12.8: Genetic Engineering

Recombinant DNA and Genetic Engineering

Ever since humans started raising crops for food and fiber (and later animals) they have modified the genetic makeup of the organisms that they use. This is particularly evident in the cultivation of domestic corn which is physically not at all like its wild ancestors. Until now, breeding has been a slow process. Starting with domestication of wild species, selection and controlled breeding have been used to provide desired properties, such as higher yield, heat and drought tolerance, cold resistance, and resistance to microbial or insect pests. For some domesticated species these changes have occurred over thousands of years. During the 1900s, increased understanding of genetics greatly accelerated the process of breeding different varieties. The development of high-yielding varieties of wheat and rice during the “green revolution” of the 1950s has prevented (or at least postponed) starvation of millions of people. A technology that enabled a quantum leap in productivity of domestic crops was the development of **hydrids** from crossing of two distinct lines of the same crop, dating in a practical sense from the mid-1900s.

Traditional breeding normally takes a long time and depends largely upon random mutations to generate desirable characteristics. One of its greatest limitations has been that it is essentially confined to the same species, whereas more often that not, desired characteristics occur in species other than those being bred. Since about the 1970s, however, humans have developed the ability to alter DNA so that organisms synthesize proteins and perform other metabolic feats that would otherwise be impossible. Such alteration of DNA is commonly known as **genetic engineering** and **recombinant DNA** technology. Organisms produced by recombinant DNA techniques that contain DNA from other organisms are called **transgenic organisms**. With recombinant DNA technology, segments of DNA that contain information for the specific syntheses of particular proteins are transferred between organisms. Most often the recipient organisms are bacteria, which can be reproduced (cloned) over many orders of magnitude from a cell that has acquired the desired qualities. Therefore, to synthesize a particular substance such as human insulin or growth hormone, the required genetic information can be transferred from a human source to bacterial cells, which then produce the substance as part of their metabolic processes.

The mechanics of recombinant DNA gene manipulation is a complex and sophisticated operation. The first step involves lyzing (opening up) a cell that has the genetic material needed and removal of this material from the cell. Through enzyme action the sought-after genes are cut from the donor DNA chain. These are next spliced into small DNA molecules. These molecules, called **cloning vehicles**, are capable of penetrating the host cell and becoming incorporated into its genetic material. The modified host cell is then reproduced many times and carries out the desired biosynthesis.

Recombinant DNA technology is a rapidly growing area that is having profound effects, especially in agriculture and medicine. It is being used increasingly to produce crops with unique characteristics, to synthesize pharmaceuticals, and to make a variety of useful raw materials as renewable feedstocks. Recombinant DNA technology has a lot of potential in the development of green chemistry and sustainability, such as in the sustainable production of chemical feedstocks and products of various kinds. An example is synthesis of polylactic acid using lactic acid produced enzymatically with corn and polymerized by standard chemical processes. In the environmental area genetic engineering offers the potential for the production of bacteria engineered to safely destroy troublesome wastes and to produce biological substitutes for environmentally damaging synthetic pesticide.

Early concerns about the potential of genetic engineering to produce “monster organisms” or new and horrible diseases have been largely allayed, although not entirely so, and resistance to the application of recombinant DNA technology is strong in some quarters, particularly in Europe. However, caution is still required with this technology. One example of a problem has been the emergence of weeds resistant to the widely used herbicide glyphosate as discussed at the beginning of this chapter.

Once plants containing desired transgenes have been produced, an exhaustive evaluation process occurs. This process has several objectives. The most obvious of these is an evaluation of the transplanted gene’s activity to see if it produces adequate quantities of the protein for which it is designed. Another important characteristic is whether or not the gene is passed on reliably to the plant’s progeny through successive generations. It is also important to determine whether the modified plant grows and yields well and if the quality of its products are high.

Only a few strains of plants are amenable to the insertion of transgenes, and normally their direct descendants do not have desired productivity or other characteristics required for a commercial crop. Therefore, transgenic crops are crossbred with high-yielding varieties. The objective is to develop a cross that retains the transgene while having desired characteristics of a commercially viable crop. The improved variety is subjected to exhaustive performance tests in greenhouses and fields for several years and in a number of locations. Finally, large numbers of genetically identical plants are grown to produce seed for commercial use.

Many kinds of genetically modified plants have been developed and more are being marketed commercially every year. These are discussed in more detail in Chapter 14.
