UNIT I - INTRODUCTION TO BIOTECHNOLOGY

Lesson 1: An Overview of Biotechnology

Competency/Objective: Summarize the importance of biotechnology to agriculture.

Study Questions

1. **What is biotechnology?**

2. **What has been the role of biotechnology in agriculture?**

3. **What is the current role of biotechnology in agriculture?**

4. **How does agricultural biotechnology influence consumer perspectives?**

5. **How does agricultural biotechnology influence producer perspectives?**

6. **What other areas of life have been affected by biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit I.

2. Suggested reference: Access Excellence's" Basic Biotechnology for Beginning Teachers" at http://www.gene.com/ae/AE/AEPC/WWC/1993/basic.html.

3. Activity Sheet

   AS 1.1: What is . . . ? Facts about Biotechnology

UNIT I - INTRODUCTION TO BIOTECHNOLOGY

Lesson 1: An Overview of Biotechnology

TEACHING PROCEDURES

A. Introduction

Biotechnology has been around for thousands of years. Almost every seed that a producer plants today is a result of crossbreeding and hybridization, which are aspects of biotechnology. Selective breeding and crossbreeding are forms of biotechnology that are standard practices in the livestock industry. Modern biotechnology takes traditional methods of crop and livestock production to a new level. Instead of breeding whole plants or animals to produce a desired trait, modern biotechnology makes it possible to transfer specific traits from one organism to another.

B. Motivation

1. Show the video “Fields of Promise” (Monsanto, 27 min.) available from MVRC.

2. Discuss the size of the biotechnology industry in the United States. Point out that in 1993, 1,300 biotechnology companies in the United States employed 80,000 people and generated $8.1 billion in annual sales. The industry has grown since 1993. Speculate on the future of the industry.

3. Bring two tomatoes to class, one from a home garden and one from a grocery store. Ask the class to compare the way they look. Drop each tomato from a height of five feet into a trash can. Did one squash or splatter more than the other? Discuss why.

C. Assignment

D. Supervised Study

E. Discussion

1. Have students define “biotechnology” in their own words. Write these definitions on the board and then compile them into one working definition. Point out the broad scope of biotechnology and that many different definitions exist.

What is biotechnology?

a) Biotechnology can be defined as the application of scientific principles to living things. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products.
b) A narrower definition of modern biotechnology includes only those processes that involve the recombination of genes from living things in a laboratory setting.

2. Have students identify examples of agricultural biotechnology. Point out that yeast was first used to brew beer and make wine as long ago as 6,000 B.C. Cheese, yogurt, bread, and cider are all common products of biotechnology. More information about the history of biotechnology is available on the Internet at the Access Excellence website “About Biotech: The Biotech Chronicles” at http://www.gene.com/ae/AB/BC/index.html.

What has been the role of biotechnology in agriculture?

a) Crop production

1) Greeks developed fruit tree grafting techniques (300 B.C.).
2) Gregor Mendel experimented with garden peas, discovering the foundations of genetics (1865).
3) The first hybrid corn plant was developed in the United States (1879).
4) Improved wheat and rice varieties were developed internationally (1946-1965).

b) Animal production
1) Selective breeding of livestock was practiced by people in the Middle East (18,000 B.C.).
2) Animal crossbreeding and purebreeding were practiced in Europe (1500 A.D.)
3) A procedure for artificial insemination was first developed in Italy (late 1700s).

c) Food processing
1) The use of bacteria to make cheese, bread, and alcohol began in Egypt (4,000-2,000 B.C.).
2) The modern distillery was invented in United States (1830).
3) Louis Pasteur discovered that fermentation was carried out by bacteria and confirmed the existence of microorganisms, leading to applications such as the large scale brewing of beer and wine (1860s).

3. Use newspaper articles or Internet sites to show examples of current developments in agricultural biotechnology.

What are the emerging areas of agricultural biotechnology?

a) The modern era of biotechnology began with the first successful recombination of DNA (1973).
b) The technique of plant tissue culture was developed (late 1970s).
c) New technologies have been developed in animal biotechnology.
1) Embryo transfer techniques were developed (early 1980s).
2) A Chinese scientist cloned a fish (1981).
3) The first adult mammal was cloned in Scotland (1997).
4) A calf was cloned from cells taken from a 30-day-old fetus (1997).
d) The ability to alter DNA through genetic engineering has made many new products possible.
1) The first genetically modified food product, an enzyme used in making cheese, was approved for use in the United States (1990).
2) The first genetically modified crop plant, a tomato plant, was approved in the United States (1994).
3) Insect-resistant and herbicide-tolerant crops were approved in the United States (1995-1996).
4) Animal vaccines were produced by genetically modified bacteria (mid-1990s).
e) Future biotechnology products may include environmentally tolerant crops or genetically modified plants used as biofuels.

4. Ask students if they have ever helped buy food at a grocery store. Ask them how they would decide whether to buy vegetables that have been genetically modified.

How does agricultural biotechnology influence consumer perspectives?

a) Positive
1) Lower food costs
2) Increased nutrient content of food
3) Availability of fresh fruits and vegetables year-round
4) Increased and cheaper food supply in developing countries
b) Negative
1) Fear of unsafe foods
2) Fear of environmental damage from genetically altered organisms

5. Ask students if they know of any local producers who plant genetically modified seed or use other inputs developed through agricultural biotechnology.

   How does agricultural biotechnology influence producer perspectives?

   a) Positive
      1) Increased profits from higher yields or lower input costs
      2) Reduction in the amount of chemicals used
      3) Profitable customized crops
   b) Negative
      1) Fear that small farms may not have the opportunity to use biotechnology and be forced out of business by more competitive, large corporate farms
      2) Fear of the creation of "super weeds"

6. Ask if anyone knows someone who is diabetic and must take insulin injections. Explain that improved insulin from bacteria modified to produce human insulin is one example of a nonagricultural advancement in biotechnology.

   What other areas of life have been affected by biotechnology?

   a) Human health industry
      1) Pharmaceuticals
         (a) Insulin produced by bacteria
         (b) Genetically engineered vaccines
         (c) Antibiotics and growth hormones
      2) Tests for detecting genetic disorders
         (a) Huntington's disease
         (b) Down's syndrome
         (c) Tay-Sachs disease
         (d) Cystic fibrosis
   b) Biomining - modified bacteria that break down metal ore
   c) Forensics - DNA fingerprinting
   d) Waste management
      1) Bacteria that break down sewage
      2) Bacteria that clean up crude oil spills
      3) Bacteria that improve soil contaminated with organic compounds
      4) Bacteria that feed on solid waste and produce methane gas for fuel

F. Other Activities

1. Show a video such as "Green Cows, Quags, and Mummies," available from MVRC.

2. Have students conduct an Internet search using the term "agricultural biotechnology" and report on their findings.

G. Conclusion

The biotechnology industry is large and is expanding at a rapid rate. New products and processes will be developed as long as a market exists for them, and agriculture will change as they are developed. How will producers and consumers react to new products? Will the products of biotechnology pose risks to humans, animals, or the environment? While the answers to these questions are not yet clear, biotechnology will have a huge impact on agriculture and many other industries.

H. Answers to Activity Sheet

AS 1.1

1. Biomining
2. Dolly
3. 1879
4. Genetic engineering
5. DNA fingerprinting
6. Egypt
7. Plant tissue culture
8. Corn
9. Biotechnology
10. Customized crop
11. 18,000 B.C.
12. 1973
13. Human insulin
14. FlavrSavr™ tomato

I. Answers to Evaluation

1. b
2. c
3. d

4. Fear that small farms will lose money on biotechnology and be forced out of business by large corporate farms; fear of the development of “super weeds”

5. Fear of unsafe foods; fear of environmental damage from genetically altered organisms

6. Biotechnology can be defined as the application of scientific principles to living things. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products.

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EVALUATION

Circle the letter that corresponds to the best answer.

1. The first successful recombination of DNA took place in:

   a. 1963
   b. 1973
   c. 1983
   d. 1993

2. Which of the following is an example of a human pharmaceutical that was developed through biotechnology?

   a. Drugs for Down's syndrome
   b. Vaccine for Tay-Sachs disease
   c. Insulin for diabetics
   d. Antibiotics for Huntington's disease

3. In what place and time period did the use of bacteria to make cheese, bread, and alcohol begin?

   a. Greece, 300 B.C.
   b. Greece, 4,000 to 2,000 B.C.
   c. Egypt, 300 B.C.
   d. Egypt, 4,000 to 2,000 B.C.

Complete the following short answer questions.

4. What are two concerns of producers about biotechnology?

5. What are two consumer concerns about biotechnology?

6. What is biotechnology?

Lesson 1: An Overview of Biotechnology Name _____

What is . . . ? Facts about Biotechnology

Objective: Identify facts about biotechnology.

Using your *Biotechnology: Applications in Agriculture* student reference, read the description in the column titled "Answers" and write in the corresponding term that completes the question.

Answers	What is . . . ?
1. Using modified bacteria to break down metal ore	1. _____
2. Name of the ewe that was the first animal cloned from an adult mammal	2. _____
3. The year that the first hybrid corn was developed in the United States	3. _____
4. A technology used to alter the genetic material of living cells to give them new characteristics	4. _____
5. Process used in the application of biotechnology to forensics	5. _____
6. The country where bacteria were first used to make cheese, bread, and alcohol	6. _____
7. Growing a full-sized plant from a few plant cells	7. _____
8. The first hybrid crop plant	8. _____
9. The application of scientific principles to living things	9. _____
10. Corn developed especially for the production of ethanol	10. _____
11. The earliest date that selective breeding was practiced	11. _____
12. The year that modern biotechnology began	12. _____
13. The first genetically engineered product approved for sale	13. _____
14. The first genetically modified crop plant approved in the U.S.	14. _____

Answers	What is . . . ?

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 1: Challenges to Biotechnology

Competency/Objective: Explain the major issues associated with agricultural biotechnology.

Study Questions

1. **What are the major issues associated with the use of biotechnology in agriculture?**

2. **What are the food safety issues associated with genetically modified foods?**

3. **What are the labeling issues associated with genetically modified foods?**

4. **What are the issues related to releasing genetically altered plants and animals into the environment?**

5. **What are the animal welfare issues raised by agricultural biotechnology?**

6. **What are other moral issues concerning agricultural biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit II.

2. Transparency Masters

   a) TM 1.1: Results of the Community Survey
   b) TM 1.2: Summary of Data

3. Activity Sheets

   a) AS 1.1: Community Survey (Instructor)
   b) AS 1.1: Community Survey (Student)

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 1: Challenges to Biotechnology

TEACHING PROCEDURES

A. Introduction

New technology has always sparked controversy, and biotechnology is no exception. Many ethical issues are emerging as genetic manipulation is used more frequently. This lesson will outline some current issues in biotechnology.

