

Microscopic Factories: Engineering Yeast into Life- Saving Insulin Lesson Plan for Grade 9-12

Lesson Plan Developed by Teresa Kagotho

Overview

Modern medicine is no longer limited to extracting chemicals from plants or synthesizing compounds in laboratories. Many life-saving medicines are produced through biotechnology, where scientists use living cells as microscopic factories to manufacture complex biological products.

In this lesson, students explore how microorganisms such as yeast (*Saccharomyces cerevisiae*), bacteria (*E. coli*), mammalian cells (CHO cells), and insect cells (Sf9) are used in biomanufacturing to produce medicines including insulin, vaccines, and therapeutic proteins.

Students investigate the question:

“Where does your medicine come from?”

Through a hands-on biotechnology activity, students prepare, feed, and observe yeast cells while learning how engineered yeast can produce human insulin. Students practice industry-related laboratory techniques including micropipetting, vortex mixing, centrifugation, and microscopy.

The lesson connects biology concepts such as DNA, gene expression, protein synthesis, and genetic engineering with real-world applications in the pharmaceutical and biotechnology industries. Students will also explore biotechnology career pathways and summer research opportunities.

The lesson follows the 5E Instructional Model (Engage, Explore, Explain, Elaborate, Evaluate) and integrates STEM education, career readiness, and laboratory skills.

Key Search Words

Biotechnology, biomanufacturing, recombinant DNA, genetic engineering, insulin production, yeast fermentation, *Saccharomyces cerevisiae*-baker's yeast, cell culture, pharmaceutical manufacturing, biopharmaceuticals, protein synthesis, gene expression, micropipetting, centrifugation, microscopy, STEM careers, biotechnology careers, 5E instructional model.

Learning Objectives

- Explain how biotechnology uses living cells as microscopic factories to produce medicines.
- Describe how recombinant DNA technology allows microorganisms to produce human proteins such as insulin.
- Compare different biological systems used in biomanufacturing, including yeast, bacteria, mammalian cells, and insect cells.
- Explain the relationship between DNA instructions, protein production, and medicine manufacturing.
- Demonstrate biotechnology laboratory skills including micropipetting, vortex mixing, centrifugation, and microscopy.
- Analyze yeast cell growth and identify evidence of reproduction through budding.
- Describe how biotechnology impacts human health and identify careers within the biopharmaceutical industry.

Curriculum Alignment

LS.Bio.8.2 Biotech Applications - Biotechnology has applications in medicine, agriculture, and environmental science.

- Biotechnology applications in medicine create access to diagnoses and treatments that can increase the quantity and quality of life (e.g., genetic risk for breast cancer, bacterial and yeast transformation to produce insulin, gene therapy to treat cystic fibrosis).
- Explain how genetic engineering is used to modify organisms for specific purposes.
 - Students investigate how yeast cells can be engineered to produce human insulin.
- Explain how biotechnology is used to manipulate organisms and their products.
 - Students explore applications of biotechnology including insulin production, vaccines, and therapeutic proteins.

Classroom time required

One 95-Minute Block Period

Engage: Introduction to Biomanufacturing

15 minutes

Explore: Yeast Biotechnology Investigation

45 minutes

Explain: Engineering Yeast to Produce Insulin

20 minutes

Elaborate: Biotechnology Careers and Opportunities

10 minutes

Evaluate: Reflection and Exit Ticket

5 minutes

Materials & Technology

Laboratory Materials

Yeast Culture Activity

- Dry active yeast (*Saccharomyces cerevisiae*)
- Lukewarm water
- Sugar solution
- Test tubes or microcentrifuge tubes
- Tube racks

- Micropipettes:
 - P1000
 - P200
 - P20 (optional)
- Pipette tips
- Vortex mixer
- Microcentrifuge
- Microscope slides
- Coverslips
- Compound microscopes
- Transfer pipettes

Biotechnology Demonstration Materials

- Images/videos of insulin manufacturing
 - Biotechnology company examples
 - Diagrams showing recombinant DNA technology
 - Career pathway resources
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Microbial Cell Factories

Yeast Cells (*Saccharomyces cerevisiae*)

Produces:

- Human insulin

Used for:

- Diabetes treatment

Companies:

