



Introduction to Biotechnology

FOURTH EDITION

William J. Thieman • Michael A. Palladino



INTRODUCTION TO
BIOTECHNOLOGY

Introduction to Biotechnology, Global Edition

Table of Contents

Front Cover

Title Page

Copyright Page

Dedication Page

About the Authors

Preface

Contents

Chapter 1 The Biotechnology Century and Its Workforce

1.1 What Is Biotechnology and What Does It Mean to You?

A Brief History of Biotechnology

The Do-It-Yourself Biotechnology Movement

Biotechnology: A Science of Many Disciplines

Products of Modern Biotechnology

Ethics and Biotechnology

1.2 Types of Biotechnology

Microbial Biotechnology

Agricultural Biotechnology

Animal Biotechnology

Forensic Biotechnology

Bioremediation

Aquatic Biotechnology

Medical Biotechnology

Biotechnology Regulations

The Biotechnology Big Picture

1.3 What Will the New Biotechnology Century Look Like? An Example from Medical Biotechnology

A Scenario in the Future: How Might We Benefit from the Human Genome Project?

1.4 The Biotechnology Workforce

The Business of Biotechnology

Top Regions for Biotechnology Jobs

Table of Contents

What Is a Biotechnology Company?

Jobs in Biotechnology

Salaries in Biotechnology

Hiring Trends in the Biotechnology Industry

Questions & Activities

Chapter 2 An Introduction to Genes and Genomes

2.1 A Review of Cell Structure

Prokaryotic Cells

Eukaryotic Cells

2.2 The Molecule of Life

DNA Structure

What Is a Gene?

2.3 Chromosome Structure, DNA Replication, and Genomes

Chromosome Structure

2.4 RNA and Protein Synthesis

Copying the Code: Transcription

Translating the Code: Protein Synthesis

2.5 Regulation of Gene Expression

Transcriptional Regulation of Gene Expression

Noncoding RNAs and Their Roles in Regulating Gene Expression

Bacteria Use Operons to Regulate Gene Expression

2.6 Mutations: Causes and Consequences

Types of Mutations

Mutations Are the Basis of Variation in Genomes and a Cause of Human Genetic Diseases

2.7 Revealing the Epigenome

2.8 Immune Response Mechanism in Prokaryotes Results in Extraordinary New Technology for Editing Genes In Vitro and In Vivo

Questions & Activities

Case Study Loss of Circular RNA Impacts miRNA Degradation and Brain Function

Chapter 3 Recombinant DNA Technology and Genomics

3.1 Introduction to Recombinant DNA Technology and DNA Cloning

Restriction Enzymes and Plasmid DNA Vectors

Transformation of Bacterial Cells and Antibiotic Selection of Recombinant Bacteria

Introduction to Human Gene Cloning and Expressing Proteins for Biotechnology

Applications

Table of Contents

What Makes a Good Vector?

3.2 How Do You Identify and Clone a Gene of Interest?

DNA Libraries: Collections of Cloned Genes

3.3 Laboratory Techniques and Applications of Recombinant DNA Technology

Agarose Gel Electrophoresis

Restriction Mapping

DNA Sequencing

Next-Generation Sequencing (NGS)

Third-Generation Sequencing Technology

Fluorescence in Situ Hybridization

Southern Blotting

Studying Gene Expression

Analyzing Gene Function

3.4 Genomics and Bioinformatics: The Hottest Disciplines in the History of Biotechnology

Whole-Genome Sequencing

Bioinformatics: Merging Molecular Biology with Computing Technology

Examples of Bioinformatics in Action

A Genome Cloning Effort of Epic Proportion: The Human Genome Project

What Have We Learned from the Human Genome?

Accessing Human Genome Information Via the Internet

The Human Genome Project Started an Omics Revolution

After the HGP: What Is Next?

3.5 Systems Biology and Synthetic Biology

Questions & Activities

Case Study The PANTHER Database

Chapter 4 Proteins as Products

4.1 Proteins as Biotechnology Products

Biotech Drugs and Other Medical Applications

Bioremediation: Treating Pollution with Proteins

4.2 Protein Structures

Structural Arrangement

Protein-Protein Interaction Map Created

Protein Folding

Post-Translational Protein Modifications

Protein Engineering by Directed Molecular Evolution

4.3 Protein Production

Table of Contents

Protein Expression: Upstream Processing

Protein Purification Methods: Downstream Processing

Verification

Preserving Proteins

Scaling Up Protein Purification

Postpurification Analysis Methods

4.4 Proteomics

Questions & Activities

Case Study Tau-Tau Protein Interaction in Alzheimer's Disease Study

Chapter 5 Microbial Biotechnology

5.1 The Structure of Microbes

Yeasts Are Important Microbes, Too

5.2 Microorganisms as Tools

Microbial Enzymes

Bacterial Transformation

Cloning and Expression Techniques

5.3 Using Microbes for a Variety of Everyday Applications

Food Products

Therapeutic Proteins

Using Microbes Against Other Microbes

5.4 Vaccines

A Primer on Antibodies

Types of Vaccines: How Are Vaccines Made?