B. Motivation

Bring in two glasses of milk, types of cheese, carrots, tomatoes, or other vegetables. Ask students to taste them to see if they can tell a difference. Tell the students that one sample could be a product of biotechnology. Ask students if they think that both of the samples are safe. How would they know if a food was genetically modified? Would they even care?

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students for examples of issues in biotechnology that they have seen in the news.

   What are the major issues associated with the use of biotechnology in agriculture?

   a) Safety of genetically modified food
   b) Labeling of genetically modified foods
   c) Safety of releasing genetically modified organisms into the environment
   d) Animal welfare issues
   e) Morality of genetic engineering

2. Ask students how they felt when told that the one of the samples of milk, cheese, or vegetables might be a product of biotechnology. Discuss the difference between perception of safety and actual safety.

   What are the food safety issues associated with genetically modified foods?

   a) The Food and Drug Administration (FDA) states that genetically engineered foods are as safe as or safer than other foods, since they must meet the same standards; many scientific studies show no differences in the chemical composition of modified and unmodified foods.
   b) Some consumers, including some restaurants and chefs, have refused to use genetically altered food, because they claim the government has not done enough to ensure their safety.
   c) Some scientists caution that since no long-term studies have been done on the effects of modified foods on human health, their long-term safety is unknown.
   d) Other consumers fear that modified foods may have genes that cause allergic reactions or reduce the effectiveness of antibiotics (through the use of antibiotic-resistant genes during the process of genetic engineering).

3. Discuss the pros and cons of labeling food as genetically modified.

What are the labeling issues associated with genetically modified foods?

a) Some people argue that the public has a right to know if food has been genetically engineered to be able to make an informed decision about whether to buy it.
   1) Some people view genetic modifications as unacceptable for religious reasons.
   2) Vegetarians may want to avoid modified foods because they may contain genes taken from animals.

b) The FDA's policy is that since genetically modified foods are no different from other foods, no need exists for labeling them as modified, with two exceptions.
   1) The FDA requires a label for foods with a gene that could cause an allergic reaction.
   2) The FDA requires a label if genetic engineering makes a significant change in a food's composition.

4. Ask students if they have seen vegetables in a garden cross-pollinate and produce different fruit. Discuss the possible problems associated with releasing genetically altered organisms.

What are the issues related to releasing genetically altered plants and animals into the environment?

a) Releasing genetically modified organisms into the environment may introduce altered genes into native populations, giving them undesired traits.
b) Releasing modified organisms may reduce biodiversity, if unmodified organisms are unable to compete.

5. Ask students to discuss what treating animals humanely means.

What are the animal welfare issues raised by agricultural biotechnology?

a) Some people question whether it is morally right to genetically engineer an animal to alter its natural ability to produce.
b) Some people argue that altering animals to produce pharmaceuticals and other health products for humans is inhumane.

6. Ask students about other ethical reasons that people oppose genetic engineering. Have students complete AS 1.1. Use TM 1.1 to tabulate the results of the surveys. TM 1.2 can be used to further illustrate the results.

What are other moral issues concerning agricultural biotechnology?

a) Some people view genetic manipulation as "playing God," which oversteps the boundaries of what is appropriate for humans.
b) Genetic manipulation may permanently alter the balance of nature.

F. Other Activities

1. Have a spokesperson who favors genetic engineering and one who is against it speak to the class. The Union of Concerned Scientists is a possible source of speakers opposed to biotechnology. University research programs and biotechnology companies such as Monsanto are good sources of biotechnology speakers in favor of genetic engineering. An Internet search may help locate speakers.

2. Have students debate the issue of labeling genetically altered foods. Divide the class into two groups, with one group favoring labeling and the other group opposing it. Have each group collect information that supports its position and then hold a formal debate in class.

3. Have students conduct an Internet search to identify additional issues connected to biotechnology.

G. Conclusion

Agricultural biotechnology promises to raise food production to a new level, but concerns held by the public may slow its acceptance. Food safety and labeling, environmental concerns, and moral issues all need to be addressed so that the public has confidence in the use of biotechnology in agriculture.

H. Answers to Activity Sheet

AS 1.1

Answers will vary.

I. Answers to Evaluation

1. d
2. c

3. Students may give either of the following answers: some people question whether it is morally appropriate to genetically engineer an animal to exceed its natural ability to produce, or some people argue that altering animals for pharmaceuticals and health products for humans is inhumane.

4. Some scientists argue that releasing genetically modified organisms into the environment is dangerous because they may introduce altered genes into native populations, giving them undesired traits. Others argue that releasing modified organisms will decrease biodiversity, because unmodified organisms will be unable to compete.

5. Answers may be either of the following: genetic engineering is “playing God,” or genetic engineering could alter the balance of nature.

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Lesson 1: Challenges to Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is <u>not</u> a major issue associated with the use of biotechnology?

   a. The safety of genetically engineered foods for human consumption
   b. The welfare of animals on which biotechnology is used
   c. The labeling of modified foods as products of biotechnology
   d. The exploitation of the microorganisms used in genetic engineering

2. When does the FDA require products of biotechnology to be labeled?

   a. Whenever foreign genetic material is introduced into a plant
   b. Whenever a gene from an animal is introduced into a plant
   c. Whenever a gene that could cause an allergic reaction is used
   d. Whenever a gene that is antibiotic-resistant is used

Complete the following short answer questions.

3. What is one issue raised by people who are concerned about the use of biotechnology on animals?

4. What are two reasons that some scientists question the safety of releasing genetically modified plants into the environment?

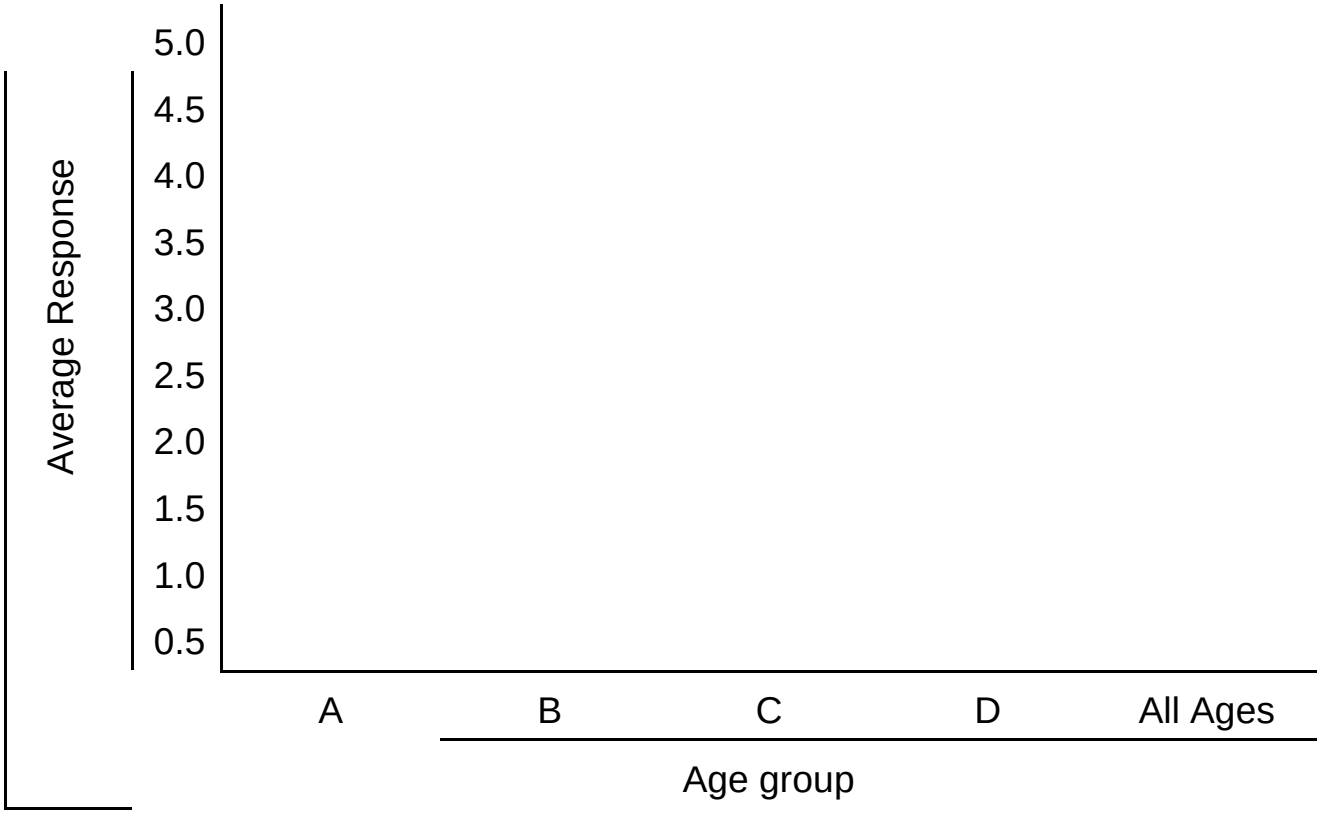
5. What is one reason that genetic manipulation may be considered morally wrong?

Results of the Community Survey

Question Number	Category A <20 yrs old Average Score	Category B 20 - 40 yrs old Average Score	Category C 40 - 60 yrs old Average Score	Category D over 60 yrs old Average Score	Overall Score
1					
2					
3					
4					
5					
6					
7					

Summary of Data

TM 1.2



Lesson 1: Challenges to Biotechnology

Community Survey

Objective: Investigate the reactions of the public to agricultural biotechnology.

1. Give each student four copies of AS 1.1, since they must interview four people.

2. When they have finished, collect the completed surveys from the students and have them assist in sorting, tabulating, and recording the survey results. TM 1.1 is provided to help tabulate the results of the survey. The results of the survey could also be given to a statistics class for further analysis or assigned to an advanced student for further analysis of the differences in responses by gender.

3. Sort the surveys by age group: <20 (Group A), 20-40 (Group B), 40-60 (Group C), and >60 (Group D).

4. Beginning with Group A, write the scores of the first question on the board. Find the average score for the question and record it on TM 1.1. Repeat this process for each age category.

5. Find the average score for each question using all of the surveys, and record the score in the "Overall Score" column of the transparency.