- Novo Nordisk
- Biocon
- Eli Lilly

CHO Cells (Chinese Hamster Ovary Cells)

Produces:

- Complex human-like proteins

Examples:

- Aduhelm (Biogen) – Alzheimer's disease
 - Taltz (Eli Lilly) – Psoriasis
 - Herceptin (Genentech) – Breast cancer
-

***E. coli* Bacteria**

Produces:

- Human growth hormone
- Some insulin products

Treats:

- Growth disorders
- Diabetes

Sf9 Insect Cells

Produces:

- Flu vaccines such as Flublok

Treats:

- Influenza prevention
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Technology

Teacher:

- Computer
- Projector
- Internet access
- Biotechnology videos

Students:

- Chromebooks/tablets/computers

Platforms:

- Google Classroom
 - Canvas
 - Labxchange
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Safety

Students should follow biotechnology laboratory safety procedures.

- Wear lab coats, safety goggles and gloves when handling laboratory materials.
- Wash hands before and after the activity.
- Do not consume laboratory materials.
- Practice proper aseptic technique.
- Handle microscopes, micropipettes, and centrifuges carefully.

- Ensure centrifuge tubes are balanced before operation.
- Keep centrifuge lids closed during operation.
- Avoid touching sterile pipette tips and slides.
- Properly dispose of biological materials according to classroom procedures.
- Clean laboratory workspaces before and after activities.

Teacher Preparation for Activity

Prepare presentation materials explaining:

- Biotechnology
- Recombinant DNA
- Insulin production
- Careers

Prepare laboratory stations.

Test equipment:

- Microscopes
- Centrifuge
- Vortex mixer

Prepare:

- Yeast samples
- Sugar solutions
- Student worksheets

Demonstrate proper:

- Review on Micropipette use
- Centrifuge balancing
- Microscope techniques

Student Preparation for Activity

- Review basic laboratory safety rules and expectations.
- Understand the importance of following written and verbal laboratory instructions.
- Be familiar with common laboratory equipment such as beakers, test tubes, and graduated cylinders.
- Understand that scientists use different units of measurement for liquid volumes, including milliliters (mL) and microliters (μL).
- Review the concepts of **accuracy** and **precision** and why they are important in scientific investigations.
- Review basic biotechnology vocabulary, including **micropipette**, **microliter (μL)**, **aspiration**, **dispense**, **contamination**, **sterile technique**, and **biotechnology**.
- Wear appropriate personal protective equipment (PPE), including safety goggles and closed-toe shoes.
- Tie back long hair and secure loose clothing or jewelry before beginning the laboratory activity.
- Read the laboratory procedures and safety guidelines before handling the micropipette.
- Be prepared to work collaboratively with a partner or small group during the laboratory activities.

Procedure

Engage: Where Does Your Medicine Come From?

Time: 15 minutes

Teacher Activity

Display a medicine bottle or insulin injection image.

Ask:

“Where does medicine come from?”

Students brainstorm responses.

Teacher introduces:

“Beyond the pill bottle, many medicines are produced inside living cells called microscopic factories.”

Explain:

Scientists use biotechnology to place human genetic instructions into cells so those cells can manufacture important proteins.

Examples:

- Yeast → insulin
- CHO cells → cancer and autoimmune medicines
- *E. coli* → growth hormone and insulin
- Insect cells → vaccines

Explore: Making, Feeding, and Observing Yeast Cells

Time: 45 minutes

Step 1: Preparing Yeast Culture

10 minutes

Students:

1. Add 1 gram dry active yeast into 10 mL lukewarm water.
2. Mix gently.
3. Observe initial yeast suspension.

Teacher explanation:

Yeast cells are living organisms that use nutrients to grow and reproduce.

Step 2: Vortex Mixing

5 minutes

Students:

1. Secure tube on vortex mixer.
2. Mix for 5–10 seconds.

Purpose:

To evenly distribute yeast cells throughout the solution.

Step 3: Feeding Yeast Cells

10 minutes

Students use micropipettes:

1. Attach fresh pipette tip.
2. Press plunger to first stop.
3. Collect 100 μL sugar solution.
4. Add sugar solution to yeast culture.

