

CONTENTS

PREFACE

xiii

1	A LITTLE MICROBIOLOGY	1
1.1	Biophysics and the Cell Doctrine	2
1.2	The Structure of Cells	3
1.3	Important Classes of Microbes	13
1.4	A Perspective for Further Study	23
2	CHEMICALS OF LIFE	26
2.1	Lipids	28
2.2	Sugars and Polysaccharides	36
2.3	From Nucleotides to RNA and DNA	41
2.4	Amino Acids into Proteins	50
2.5	The Hierarchy of Cellular Organization	67
3	THE KINETICS OF ENZYME-CATALYZED REACTIONS	78
3.1	The Enzyme-Substrate Complex and Enzyme Action	84
3.2	Simple Enzyme Kinetics with One and Two Substrates	90
3.3	Determination of Elementary Step Rate Constants	103
3.4	Other Patterns of Substrate-Concentration Dependence	110
3.5	Modulation and Regulation of Enzymatic Activity	116
3.6	Other Influences on Enzyme Activity	127
3.7	Enzyme Reactions in Heterogeneous Systems	137

4 ISOLATION AND UTILIZATION OF ENZYMES	155
4.1 Production of Crude Enzyme Extracts	159
4.2 Enzyme Purification	163
4.3 Enzyme Immobilization	183
4.4 Applications of Hydrolytic Enzymes	189
4.5 Other Enzyme Applications	199
4.6 Immobilized-Enzyme Technology	203
4.7 The Scale of Enzyme Technology	214
5 METABOLIC PATHWAYS AND ENERGETICS OF THE CELL	221
5.1 The Concept of Energy Coupling: ATP and NAD	226
5.2 Anaerobic Metabolism: Fermentation	232
5.3 Respiration and Aerobic Metabolism	241
5.4 Photosynthesis: Tapping the Ultimate Source	254
5.5 Biosynthesis	260
5.6 Transport across Cell Membranes	267
5.7 Concluding Remarks	274
6 CELLULAR GENETICS AND CONTROL SYSTEMS	281
6.1 Molecular Genetics	281
6.2 Growth and Reproduction of a Single Cell	300
6.3 Alteration of Cellular DNA	312
6.4 Commercial Applications of Microbial Genetics and Mutant Populations	322
7 KINETICS OF SUBSTRATE UTILIZATION, PRODUCT YIELD, AND BIOMASS PRODUCTION IN CELL CULTURES	334
7.1 Growth-Cycle Phases for Batch Cultivation	337
7.2 Mathematical Modeling of Batch Growth	357
7.3 Product-Synthesis Kinetics	371
7.4 Overall Kinetics in Cases of Chemical-Reaction-Mass-Transport Interaction	389
7.5 Thermal Death Kinetics of Cells and Spores	401
8 TRANSPORT PHENOMENA IN MICROBIAL SYSTEMS	411
8.1 Gas-Liquid Mass Transfer in Microbial Systems	413
8.2 Determination of Oxygen Transfer Rates	424
8.3 Mass Transfer for Freely Rising or Falling Bodies	432
8.4 Mass Transfer across Free Surfaces	439
8.5 Forced Convective Mass Transfer	443
8.6 Surface-Area Correlations for Mechanically Agitated Vessels	449
8.7 Other Factors Affecting $k_t a$	452
8.8 Non-Newtonian Fluids	454

8.9 Scaling of Mass-Transfer Equipment	462
8.10 Particulate Mass Transfer: Filtration	464
8.11 Heat Transfer	473
9 DESIGN AND ANALYSIS OF BIOLOGICAL REACTORS	497
9.1 The Ideal Continuous-Flow Stirred-Tank Reactor (STR)	498
9.2 Residence-Time Distributions	519
9.3 Tubular and Tower Reactors	525
9.4 Sterilization Reactors	545
9.5 Relationships between Batch and Continuous Biological Reactors	554
10 BIOLOGICAL REACTORS, SUBSTRATES AND PRODUCTS I: SINGLE-SPECIES APPLICATIONS	574
10.1 Fermentation Technology	574
10.2 Product Manufacture by Fermentation	587
10.3 Reactors for Biomass Production	609
11 ANALYSIS OF MULTIPLE INTERACTING MICROBIAL POPULATIONS	635
11.1 Neutralism, Mutualism, Commensalism, and Ammensalism	636
11.2 Mathematical Preliminaries	642
11.3 Competition: Survival of the Fittest	647
11.4 Predation and Parasitism	654
11.5 Effects of the Number of Species and Their Web of Interactions	665
11.6 Spatial Patterns	674
12 BIOLOGICAL REACTORS, SUBSTRATES, AND PRODUCTS II: MIXED MICROBIAL POPULATIONS IN APPLICATIONS AND NATURAL SYSTEMS	683
12.1 Uses of Well-defined Mixed Populations	684
12.2 Spoilage and Product Manufacture by Spontaneous Mixed Cultures	691
12.3 Microbial Participation in the Natural Cycles of Matter	693
12.4 Biological Waste-Water Treatment	702
INDEX	745