Major Targets for Vaccine Development

5.5 Microbial Genomics

Why Sequence Microbial Genomes?

Metagenomic Studies Sequence Genomes from Microbial Communities

Viral Genomics

Creating Synthetic Genomes

5.6 Microbial Diagnostics

Detecting and Tracking Disease-Causing Microorganisms

5.7 Combating Bioterrorism

Microbes as Bioweapons

Targets of Bioterrorism

Using Biotechnology against Bioweapons

5.8 Microbes for Making Biofuels

Table of Contents

Questions & Activities

Case Study Designer Microbes Rely on Synthetic Amino Acids

Chapter 6 Plant Biotechnology

6.1 Uses of Biotechnology to Enhance Selective Breeding

Marker-Assisted Selection

Mutation Breeding

Protoplast Fusion

6.2 Genetic Engineering of Plants

Using Agrobacterium to Insert Genes

The Leaf Fragment Technique

Gene Guns

Chloroplast Engineering

Gene Inactivation Using CRISPR-Cas Technology

Antisense Technology

Gene Stacking

6.3 Practical Applications

Protecting Plants from Viruses

Genetic Pesticides

Herbicide Resistance

Enhanced Nutrition

Biopharming

Engineered Deletion of Gene Promoters Rather Than Genes

6.4 Health and Environmental Concerns

Concerns about Human Health

Concerns about the Environment

Regulations

Questions & Activities

Case Study Can RNA Interference Silence Genes in a Citrus Pest?

Chapter 7 Animal Biotechnology

7.1 Animals in Research

Why Use Animals in Research?

Types of Animals Used in Research

Regulations in Animal Research

Alternatives to the Use of Animals

Regulation of Animal Research

Veterinary Medicine: Benefits for Humans and Animals

Table of Contents

7.2 Cloning

- Creating Dolly: A Breakthrough in Cloning
- Limits to Cloning
- Human Organ Development in GM Animals

7.3 Transgenic Animals

- Transgenic Techniques
- GM Animals for the Agriculture Industry
- Transgenic Animals as Bioreactors
- Kidney on a Chip Determines Drug Dosing
- Gene Editing Technologies in Animals

7.4 Producing Human Antibodies in Animals

- Monoclonal Antibodies

Questions & Activities

Case Study Using Zebrafish as a Heart Disease Model

Chapter 8 DNA Fingerprinting and Forensic Analysis

8.1 What Is a DNA Fingerprint?

- How Is DNA Typing Performed?

8.2 Preparing a DNA Fingerprint

- Specimen Collection
- Extracting DNA for Analysis
- PCR and STR Analysis
- STR Analysis

8.3 Putting DNA to Use

- The Narborough Village Murder Case Led to a New Method of DNA Separation
- How Significant Is Contamination?
- World Events Lead to the Development of New Technologies

8.4 DNA and the Rules of Evidence

- DNA Fingerprinting and the Chain of Evidence
- Human Error and Sources of Contamination
- DNA Forensics from Touch DNA

8.5 Familial Relationships and DNA Profiles

- Mitochondrial DNA Analysis
- Y-Chromosome Analysis

8.6 Nonhuman DNA Analysis

- Identifying Plants through DNA
- Protein Analysis May Join DNA Forensics

Table of Contents

Animal DNA Analysis

Food FraudA Recent DNA Forensics Application

Genetically Modified Organism (GMO) Testing

Questions & Activities

Case Study Mouse Cell Line Contamination ID Using DNA Forensics

Chapter 9 Bioremediation

9.1 What Is Bioremediation?

Why Is Bioremediation Important?

9.2 Bioremediation Basics

What Needs to Be Cleaned Up?

Chemicals in the Environment

Fundamentals of Cleanup Reactions

The Players: Metabolizing Microbes

Bioremediation Genomics Programs

9.3 Cleanup Sites and Strategies

Soil Cleanup

Bioremediation of Water

9.4 Turning Wastes into Energy

9.5 Applying Genetically Engineered Strains to Clean Up the Environment

Petroleum-Eating Bacteria

Engineering Microbes to Clean Up Heavy Metals

Genetically Modified Plants and Phytoremediation

Biosensors

9.6 Environmental Disasters: Case Studies in Bioremediation

The Exxon Valdez Oil Spill

Oil Fields of Kuwait

The Deepwater Horizon Oil Spill

9.7 Challenges for Bioremediation

Recovering Valuable Metals

Bioremediation of Radioactive Wastes

Degrading Macro- and Microplastics in the Environment

Questions & Activities

Case Study Turning Outhouses into Light houses?

