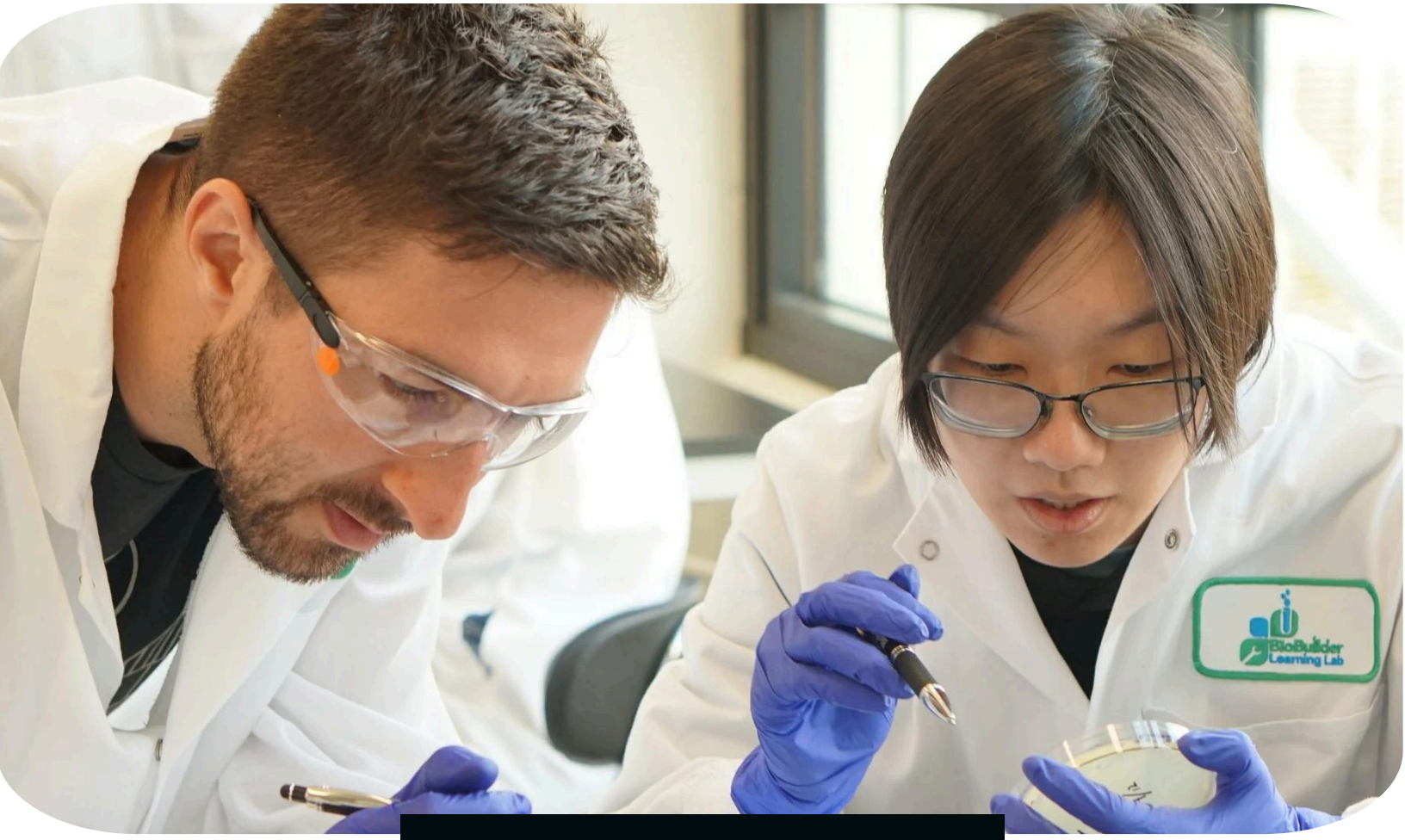
TEACHER'S GUIDE



BioTechBuilder LAB SKILLS

TOPIC: BUILDING A SOLID FOUNDATION
TOPIC: MAKING SOLUTIONS
TOPIC: GROWING CELLS

This module introduces students to fundamental concepts, math, and techniques needed to operate in any laboratory environment.