6. A bar graph has been included in TM 1.2 that can be used to compare the response for each question.

7. Interpret the data. An average median score of 2.5 for a statement shows that the community is neutral about it. A score greater than 2.5 shows an attitude that supports the statement. A score less than 2.5 shows an attitude that does not support the statement. Discuss the attitudes revealed by this survey. Is age a factor in the attitudes displayed by the community? What is the overall perception of biotechnology in the community? Discuss the limitations and accuracy of this survey and its results.

   Note: Some statements are positive, while others are stated in a negative form. Response scores must be interpreted in the context of the original form of the statement.

Lesson 1: Challenges to Biotechnology Name _____

Community Survey

Objective: Investigate the reactions of the public to agricultural biotechnology.

To understand current societal attitudes toward agricultural biotechnology in your community, use the statements below to survey four people. Survey one person from each age group. Record each person's approximate age and gender and their level of agreement or disagreement with each statement.

Age Group (circle one): Under 20 20-40 40-60 Over 60

Gender: Male Female

1. Foods products from genetically modified plants are safe to eat.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

2. Genetically modified crops pose no real threat to nature or the environment.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

3. Genetically modified foods sold in a grocery store should carry a label that states that they are genetically modified.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

4. Genetically modifying animals is inhumane.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

5. Genetically modifying plants is morally wrong.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

6. Genetically modifying animals is morally wrong.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

7. Genetic engineering will significantly increase food production over the next ten years.

   1 2 3 4
   Strongly disagree Disagree Agree Strongly agree

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 2: Agencies Involved in Biotechnology

Competency/Objective: Identify government agencies involved in biotechnology.

Study Questions

1. **What is the role of the Environmental Protection Agency (EPA) in biotechnology?**
2. **What is the role of the United States Department of Agriculture (USDA) in biotechnology?**
3. **What is the role of the Food and Drug Administration (FDA) in biotechnology?**
4. **What is the role of the Occupational Health and Safety Administration (OSHA) in biotechnology?**
5. **What is the role of the National Institutes of Health (NIH) in biotechnology?**
6. **What is the role of the Nuclear Regulatory Commission (NRC) in biotechnology?**
7. **How is the international trade of biotechnology products regulated?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit II.
2. Activity Sheet
   a) AS 2.1: Solving the Regulatory Puzzle

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 2: Agencies Involved in Biotechnology

TEACHING PROCEDURES

A. Review

The first lesson of this unit discussed several issues concerning biotechnology. These issues may be addressed by federal agencies. Federal agencies have been given the responsibility of overseeing areas such as food and environmental safety. This lesson reviews the roles that each of these agencies plays in monitoring biotechnology.

B. Motivation

1. Ask students "Have any of you ever been concerned about buying or eating food that was unsafe?" Remind the students of instances when meat was contaminated with the *E. coli* bacteria. How does one know that America's food supply is safe? The federal government has answered this question by giving the responsibility of safeguarding America's food supply to a federal agency known as the Food and Drug Administration (FDA).

2. Write the following acronyms on the chalkboard and have students identify the agency: FDA, EPA, USDA, OSHA, NIH, and NRC. Ask students to describe the role of each agency in biotechnology.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students for examples of areas that the EPA regulates. Explain the EPA's role in overseeing biotechnology.

What is the role of the Environmental Protection Agency (EPA) in biotechnology?

a) The EPA regulates any pesticidal quality that might be present in plants that have been genetically engineered.
   1) The EPA must issue an experimental use permit before approving a field test for a modified plant.
   2) The applicant for the permit must submit a detailed plan of the proposed field test.
b) The EPA regulates the use of pesticides on genetically modified plants.
c) All genetically modified microorganisms are regulated by the EPA.

2. Discuss examples of the areas of biotechnology that the USDA oversees.

What is the role of the United States Department of Agriculture (USDA) in biotechnology?

a) Funds research in biotechnology
b) Regulates agricultural research and products through its Animal and Plant Health Inspection Service (APHIS)
   1) APHIS requires permits for the field testing, shipping, and delivery of any seed or plant modified through biotechnology. In 1993 an exception to the prior approval requirement was made for six crops (corn, soybeans, cotton, potatoes, tobacco,

and tomatoes) that have a history of safe genetic modification. Only notification 30 days prior to field testing modified crops is required.
2) APHIS reviews how research was conducted and its results and outlines possible concerns posed by the release of the new crop or product.

3. Discuss with students the important role that the FDA plays in regulating biotechnology.

What is the role of the Food and Drug Administration (FDA) in biotechnology?

a) The FDA, which is responsible for ensuring the safety of the nation's food supply, issued a statement in 1992 that is the basis of its policy concerning plant biotechnology.
   1) Genetically modified food products or food additives will be regulated in the same way as food products or additives produced by other means; only the characteristics of the food are important.
   2) The FDA allows foods to be introduced to the commercial market with notification of its planned introduction.
   3) The FDA has the power to remove a food from the market if it suspects the food is unsafe.
   4) Approval prior to marketing is required for some genetically modified foods; they may have to be labeled as well.
      (a) Foods containing a substance known to cause allergic reactions
      (b) Foods in which the nutritional value has changed
      (c) Foods that contain genetic material from a source not currently in the food supply
b) The FDA also regulates all drugs and drug delivery systems, including genetically engineered animal vaccines.

4. Ask students to describe what they know about OSHA. Explain that most companies are required to follow OSHA safety regulations.

What is the role of the Occupational Safety and Health Administration (OSHA) in biotechnology?

OSHA's mission is "to save lives, prevent injuries, and protect the health of American workers." OSHA's involvement in agricultural biotechnology is primarily to ensure that workers in biotechnology work in a safe environment.

5. Ask students to describe the NIH and to explain its role in biotechnology.

What is the role of the National Institutes of Health (NIH) in biotechnology?

a) NIH is a federally funded agency whose mission is "to uncover new knowledge that will lead to better health for everyone;" it is involved in biotechnology in many ways.
   1) Conducts research in biotechnology in its own laboratories
   2) Supports the research of nonfederal scientists in various public and private institutions within and outside of the United States
   3) Helps in training of research scientists by funding graduate student research efforts
   4) Fosters biomedical communication
b) NIH regulates the research that it funds through a set of guidelines, but has no control over other research.
c) Many researchers in both public and private institutions voluntarily follow NIH guidelines.

6. Ask students if they know when the NRC was established (1974). Note that the primary role of the NRC is regulating nuclear reactors. Discuss the NRC's role in overseeing biotechnology.

What is the role of the Nuclear Regulatory Commission (NRC) in biotechnology?

a) Regulates the use of radioactive materials by academic and industrial biotechnology research laboratories
b) Requires a special permit for the transport, handling, storage, and disposal of radioactive materials

7. Ask students if they know of any other agencies that might be involved in overseeing biotechnology. Discuss the international trade of products of biotechnology and how it is regulated. Have students complete AS 2.1.

How is the international trade of biotechnology products regulated?

International committees are meeting to try to establish voluntary guidelines for the movement of genetically modified organisms between nations.

F. Other Activities

1. Have a guest speaker (e.g., county health or local environmental employee) discuss biotechnology.

2. Have students do research and write a report on different regulatory agencies.

G. Conclusion

Many federal agencies are involved in overseeing biotechnology. Some companies have complained that they are required to complete unnecessary steps to comply with the inflexible rules of these agencies. Some consumer groups complain that the agencies responsible for monitoring biotechnology are not trained in biotechnology and know little about it. Still other people feel that these agencies are doing an adequate job in regulating biotechnology. However, nearly everyone agrees that some regulation is needed.

H. Answers to the Activity Sheet

1. Approval/permits: EPA - to obtain an experimental use permit due to pesticidal properties
FDA - due to the change in the composition of the potato
Notifications: USDA - notification required prior to field testing

2. Approval/permits: EPA - to obtain an experimental use permit due to pesticidal properties
USDA - to obtain a field test permit
Notifications: FDA - notification required for the planned introduction of a new food product

I. Answers to Evaluation

1. b
2. c
3. b
4. c
5. a
6. d
7. d

8. The NRC regulates the use of radioactive materials by academic and industrial biotechnology research laboratories. It requires a special permit for the transport, handling, storage, and disposal of radioactive materials.

9. The FDA evaluates genetically modified food products or food additives in the same way as food products or additives produced by other means. Only the characteristics of a food are important.

10. International committees are meeting to try to establish voluntary guidelines for the movement of genetically modified organisms between nations.

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Lesson 2: Agencies Involved in Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The Animal and Plant Health Inspection Service (APHIS) is a part of the:

   a. Environmental Protection Agency (EPA)
   b. United States Department of Agriculture (USDA)
   c. Food and Drug Administration (FDA)
   d. National Institutes of Health (NIH)

2. The federal agency that regulates the labeling of a food is the:

   a. Environmental Protection Agency (EPA)
   b. United States Department of Agriculture (USDA)
   c. Food and Drug Administration (FDA)
   d. National Institutes of Health (NIH)

3. What agency regulates the environment in which employees work in agricultural biotechnology?

   a. Environmental Protection Agency (EPA)
   b. Occupational Safety and Health Administration (OSHA)
   c. Food and Drug Administration (FDA)
   d. National Institutes of Health (NIH)

4. The National Institutes of Health (NIH) performs which of the following roles in overseeing biotechnology?

   a. NIH plays a major role in regulating the health and safety aspects in all biotechnology laboratories.
   b. NIH uses a set of guidelines to regulate drug research in all public research institutions.
   c. NIH can only regulate research that it funds, but its guidelines influence the actions of many other researchers.
   d. NIH is not involved in regulating biotechnology research.

5. From which agency must a researcher obtain an experimental use permit?

   a. Environmental Protection Agency (EPA)
   b. Food and Drug Administration (FDA)
   c. Occupational Safety and Health Association (OSHA)
   d. National Institutes of Health (NIH)

6. A new corn plant genetically modified to resist the European corn borer would need approval from which of the following agencies?

   a. Nuclear Regulatory Commission (NRC)
   b. National Institutes of Health (NIH)
   c. Occupational Safety and Health Administration (OSHA)
   d. Environmental Protection Agency (EPA)

7. A genetically modified bacterium that helps wheat use nitrogen from the air would need approval from which two agencies?

   a. FDA and EPA
   b. USDA and NRC
   c. NIH and OSHA
   d. EPA and USDA

Complete the following short answer questions.

8. What is the role of the Nuclear Regulatory Commission (NRC) in regulating biotechnology?

9. How does the FDA regulate genetically modified foods or food additives?

10. How are nations attempting to regulate the international trade of organisms created using biotechnology?

Lesson 2: Agencies Involved in Biotechnology Name _____

Solving the Regulatory Puzzle

Objective: Identify the agencies involved in overseeing biotechnology.

