction enzymes. Recall from Chapter 2 that plasmids are small circular pieces of DNA that can exit and enter bacterial cells (**Figure 1**). **Restriction enzymes** are like chemical scissors that can cut DNA at specific sequences (**Figure 2**). After the DNA is cut, each end has a short set of exposed complementary bases called "sticky ends." The same restriction enzyme always creates the same matching sticky ends.

restriction enzyme a molecule that has the ability to cut DNA at a specific site; different restriction enzymes recognize and cut different sites

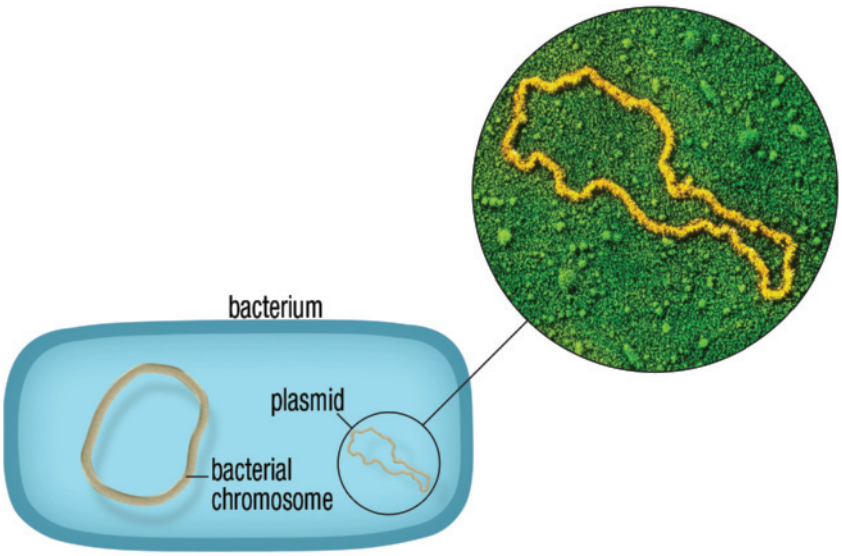

Figure 1 Plasmids are rings of DNA that have the ability to enter and exit a bacterial cell.

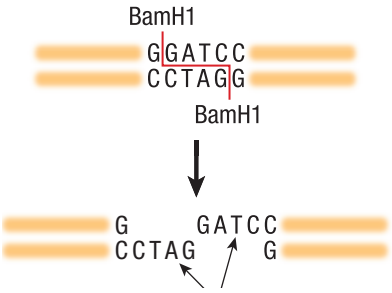

Figure 2 Restriction enzymes cut DNA molecules wherever they encounter a particular sequence of bases. In this case, BamH1 restriction enzyme cuts DNA at all GGATCC locations.

The use of plasmids and restriction enzymes led to modern recombinant DNA techniques. **Recombinant DNA** is a fragment of DNA made by combining nucleotide sequences that would not normally be present together in nature.

recombinant DNA a fragment of DNA consisting of nucleotide sequences from at least two different sources

Recombinant DNA can be made from any two pieces of DNA that have been cut with the same restriction enzyme. For example, if pieces of DNA from two different organisms are exposed to the restriction enzyme BamH1, they will both be cut into pieces ending with the same sticky ends—the four unpaired bases CTAG. Then pieces of DNA from each organism can be joined together by matching up these sticky ends. Geneticists can use this technique to transfer a piece of DNA with a gene of interest from one species into another.

Figure 3 provides a general overview of how bacteria can be used to engineer plants with new characteristics. The bacterium *Agrobacterium tumefaciens* is often used in the genetic engineering of plants.