TOPIC: BUILDING A SOLID FOUNDATION

Starting with lab safety and chemical handling, students progress through weighing solid chemicals, preparing common solutions, and culturing bacteria using aseptic techniques.

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. Safety First!	Lab Safety Equipment Scavenger Hunt	Slides, Wrap Up, Homework
Students are introduced to key safety equipment in the lab through a scavenger hunt that culminates in creation of a map of their lab space.		
2. Handling Hazards	Case Study: Responding to a Chemical Spill	Slides, Pre-lab Quiz
Students learn how to assess and manage hazards posed by chemicals used in the lab and show their understanding through a role playing activity.		
3. Measuring in Metric	Weighing Solids	Slides, Pre- and Post-lab Quiz
Students learn to collect and record accurate measurements with an electronic balance by weighing solids using different metric units.		
4. Keeping a Lab Notebook	Weighing Solids for Solutions	Slides, Pre-lab Quiz, Rubric, Homework
Students begin to take ownership of their experiments by creating their first protocol and lab notebook entry as they weigh solid chemicals.		
5. Lab Practical	Assessment	Slides, Answer Key
Students demonstrate their understanding of lab safety, safe handling of hazardous chemicals, and keeping of a lab notebook.		

TOPIC: MAKING SOLUTIONS

Students learn the math and procedures used to prepare and dilute solutions, measure and adjust pH, and use heat and aseptic techniques where needed.

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. Getting to Know Glassware	Glassware Scavenger Hunt	Slides, Wrap Up
Students become familiar with the glassware used to make solutions, as well as how to estimate and read volumes.		
2. Making Stock Solutions	Prepare a Kool-Aid® Stock Solution	Slides, Pre-lab Quiz, Wrap Up, Homework
Students practice molarity calculations and prepare a single-solute stock solution.		
3. Diluting Solutions	Serial Dilutions	Slides, Pre-lab Quiz, Wrap Up, Homework
Students are introduced to serological pipettes and how to prepare serial dilutions and notebook self evaluations.		
4. Micropipetting	Micropipetting Practice	Slides, Pre-lab Quiz, Wrap Up
Students are introduced to micropipettes and use them to practice transferring liquids.		
5. Lab Practical 1	Assessment	Slides, Rubric
Students exchange mystery solutions and use spectrophotometry to prepare a standard curve and measure the mystery solution concentration.		
6. Making Multi-Solute Solutions	Making 1X PBS	Slides, Pre-lab Quiz, Wrap Up, Rubric
Students review solution calculations and prepare solutions with multiple solutes.		
7. Perfecting pH	Measuring and adjusting pH of 1XPBS	Slides, Pre-lab Quiz, Optional Activity, Homework
Students learn how to measure and adjust the pH of a solution.		
8. Saturating Solutions	Making a Supersaturated Solution	Slides, Pre-lab Quiz, Optional Activity
Students learn how to prepare a saturated solution while practicing %w/v and %v/v calculations and safe operation of a hot plate.		
9. Preventing Bacterial Contamination	Pipetting Using Aseptic Technique	Slides, Rubric, Optional Activity, Homework
Students learn about and practice aseptic technique while pipetting solutions.		
10. Lab Practical 2	Assessment	Slides, Set Up, Rubric
Students demonstrate mastery by writing their own lab protocol and preparing solutions.		

TOPIC: GROWING CELLS

This topic introduces students to methods for culturing bacteria on solid and liquid media and the use of a spectrophotometer and plating to measure viabiality.

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. Pouring Plates	Pouring Plates	Slides
Students pour agar plates while learning the fundamentals of bacterial cell structure and culturing methods.		
2. Streaking for Single Colonies	Streaking for Colony Isolation	Slides, Pre-lab Quiz, Rubric
Students streak for single colonies from a bacterial slant while learning about phases of a growth curve.		
3. Culturing a Colony	Preparing Overnight Cultures	Slides, Pre-lab Quiz, Optional Activity
Students learn about selective media, then use aseptic technique to prepare liquid selective media and transfer a single colony into the media for growth overnight.		
4. Measuring Cell Concentration	OD600 vs Counting Colonies	Slides, Pre-lab Quiz, Homework
Students measure OD600 of their overnight culture and prepare a serial dilution of for viability assay plating.		
5. Lab Practical part 1	Assessment	Slides, Rubric
Students learn how cell concentration and viable cells differ, then count the colonies on their plates to calculate the viability of their bacterial cells. Each student repeats the viability assay experiment for skills assessment.		
6. Lab Practical part 2	Assessment	Slides
Students repeat the analysis and calculation of the bacterial cell viability using their plates from Lab Practical part I, and submit their lab notebook for assessment.		