Read the following paragraphs that describe genetically modified agricultural products that are or could be developed. List the agencies that must be notified about the product and those from which approval or a permit must be secured. Explain why each agency must be contacted.

1. Monsanto has developed a potato called the NewLeaf® potato that can protect itself from the Colorado potato beetle. This insect can destroy a field of potatoes in two or three days by stripping the plants of their leaves. If this potato was further modified to produce potatoes with a higher solids content that absorbs less oil when cooked, what are the regulatory requirements that Monsanto would have to meet?

   a) Approval/permits needed:

   b) Notifications needed:

2. *Bacillus thuringiensis (Bt)* is a naturally occurring bacterium found in the soil that is noted for its ability to control pests. Gardeners have been using *Bt* as a biological insecticide spray for nearly 100 years. Many crops are being developed that will contain *Bt* genes. If a carrot was developed containing this gene, what regulatory requirements would its developer need to meet?

   a) Approval/permits needed:

   b) Notifications needed:

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 3: Biotechnology Patents

Competency/Objective: Identify procedures involved in obtaining a patent for a biotechnology product.

Study Questions

1. **What is a patent?**
2. **What are the requirements for obtaining a utility patent for a product of biotechnology?**
3. **What are the issues surrounding the patenting of biotechnology products?**
4. **What is DNA fingerprinting?**
5. **What are the problems associated with the handling of genetic material?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit II.
2. Transparency Master
   a) TM 3.1: Section of a DNA Fingerprint
3. Activity Sheet
   a) AS 3.1: Patent Debate

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 3: Biotechnology Patents

TEACHING PROCEDURES

A. Review

Lesson 2 discussed various regulatory agencies that affect the development of products using biotechnology. Before marketing or even field testing such a product, the developer usually secures a patent to protect the research investment. Patents for biotechnology products have played a major role in shaping the biotechnology industry. Companies have purchased other companies just to obtain certain patents. However, strong opposition to patenting genetically modified life forms has developed. This lesson will discuss patents and the issues surrounding patenting products of biotechnology.

B. Motivation

1. In 1996, biotechnology generated nearly $13 billion in annual revenues in the United States. The value of biotechnology patents ranges from millions of dollars to less than the patent application fee itself. Many people refer to this search for profitable patents as a high-tech gold rush. Few prospectors will strike it rich, but many will dig for gold.

2. Using an ink pad and small Post-It™ notes, have each student make a copy of his or her fingerprint. Display them to the class to show the differences. Discuss the process of genetic fingerprinting.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students what a patent is. Discuss examples of products that have been patented (including plants and animals).

What is a patent?

a) A patent grants property rights that exclude others from making, using, or selling the patented invention throughout the United States for a stated period of time, normally 17 years.
b) The U.S. Patent and Trademark Office grants three types of patents.
    1) Utility patent - granted for “new and useful” inventions that meet certain statutory requirements; the most common type of patent
    2) Plant patent - issued to anyone who invents or discovers and asexually reproduces any new variety of plant, including cultivated spores, mutants, hybrids, and newly found seedlings
    3) Design patent - granted for any new, original, and ornamental design for a manufactured article

2. Ask students what is required to obtain a patent. Discuss the requirements for obtaining a utility patent.

What are the requirements for obtaining a utility patent for a product of biotechnology?

a) Statutory requirements
    1) The invention must be a new and useful process, machine, manufactured item, or composition of matter; most biotechnology products fall into the “composition of matter” category since they are essentially rearrangements of DNA.

2) The invention must be novel and nonobvious. An invention is obvious if it can be readily deduced from information available to the public by a person knowledgeable in the relevant technological field.
3) The invention must be fully described and clearly claimed in a patent application.

b) Additional qualifications
1) The invention must be patentable. The laws of nature, physical phenomena, and abstract ideas are not patentable.
2) A patent cannot remove anything from the public domain. This means that something already commonly used cannot be patented.
3) The granting of the patent must add adequate information about the invention to the public domain.

3. Discuss with students whether they think it is acceptable to patent life-forms. Have students complete the debate outlined in AS 3.1.

What are the issues surrounding the patenting of biotechnology products?

a) The question of ownership of genetically modified organisms
b) The patenting of the genetic material of plants and animals native to countries other than the United States

4. Ask students what makes fingerprints different. Just as the different line patterns make each fingerprint unique, the different locations of bands on an electrophoresis gel make each DNA fingerprint unique.

What is DNA fingerprinting?

a) DNA fingerprinting is the process of using laboratory analysis of DNA to generate a pattern that is unique to an individual organism.
b) DNA fingerprinting involves several steps.
1) Isolating the DNA
2) Cutting, sizing, and sorting the DNA
3) "Tagging" the DNA with a probe dye

5. Discuss some of the problems associated with handling genetic material.

What are the problems associated with the handling of genetic material?

a) Preventing the theft of genetic material
b) Flawed results from testing
c) Preserving the privacy of genetic information

F. Other Activities

Have students further research the controversy surrounding patents on biotechnology by focusing on the issue of whether the government should have the right to grant itself patents. Have the students research cases in which the U.S. government issued a patent to itself for a product of biotechnology. Encourage students to use the Internet in their research.

G. Conclusion

Patents play an important role in the biotechnology industry. Biotechnology companies view patents as vital because they protect their research investments. However, patents on genetic material and products of biotechnology have sparked new debate as to exactly what should be eligible for a patent. Ultimately, U.S. courts will have to decide the answer to this difficult question as lawsuits are filed to challenge certain patent rights.

H. Answers to Activity Sheet

AS 3.1

Answers will vary.

I. Answers to Evaluation

1. b
2. a
3. c

4. DNA fingerprinting is the process of using the laboratory analysis of DNA to generate a pattern that is unique to an individual organism.

5. The question of ownership of genetically modified organisms and the patenting of the genetic material of plants and animals native to countries other than the United States

6. Preventing the theft of genetic material, flawed results from testing, and preserving the privacy of genetic information

UNIT II - ISSUES IN BIOTECHNOLOGY Name _____

Lesson 3: Biotechnology Patents Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. A patent is the:

   a. Permanent right to the profits received from the marketing of the patented invention.
   b. Right to exclude others from making, using, or selling the patented invention.
   c. Right to keep confidential the details of an invention.
   d. Temporary right to use an invention in the United States.

2. The most common type of patent obtained for an invention using biotechnology is the:

   a. Utility patent.
   b. Design patent.
   c. Plant patent.
   d. Genetic patent.

3. Which of the following is <u>not</u> a statutory requirement for a utility patent?

   a. The invention must be a new and useful process, machine, manufactured item, or composition of matter.
   b. The invention must be novel and nonobvious.
   c. The invention must be an abstract idea.
   d. The invention must be fully described and clearly identified in the patent application.

Complete the following short answer questions.

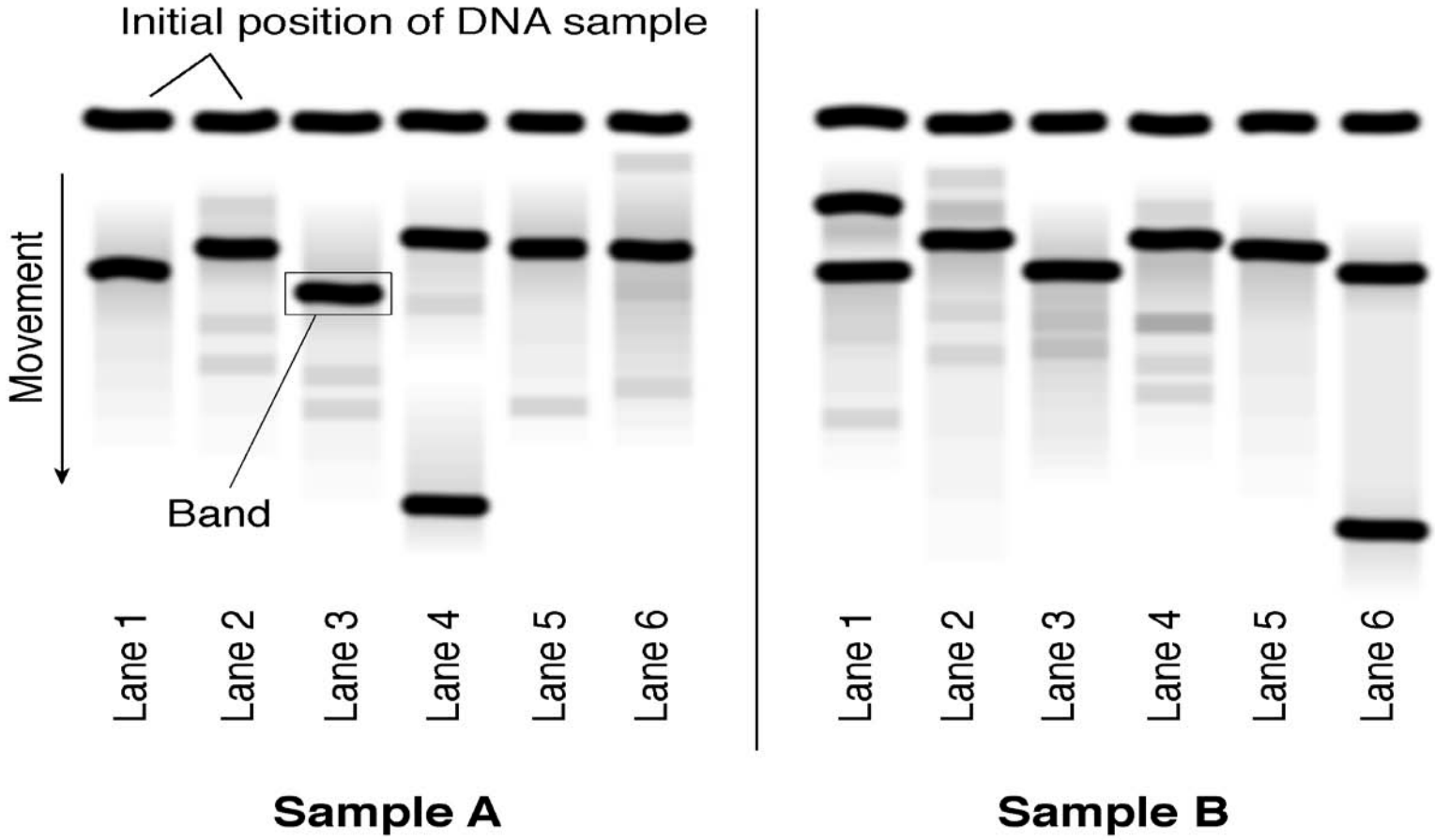
4. What is DNA fingerprinting?

