



**Figure 3.23.** A flowsheet for the production of an extracellular enzyme.

*Aspergillus niger*; lactases are produced by yeast and *Aspergillus*; lipases are produced by certain strains of yeasts and fungi; glucose isomerase is produced by *Flavobacterium arborescens* or *Bacillus coagulans*. After the cultivation step, cells are separated from the media usually by filtration or sometimes by centrifugation. Depending on the intracellular or extracellular nature of the enzyme, either the cells or the fermentation broth is further processed to separate and purify the enzyme. The recovery of intracellular enzymes is more complicated and involves the disruption of cells and removal of cell debris and nucleic acids. Figure 3.23 depicts a schematic of an enzyme plant producing intracellular enzymes.

In some cases, enzyme may be both intracellular and extracellular, which requires processing of both broth and cells. Intracellular enzymes may be released by increasing the permeability of cell membrane. Certain salts such as  $\text{CaCl}_2$  and other chemicals such as dimethylsulfoxide (DMSO) and pH shift may be used for this purpose. If enzyme release is not complete, then cell disruption may be essential.

The processes used to produce these industrial enzymes have much in common with our later discussions on processes to make proteins from recombinant DNA.

### 3.6. MEDICAL AND INDUSTRIAL UTILIZATION OF ENZYMES

Enzymes have been significant industrial products for more than a hundred years. However, the range of potential application is increasing rapidly. With the advent of recombinant DNA technology it has become possible to make formerly rare enzymes in large