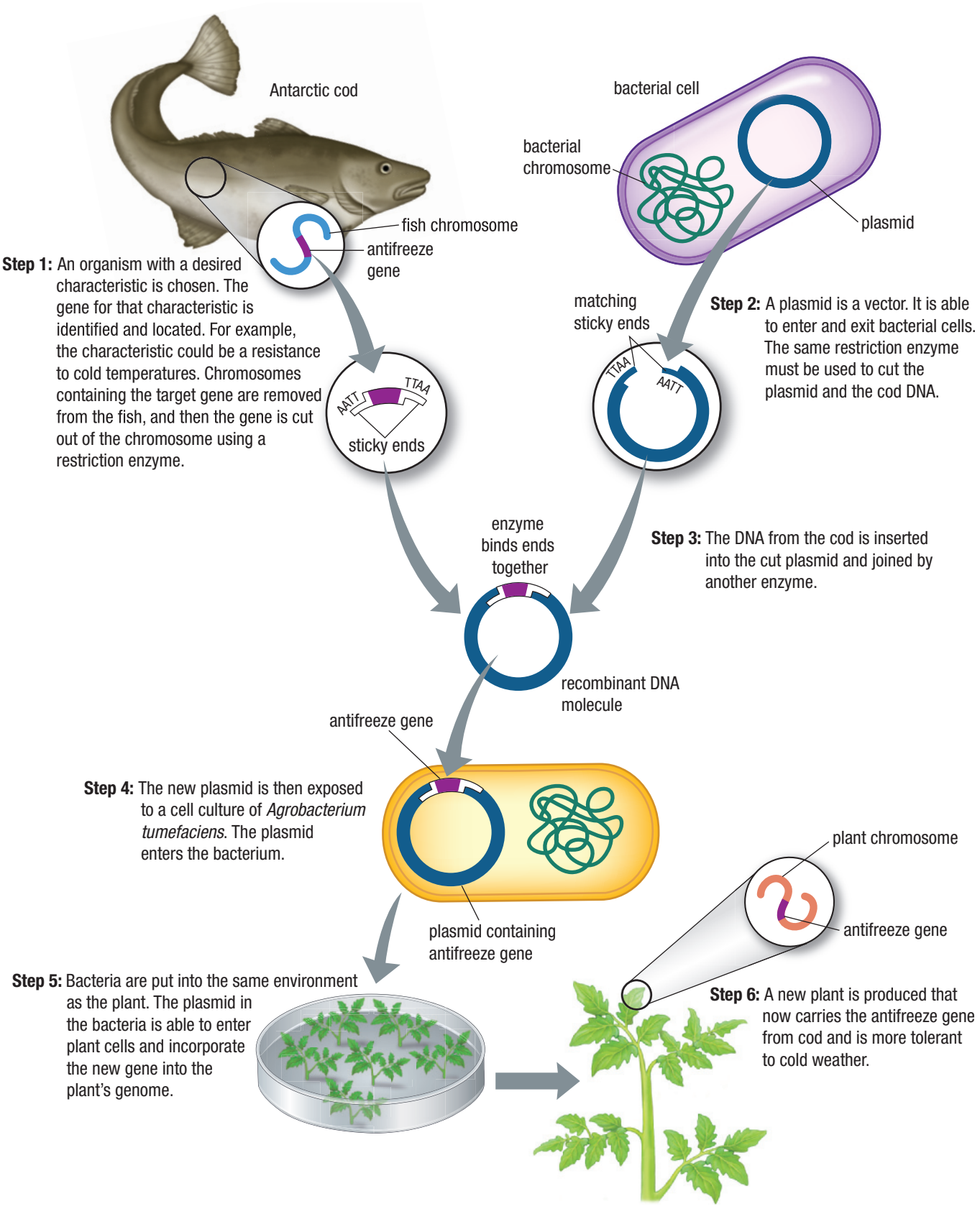

Figure 3 The antifreeze gene in cod is isolated and then inserted into the genome of a plant. The new plant will be able to tolerate lower temperatures.

Products of Genetic Engineering

There are many methods of genetic engineering. The method used depends on the origin of the gene to be inserted and where the genetic researcher wants to place it. However, no matter which method is used, many important products have been engineered for industry, medicine, and agriculture. Spider silk and Bt corn are two examples of products that have undergone genetic engineering. Spider silk is primarily used for research in the development of biomaterials, whereas Bt corn is produced commercially.

Spider Silk

Dragline fibre is the name given to the type of silk spiders use to build their webs. Scientists estimate that spider silk is at least five times as strong as steel and twice as strong as Kevlar—the material in bulletproof vests—of the same mass. It is also waterproof and ductile (stretchable). It stretches 30 % more than the most elastic nylon. Scientists hope to produce artificial fibres of a similar strength by studying the structure of spider silk to be used to manufacture such things as biomaterials for the aerospace industry, strings for tennis rackets, and airbags in vehicles (**Figure 4**).

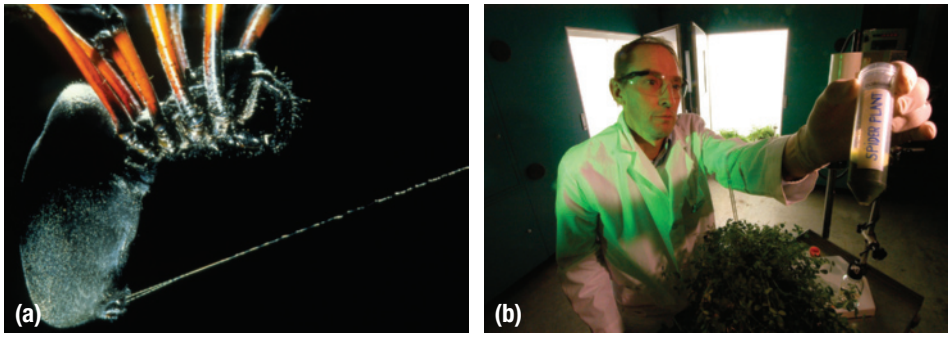

Figure 4 (a) This female golden orb-weaver spider (Nephila sp.) produces silk in webs up to 2 m across! The silk produced by these spiders is amongst the strongest known, and their webs often catch small birds. Spider silk is, weight for weight, stronger than steel. (b) This researcher holds a jar containing spider silk extracted from plants. Specific spider genes are inserted into plants, which then produce the proteins necessary to make spider silk. The mass-produced proteins and fibres can then be used in a number of applications.