5. What are the issues surrounding the patenting of biotechnology products?

6. What problems exist with the handling of genetic material?

Section of a DNA Fingerprint

TM 3.1



Do the bands in Sample A match the bands in Sample B?

Lesson 3: Biotechnology Patents Name _____

Patent Debate

Objective: Examine issues surrounding the patenting of products of biotechnology.

Your instructor will divide the class into two groups. The first group represents the scientists and the corporations who want to strengthen their right to patent biotechnology products. The second group represents the groups opposed to patenting life-forms. Each group should search the Internet and other sources for information that will support their argument. The questions below should be used to help guide the research. A group must have four major arguments to support its case and be ready to answer the other group's objections. Select one person in each group to record the arguments and answers to possible objections.

- Are patents necessary to protect the monetary investment made by researchers in developing useful products?
- Should plant, animal, or human DNA be patented, since it is not an invention?
- Who owns or controls the genes of plants and animals?
- What international trade problems have arisen or could arise due to patents on genetically modified plants and animals?

Your teacher will moderate the debate. Each side will take turns making a point and then giving the other group the opportunity to raise an objection to the point. This process will continue until both groups have raised their four points. Each group will then be given a short time for closing arguments.

UNIT III: BASIC LABORATORY SKILLS

Lesson 1: The Scientific Method

Competency/Objective: Describe the steps in the scientific method.

Study Questions

1. **What are the steps of the scientific method?**

2. **Why is it important to follow the scientific method?**

3. **What information should a laboratory notebook include?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit III.

2. Activity Sheet

   a) AS 1.1: Using the Scientific Method

UNIT III: BASIC LABORATORY SKILLS

Lesson 1: The Scientific Method

TEACHING PROCEDURES

A. Introduction

This unit will introduce some basic laboratory skills that are important in almost every type of biotechnology research. This lesson focuses on the scientific method and its application in biotechnology. The scientific method is an important and widely used research strategy. Scientific research is essentially a rational and logical search for answers to scientific questions. This search must be done in a calculated way to increase the chances of finding the desired answer.

B. Motivation

Trip the breaker for the classroom. Have students use the scientific method to analyze the problem. Guide them through the process using the steps below.

Step 1: Identify the problem. (Why are the lights in the classroom off?)

Step 2: Research the available information. (Is the switch on, are there light bulbs in the sockets, have the lights been on before, etc.?)

Step 3: Formulate a hypothesis. (The lights went off because the breaker was tripped.)

Step 4: Design the investigation/experiment. (The breaker will be turned back on.)

Step 5: Conduct the experiment and collect data. (The breaker is turned on and the lights are observed.)

Step 6: Draw conclusions. (The breaker being tripped caused the lights to go out.)

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to list the steps of the scientific method.

What are the steps of the scientific method?

a) Identify the problem in a statement that expresses the general purpose of the research.
b) Investigate earlier research to identify alternative explanations or solutions to the problem.
c) Formulate a hypothesis about the anticipated outcome of the research.
d) Design the experiment.
e) Conduct the experiment and collect data.
f) Analyze the data and draw conclusions about the success of the experiment in terms of the hypothesis.

2. Ask students why following the scientific method is important.

Why is it important to follow the scientific method?

a) The scientific method provides a logical approach to solving a problem.
b) The scientific method helps researchers look objectively at their research.
c) The scientific method allows experiments to be repeated by other researchers (replication), which is necessary to establish the validity of the experiment.

3. Ask students why it is important for businesses to keep a financial record book (to be able to analyze the business, to show weak areas, and to provide a credible record for the IRS). Laboratory notebooks are like financial record books; they are kept to analyze experiments, show weak areas, and provide a credible record for other professionals. Relate recording research to the activities of farmers or businesspeople who must keep an accurate record of his or her operation.

What information should a laboratory notebook include?

a) Cover that identifies the subject of the research
b) Table of contents
c) Laboratory sheets
    1) Title of the experiment, date, and name(s) of the investigator(s) of the experiment
    2) Brief description of the purpose of the experiment
    3) List of materials needed
    4) Procedures for the experiment
    5) A record of the results of the experiment, including data and observations
    6) Conclusions drawn from the research

F. Other Activities

G. Conclusion

The scientific method has been used to guide the research process for centuries. It provides a clear, logical method for investigating phenomena. The way a researcher approaches a problem is critical to the success of the investigation. The approach must be documented in a laboratory notebook. This documentation is important for many reasons, including the fact that it often is needed to prove ownership of research.

H. Answers to Activity Sheet

AS 1.1

1. (Answers will vary.) The use of an ultraviolet light is a better method of preventing culture media contamination than the use of either 70 percent alcohol or a 10 percent bleach solution.

2. (Answers will vary.) Exposure to the air, the procedure, the temperature, etc.

3. The sterile cotton swab or ball placed in the petri dish without being swabbed

I. Answers to the Evaluation

1. d
2. b
3. Problem statement
4. Hypothesis
5. a) 5 d) 1
    b) 6 e) 4
    c) 3 f) 2

UNIT III: BASIC LABORATORY SKILLS Name _____

Lesson 1: The Scientific Method Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The scientific method is important to biotechnology researchers because it:

   a. Guarantees that the research will be successful.
   b. Has always been used in scientific research.
   c. Provides a biased view of a research effort.
   d. Gives a logical structure to a research effort.

2. Which of the following is <u>not</u> necessarily a part of a laboratory sheet?

   a. Date of research and names of researchers
   b. Table of contents
   c. Description of experimental procedures
   d. Observations

Fill in the blanks with the most appropriate term(s).

3. A statement that describes the general purpose of the research is called the _____.

4. A focused and detailed statement that indicates the anticipated outcome of the research is called the _____.

Number the six steps of the scientific method in the order in which they occur.

5.
   a. _____ Conduct the experiment and collect data.

   b. _____ Draw conclusions.

   c. _____ Formulate a hypothesis.

   d. _____ Identify the problem.

   e. _____ Design the experiment.

   f. _____ Investigate earlier research.

Lesson 1: The Scientific Method Name _____

Using the Scientific Method

Objective: Perform a simple experiment following the principles of the scientific method and document the experiment in a laboratory notebook.

Materials and Equipment:

4 petri dishes or test tubes purchased with sterile culture media
4 sterile cotton swabs or balls
4 pairs of sterile latex gloves or regular latex gloves dipped in alcohol and allowed to dry
4 strips of Parafilm™ or clear tape
2 strips of sterile first aid gauze
1 bottle of a 10 percent bleach solution
1 ultraviolet light
Clean table or countertop divided into three sections by cardboard dividers taped to the surface

To successfully complete genetic manipulation techniques, a microbe-free or aseptic environment is necessary. This aseptic environment can be obtained in several ways, including wiping the surfaces with 70 percent alcohol, wiping the surfaces with a 10 percent bleach solution, or exposing the surfaces to an ultraviolet light. This experiment will determine which of these methods is most effective.

Procedure:

1. Your teacher will divide the class into groups. Before beginning the experiment, record the title of this experiment, the date, and the names of the members of your group on a lab sheet.

2. Write down a brief statement of the purpose of the experiment.

3. List the materials that will be used on your lab sheet.

4. Carry out the experiment. As you do, write down the steps of the procedure in the form of a descriptive paragraph.

5. Label each section of the table to match one of the treatment methods being used.

6. Using a piece of sterile gauze, wipe down one section of the table with 70 percent alcohol.

7. Using a new piece of sterile gauze, wipe down another section of the table with 10 percent bleach solution.

8. After these sections of the table have completely dried, put on sterile latex gloves and swab one section with a sterile cotton swab or ball.

9. Place the swab immediately into a petri dish or test tube containing sterile culture media. Seal the container with Parafilm™ or tape.

10. Label the petri dish or test tube with the name of the section of the table.

11. Repeat this process for the second section of the table using a new pair of sterile gloves.

12. Expose the third section of the table to an ultraviolet light overnight.

13. Immediately after the light is turned off, swab the table area using the same procedure as in steps 8 and 9.

14. Using a new pair of sterile gloves, open the fourth petri dish or test tube and place a sterile cotton swab or ball in it. Seal the lid in the same way as the others.

15. Keep the petri dishes or test tubes in a warm place for one to three weeks. Observe the results and record them daily on the laboratory sheet.

16. At the end of the period, write down the conclusions drawn from the experiment.

Key Questions:

1. What is a possible hypothesis for this experiment?

2. What factors were kept equal for all samples?

3. What is the control in this experiment?

Title:

Date:

Name(s):

Purpose:

Materials Needed:

Procedure:

Results:

Conclusions:

UNIT III: BASIC LABORATORY SKILLS

Lesson 2: Laboratory Equipment and Techniques

Competency/Objective: Demonstrate the proper use of laboratory equipment and techniques.

Study Questions

1. **What equipment is commonly used in a biotechnology laboratory?**
2. **What are the parts of a microscope, and how are they used?**
3. **What are the procedures for manipulating microscopic specimens?**
4. **What is meant by aseptic techniques?**
5. **Why is it important to follow aseptic techniques?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit III.

2. Activity Sheet

    a) AS 2.1: Parts of a Microscope

UNIT III - BASIC LABORATORY SKILLS

Lesson 2: Laboratory Equipment and Techniques

TEACHING PROCEDURES

A. Review

Researchers must be familiar with biotechnology laboratory equipment to select the proper experimental methods to use to accept or reject a hypothesis using the scientific method discussed in Lesson 1. This lesson reviews equipment commonly found in a laboratory, the parts and use of the microscope, and aseptic techniques.

B. Motivation

Swab a school drinking fountain or a tabletop with a sterile cotton ball or cotton swab. Place this swab in a petri dish containing autoclaved agar in an incubator or another warm space (such as in a greenhouse out of direct sun, in a 1' $\times$ 1' cardboard box heated by 10 watt bulb, or on a shelf a foot away from a warm radiator). The resulting bacterial growth will appear overnight, displaying the need for aseptic techniques. Use an autoclave or pressure cooker to kill the bacteria before disposal.

C. Assignment

D. Supervised Study

E. Discussion

1. Discuss the various pieces of equipment commonly used in a laboratory. Display any available laboratory equipment. Use pictures in catalogs from lab equipment suppliers (such as Fisher Scientific) to show equipment that is not available.

