4.3. DNA Replication: Preserving and Propagating the Cellular Message 107
4.4. Transcription: Sending the Message 110
4.5. Translation: Message to Product 113
4.5.1. Genetic Code: Universal Message , 113
4.5.2. Translation: How the Machinery Works, 113
4.5.3. Posttranslational Processing: Making the Product Useful, 115
4.6. Metabolic Regulation 119
4.6.1. Genetic-level Control: Which Proteins Are Synthesized?, 119
4.6.2. Metabolic Pathway Control, 123
4.7. How the Cell Senses Its Extracellular Environment 124
4.7.1 Mechanisms to Transport Small Molecules across Cellular Membranes, 124
4.7.2. Role of Cell Receptors in Metabolism and Cellular Differentiation, 127
4.8. Summary 128
4.9. Appendix: Examples of Regulation of Complex Pathways 129
Suggestions for Further Reading 131
Problems 131

5 MAJOR METABOLIC PATHWAYS 133

5.1. Introduction 133
5.2. Bioenergetics 134
5.3. Glucose Metabolism: Glycolysis and the TCA Cycle 137
5.4. Respiration 141
5.5. Control Sites in Aerobic Glucose Metabolism 142
5.6. Metabolism of Nitrogenous Compounds 143
5.7. Nitrogen Fixation 144
5.8. Metabolism of Hydrocarbons 144
5.9. Overview of Biosynthesis 145
5.10. Overview of Anaerobic Metabolism 148
5.11. Overview of Autotrophic Metabolism 150
5.12. Summary 152
Suggestions for Further Reading 154
Problems 154

6 HOW CELLS GROW 155

6.1. Introduction 155
6.2. Batch Growth 156
6.2.1. Quantifying Cell Concentration, 156
6.2.2. Growth Patterns and Kinetics in Batch Culture, 160
6.2.3. How Environmental Conditions Affect Growth Kinetics, 169
6.2.4. Heat Generation by Microbial Growth, 173
6.3. Quantifying Growth Kinetics 175