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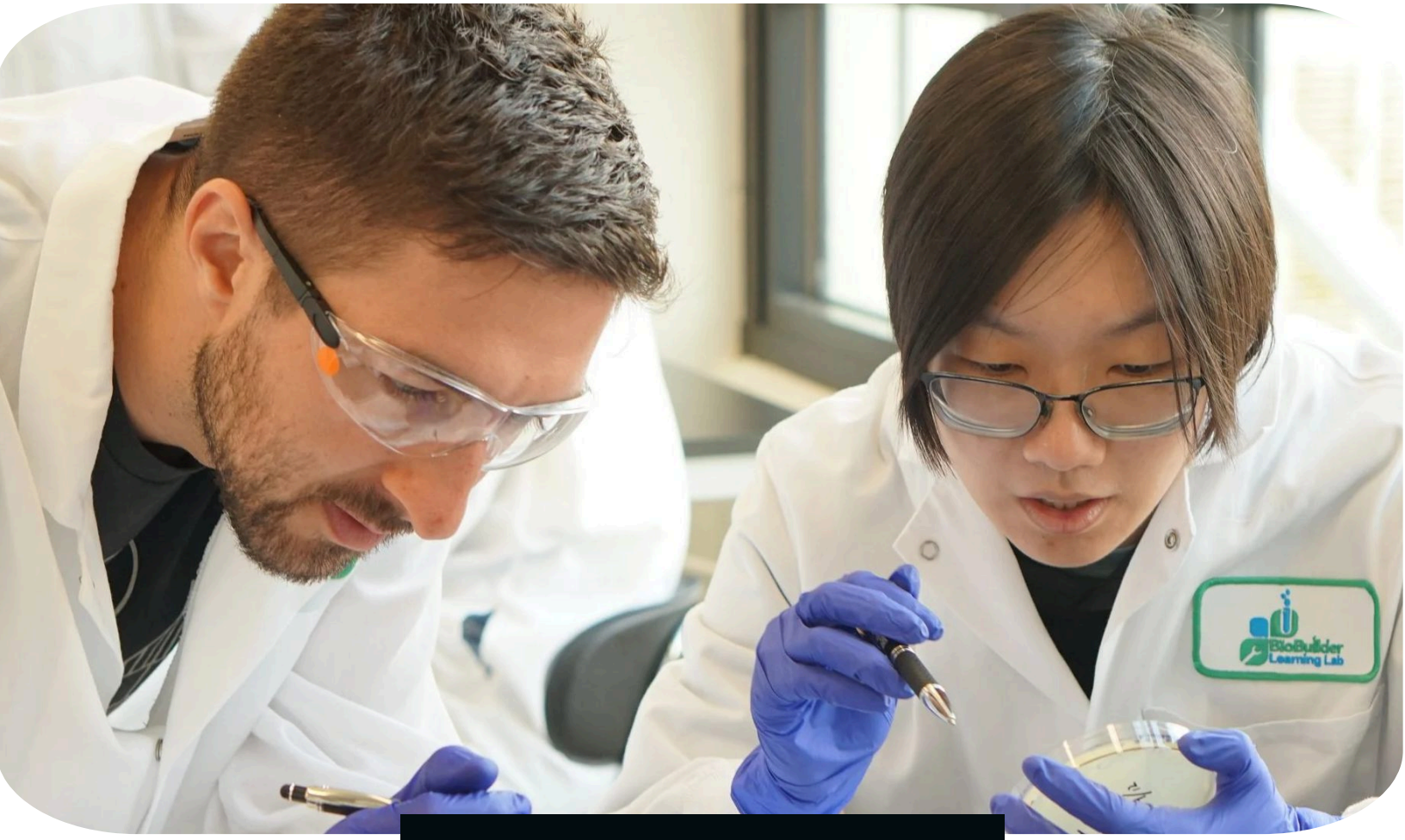

BioTechBuilder FOUNDATIONS

TOPIC: ANALYZING DNA
TOPIC: ANALYZING PROTEINS

This module uses a molecular framework to introduce techniques in DNA and protein analysis.