Chapter 10 Aquatic Biotechnology

10.1 Introduction to Aquatic Biotechnology

Table of Contents

10.2 Aquaculture: Increasing the Worlds Food Supply through Biotechnology

The Economics of Aquaculture

Fish-Farming Practices

Improving Strains for Aquaculture

Enhancing the Quality and Safety of Seafood

Barriers and Limitations to Aquaculture

10.3 Genetic Technologies and Aquatic Organisms

Analysis of Novel Genes from Aquatic Species

Genetic Manipulations of Finfish and Shellfish

10.4 Medical Applications of Aquatic Biotechnology

Bioprospecting to Isolate Medicines from the Sea

10.5 Nonmedical Products

A Potpourri of Products

Aquatic Biomass and Bioprocessing Applications

10.6 Environmental Applications of Aquatic Biotechnology

Antifouling Agents

Biosensors

Environmental Remediation

Questions & Activities

Case Study Massive Fish Escape Jeopardizes New Salmon Farm

Chapter 11 Medical Biotechnology

11.1 Animal Models of Human Disease

11.2 Detecting and Diagnosing Human Disease Conditions

Biomarkers for Disease Detection

The Human Genome Project Revealed Disease Genes on All Human Chromosomes

Genetic Testing: Detecting Chromosomal Abnormalities and Defective Genes

11.3 Sequence Analysis of Individual Genomes

Whole-Exome Sequencing

Genomic Analysis of Single Cells by DNA and RNA Sequencing

Genome-Wide Association Studies Identify Genome Variations in Populations

11.4 Precision Medicine and Biotechnology

What Is the Precision Medicine Initiative?

Harnessing the Immune System for Treating Disease: Antibodies and Immunotherapy

11.5 Gene Therapy

How Is It Done?

Genome Editing Approaches for Gene Therapy

Table of Contents

Curing Genetic Diseases: Targets for Gene Therapy

Challenges Facing Gene Therapy

Future Challenges to Address

11.6 The Potential of Regenerative Medicine

Cell and Tissue Transplantation

Tissue Engineering

Stem Cells

Cloning

Therapeutic Cloning and Reproductive Cloning

Regulations Governing Embryonic Stem Cell and Therapeutic Cloning in the United States

Questions & Activities

Case Study Personal Genomics Helps Elizabeth Davis Walk Again

Chapter 12 International Biotechnology Regulations

12.1 Overview of International Regulations

12.2 Protection of Human, Animal, and Plant Health

Biotechnology for Disease Control, Surveillance, and Response

Safe Handling, Transfer, and Use of Biological Materials

Food Safety

12.3 Biodiversity Conservation and the Cartagena Protocol on Biosafety

12.4 Management of Genetic Resources

State Sovereign Rights

The Nagoya Protocol

International Treaty on Plant Genetic Resources for Food and Agriculture

The Pandemic Influenza Preparedness Framework

12.5 Trade and Intellectual Property Rights

Trade in Biotechnology Products

Intellectual Property Rights

Plant Variety Rights

12.6 Human Rights

12.7 Preventing the Hostile Use of Biotechnology

12.8 Role of Scientists in the Development of International Regulations

Questions & Activities

Case Study How Should the Safe Transport of Infectious Substances Be Ensured?

Chapter 13 Ethics and Biotechnology

13.1 What Is Ethics?

Table of Contents

Approaches to Ethical Decision Making

Ethical Exercise Warm-up

13.2 Examples of Ethics and Biotechnology

Cells and Products

GM Crops: Are You What You Eat?

Animal Husbandry or Animal Tinkering?

Synthetic Genomes and Synthetic Biology

Drug Trials with Human Patients

What Does It Mean to Be Human?

Spare Embryos for Research Versus Creating Embryos for Research

Should Humans and Other Animals Be Cloned for Any Reason?

Mitochondrial Replacement Therapy

Patient Rights and Biological Materials

Genetic Information and Genetic Privacy

More or Less Human?

Genome Editing and Germline Gene Modifications

13.3 Economics, the Role of Science, and Communication

Questions & Activities

Case Study The GTEx Project, Cadavers, and Family Rights

Appendix 1: Answers to Questions & Activities

Appendix 2: The 20 Amino Acids of Proteins

Credits

Glossary

Index