Discussion:

Cells require nutrients for metabolism and growth.

Biomanufacturing companies carefully control nutrients to maximize production.

Step 4: Centrifugation

10 minutes

Students:

1. Transfer sample into centrifuge tube.
2. Balance centrifuge.
3. Run at 2,000–3,000 RPM for 3 minutes.

Observation:

Students identify:

- Yeast pellet
- Liquid layer

Connection:

Industrial biotechnology uses centrifugation to separate cells and biological products.

Step 5: Microscopic Observation

10 minutes

Students:

1. Place yeast drop onto microscope slide.
2. Add coverslip.
3. Observe under microscope.

Students record:

- Cell shape
- Clusters
- Budding cells

Discussion:

Budding demonstrates yeast reproduction.

Differentiation

This lesson incorporates hands-on biotechnology activities, visual learning, collaborative work, and career connections to support diverse learners. Differentiation strategies allow all students to participate in biotechnology laboratory experiences while meeting the lesson objectives.

Students with Learning Disabilities (LD)

Intended Audience:

Students who require additional academic support, organizational assistance, or modified learning approaches.

Instructional Modifications:

- Provide a simplified version of the laboratory procedure with numbered steps and pictures.
- Use visual guides showing:
 - Yeast cells
 - Micropipette parts
 - Centrifuge setup
 - Microscope procedures
- Break the activity into smaller sections and provide teacher check-ins after each step.
- Provide vocabulary cards with definitions and images for terms such as:
 - Biotechnology
 - DNA
 - Protein
 - Yeast
 - Insulin
 - Micropipette
- Allow students additional time to complete observations and record data.
- Provide opportunities for students to verbally explain concepts before writing responses.

Alternative Assessment:

- Students may complete a teacher-guided oral assessment.
- Students may demonstrate laboratory skills using a checklist instead of completing written responses.

- Students may label diagrams of yeast cells and biotechnology equipment as evidence of understanding.
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English Language Learners (ELL)

Intended Audience:

Students developing English language proficiency.

Instructional Modifications:

- Introduce biotechnology vocabulary before the lesson using pictures, videos, and real laboratory equipment.
- Provide bilingual vocabulary supports when available.
- Use sentence starters during discussions:

Examples:

- "Yeast is used to produce _____."
- "Scientists modify DNA to _____."
- "The purpose of a centrifuge is _____."
- "I observed _____ under the microscope."
- Use visual models showing:
 - DNA → Gene → Protein → Medicine
 - Yeast cell → Insulin production
- Allow students to discuss ideas with peers before responding to the class.
- Pair students strategically with supportive classmates during laboratory activities.

Alternative Assessment:

- Students may explain concepts through:
 - Oral responses
 - Diagrams
 - Labeled illustrations
 - Demonstration of laboratory procedures
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Gifted and Academically Advanced Students (AIG)

Intended Audience:

Students who require enrichment and deeper scientific challenges.

Instructional Modifications:

- Ask students to research additional examples of engineered microorganisms used in medicine.
- Challenge students to compare different production systems:
 - Yeast cells
 - E. coli
 - CHO cells
 - Insect cells
- Have students investigate why some proteins require mammalian cells instead of yeast.
- Allow students to design a hypothetical biomanufacturing process for producing a new medicine.
- Encourage students to research biotechnology careers and pathways.

Extension Activities:

Students may investigate:

- Recombinant DNA technology
- CRISPR gene editing
- Synthetic biology
- Pharmaceutical manufacturing processes

Alternative Assessment:

- Students create a biotechnology infographic, research poster, or short presentation explaining a biotechnology application.

Assessment/Check for Understanding

Student learning will be evaluated through formative and summative assessments aligned with the lesson objectives and **NC Biology Standard LS.Bio.8.2: Biotechnology Applications**.

Students will demonstrate understanding of how biotechnology uses living organisms to produce medicines and will apply laboratory skills including micropipetting, centrifugation, vortex mixing, and microscopy.

Formative Assessment**Teacher Observation During Laboratory Activity**

The teacher will monitor students during the yeast biotechnology activity and assess whether students can:

- Follow laboratory safety procedures.
- Properly use biotechnology equipment.
- Explain the purpose of micropipetting.
- Correctly measure and transfer liquids.
- Balance centrifuge tubes before operation.
- Identify yeast cells under the microscope.
- Recognize budding as evidence of yeast reproduction.