TOPIC: ANALYZING DNA

This topic introduces students to DNA techniques used in modern biotechnology including DNA isolation, PCR, restriction digest analysis, gel electrophoresis, and sequencing. This topic reinforces solution preparation and lab math, micropipetting, and documentation.

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. DNA Foundations Overview	Streaking BB1 for Single Colonies	Slides, Overview Activity
Students streak a transformed *E. coli* strain for single colonies while learning why it is necessary to verify DNA.		
2. Calibrating Pipettes	Pipette Calibration	Slides, Pre-lab Quiz, Homework
Students revisit micropipetting and calibrate their instruments to ensure consistent and accurate measurements.		
3. Making Miniprep Solutions	Solution Preparation	Slides
Students prepare plasmid DNA isolation buffers while learning about the process of DNA isolation by miniprep.		
4. Isolating DNA 1	Plasmid Isolation, Day 1	Slides
Students learn to safely operate a centrifuge as they begin extracting DNA from their bacterial cultures using miniprep protocol.		
5. Isolating DNA 2	Plasmid Isolation, Day 2	Slides, Homework
Students map the recombinant DNA components of the engineered strain and complete the plasmid isolation.		

TOPIC: ANALYZING DNA (CONTINUED)

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
6. Amplifying DNA 1	Write a PCR proctocol	Slides, Pre-lab Quiz
Students learn how the polymerase chain reaction can be used to amplify and verify DNA segments.		
7. Amplifying DNA 2	PCR Verification of pBTB1	Slides, Quiz Review
Students evaluate their PCR protocol then amplify the DNA they isolated from their bacterial cultures.		
8. Quiz I	Assessment	Slides, Answer Key
Students design primers, calculate reagent volumes, and predict the length of a PCR product.		
9. Digesting DNA	Restriction Digest of PCR Product	Slides, Pre-lab Quiz, Homework
Students learn about restriction enzymes and apply their understanding to verify and analyze their PCR products.		
10. Visualizing DNA 1	Pouring an Agarose Gel	Slides
Students learn the principles of gel electrophoresis and pour gels to analyze their digested PCR DNA.		
11. Visualizing DNA 2	Gel Loading Practice	Slides, Pre-lab Quiz, Homework
Students learn features of an agarose gel then practice loading and interpreting gels.		
12. Visualizing DNA 3	Gel Electrophoresis	Slides, Quiz Review
Students analyze their PCR and digested DNA by gel electrophoresis.		
13. Quiz II	Assessment	Slides, Answer Key
Students select enzymes, calculate the length of the DNA digestion products, and predict the results of agarose electrophoresis.		
14. Lab Practical I	Assessment	Slides, Set-Up, Answer Key
Students demonstrate gel electrophoresis competency by pouring, loading, running, and analyzing agarose gel.		
15. Sequencing DNA	Analyzing Sequencing Data	Slides, Quiz Review
Students learn how DNA sequencing works and how to read and interpret DNA sequencing results of sample DNA.		
16. Quiz III	Assessment	Slides, Homework, Answer Key
• Students demonstrate techniques used to verify DNA by answering fundamental and situational questions.		
17. Lab Practical II	Assessment	Slides, Set-Up, Answer Key
Students use different DNA verification techniques to solve a forensic mystery.		

TOPIC: ANALYZING PROTEINS

This topic teaches students to express and analyze a protein of interest. Hands-on experiments unify and apply content related to gene expression, protein induction, enzyme activity, protein concentration measurements, and separation techniques including column chromatography and SDS-PAGE.

• LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. Protein Foundations Overview	Streaking for Colony Isolation	Slides, Overview Activity
Students review central dogma, inducible gene expression (lac operon), and streaking for single cells.		
2. Bacterial Growth Curves	Overnight Induced Culture	Slides, Pre-lab Quiz
Students learn about bacterial growth curves and transfer a strain from solid to llquid media.		
3. Protein Induction	Measuring Cell Density	Slides, Pre-lab Quiz, Homework
Students learn how a chemical can induce bioproduction of an enzyme then induce the cells they have grown.		
4. Cell Viability 1	Assay, day 1	Slides, Homework
Students use spectrophotometry and serial dilution to evaluate growth and viability of their induced bacterial strain.		
5. Cell Viability 2	Assay, day 2	Slides
Students assess cell growth data, calculate viability, and analyze the impact of enzyme overproduction on cellular fitness.		
6. Lab Practical I, part 1	Assessment	Slides, Rubric
Students repeat the viability assay to assess the impact of cold storage on the induced bacterial strain.		
7. Lab Practical I, part 2	Assessment	Slides, Homework
Students analyze the viability assay plates and summarize the impact of cold storage on induced bacterial strain, then learn about enzymes as catalysts.		
8. Solution Preparation	Making Solutions for Assay	Slides
Students prepare reagents necessary for enzyme activity measurement.		

TOPIC: ANALYZING PROTEIN (CONTINUED)

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
9. Enzyme Activity Measurement	b-gal Activity Assay	Slides, Quiz Review
Students learn how colorimetric enzyme assays work, and then measure enzyme activity in their uninduced and induced bacterial cells to calculate enzyme activity.		
10. Quiz I	Assessment	Slides, Answer Key
Students are evaluated on their understanding of cell growth, induction, viability, and activity calculation.		
11. Standard Curve	Cell Lysis	Slides, Homework
Students learn about the linear relationship between concentration and absorbance, and then serially dilute a known protein to prepare a standard curve.		
12. Protein Concentration	Bradford Assay	Slides
Students plot absorbance vs concentration and use that standard curve to determine the protein concentration in their induced and uninduced bacterial cells.		
13. Protein Purification I	Nickel Resin, day 1	Slides, Homework
Students study affinity-based purification methods and prepare nickel resin for subsequent lesson.		
14. Protein Purification II	Nickel Resin, day 2	Slides, Homework
Students use affinity chromatography to purify the overproduced enzyme.		
15. Visualizing Protein I	SDS-PAGE, day 1	Slides, Pre-lab Quiz
Students learn how denaturing gel electrophoresis separates proteins by size, then prepare select fractions for SDS-PAGE.		
16. Visualizing Protein II	SDS-PAGE, day 2	Slides, Homework
Students load samples onto SDS-PAGE and use Coomassie to stain the gel.		
17. Visualizing Protein III	SDS-PAGE, day 3	Slides, Quiz Review
Students destain gels to compare their data to their documented predictions.		
18. Quiz II	Assessment	Slides, Answer Key
Students demonstrate their knowledge of standard curves, affinity-based purification, and protein gel electrophoresis.		
19. Lab Practical II	Assessment	Slides, Answer Key
Students will be assessed on their ability to generate a standard curve and use that curve to measure the concentration of an unknown solution		

