

# Biotechnology: A Laboratory Skills Course, Second Edition

## Detailed Chapter Outlines



Below is a chapter-by-chapter outline of the student edition of *Biotechnology: A Laboratory Skills Course*, second edition. The vignettes and student activities are listed at the end of each chapter outline. Please visit [bio-rad.com/textbook](http://bio-rad.com/textbook) for more information.

### Chapter 1: Biotechnology Industry

- 1.1 What Is Biotechnology?
  - The Biotechnology Toolkit
- 1.2 Who Uses Biotechnology?
  - Life Science Research
    - -Omics and Systems Biology
  - Healthcare
    - Drug Discovery, Development, and Testing
    - Protein-Based Drug Production
    - Personalized Medicine
    - Clinical Diagnostics
  - Agriculture
  - Food
  - Industrial Manufacturing
  - Biofuels
  - Mining
  - Pollution Monitoring and Waste Management
  - Conservation
  - Biodefense
  - Forensics
  - Human Origins
  - Nanotechnology
- 1.3 The Biotechnology Industry
  - What Is a Biotechnology Company?
  - Biotechnology Product Development
  - Funding Biotechnological Advancement
  - Patents
- 1.4 Governmental Regulation of Biotechnology
  - Regulation of Genetically Modified Organisms
  - Regulation of Products in Healthcare
  - Preclinical Research
  - Clinical Trials
  - Regulation of Animal Research
  - Regulation of Human Research
  - Regulation of Waste Disposal
  - Regulation of Nanotechnology
  - Workplace Safety Regulation

- 1.5 Industry Practices
  - Good Laboratory Practice
  - Good Manufacturing Practice
- 1.6 Biotechnology Company Structure
- 1.7 Careers in Biotechnology
  - Careers in the Laboratory
    - Laboratory Technician
    - Quality Assurance Technician
    - Research Associate
    - Research and Development Scientist
    - Clinical Scientist
    - Engineer
  - Non-Laboratory Career

#### Chapter 1 Vignettes

*Bioethics* — Biotechnology: Good or Bad?

*Biotech in the Real World* — Affecting Government Policy

*Biotech in the Real World* — Bio-Rad: Then and Now

*Careers in Biotech* — Timothy Balmorez, Chemist, Bio-Rad Laboratories, Inc.

*How To...* Write an SOP

### Chapter 2: Laboratory Skills

- 2.1 Laboratory Safety
  - Operating Safely in a Laboratory
  - Safety Training
  - Personal Protective Equipment
  - Chemical Safety
  - Biological Safety
  - General Laboratory Safety
  - Waste Disposal
  - Cleanrooms
- 2.2 Laboratory Notebooks
  - Laboratory Notebook Structure
  - Components of a Laboratory Notebook Entry

## 2.3 Laboratory Equipment

- Measuring volumes
  - Graduated Cylinders
  - Volumetric Flasks
  - Vacuum-Assisted Pipettes
  - Micropipets
  - Burettes
- Liquid Containers
  - Erlenmeyer Flasks
  - Reagent Bottles
- Measuring Mass
  - Balances
- Measuring Temperature
  - Thermometers
- Measuring pH
  - pH Meters
- Calibration
- Washing Glassware
- Disinfecting and Sterilizing
  - Autoclaving
  - Disinfecting Surfaces with Bleach
  - Disinfecting Surfaces with Alcohol
  - Disinfecting Using a Microwave Oven
  - Disinfecting with Germicidal UV Light
  - Sterilizing Solutions
- Labeling

## 2.4 Numerical Data

- Significant Figures
- Scientific Notation
- Units of Measure
  - Metric Prefixes

## 2.5 Preparing Solutions

- Percent Solutions
  - Mass per Volume Percent Solutions
  - Volume per Volume Percent Solutions
  - Percentages, Ratios, and Proportions
  - Diluting Percent Solutions
- Using Stock Solutions Given in Terms of “x”
- Molar Solutions
  - The Mole
  - Molarity
  - Making Molar Solutions
    - a. Proportional Method
    - b. Unit Cancellation Method
- Making Compound Molar Solutions
- Diluting Molar Solutions
- Preparing Small Volume Dilutions
- Normality

## Chapter 2 Vignettes

*Bioethics* — Waste Disposal

*Biotech in the Real World* — Who Invented Claritin? How Laboratory Notebooks Played Their Part