What equipment is commonly used in a biotechnology laboratory?

a) Pipettor - used to measure and transfer amounts of liquid smaller than one milliliter (ml)
b) Plastic ware and glassware
    1) Pipette tips
    2) Test tubes
    3) Centrifuge tubes
    4) Petri dishes
    5) Beakers
    6) Flasks
    7) Test tubes
c) Autoclave - used to sterilize glassware, plastic ware, etc.
d) Fume hood - vents air to the outside, getting rid of fumes
e) Incubator - used for tissue culture and the propagation of bacteria
f) Electrophoresis unit - uses an electric current to separate DNA fragments by size
g) Transilluminator - used to view an electrophoresis gel
h) PCR equipment - may be hot water baths or a thermocycler; used to cause the replication of DNA
i) Microcentrifuge - separates solids from liquids
j) Vortex - mixes a solid with a liquid in test tubes
k) Microscope - used to enlarge and view microorganisms or specimens not visible to the naked eye

2. Display an actual microscope and identify each part. Have students complete AS 2.1.

What are the parts of a microscope, and how are they used?

a) Ocular or eyepiece - initial point for viewing a specimen that contains the first lens system, usually magnifying 10 times
b) Objective - second lens system that magnifies the image and projects it up to the ocular
c) Nosepiece - rotating piece that holds the objectives
d) Body tube - holds the ocular and objective the correct distance apart
e) Arm - curved support connecting the body tube and base
f) Base - stand on which the microscope rests
g) Stage - place where the specimen is placed for observation
h) Disc diaphragm - contains a series of openings of different sizes that control the amount of light shining on the specimen
i) Light source - usually a mirror or electric lamp
j) Condenser - focuses light from the lamp on the specimen
k) Coarse adjustment - Large dial, used first to focus the low-power objective
l) Fine adjustment - Small dial, used to refine the focus or to focus the high power objective

3. Ask students who have used a microscope to recall how to view a specimen slide under a microscope. Demonstrate and explain the procedures used when viewing specimens.

What are the procedures for manipulating microscopic specimens?

a) The specimen must be mounted on a glass slide, with a drop of water added for a wet mount.
b) A cover slip is usually placed on top of the specimen.
c) Some specimens may need to be stained.
d) The slide is placed on the stage and secured by the clips.
e) The light source is turned on and adjusted.
f) The low-power objective is selected, and the coarse adjustment is used to focus the image.
g) If needed, the high-power objective is selected and the fine adjustment is used to focus the image by moving the objective up and away from the stage.

4. Ask students why hospital operating rooms are kept sterile. Compare biotechnology techniques such as tissue culture to surgery. Discuss the aseptic techniques used in research in biotechnology.

What is meant by aseptic techniques?

Aseptic techniques are procedures used to create and maintain a working area free of bacteria and other microorganisms that might contaminate delicate experiments.

a) Controlled air movement - The researcher works in an enclosed chamber, which allows the flow of air to be controlled.
b) Disinfection - The work area is disinfected with a 10 percent bleach solution. Then the instruments and work area are sprayed with a 70 percent ethanol solution and allowed to air dry.
c) Scrubbing up - The researcher scrubs his or her hands and arms thoroughly and allows them to air dry. He or she then sprays them with a 70 percent ethanol solution.
d) Sterilization - Researchers use an autoclave to sterilize all materials and instruments. An ultraviolet light kills microorganisms in the work area.

5. Ask students why aseptic techniques are important. Remind students about the motivation for this lesson.

Why is it important to follow aseptic techniques?

Experimental procedures like tissue culture and most DNA analysis techniques require proper aseptic techniques to be successful. Contaminants can disrupt many biotechnology experiments.

F. Other Activities

1. Using a microscope and a prepared slide, have students practice focusing it in the proper manner.

2. Watch a sterile and a non sterile test tube containing fruit for several days to observe bacterial growth.

G. Conclusion

Many different types of laboratory equipment used in biotechnology have been introduced in this lesson. The microscope has been examined in detail, since it is a common tool used in examining microorganisms. The importance of aseptic techniques has been described as well. These basic laboratory skills are important, and all researchers must master them.

H. Answers to Activity Sheet

AS 2.1

1. Ocular or eyepiece
2. Body tube
3. Nosepiece
4. Objective
5. Stage
6. Disc diaphragm
7. Condenser
8. Arm
9. Fine adjustment
10. Coarse adjustment
11. Light source
12. Base

I. Answers to Evaluation

1. a
2. c
3. c
4. b
5. d
6. a
7. d

8. Students may list any two of the following: controlled air movement, disinfection, scrubbing up, or sterilization.

9. Experimental procedures like tissue culture and most DNA analysis techniques require proper aseptic techniques to be successful. Contaminants can disrupt many biotechnology experiments.

UNIT III: BASIC LABORATORY SKILLS Name _____

Lesson 2: Laboratory Equipment and Techniques Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The lens system that is found at the top end of the body tube and normally magnifies 10 times is called the:

   a. Ocular.
   b. Objective.
   c. Disc diaphragm.
   d. Arm.

2. The part of a microscope that controls the amount of light placed on the specimen is called the:

   a. Ocular.
   b. Objective.
   c. Disc diaphragm.
   d. Coarse adjustment.

3. Which of the following should be used to adjust the high-power objective?

   a. Ocular
   b. Objective
   c. Fine adjustment
   d. Coarse adjustment

4. Which of the following is <u>not</u> a common piece of biotechnology equipment?

   a. Transilluminator
   b. Electrotransfectionator
   c. Electrophoresis unit
   d. PCR equipment

5. A microcentrifuge is used in the biotechnology laboratory to:

   a. Mix substances in a test tube.
   b. Separate DNA fragments of different sizes.
   c. Increase the quantity of a DNA sample.
   d. Separate solids from liquids.

6. Pipettors are used to:

   a. Measure and transfer amounts of liquid smaller than one milliliter.
   b. Measure and transfer amounts of liquid larger than one milliliter.
   c. Mix substances in a test tube.
   d. Maintain a suitable environment for the propagation of bacteria.

7. Which of the following is not a procedure for manipulating microscopic specimens?

   a. The specimen must be placed on a glass slide.
   b. A light source must be used so that light passes through the specimen.
   c. The low-power objective and the coarse adjustment are used to obtain the initial focus.
   d. The microscope should be refocused using the coarse adjustment and the high-power objective.

Complete the following short answer questions.

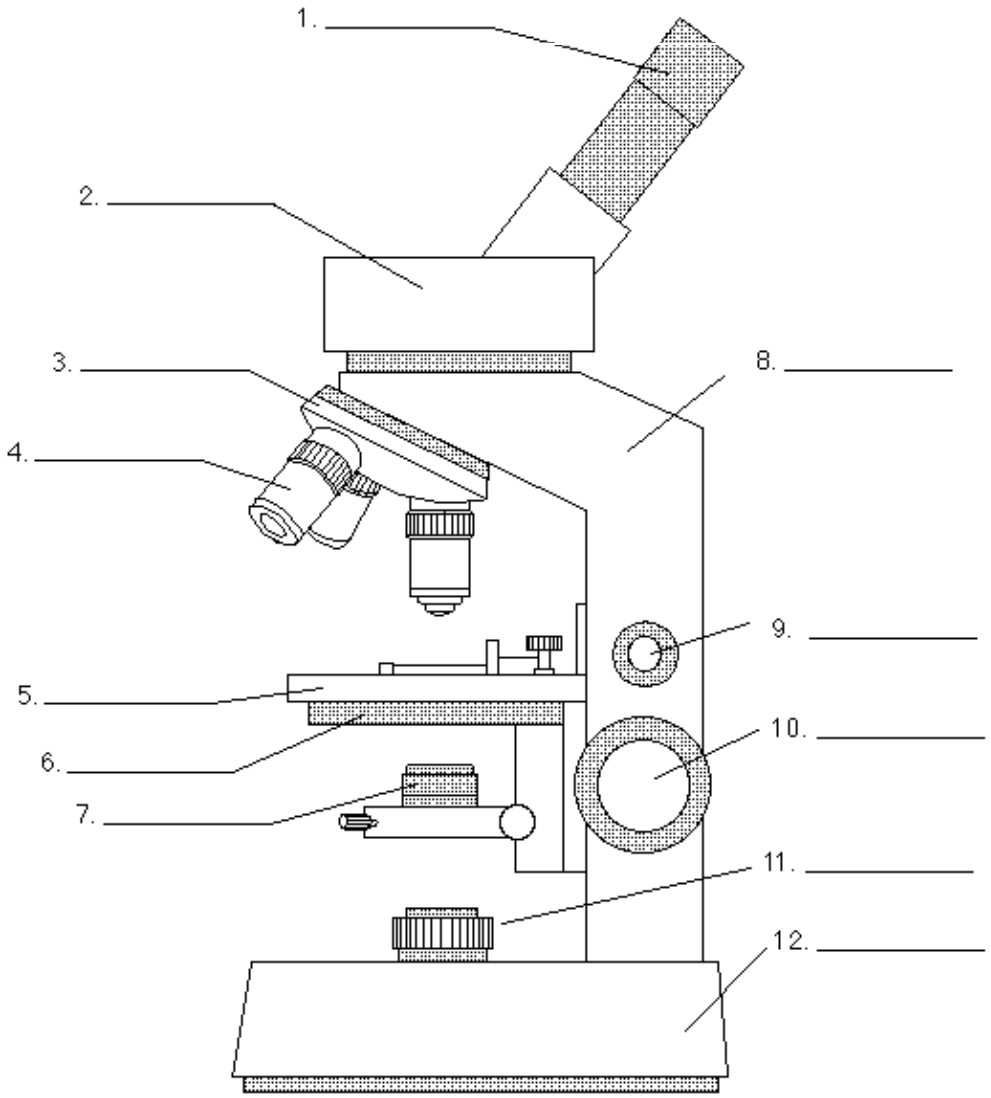
8. What are two aseptic techniques?

9. Why is it important to use aseptic techniques?

Parts of a Microscope

Objective: Identify the parts of a microscope.

Label the parts of the microscope in the spaces provided.



UNIT III - BASIC LABORATORY SKILLS

Lesson 3: Biotechnology Laboratory Safety

Competency/Objective: Explain why safety practices should be followed in the laboratory.