Teacher questioning during the activity:

- "Why are yeast cells considered microscopic factories?"
 - "How does DNA provide instructions for making insulin?"
 - "Why do scientists engineer cells to produce medicines?"
 - "Why is accuracy important when using a micropipette?"
 - "What evidence shows that yeast cells are alive?"
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Student Laboratory Worksheet Assessment

Students complete a biotechnology investigation worksheet including:

Data Collection

Students record:

- Appearance of yeast before feeding.
- Changes after adding sugar.
- Microscope observations.
- Evidence of budding.
- Centrifuge observations.

Analysis Questions

1. Why is yeast useful in biotechnology?
 2. How can scientists modify yeast cells to produce human insulin?
 3. What is the relationship between DNA and proteins?
 4. Why are different cell types used to manufacture different medicines?
 5. How do laboratory tools improve accuracy in biotechnology?
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Practical Skills Assessment

Students complete a biotechnology skills checklist.

Laboratory Skills Rubric (20 points)

Skill	4 Points	2–3 Points	1 Point
Micropipette Use	Uses correct technique independently	Uses technique with reminders	Requires assistance
Equipment Safety	Follows all safety procedures	Minor reminders needed	Frequently unsafe
Microscope Use	Correctly prepares and observes samples	Needs guidance	Unable to operate independently
Data Recording	Accurate observations recorded	Some missing information	Limited observations
Scientific Explanation	Clearly explains biotechnology concepts	Partial explanation	Needs additional support

Summative Assessment

Exit Ticket

Students answer:

1. In one sentence, explain how biotechnology helps humans.
 2. Why are yeast cells called microscopic factories, and what is one thing you learned about their role in medicine production?
 3. Explain how recombinant DNA technology allows yeast to produce insulin.
 4. Describe one difference between yeast cells and CHO cells used in medicine production.
 5. Why are micropipettes important in biotechnology laboratories?
 6. Name one biotechnology career related to medicine production, and would you consider pursuing it? Why or why not? [[1](#), [2](#)]
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Alternative Assessments

Students with Learning Disabilities

- Oral explanation of biotechnology concepts.
- Diagram labeling:
 - DNA → Protein → Medicine
- Demonstration of laboratory skills.

English Language Learners

- Vocabulary matching activity.
- Picture-based explanations.
- Oral responses using sentence starters.

Advanced Learners

- Research presentation comparing biotechnology production systems.
- Design a hypothetical engineered microorganism.

Required resources

Laboratory Resources

- Dry active yeast (*Saccharomyces cerevisiae*)
- Sugar solution
- Lukewarm water
- Test tubes or microcentrifuge tubes
- Tube racks
- Micropipettes:
 - P20
 - P200
 - P1000
- Pipette tips

- Vortex mixer
 - Microcentrifuge
 - Microscope slides
 - Coverslips
 - Compound microscopes
 - Transfer pipettes
 - Student worksheets
 - Laboratory safety equipment:
 - Safety goggles
 - Gloves
 - Lab coats/aprons
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Digital Resources

Amgen Biotech Experience (ABE)

<https://www.amgenbiotechexperience.com/>

Use:

Provides biotechnology education resources, laboratory activities, and examples of biotechnology careers.

LabXchange – Harvard University

<https://www.labxchange.org/>

Use:

Provides biotechnology simulations, virtual laboratories, and resources for understanding genetic engineering and protein production.

North Carolina Department of Public Instruction Science Standards

<https://www.dpi.nc.gov/>

Use:

Provides North Carolina Biology curriculum standards and instructional resources.

PreMiEr Engineering Research Center

<https://premier-erc.org/>

Use:

Provides connections to engineering, microbiome research, biotechnology, and STEM career pathways.

Supplemental resources

- Biotechnology company educational resources:
 - Novo Nordisk insulin production resources
 - Eli Lilly biotechnology resources
 - Biogen biotechnology career information
- Videos:
 - Recombinant DNA technology animations
 - Insulin production processes
 - Cell culture and biomanufacturing demonstrations
- Career exploration resources:
 - Manufacturing Associate
 - Bioprocess Engineer
 - Quality Control Scientist
 - Cell Culture Technician
 - Molecular Biologist

Author comments

This lesson was developed to introduce high school students to modern biotechnology and connect classroom biology concepts with real-world applications in medicine manufacturing.