*Careers in Biotech* — Joshua Moore, Bio-Containment Protocol Support Supervisor, U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID)

*How To...* Use an Adjustable-Volume Micropipet

## Chapter 2 Activities

2.A DNA Extraction and Precipitation

2.B Pipetting

2.C Kool-Aid Column Chromatography

2.D Making Solutions

2.E Titration

2.F Writing a Standard Operating Procedure

## Chapter 3: Microbiology and Cell Culture

3.1 Microbiology and Cell Biology

- Three Domains of Life
- Microorganisms and History

3.2 Bacteria

- Names and Shapes of Bacteria
- Bacterial Environments

3.3 Uses of Bacteria in Biotechnology

- Food Production
- Protein Production

3.4 Culturing Bacteria in the Laboratory

- Growth Media
  - Solid Media
  - Antibiotic Selection
  - Liquid Media

3.5 Microbiological Techniques

- Tools
- Aseptic Technique
- Using Streak Plate Technique to Isolate Single Colonies
- Labeling Media
- Quantifying Bacteria
  - Serial Dilution and Plate Counts
  - Optical Density of Bacteria
- Identification of Bacteria

3.6 Eukaryotic Cells

- Organelles
- Other Eukaryotic Cells

### 3.7 Uses of Eukaryotic Cells in Biotechnology

- Fermentation
- Protein Production
- Stem Cells

### 3.8 Eukaryotic Cell Culture

- Growth Media
- Environment
- Sterility
- Visualization

#### Chapter 3 Vignettes

*Bioethics* — Should Human Embryos Be Used for Research?

*Biotech in the Real World* — Artificial Life!

*Careers in Biotech* — Katie Dalpozzo, Laboratory Research Associate, Bavarian Nordic

*How To...* Use Aseptic Technique to Transfer Bacteria

#### Chapter 3 Activities

- 3.A Making Microbiology Media
- 3.B Disk Diffusion Test (Modified Kirby-Bauer Test)
- 3.C Microbes and Health: An Illustration of Koch's Postulates
- 3.D Gram Staining
- 3.E Quantifying Bacterial Numbers
- 3.F Staining Eukaryotic Cells

## Chapter 4: DNA Structure and Analysis

### 4.1 Molecular Biology

- The Central Dogma of Molecular Biology

### 4.2 DNA Structure

### 4.3 Recombinant DNA Technology

- Restriction Enzymes
- Ligases
- Nontraditional Cloning Techniques
  - Golden Gate Assembly
  - Gibson Assembly
  - TOPO (TA) Cloning
- Using Enzymes in the Laboratory
- CRISPR-Cas9 Technology
  - How CRISPR works
  - Applications of CRISPR Technology
    - a. Agriculture
    - b. Industry
    - c. Public Health
    - d. Medicine

### 4.4 DNA Analysis Techniques

- Horizontal Agarose Gel Electrophoresis
- Agarose Gels and Running Buffer
- Standards for DNA Electrophoresis
- Equipment
  - Horizontal Gel Electrophoresis Chambers
  - Power Supplies
- Running an Agarose Gel
- Agarose Gel Staining and Imaging

### 4.5 Restriction Enzymes as Forensic Tools

- Restriction Fragment Length Polymorphisms
- Southern Blotting

#### Chapter 4 Vignettes

*Bioethics* — Personal Genetic Information

*Biotech in the Real World* — Fighting Crime with DNA

*Careers in Biotech* — Elisa Ciullo, Sr. Supervisor, Clinical Filing Operations, Genentech

*How To...* Set Up a Restriction Digest

#### Chapter 4 Activities

- 4.A Restriction Site Prediction Using NEBcutter
- 4.B Casting Agarose Gels
- 4.C Dye Electrophoresis
- 4.D Restriction Digestion and Analysis of Lambda DNA
- 4.E Forensic DNA Fingerprinting
- 4.F Plasmid Mapping

## Chapter 5: Bacterial Transformation and Plasmid Purification

### 5.1 History of Bacterial Transformation and Plasmids Bacteria

- Plasmid Structure
- Features of Plasmids
- Using Plasmids in Biotechnology
- Transcriptional Regulation of Plasmids
- Genetically Engineering the pGLO Plasmid
- Plasmids for Eukaryotic Expression

### 5.2 Transforming Cells

- Selection of Transformed Cells
- Transformation Efficiency

### 5.3 Plasmid Purification and Quantitation

- Growing Bacteria in a Liquid Culture
- Purifying Plasmid DNA from a Culture
- DNA Quantitation
  - Gel Quantitation
  - Spectrophotometric Quantitation
  - Quantitation of DNA with a Fluorometer

## Chapter 5 Vignettes

*Bioethics* — A World without Antibiotics?

