

Preface

"Nature is by far the best chemist and the best engineer. Nature also has the best engineering process: evolution."

Dr. Frances H. Arnold,
Linus Pauling Professor of Chemical Engineering at Caltech,
2018 Nobel Laureate in Chemistry.

In the endeavor of the chemical industry to reduce dependence on fossil raw materials, the application of microorganisms contributes to an increasing extent. Not only bacteria and fungi but also archaea are able to explore renewable resources efficiently and environmentally friendly and convert them into sustainable products. As an innovative cross-disciplinary field, the application of industrial microbiology will gain importance not only in the traditionally related areas of food and pharmaceutical industry but also increasingly in the chemical industry. Today, the global market for microbial products is in the order of 10^{11} US\$. In many states, funding programs are running to replace significant proportions of chemical processes with biological ones.

The future potential of industrial microbiology lies in the fact that it bundles the know-how of biologists, chemists, engineers, and bioinformaticians. This leads to a quality that no specialist can achieve on their own. In recent decades, microbiology, especially by the successful approaches of molecular biologists, has developed fundamentally. The foundation of microbial strain development was and is still random mutagenesis and subsequent selection. However, the modern methods of genetic engineering lead to a targeted change in production strains, down to the position of a single base pair in the DNA, more quickly and accurately. This discipline called Metabolic Engineering is not only suitable to overproduce metabolites, but, in the form of the so-called Synthetic Microbiology, will also help to become independent from secondary metabolism of rare organisms such as plants, fungi, or unculturable bacteria. Not a single one of the dangers of genetic engineering feared in the 1980s become true. On the contrary, drugs produced by Genetically Modified Organisms (GMOs) fill the shelves in pharmacies and are safe and successful.

This textbook is an update of a German edition published by SPRINGER in 2013. Experienced scientists working at universities, research units, or in industry report selected aspects concerning successfully applied processes of industrial microbiology. Representative examples show which processes lead to recyclable

materials of special quality. In the first two chapters, a historical overview is given first (Chapter 1) followed by an introduction to process engineering (Chapter 2). Both chapters are of paramount importance. As food is the most important commodity to the reader as a human being, it will be discussed as the first product group (Chapter 3), allowing the students to rediscover it from a new perspective. In Chapter 4, "Technical Alcohols and Ketones" as well as in Chapter 5 "Organic Acids", it becomes clear that yields related to sugar as a substrate reach around 100%. In the production of L-enantiomers of amino acids (Chapter 6), the high selectivity of enzymes is most important. The importance of vitamins (Chapter 7) and antibiotics (Chapter 8) is well known. About 10^5 tons of vitamin C per year are produced with the help of bacteria. The penicillins excreted by fungi, cultivated in steel vessels as large as houses, exceed an annual market value of 10^{10} US\$. In Chapter 9, the realization of the great promise of industrial microbiology becomes clear. With the help of genetic engineering pharmaceutical proteins, human-identical insulin and even analogues with improved active profiles can be produced by microorganisms on an industrial scale, so that the needs of more than 10^8 diabetics can be met. This not only means availability in principle but also affordability. Microbially produced enzymes (Chapter 10) are used in a wide range of applications. Today, everyone can use protease-containing detergents at home, e.g. for washing or in tiny amounts to clean contact lenses. Large companies in the United States apply bacterial amylases to hydrolyze more than 10^9 bushels (about 10^8 tons) of corn starch annually, which can then be used in other microbial processes, e.g. by brewer's yeast for the production of 10^{10} gallons (about 10^9 liters) of fuel alcohol. Microorganisms are also used in the production of polysaccharides (Chapter 11). Xanthan for example is added as a thickener to food products such as ketchup. In order to modify steroids for the production of cortisone or contraceptives, microorganisms are used for regioselective biotransformations in multistep processes (Chapter 12). As hydrometallurgy can be accelerated by iron- and sulfur-oxidizing bacteria, both, not only vessel-based but also open pit mining in kilometer scale is increasing to extract copper even from sources where classical techniques are inefficient (Chapter 13). In Chapter 14, highly developed waste water treatment plants are described, where microorganisms not only have a high potential for biosynthesis but also are suitable for degradation. In the future, we will be well advised to not only produce substances but also to consider during the design phase how microorganisms can quickly degrade them in order to prevent their accumulation in any environment. As microorganisms play key roles in nature's material cycle, they might become more important to close cycles urgently needed for human economy.

We are grateful to our colleagues who contributed to this textbook by writing their chapters. It was a pleasure for us to cooperate with internationally recognized scientists. Our colleagues in industry deserve special praise for sacrificing nights or weekends for their contributions. Sometimes, graphically presented relationships had to be simplified in their complexity without getting wrong. We thank Susanne Nieland, MSc, who did not give up until both discussion partners, authors and editors, were satisfied with a recognizable focus of a black and white or a rarely colored graphic. Furthermore, we are grateful to WILEY-VCH

especially Dr. Frank Weinreich and Dr. Andreas Sendtko, for their help and patience because more than one round was needed to reach the wished quality.

Sadly, during the development of this book, our first editor, David, fell seriously ill and was not able to continue working with us any longer. The idea of an American–German coedition was born after an invited talk David gave at a special meeting of the German Association of General and Applied Microbiology in Senftenberg. David was a very generous and thoughtful colleague, researcher, and teacher who was a pioneer in the study of cellulases and was devoted to the goal of deriving clean fuels from plants. We are very pleased that his efforts helped to bring about this textbook and hope that we helped our authors explain the topics selected in a way that both undergraduate and graduate students can understand. As science and engineering develop at an increasingly rapid pace, causal explanations can only be given for selected topics. We strongly support efforts to discuss open issues in seminars as many outstanding questions remain, e.g. the reason for citrate overproduction of *Aspergillus niger*.

We also hope that this textbook will arise the interest of many students of natural sciences and engineering. We are convinced that industrial microbiology will continue to be a success and hope that our book will help both our teaching colleagues and very young people to make their own contributions, whether at a research or teaching institution or in an industry.

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