import. The plant had to grow for at least two to three years before reaching harvestable size; at harvest, about 1% to 2% of the dry weight was shikonin. Using a combination of strain selection and optimization of reactor conditions, a commercial process that could produce cells with 14 wt % shikonin in a three-week batch cultivation period was established.

However, the role of bioreactors in plant cell tissue is not limited to chemical production. Also, transgenic plant cell cultures can be used to produce proteins such as vaccines. The production of propagules or of artificial seeds may be economically important. The use of efficient submerged cultivation devices to generate elite plants may replace the current labor-intensive processes for the micropropagation of plants.

Whether the product is a chemical or a new plant, the bioprocess engineer must become familiar with some basic characteristics of plants and their implications for reactor design.

13.2. PLANT CELLS IN CULTURE COMPARED TO MICROBES

Plant cells in culture are not microbes in disguise. Aspects of plant cell structure and physiology were discussed in Chapter 2. See Fig. 13.1 for a summary of plant cell structure. The primary difference between plant cells and microbes is the ability of the cells to

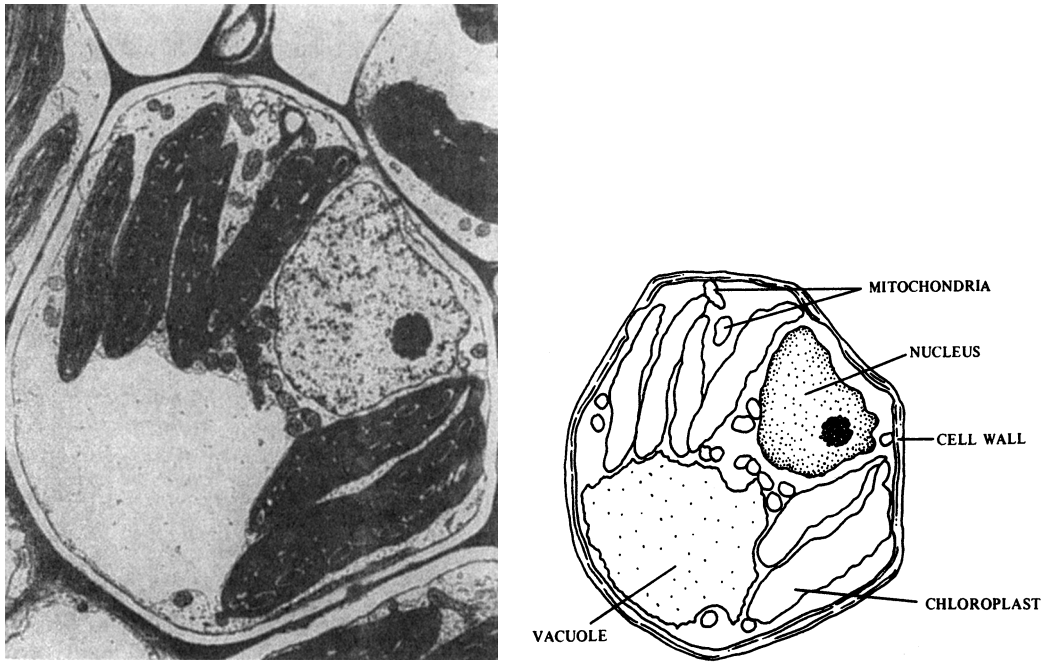

Figure 13.1. (Left) Cross section of a plant cell enlarged about 9000 times its actual size by an electron microscope. (Right) The labeled drawing identifies some of the cell's structures and organelles, those specialized cell parts that resemble and function as organs. This particular cell is a bundle sheath cell from the leaf of a *Zea mays* plant. Cells like this one are part of the veins of the leaf and completely surround the water- and food-conducting tissues (xylem and phloem) of the veins. (With permission, from Michael A. Walsh, Utah State University.)