The lesson combines:

- Biology content
- Engineering practices
- Biotechnology laboratory skills
- STEM career awareness

The hands-on yeast activity was selected because yeast provides students with an accessible model organism for understanding how living cells can be engineered to produce valuable products such as insulin.

Possible modifications:

- The lesson can be shortened by focusing only on yeast observation and biotechnology discussion.
- The lesson can be expanded by adding DNA extraction, transformation activities, or biotechnology career research projects.

Student feedback can be collected through reflection questions asking students how biotechnology connects biology concepts to future careers.

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Appendices

Student Worksheet

Appendix A: Student Laboratory Worksheet

Microscopic Factories: Engineering Yeast into Life-Saving Insulin

Name: _____

Date: _____

Class: _____

Partner(s): _____

Learning Objectives

By the end of this investigation, I can:

- ☐ Explain how biotechnology uses living cells to produce medicines.
 - ☐ Describe how engineered yeast can produce human insulin.
 - ☐ Use biotechnology equipment safely and correctly.
 - ☐ Observe yeast cells under a microscope.
 - ☐ Explain how DNA provides instructions for protein production.
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Part 1 – Before the Investigation

1. What do you think biotechnology means?

2. Where do you think insulin comes from?

- ☐ Plants
 - ☐ Animals
 - ☐ Engineered microorganisms
 - ☐ I don't know
-

Part 2 – Laboratory Safety

Place a ✓ beside each statement after your teacher reviews laboratory safety.

- ☐ Wear safety goggles.
 - ☐ Keep long hair tied back.
 - ☐ Never eat or drink in the laboratory.
 - ☐ Handle microscopes carefully.
 - ☐ Balance the centrifuge before use.
 - ☐ Dispose of materials properly.
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Part 3 – Laboratory Observations

Step 1: Preparing Yeast

Describe the appearance of the yeast before sugar was added.

Color:

Texture:

Other observations:

Step 2: Feeding the Yeast

What was added to the yeast?

Why do yeast cells need sugar?

Step 3: Vortex Mixing

Why was the sample mixed?

Step 4: Centrifugation

Draw and label what you observed after centrifugation.

Label:

- Pellet
- Liquid (supernatant)

Step 5: Microscopy

Describe what you observed.

Cell shape:

Arrangement:

Did you observe budding?

☐ Yes

☐ No

Draw one yeast cell below.

Drawing

Magnification:

Part 4 – Data Table

Observation	Results
Yeast before feeding	
Yeast after feeding	
After centrifugation	
Under microscope	
Evidence of budding	

Part 5 – Analysis Questions

1. Why are yeast called microscopic factories?

2. How can scientists engineer yeast to produce insulin?

3. What role does DNA play in insulin production?

4. Why are micropipettes important in biotechnology laboratories?

5. Why do scientists use different organisms (yeast, bacteria, CHO cells) to produce medicines?

6. What evidence showed that the yeast cells were alive?

Part 6 – Vocabulary

Match each term with its definition.

Term	Definition Letter
Biotechnology	_____
Recombinant DNA	_____
Micropipette	_____
Yeast	_____
Protein	_____

Definitions

- A. Instrument used to measure tiny liquid volumes
 - B. Living organism used to produce medicines
 - C. Technology using living organisms to make useful products
 - D. DNA that has been modified by scientists
 - E. Molecule made from amino acids that performs cellular functions
-

Part 7 – Career Connection

Circle one biotechnology career that interests you.

Manufacturing Associate

Cell Culture Technician

Quality Control Scientist

Bioprocess Engineer

Molecular Biologist

Why did you choose this career?

Part 8 – Reflection

What was the most interesting thing you learned today?

How does biotechnology improve people's lives?

Exit Ticket

1. Explain how biotechnology helps humans.

2. How can engineered yeast produce insulin?

3. What laboratory skill did you improve today?

4. Would you consider a biotechnology career? Why or why not?
