ChE book review

BIOREACTION ENGINEERING PRINCIPLES

by Jens Nielsen and John Villadsen

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To non-practitioners, biochemical reactions appear to be nebulous, formidably complex, and even a bit magical. To students and practitioners of biochemical engineering, biochemical reactions remain too unpredictable to warrant quantitative and theoretical analysis. However, no one denies that bioreaction systems must obey the fundamental laws of chemistry and physics, and that given sufficient information, bioreaction systems can be mathematically modeled. The question is whether we know enough now to model the bioreaction systems, and given the information available today, how can mathematical models help us. The authors of *Bioreaction Engineering Principles* have taken a positive approach to highlight the contribution of mathematical analysis and to prepare students for future developments in this area.

Although it is uncommon to teach bioreactions from theoretical and mathematical viewpoints (an approach that is commonly adopted in chemical reaction engineering), there is no reason why bioreactions cannot be subjected to mathematical rigor. With such a philosophy in mind, the authors have provided a mathematical treatment for every aspect of bioreaction systems. The result is a clear and logical introduction to bioreaction systems with useful examples and stimulating problems. This book is one of the few texts, if not the only one, attempting to carry the instructional approach and philosophy of chemical reaction engineering to bioreaction systems. Although the book is mathematically oriented, the authors showed "a deep respect for the wonderful complexity of microbial reactions," making the volume highly relevant to modern microbial biotechnology.

For chemical engineers, the book is an excellent introduction to the subject of microbial reaction systems. All the intracellular reactions are introduced with mass and energy balances in mind, making chemical engineers feel quite at home. For students without a mathematical background, however, the book is a little intimidating: matrices, vectors, integrals, and lots of Greek letters. The teacher will have lots of coaching to do. Given the plethora of biochemistry and microbiology textbooks that aim toward students without a mathematical background, this book provides a unique and useful view at the other end of the spectrum.

After an introductory chapter, the book begins with various mechanisms of nutrient transport and major metabolic pathways. Instead of the typical metabolic maps and molecular mechanisms seen in biochemistry texts, it emphasizes stoichiometry, overall reactions, and energy and mass balances. The authors introduce mathematical representation of flux and elemental balances, often under-appreciated in the area of biotechnology. The analysis is rigorous and involves very few assumptions. The equations provide a basis for further analysis of reaction rates. This chapter also discusses the energetics of anaerobic and aerobic processes, which are important considerations in bioreactor systems. With a little touch of thermodynamics, this chapter provides a starting point for biochemical engineers to take a serious look at energy balance and the energetic aspects of biosystems.

Chapter three deals with metabolic flux analysis, metabolic control analysis, and identification of measurement errors, topics of significant scientific and practical interests. The discussion gives a clear introduction to the methodology. Mathematically inclined students will find the discussion concise and precise—others may need more time to digest the equations. The examples here are the best tutors. The authors took the time to digest all current literature in these areas and present a cohesive view of the methodology with some nice ideas in examples and problems. Chapters 2 and 3 are perhaps the most unique features of the book compared to other similar titles in biochemical engineering.

With a strong basis of intracellular reaction analysis, the book then goes into modeling of cell growth and morphology. A general mathematical formulation is first presented as a framework for discussion. Kinetics of cell growth, structured and unstructured, and population balances based on cell number are then discussed with sufficient details. The general formulation may seem meaningless for beginners, but with some understanding of the system, it offers an overall picture of the problem under investigation. Again, the authors designed excellent examples and problems for illustration and practice.

The last part of the book is the application of hard-core chemical engineering to bioreactors: mass transfer, interfacial and bubble behavior, batch reactors, continuous stirred tank reactors, plug-flow reactors, mixing, and scale-up. For chemical engineering students, these chapters offer good examples to learn mass transfer and reactor design in an unconventional area—biotechnology. For biotechnologists, following the equations may be difficult in the beginning. With the help of examples, the task becomes much easier. Furthermore, simply going through the discussion will gain a useful picture of engineering approaches to biotechnology problems.

In summary, this is an excellent book dedicated to bioreaction engineering. With increased understanding of cellular and intracellular functions, it is a timely addition to the textbooks available in biochemical engineering. The book set the foundation for systematic and rigorous modeling in this area. ❐