Study Questions

1. **What are some of the common biotechnology laboratory safety concerns?**
2. **How is a spill cleaned up?**
3. **What are the methods for disposing of materials used in biotechnology?**
4. **What procedures should be followed in case of fire?**
5. **What personal protective equipment should be worn in the laboratory?**
6. **What should be done if an injury occurs?**
7. **What ventilation is needed in a laboratory?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit III.
2. Activity Sheet
    a) AS 3.1: Using a Material Safety Data Sheet (MSDS)

UNIT III - BASIC LABORATORY SKILLS

Lesson 3: Biotechnology Laboratory Safety

TEACHING PROCEDURES

A. Review

Lesson 2 discussed some of the equipment used in biotechnology laboratories as well as aseptic techniques to reduce contamination of laboratory experiments. This lesson will examine the topic of laboratory safety. Laboratory safety is always important, especially in biotechnology laboratories. In the late 1970s and early 1980s, laboratories doing genetic manipulation were contained in a nearly sealed environment because of the fear of releasing pathogens, as well as other unknown risks. Today researchers have a much better understanding of the dangers of such research and take necessary precautions when needed. All laboratory research poses some risks that can be addressed by following a detailed safety plan. Laboratory safety is a top priority in every biotechnology laboratory.

B. Motivation

Before students arrive for class, create a "chemical spill" on a countertop in the laboratory that students will notice as they arrive. The chemical spill can simply be water mixed with a few tablespoons of baking soda and a teaspoon of lemon juice. Do not use an actual laboratory chemical or something that will stain the countertop. When students arrive, explain that the spill must be cleaned up, but the correct process must first be determined. Ask them how they would go about cleaning up the spill. Have students speculate as to what types of spills might occur in a biotechnology laboratory.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to list the safety concerns that they would have if they were working in a biotechnology laboratory.

What are some of the common biotechnology laboratory safety concerns?

a) Microorganisms - Pathogenic microbes are dangerous because they can cause disease, and even nonpathogenic microorganisms can be harmful in certain cases.
b) Chemicals
c) Radioactivity - Researchers must be trained to handle and dispose of radioactive materials safely.
d) Electrical hazards - Electrophoresis equipment can cause electrical shock.
e) Physical hazards - Centrifuges can injure fingers, and the ultraviolet light from transilluminators can damage retinas and skin.

2. Ask students to list the types of substances that might be spilled in a biotechnology laboratory (acids, bases, stains, microbe cultures, buffer solutions, etc.). Discuss the clean up procedure and demonstrate the procedure by cleaning up the spill.

How is a spill cleaned up?

a) When the spilled chemical is known, the Material Safety Data Sheet (MSDS) outlines the proper clean up procedures.

b) When the substance is an unknown liquid, it should be absorbed using a special spill pillow; the spill pillow should then be disposed of as hazardous waste.
c) If the spill is an unknown solid or powder, it can be gently swept into a glass container and disposed of as hazardous waste.
d) Next, the spill area should be cleaned with a disinfectant and an ethanol solution.

3. Discuss with students the different types of waste generated in a biotechnology laboratory and how wastes should be discarded.

What are the methods for disposing of materials used in biotechnology?

a) All cultures and equipment that come in contact with microbes should be autoclaved or disinfected with hospital-type disinfectants before being thrown away.
b) The MSDS should be followed for chemicals.

4. Ask students to if they know the classroom fire plan. Discuss the procedures to be followed if a fire breaks out.

What procedures should be followed in case of fire?

a) The fire exit plan should be practiced during fire drills and followed when a fire occurs.
b) Everyone should know the location of the fire extinguisher, fire blanket, and fire alarm switch.

5. Ask students to describe the personal protective equipment (PPE) needed for handling pesticides. Compare this list with the PPE needed for most biotechnology laboratories.

What personal protective equipment should be worn in the laboratory?

a) Safety glasses or goggles
b) Disposable latex gloves
c) Lab coat or apron

6. Ask students if they know what to do for various types of injuries.

What should be done if an injury occurs?

a) Simple first-aid procedures, like applying pressure to stop blood loss or flushing skin or eyes with water if they come in contact with chemicals, should be done immediately.
b) In a classroom lab, the instructor should also be notified without delay so that he or she can follow the school procedure for emergencies.

7. Ask students to list some of the airborne hazards found in biotechnology laboratories (gases, fine powders, microbes, etc.).

What ventilation is needed in a laboratory?

a) Fume hoods are used to remove bad odors or harmful vapors from the laboratory and to maintain a sterile environment for certain laboratory procedures.
b) Ventilated lockable chemical storage cabinets prevent the build up of gases that could cause an explosion or a fire.

F. Other Activities

1. Show a video on laboratory safety, such as the video *Beginning Chemistry Laboratory* available from Carolina Biological Supply Company.

2. Use Glo-Germ to show the need for correct manipulation of bacteria and fungi. Glo-Germ is a substance that is visible only under a black light. Place Glo-Germ in a petri dish to represent a culture. Have students perform tasks such as culture transfers, adding nutrients or changing the culture media, or tissue culture procedures. The spread of Glo-Germ to other surfaces represents "contamination" of work areas. If the Glo-Germ is not present on any surfaces, then the students have been successful.

G. Conclusion

Safety in the biotechnology laboratory is critical. Careful, safe working habits help produce successful research results. If chemicals, cultures, or equipment are mishandled, the research is exposed to unnecessary hazards and may fail. Researchers can work safely and effectively if proper precautions are taken in the laboratory.

H. Answers to Activity Sheet

AS 3.1

1. Students may list any five of the following: chemical product and company identification; composition, information on ingredients; hazards identification; first aid measures; fire fighting measures; accidental release measures; handling and storage; exposure controls, personal protection; physical and chemical properties; stability and reactivity; toxicological information; ecological information; disposal considerations; transport information; regulatory information; and other information.

2. In a manner consistent with federal, state, and local regulations

3. Strong oxidizing agents; may form an explosive mixture with fluorine or potassium nitrate

4. It is not listed as a carcinogen.

5. Get medical aid. Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes.

6. Odorless to a slightly acetic-like odor

7. Safety glasses with side shields, gloves, protective clothing to prevent skin exposure, and a NIOSH/MSHA-approved air purifying dust or mist respirator

8. It may cause respiratory and digestive tract irritation. It may also cause eye and skin irritation.

I. Answers to Evaluation

1. b
2. d
3. a

4. The fire exit plan should be practiced during fire drills and followed when a fire occurs. Everyone should know the location of the fire extinguisher, fire blanket, and fire alarm switch.

5. Safety glasses or goggles, disposable latex gloves, and a lab coat or apron

6. Spill pillow

7. Flush the area with water and notify the instructor.

8. d
9. c
10. e
11. b
12. a

 Name _____

Lesson 3: Biotechnology Laboratory Safety Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What equipment is used in a laboratory for ventilation?

   a. None
   b. Fume hood
   c. Fume cabinet
   d. Open window

2. An MSDS contains important information about:

   a. Radioactive substances.
   b. Specialty laboratory equipment.
   c. Cultures of microorganisms.
   d. Chemical substances.

3. Before microbial cultures are disposed of they should be:

   a. Autoclaved.
   b. Sterilized.
   c. Sealed in an airtight container.
   d. Carefully scrubbed.

Complete the following short answer questions.

4. What procedures should be followed in a laboratory to safeguard against fires?

5. What personal protective equipment (PPE) should be worn in the laboratory?

6. What should be used to clean up an unknown liquid that has spilled?

7. What should be done if acid is spilled on a student's hand in the laboratory?

Match the following hazards with an action in the second column that will help to protect the biotechnology researcher from the hazard.

8.	_____ Physical hazards	a.	Aseptic techniques
9.	_____ Electrical hazards	b.	Following the MSDS
10.	_____ Radioactivity	c.	Careful use of electrophoresis equipment
11.	_____ Chemicals	d.	Careful use of centrifuges and transilluminators
12.	_____ Microorganisms	e.	Special training

Lesson 3: Biotechnology Laboratory Safety Name _____

Using a Material Safety Data Sheet (MSDS)

Objective: Identify important information from an MSDS.

Using the MSDS provided, answer the following questions.

1. What are five of the major sections common to an MSDS sheet?

2. How should the chemical be disposed of, according to the MSDS sheet?

3. With what materials is the chemical incompatible?

4. Is the chemical a known carcinogen?

5. What first aid measures should be taken if the chemical comes in contact with the skin?

6. Does the chemical have an odor?

7. What personal protective equipment should be worn when using the chemical?

8. What are the health effects of this chemical?

ACC# 20860

Fisher Scientific

Print Date: 10/23/97

Material Safety Data Sheet

Sodium acetate, anhydrous

Section 1 - Chemical Product and Company Identification

MSDS Name:
Sodium acetate, anhydrous

Catalog Numbers:
BP333 1, BP333 500, BP333-1, BP333-500, BP3331, BP333500, S207 10, S20710, S210 2, S210 500, S210-2, S210-3, S210-500, S2102, S2103, S210500, S78228, S782291

Synonyms:
Acetic acid,sodium salt, Sodium acetate

Company Identification:
Fisher Scientific - Fairlawn
Fairlawn, NJ 07410

Company Phone Number:
(201) 796-7100

Emergency Phone Number:
(201) 796-7100

CHEMTREC Phone Number, US:
(800) 424-9300

CHEMTREC Phone Number, Europe:
(202) 483-7616

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name:	Percent	EINECS/ELINCS
127-09-3	Sodium acetate	100	204-823-8

Hazard Symbols:
Risk Phrases:

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white
Caution! Hygroscopic. May cause respiratory and digestive tract irritation. May cause eye and skin irritation.
Target Organs: None.

Potential Health Effects

Eye:
May cause mild eye irritation.

Skin:
May cause skin irritation.

Ingestion:
May cause irritation of the digestive tract.

Inhalation:
May cause respiratory tract irritation.

Chronic:
Prolonged or repeated skin contact may cause irritation.

Material Safety Data Sheet

Sodium acetate, anhydrous

Section 4 - First Aid Measures

Eyes:
Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower lids. Get medical aid.

Skin:
Get medical aid. Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes.

Ingestion:
If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid.

Inhalation:
Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.

Notes to Physician:
None

Antidote:
None reported

Section 5 - Fire Fighting Measures

General Information:
As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts at sufficient concentrations can form explosive mixtures with air. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products.

Extinguishing Media:
For small fires, use water spray, dry chemical, carbon dioxide or chemical foam.

Autoignition Temperature:
607°C (1,124.60°F)

Flash Point:

NFPA Rating:
Not published.

Explosion Limits:
Lower: Upper:

Section 6 - Accidental Release Measures

General Information:
Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks:
Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions.

Section 7 - Handling and Storage

Handling:
Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation.

Storage:
Store in a cool, dry, well-ventilated area away from incompatible substances.

Storage Code:
Gray

Material Safety Data Sheet
Sodium acetate, anhydrous

Section 8 - Exposure Controls, Personal Protection

Engineering Controls:
Good general ventilation should be sufficient to control airborne levels.

Exposure Limits

Chemical Name:	ACGIH	NIOSH	OSHA
Sodium acetate	None listed.	None listed.	None listed.

