is not easy to combine the skills of the engineer with those of the biologist. Our intent is to help you begin to develop these skills. This book and a one-term course are not enough to make you a complete bioprocess engineer, but we intend to help you form the necessary foundation.

## 1.2. BIOTECHNOLOGY AND BIOPROCESS ENGINEERING

When new fields emerge from new ideas, old words are usually not adequate to describe these fields. Biotechnology and what constitutes engineering in this field are best described with examples rather than single words or short phrases.

*Biotechnology* usually implies the use or development of methods of direct genetic manipulation for a socially desirable goal. Such goals might be the production of a particular chemical, but they may also involve the production of better plants or seeds, or gene therapy, or the use of specially designed organisms to degrade wastes. The key element for many workers is the use of sophisticated techniques outside the cell for genetic manipulation. Others interpret biotechnology in a much broader sense and equate it with applied biology; they may include engineering as a subcomponent of biotechnology.

Many words have been used to describe engineers working with biotechnology. *Bioengineering* is a broad title and would include work on medical and agricultural systems; its practitioners include agricultural, electrical, mechanical, industrial, environmental and chemical engineers, and others. *Biological engineering* is similar but emphasizes applications to plants and animals. *Biochemical engineering* has usually meant the extension of chemical engineering principles to systems using a biological catalyst to bring about desired chemical transformations. It is often subdivided into bioreaction engineering and bioseparations. *Biomedical engineering* has been considered to be totally separate from biochemical engineering, although the boundary between the two is increasingly vague, particularly in the areas of cell surface receptors and animal cell culture. Another relevant term is *biomolecular engineering,* which has been defined by the National Institutes of Health as ". . . research at the interface of biology and chemical engineering and is focused at the molecular level."

There is a difference between bioprocess engineering and biochemical engineering. In addition to chemical engineering, *bioprocess engineering* would include the work of mechanical, electrical, and industrial engineers to apply the principles of their disciplines to processes based on using living cells or subcomponents of such cells. The problems of detailed equipment design, sensor development, control algorithms, and manufacturing strategies can utilize principles from these disciplines. Biochemical engineering is more limited in the sense that it draws primarily from chemical engineering principles and broader in the sense that it is not restricted to well-defined artificially constructed processes, but can be applied to natural systems.

We will focus primarily on the application of chemical engineering principles to systems containing biological catalysts, but with an emphasis on those systems making use of biotechnology. The rapidly increasing ability to determine the complete sequence of genes in an organism offers new opportunities for bioprocess engineers in the design and monitoring of bioprocesses. The cell, itself, is now a designable component of the overall process.