*Biotech in the Real World* — Biotech on the Pharm

*Careers in Biotech* — Denise Gangadharan, PhD, Associate Director for Science, Centers for Disease Control and Prevention

*How To...* Transform *E. coli* Using Electroporation

*How To...* Use a Microcentrifuge

## Chapter 5 Activities

5.A Bacterial Transformation with S3 Plasmid

5.B Bacterial Transformation with pGLO Plasmid

5.C Purification of S3 and pGLO Plasmids

5.D DNA Quantitation

## Chapter 6: The Polymerase Chain Reaction

6.1 Invention of PCR

6.2 What Is PCR?

- Three Stages of PCR
  - Denaturation
  - Annealing
  - Extension
- PCR and DNA Replication
- Components of a PCR Reaction
- Setting Up a PCR Reaction
  - Master Mixes
- Analysis of PCR Products

6.3 Thermal Cyclers

6.4 Types of PCR

- Real-Time, or Quantitative, PCR
- Digital PCR
- Reverse Transcription PCR
- Multiplex PCR
- Degenerate PCR
- Nested PCR
- Fast PCR
- Isothermal PCR
- Random Amplification of Polymorphic DNA

6.5 PCR Optimization

- Quality of Template DNA
- Primer Design
- Cycling Parameters
- Magnesium Concentration

6.6 Techniques Based on PCR

- DNA Microarrays
- DNA Sequencing
  - Primer Sequences
- Next-Generation Sequencing
  - Sequencing by Synthesis
  - Pyrosequencing
  - Ion Semiconductor Sequencing
  - Sequencing by Ligation
- Sequence Data Analysis Using Bioinformatics

6.7 Real-World Applications of PCR

- PCR in Medicine
- PCR in Agriculture
- PCR in Forensics
- PCR in Paternity Testing
- PCR in Human Migration
- PCR in Wildlife Conservation

## Chapter 6 Vignettes

*Bioethics* — Forensic DNA Databases — Is Your Privacy Protected?

*Biotech in the Real World* — A Universe of Viruses

*Careers in Biotech* — Dora Barbosa, Research Associate, University of California San Francisco

*How To...* Program a Thermal Cycler

## Chapter 6 Activities

6.A STR PCR Analysis

6.B GMO Detection by PCR

6.C Detection of the Human PV92 Alu Insertion

6.D Fish DNA Barcoding

## Chapter 7: Protein Structure and Analysis

7.1 Protein Synthesis

- Bacterial Transcription
- Eukaryotic Transcription
- Translation
- Posttranslational Modifications

7.2 Protein Structure

- Amino Acids
- Protein Folding

7.3 Proteins in Biology

- Fibrous Proteins
- Globular Proteins
  - Enzymes

7.4 Proteins in Biotechnology

- Proteins in Industry
- Proteins in Healthcare
- Proteins as Tools in Life Science Research

## 7.5 Methods of Protein Analysis

- Protein Quantitation
  - Biuret Test
  - Lowry Assay
  - Bradford Assay
- Protein Properties Used in Analysis
  - Protein Size
  - Protein Charge
- Protein Mass Spectrometry
- Protein Electrophoresis
  - Polyacrylamide Gels
  - Electrophoresis Running Buffer
  - Discontinuous Buffer Systems
  - Visualizing Proteins in Polyacrylamide Gels
- Other Types of PAGE
  - Native PAGE
  - Isoelectric Focusing
  - Two-Dimensional PAGE
  - Nucleic Acid Separation
- Protein Chromatography
  - Size Exclusion Chromatography
  - Hydrophobic Interaction Chromatography
  - Ion Exchange Chromatography
  - Affinity Chromatography
  - Analyzing the Results of Chromatography
  - Scaling Chromatography
- Protein Analysis Using Bioinformatics

## 7.6 Protein Production in Industry

- Protein Production
- Quality Control in Protein Production

### Chapter 7 Vignettes

*Bioethics* — Editing Genes to Cure Disease

*Biotech in the Real World* — Vaccines in Bananas

*Careers in Biotech* — Scott Chilton, Marketing Manager, Maravai Life Sciences

*How To...* Set Up a Vertical Electrophoresis System

### Chapter 7 Activities

- 7.A Protein Quantitation Using the Bradford Assay
- 7.B Size Exclusion Chromatography
- 7.C GFP Purification by Hydrophobic Interaction Chromatography
- 7.D SDS-PAGE of Fish Muscle
- 7.E Biofuel Enzyme Assay
- 7.F Exploring Bioinformatics with GFP