Engineers are keenly interested in the strength of spider silk. Similar synthetic materials are not as strong. Because of the qualities of spider silk, biomaterials scientists are very interested in finding a way to produce large amounts of it.

Recombinant DNA technology has provided a way to make spider silk fibre outside a spider's body. The gene that produces the spider silk has already been isolated from spider cells and inserted into the genome of a goat! The goal is to create goats that produce spider silk protein in their milk. The silk would then be purified and used for the construction of new materials to be used in manufacturing, outerwear, parachutes, and other applications.

Bt Corn

Changes to the food industry have rarely been immediately welcomed. When milk was first pasteurized, it was greeted with suspicion, despite the fact that unpasteurized milk quite regularly causes illness and death, and that the new process eliminated many disease-causing microbes. Similarly, canned goods did not receive a warm welcome when they were first introduced, yet canned food is very common nowadays.

The latest revolution in food production is the use of recombinant DNA technology to make foods less susceptible to rotting, to enhance nutritional value, and to make crops resistant to pests and herbicides. In the past, farmers had these same objectives, but traditional methods required generations of trial and error to produce reliable seeds for plants with improved characteristics.

CAREER LINK

Biomaterials Engineer

Biomaterials engineers must have a good understanding of the properties of biomaterials. They try to design and build new products that mimic biological products. To learn more about a career as a biomaterials engineer,

GO TO NELSON SCIENCE

WEB LINK

To learn more about spider silk and how it is made outside of a spider's body,

GO TO NELSON SCIENCE

Figure 5 The European corn borer causes extensive damage to cornfields.

Bacillus thuringiensis (Bt) is a bacterium found in soil. Bt produces a natural pesticide of crystal proteins that are lethal to certain insects and their larvae but are harmless to humans. The genes for the crystal proteins have been inserted into a number of plants, such as corn, using recombinant DNA technology. As a result, the corn, now referred to as Bt corn, is able to produce its own pesticides against insects such as the European corn borer (**Figure 5**). Bt corn is a genetically modified (GM) food.

Using a pesticide in this manner is advantageous for several reasons. It reduces the need to spray crops with synthetic pesticides. Pesticides may be health hazards and produce runoff that contaminates lakes, rivers, and groundwater. Since farmers who grow Bt corn use fewer pesticides, their cost of production may go down depending on the added cost of the Bt corn seed. Yet there are concerns with producing a food product with a built-in natural pesticide. Some are worried that this new protein might cause an allergic response in certain people. If most farmers switch to this single GM variety, the genetic diversity of corn will be drastically lowered. Scientists and farmers are also concerned because they do not know what would happen if the Bt gene were ever to escape into wild plant populations.

6.4 Summary

- Genetic engineers can cut a gene from the genome of one organism and insert it into the genome of a different organism, where it is expressed.
- Restriction enzymes are chemical scissors that are able to cut out a gene fragment from a DNA source.
- Plasmids are circular pieces of DNA that are able to exit and enter bacteria cells and can be used to introduce new genes into an organism.
- Recombinant DNA technology uses plasmids and restriction enzymes to produce organisms with new characteristics.
- The agriculture, health, and manufacturing industries use recombinant DNA technology to increase disease resistance in crops and improve nutrition in foods.
- Recombinant DNA spider silk is a product that one day may be used in numerous applications as an alternative material.
- Bt corn has a gene that codes for a pesticide embedded within its genome. The use of Bt corn allows farmers to use less pesticides in cornfields.

6.4 Questions

1. What is recombinant DNA? Provide an example. K/U
2. Distinguish between restriction enzymes and plasmids. Why are they useful tools to have in a molecular biology lab? T/I
3. Construct a flowchart to describe the process by which a foreign gene is inserted into a genome. K/U C
4. Why are biomaterials engineers interested in being able to produce large amounts of spider silk? K/U T/I
5. What is Bt corn? Why would it be advantageous for a farmer to plant Bt corn rather than regular corn? T/I A
6. Make a list of pros and cons of using recombinant DNA technology in the food industry. T/I C A