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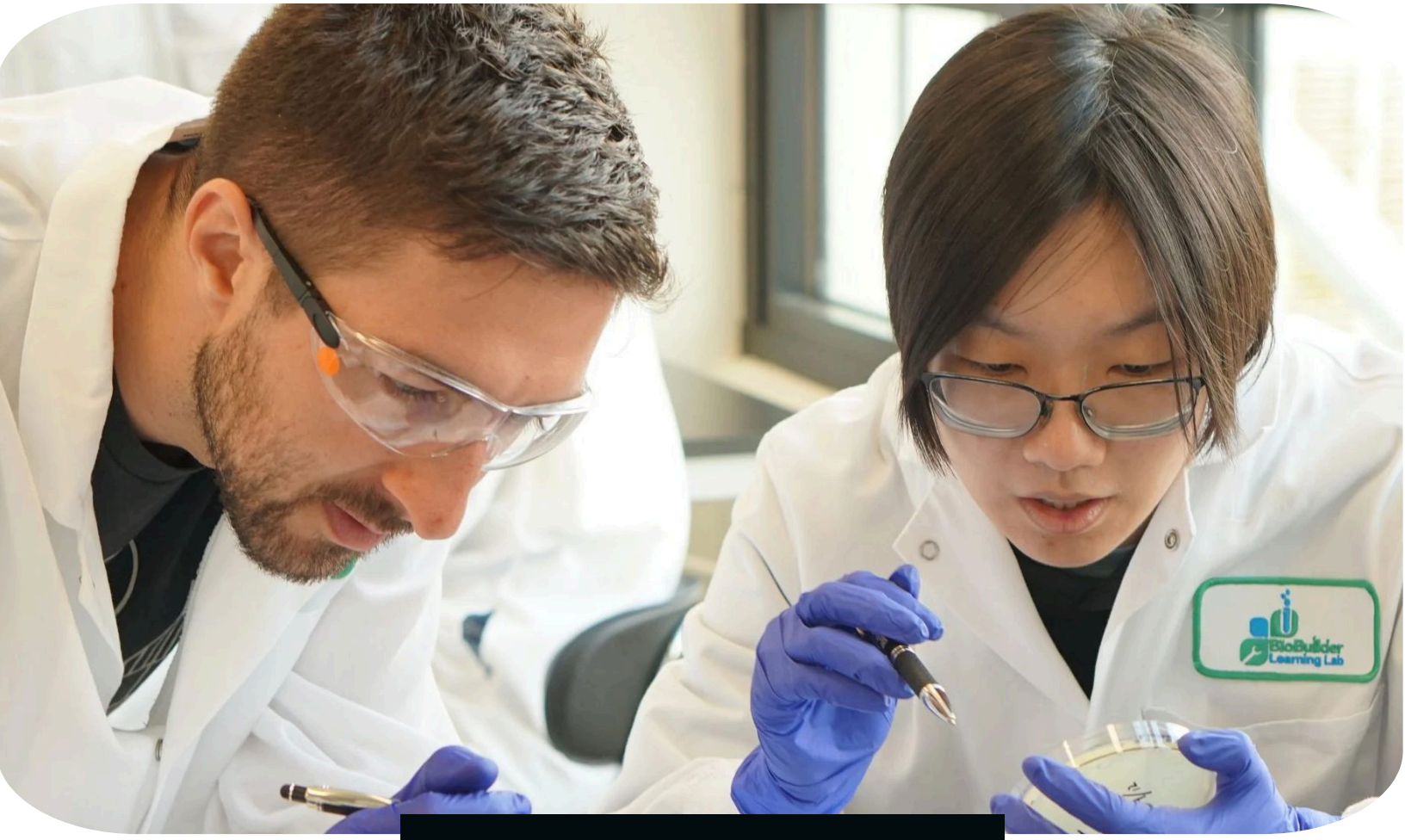


BioTechBuilder APPLICATIONS

TOPIC: BIOMANUFACTURING
TOPIC: SYNTHETIC BIOLOGY

This module introduces students to industrial applications and professional practices that enable commercialization of biotechnologies.

TOPIC: BIOMANUFACTURING

This topic explores the life cycle for production and manufacturing of bioproducts from upstream processing to downstream processing. What it means to be GMP compliant and differences between Quality Assurance and Quality Control is emphasized. The labs include seed train process, viability assays, and product activity tests while students document every step using batch production records.

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. BioManufacturing Overview	Prepare Starter Culture	Slides, Set-up, Homework
Students investigate commercially available bioproducts and discuss their benefits and importance in the current market.		
2. Fermentation I	Expand Seed Train to 10 ml	Slides
Students learn about the stepwise process for growing large cell volumes, and then expand a cell stock into a 10 ml culture.		
3. Fermentation II	Concentration vs Viability	Slides, Homework, Batch Record
Students are introduced to Good Manufacturing Practices and Batch Records.		
4. Fermentation III	Cell Expansion with VCD	Slides
Students calculate the # and % of viable cells, then seed a 100 ml culture with a known number of viable cells.		
5. Fermentation IV	TCD and Viability	Slides, Homework, Batch Record
Students calculate cell viability and are introduced to hemocytometer-based cell counting.		
6. Fermentation V	Hemocytometer Counts	Slides, Quiz Review
Using an online simulation, students perform hemocytometer-based cell counting and data analysis.		
7. Quiz I	Assessment	Slides, Answer Key
Students use sample data to calculate cell concentration and viability in a microbial and mammalian cell sample.		
8. Lab Practical I	Assessment	Slides, Set-Up, Answer Key
Students use OD600 data to determine TCD and VCD, then determine viable cells needed for the next expansion culture.		