## Chapter 8: Immunological Applications

### 8.1 The Immune System

- Cells of the Immune System
- Antibodies
- Immune Response

### 8.2 Antibodies as Tools

- Polyclonal Antibodies
- Monoclonal Antibodies
- Humanized Monoclonal Antibodies for Medical Use

### 8.3 Immunoassays

- Labeling and Detecting Antibodies
- Enzyme-Linked Immunosorbent Assay (ELISA)
  - ELISA for Direct Antigen Detection
  - ELISA for Indirect Antigen Detection
  - Sandwich ELISA for Antigen Detection
  - ELISA for Antibody Detection
  - Instruments for ELISA
- Ouchterlony Double Diffusion Assay
- Western Blotting
  - Electrophoresis
  - Immunodetection
  - Western Blotting in Diagnostic Testing
- Using Antibodies to Study Cells and Tissues
- High-Throughput Immunoassays
  - Multiplex Bead Assays
  - Fluorescence-Activated Cell Sorting

### Chapter 8 Vignettes

*Bioethics* — Testing for HIV Status at Home

*Biotech in the Real World* — Using Immunodetection to Save the Panda

*Biotech in the Real World* — Car T Cell Therapy — A New Horizon in Cancer Treatment

*Careers in Biotech* — Sophy Wong, MD, Associate Clinical Professor of Medicine, University of California San Francisco, CA; Medical Director for HIV ACCESS and AETC

*How To...* Select an Antibody

### Chapter 8 Activities

- 8.A Ouchterlony Double Immunodiffusion Assay
- 8.B Serum Antibody Detection by ELISA
- 8.C Quantitative ELISA
- 8.D Western Blotting

## Chapter 9: Research Projects

### 9.1 What Is Research?

- Deductive and Inductive Research
- Conducting Research in the Real World
- Peer Review
- Sharing of Scientific Information
  - Peer-Reviewed Publications
  - Conferences, Meetings, Seminars, and Posters

### 9.2 Student Research Projects

- Whole Class Projects
- Group Projects
- Individual Projects
- Collaborating with Scientists
- Venues for Conducting Research or Entering Competitions
  - High School Research
  - Undergraduate Research
- Choosing a Research Project
- Scoping a Research Project
- Planning a Project
- Performing Background Research
  - Internet
  - Libraries
  - Peer-Reviewed Journal Articles
  - Mentors
- Experimental Design
  - Methods
  - Controls
  - Trials and Sample Size
- Data Analysis
  - Example of Data Analysis
  - Calculating the Mean
  - Calculating the Standard Deviation
  - Drawing Conclusions from Statistical Data
- Funding Research Projects

### 9.3 Communicating Research

- Posters
- Research Papers
- Oral Presentations

### 9.4 Project Ideas

- Research Tools and Techniques
- Agricultural and Animal Research
- Food Science
- Humans and Health
- Forensics
- Energy and the Environment

### 9.5 Considerations and Tips for All Laboratory Projects

- Microbiology
- Animal Research
- Research on Human Subjects
- Molecular Biology
  - Guidelines for Working with Recombinant DNA
  - Restriction Enzymes
  - PCR
  - Extracting DNA
  - Primer Design
  - Master Mixes
  - Determining the Annealing Temperature
  - Ligation and Transformation
  - DNA Sequencing
- Proteins
  - Obtaining Antibodies
  - Optimizing Immunoassays
  - Enzymes and Substrates
  - Chromatography

### Chapter 9 Vignettes

*Bioethics* — Clinical Trials and Data Fraud

*Biotech in the Real World* — Regeneron Science Talent Search

*Careers in Biotech* — Sunny Choe, PhD, Senior Medical Scientist, Gilead Sciences, Inc.

*How To... Read a Journal Article*

### Appendices

- A: Fast Gel Protocol
- B: Alternative Staining Methods for Agarose Gels
- C: Stain-Free SDS-PAGE Gel Imaging
- D: Glossary
- E: Laboratory Skills Assessment Rubric
- F: Laboratory Notebook and Project Rubrics

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