Unit 1: Introduction

1.1. 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.

1.2. BIOLOGISTS AND ENGINEERS DIFFER IN THEIR APPROACH TO RESEARCH

The fundamental trainings of biologists and engineers are distinctly different. In the development of knowledge in the life sciences, unlike chemistry and physics, mathematical theories and quantitative methods (except statistics) have played a secondary role. Most progress has been due to improvements in experimental tools. Results are qualitative and descriptive models are formulated and tested. Consequently, biologists often have incomplete backgrounds in mathematics but are very strong with respect to laboratory tools and, more importantly, with respect to the interpretation of laboratory data from complex systems.

Engineers usually possess a very good background in the physical and mathematical sciences. Often a theory leads to mathematical formulations, and the validity of the theory is tested by comparing predicted responses to those in experiments. Quantitative models and approaches, even to complex systems, are strengths. Biologists are usually better at the formation of testable hypotheses, experimental design, and data interpretation from complex systems. Engineers are typically unfamiliar with the experimental techniques and strategies used by life scientists.

The skills of the engineer and life scientist are complementary. To convert the promises of molecular biology into new processes to make new products requires the integration of these skills. To function at this level, the engineer needs a solid understanding of biology and its experimental tools. In this book we provide sufficient biological background for you to understand the chapters on applying engineering principles to biosystems. However, if you are serious about becoming a bioprocess engineer, you will need to take further courses in microbiology, biochemistry, and cell biology, as well as more advanced work in biochemical engineering. If you already have these courses, these chapters can be used for review.

1.3. THE STORY OF PENICILLIN: HOW BIOLOGISTS AND ENGINEERS WORKTOGETHER

In September 1928, Alexander Fleming at St. Mary's Hospital in London was trying to isolate the bacterium, *Staphylococcus aureus,* which causes boils. The technique in use was to grow the bacterium on the surface of a nutrient solution. One of the dishes had been contaminated inadvertently with a foreign particle. Normally, such a contaminated plate would be tossed out. However, Fleming noticed that no bacteria grew near the invading substance (see Fig. 1.1).

Fleming's genius was to realize that this observation was meaningful and not a "failed" experiment. Fleming recognized that the cell killing must be due to an antibacterial agent. He recovered the foreign particle and found that it was a common mold of the *Penicillium* genus (later identified as *Penicillium notatum).* Fleming nurtured the mold to grow and, using the crude extraction methods then available, managed to obtain a tiny quantity of secreted material. He then demonstrated that this material had powerful antimicrobial properties and named the product penicillin. Fleming carefully preserved the culture, but the discovery lay essentially dormant for over a decade.