TOPIC: BIOMANUFACTURING (CONTINUED)

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
9. Measuring Bioproduct I	Overnight Induced Culture	Slides, Homework, Batch Record
Students induce a bioproduct (β-galactosidase) and learn about SOPs for Quality Assurance.		
10. Measuring Bioproduct II	Solutions and Batch Records	Slides, Homework
Students follow SOP to make solutions for an enzyme activity assay, record their work in BPR forms, and distinguish Quality Assurance and Quality Control.		
11. Measuring Bioproduct III	Activity Measurement	Slides, Batch Record
Students measure the activity of the bioproduct to ensure the scaled-up *E. coli* cells are behaving as expected.		
12. Industrial Fermentation I	Bioreactor Simulation	Slides, Homework
Students learn bioreactor types and parameters to monitor, then use an online simulation of a 2000 liter bioreactor.		
13. Industrial Fermentation II	Writing an SOP	Slides, Quiz Review
Students develop an SOP as an in-class activity then learn about biosafety cabinet form and function.		
14. Quiz II	Assessment	Slides, Answer Key
Students demonstrate their knowledge and understanding of GMP regulation, QA, and QC.		
15. Lab Practical II	Assessment	Slides, Set-Up, Answer Key
Students identify the errors in Batch Record form, SOP, and a calculation.		
16. Downstream Processing I	Separation Simulation	Slides, Homework
Students consider extracellular vs intracellular localization, and simulate harvesting techniques based on this property.		
17. Downstream Processing II	Purifying Lysozyme	Slides, Set-Up
Students learn about chemical, mechanical, and temperature-dependent cell disruption techniques.		
18. Downstream Processing III	Lysozyme Activity Assay	Slides
Students learn about protein purification methods including chromatography and tangenial flow filtration.		
19. Downstream Processing IV	Gowning for Cleanroom	Slides, Quiz Review
Students consider product formulation and packing, cleanrooms to prevent contamination, and protein purification data.		
20. Quiz III	Assessment	Slides, Answer Key
Students are asked about downstream processing from lysate preparation to purification to concentration and packaging.		
21. Lab Practical III	Assessment	Slides, Answer Key
Students must trace the production of a novel product and troubleshoot errors in workflow.		

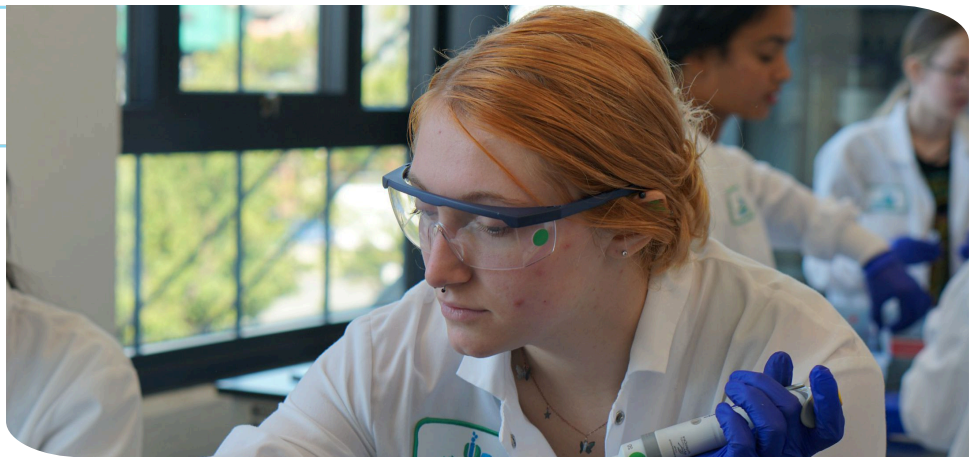
TOPIC: SYNTHETIC BIOLOGY

This topic allows students to explore each stage of the engineering "Design-Build-Test-Learn" (DBTL) cycle, first using existing BioBuilder kits and then through the application of BioBuilder's abstraction hierarchy to design a novel biotechnology of their own. Lab skills focus on microbial culturing, transformation of both bacteria and yeast, and measurement of cellular outputs.

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
1. Synthetic Biology Overview	Streaking Isolated Colonies	Slides, Homework
Students are introduced to the Design-Build-Test-Learn cycle and an abstraction hierarchy for biodesign.		
2. Design Cycle I	Growing Overnight Cultures	Slides, Homework
Students consider the design process that invented a banana-smelling bacteria.		
3. Design Cycle II	Growing Larger Volumes	Slides, Homework
Students examine the genetic elements that were engineered to control banana-scent production.		
4. Design Cycle III	Smell and Density Data	Slides, Quiz Review
Students discuss and collect qualitative and quantitative data and consider appropriate graphical representation.		
5. Quiz I	Assessment	Slides, Answer Key
Students apply the design process to specify a plastic eating bacteria and design a preliminary experiment.		
6. Build Cycle I	Streaking Isolated Colonies	Slides, Homework
Students consider the design process that invented a color-generating bacteria, then streak two strains on solid media.		
7. Build Cycle II	Solution Preparation	Slides
Students explore the concept of cellular chassis, then prepare solutions for bacterial transformation.		
8. Build Cycle III	Transformation	Slides, Homework
Students discuss positive and negative controls, then transform two plasmids into two host strains.		
9. Build Cycle IV	Patching Cells	Slides, Evaluation Rubric
Students analyze transformation data and develop protocol variation to improve results.		
10. Lab Practical I	Assessment	Slides, Rubric, Set-Up
Students repeat bacterial transformation under different experimental conditions.		

TOPIC: SYNTHETIC BIOLOGY (CONTINUED)

LESSON	LAB ACTIVITY	ADDITIONAL RESOURCES
11. Test Cycle I	Streaking Isolated Colonies	Slides, Set Up, Homework
Students compare bottom-up and top-down design processes, then grow four bioengineered bacterial strains.		
12. Test Cycle II	Growing Overnight Cultures, Making Solutions	Slides
Students use bioinformatics to consider sequence variations, and follow abbreviated Batch Record to prepare solutions.		
13. Test Cycle III	Enzyme Assay	Slides, Set-Up, Quiz Review, Optional Activity
Students are introduced to concensus sequences and measure enzyme activity in four strains.		
14. Quiz II	Assessment	Slides, Answer Key
Students analyze the protocol and data for 10 strains that are variations of the four tested.		
15. Test Cycle IV	Growing Overnight Cultures, Making Solutions	Slides
Students learn basic statistical analysis of data, standardization of DNA parts, and grow triplicate overnight for one bioproduction strain.		
16 & 17. Lab Practical II	Assessment	Slides, Rubric
Over two lab periods, students perform triplicate measurements of enzyme activity, calculation, analysis, and submit lab notebook for evaluation.		
18. Redesign I	Pouring Plates	Slides, Homework
Students consider the engineering approach to reliable performance, then pour YPD petri dishes.		
19. Redesign II	Isolating Yeast Colonies	Slides, Set-Up
Students look at yeast as a model organism, and then streak yeast cells for single colonies.		
20. Redesign III	Reisolating Yeast Colony	Slides, Homework
Students learn about yeast re-engineered to produce Vitamin A, then streak engineered yeast for single colonies.		
21. Lab Practical III	Assessment	Slides, Answer Key
Students develop a PCR protocol for a new gene of interest, and predict the size of the PCR product.		
22. Redesign IV	Yeast Transformation	Slides
Students explore the concept of codon shuffling, then transform white yeast with a codon shuffled copy of a gene.		
23. Quiz III	Assessment	Slides, Answer Key
Students illustrate their understanding of genetic complementation and positive and negative controls.		



TOPIC: SYNTHETIC BIOLOGY (CONTINUED)

LESSON	CONTENT	ADDITIONAL RESOURCES
24. Biodesign I	Students analyze their yeast transformation experiment and present their data with a slide.	Slides
25. Biodesign II	Students evaluate current synthetic biology products, and consider their role in shaping the development and use of new technologies.	Slides, Role-Playing Activity
26. Biodesign III	Students brainstorm new biotechnology ideas for various topics.	Slides, Collaboration Document
27. Biodesign IV	Students consider historical debates surrounding the ethical application of biotechnology.	Slides, Video Transcript
28. Final Project	Students present their biotechnology ideas using abstraction from systems to devices then parts.	Slides