OSHA Vacated PELs

Personal Protective Equipment

Eyes:
Wear safety glasses with side shields.

Skin:
Wear appropriate gloves to prevent skin exposure.

Clothing:
Wear appropriate protective clothing to prevent skin exposure.

Respirators:
A NIOSH/MSHA approved air purifying dust or mist respirator.

Section 9 - Physical and Chemical Properties

Physical State:	Solid
Appearance:	white
Odor:	odorless to slight acetic-like odor
pH:	No information available.
Vapor Pressure:	No information available.
Vapor Density:	No information available.
Evaporation Rate:	No information available.
Viscosity:	No information available.
Boiling Point:	@ 760.00mm Hg
Freezing/Melting Point:	324.00°C
Decomposition Temperature:	No information available.
Solubility:	1190 g/l (20 c)
Specific Gravity/Density:	No information available.
Molecular Formula:	C2H3O2Na
Molecular Weight	82.03

Section 10 - Stability and Reactivity

Chemical Stability:
Stable.

Conditions to Avoid:
Incompatible materials.

Incompatibilities with Other Materials
Strong oxidizing agents. Explosive mixtures may be formed with fluorine or potassium nitrite.

Hazardous Decomposition Products
Carbon monoxide, carbon dioxide, toxic fumes of sodium oxide.

Hazardous Polymerization
Has not been reported.

Section 11 - Toxicological Information

RTECS:
CAS# 127-09-3: AJ4300010.

LD50/LC50:
CAS# 127-09-3:
Oral, mouse: LD50 = 6891 mg/kg
Oral, rat: LD50 = 3530 mg/kg.

Carcinogenicity:
CAS# 127-09-3: Not listed as a carcinogen by ACGIH, IARC, NIOSH, NTP, OSHA, or CA Prop 65.

Epidemiology:
No data

Teratogenicity:
No data

Reproductive:
No data

Mutagenicity
No data

Neurotoxicity
No information reported

Section 12 - Ecological Information

Ecotoxicity:
No information reported
Acute aquatic effects: 96-hour LC50 for fathead minnow: GT 100mg/L, 96-hour LC50 for water flea: GT 1000mg/L.
This chemical has a low potential to affect aquatic organisms.

Environmental:
This chemical is readily biodegradable and is not likely to bioconcentrate.

Physical:
None.

Other:
This chemical has a high biological oxygen demand, and it is expected to cause significant oxygen depletion in aquatic systems.

Section 13 - Disposal Considerations

Dispose of in a manner consistent with federal, state, and local regulations.

RCRA D-Maximum Concentration of Contaminants
None of the components are on this list.

RCRA D Series - Chronic Toxicity Reference Levels
None of the components are on this list.

RCRA F Series Wastes
None of the components are on this list.

RCRA P Series Wastes
None of the components are on this list.

RCRA U Series Wastes
None of the components are on this list.

RCRA Substances Banned from Land Disposal
None of the components are on this list.

Material Safety Data Sheet
Sodium acetate, anhydrous

Section 14 - Transport Information

	US DOT	IATA	IMO	RID/ADR	Canadian TDG
Shipping Name:	No information available.	No information available.	No information available.	No information available.	No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US Federal

TSCA
CAS# 127-09-3 is listed on the TSCA Inventory.

Health and Safety Reporting List
None of the components are on this list.

Chemical Test Rules
None of the components are on this list.

TSCA Section 12b
None of the components are on this list.

TSCA Significant New Use Rule (SNUR)
None of the components are on this list.

CERCLA Reportable Quantities (RQ)
None of the components are on this list.

SARA Threshold Planning Quantities (TPQ)
None of the components are on this list.

SARA Hazard Categories
None of the components are on this list.

SARA Section 313
None of the components are on this list.

Clean Air Act - Hazardous Air Pollutants (HAPs)
None of the components are on this list.

Clean Air Act - Class 1 Ozone Depletors
None of the components are on this list.

Clean Air Act - Class 2 Ozone Depletors
None of the components are on this list.

Clean Water Act - Hazardous Substances
None of the components are on this list.

Clean Water Act - Priority Pollutants
None of the components are on this list.

Clean Water Act - Toxic Pollutants
None of the components are on this list.

OSHA - Highly Hazardous
None of the components are on this list.

US State

Material Safety Data Sheet
Sodium acetate, anhydrous

State Right to Know

California Prop 65

California No Significant Risk Level
No information available.

European/International Regulations

European Labelling in Accordance with EC Directives:
Hazard Symbols:
Risk Phrases:
Safety Phrases: S 24/25 Avoid contact with skin and eyes.

WGK (Water Danger/Protection)
No information available.

Canadian DSL/NDSL
CAS# 127-09-3 is listed on Canada's DSL/NDSL List.

Canadian WHMIS Classifications
This product has a WHMIS classification of D2B.

Canada Ingredient Disclosure List
CAS# 127-09-3 is not listed on Canada's Ingredient Disclosure List.

Exposure Limits

Section 16 - Other Information

Color information has been reworded.
MSDS Creation Date: December 13, 1994
Revision Date: October 23, 1997

UNIT IV: FOUNDATIONS OF GENETIC ENGINEERING

Lesson 1: The Mechanics of Cells and DNA

Competency/Objective: Identify the parts of a cell, including DNA, and their functions.

Study Questions

1. **What are the parts of a cell and their functions?**

2. **What is DNA?**

3. **What is the structure and function of DNA?**

4. **How does DNA replicate?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit IV.

2. Transparency Masters

   a) TM 1.1: The Parts of a Cell
   b) TM 1.2: The Cellular Chain of Command
   c) TM 1.3: DNA Replication

3. Activity Sheet

   a) AS 1.1: Comparing Plant and Animal Cells

UNIT IV: FOUNDATIONS OF GENETIC ENGINEERING

Lesson 1: The Mechanics of Cells and DNA

TEACHING PROCEDURES

A. Introduction

Just as an automobile mechanic must understand the basics of how an engine works, so the biotechnology researcher must understand the cell, its parts, and how they work. This lesson will provide a review of concepts taught in biology and will lay the foundation for future lessons on the manipulation of genetic material.

B. Motivation

1. Use a model of DNA to illustrate its structure. A model can be purchased, or a flat model of DNA can be put together using a series of cards with the base pairs written on them. Students could also hold these cards in the appropriate position to simulate the double helix structure.

2. To observe cell walls in a plant cell, slice a carrot very thinly, so that light can easily be seen through it. Freeze the carrot slices. Take a frozen slice and place it under a microscope. Quickly observe the cell walls as they deteriorate when the cells thaw.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to name as many parts of a cell as they can. Have a student write these on the board. Add any parts that they might have missed. Use TM 1.1 to illustrate the parts. Have students complete AS 1.1.

What are the parts of a cell and their functions?

a) Animal cell
   1) Cell (plasma) membrane - controls movement of materials into and out of the cell
   2) Cytoplasm - the contents of the cell, excluding the nucleus; contains fluid that helps control the movement of substances within the cell and includes the organelles
   3) Mitochondria - powerhouses of the cell; break down nutrients to provide energy
   4) Endoplasmic reticulum - network of membranes that transports materials within the cell; location of the ribosomes
   5) Ribosomes - primary location for protein synthesis
   6) Golgi apparatus - packages protein molecules for movement within and outside the cell
   7) Vacuole - stores water, enzymes, pigments, and other substances
   8) Nucleus - control center for the cell; contains chromosomes
   9) Chromosomes - tightly wrapped pieces of DNA; location of genes
   10) Genes - a segment of DNA on a chromosome that produces a polypeptide (protein) and is responsible for the expression of genetic traits

b) Plant cell - contains all of the structures found in animal cells with two additions
   1) Chloroplasts - contain chlorophyll, which is used in photosynthesis
   2) Cell wall - rigid outer layer that provides support for the plant cell and works collectively with other cells to support the plant

c) Bacteria cell
    1) Cell wall
    2) Cell membrane
    3) Ribosomes
    4) Nucleoid region - chromosomal material not contained within a nucleus
    5) Plasmid - small circular piece of DNA that codes for specific traits and replicates independently of chromosomal DNA; normally contains only a few genes

2. Ask a student to look up the definition of DNA, or deoxyribonucleic acid, in a dictionary or a CD-ROM encyclopedia.

What is DNA?

a) DNA (deoxyribonucleic acid) is the genetic material of the cell composed of small chemical units called nucleotides, which consist of three parts.
    1) A phosphate group
    2) A sugar (called deoxyribose) unit
    3) One of four nitrogen base units (adenine, guanine, thymine, and cytosine)
b) A single strand of DNA may contain more than 100 million base pairs.

3. Ask students to list as many words on the board as they can that describe what a DNA molecule looks like. Use TM 1.2 to illustrate the structure of DNA.

What is the structure and function of DNA?

a) Structure
    1) Two strands of nucleic acid are intertwined in a double helix structure that looks like a twisted or spiraling ladder.
    2) The phosphate and sugar units form the sides of the ladder, while the nitrogen base units form the rungs.
    3) The base units are found in one of two bonding arrangements, adenine bonded to thymine or guanine bonded to cytosine; hydrogen bonds join the base units.
b) Function
    1) DNA determines what types of proteins to build in protein synthesis.
        (a) DNA functions in sections called codons, which are sets of three nucleotides that code for one of the twenty amino acids.
        (b) These amino acids are then linked together to form polypeptides.
        (c) Two or more polypeptides are linked together to form a protein.
    2) In DNA replication, DNA makes a copy of itself to pass on its code to new cells formed by cell division.

4. Using TM 1.3, ask students why DNA needs to replicate. Explain that DNA must replicate, or each time a cell divided, it would lose half its DNA. Next, have students explain how DNA replication takes place.

How does DNA replicate?

a) A protein made by the cell binds to a place on the DNA called the origin.
b) An enzyme begins to break the hydrogen bonds that hold the two strands of the helix together, causing the double helix to “unzip.”
c) A complex enzyme (DNA polymerase) binds to each DNA strand segment and begins to add a new base unit to the strand; the added base must be compatible with the base on the parent DNA strand.
d) Another enzyme then bonds the new nucleotides with the parent DNA strand.
e) Each DNA molecule now consists of one parent strand and one newly formed strand.

F. Other Activities

1. Have students use cardboard puzzle pieces made to look like bases to show how DNA replicates.

2. Have students research and present a report about the discovery of the structure of DNA by Watson and Crick.

G. Conclusion

Plant, animal, and bacteria cells are all different in some respects. However, they all contain at least one chromosome, and therefore they contain DNA. The DNA in a plant, animal, or bacteria cell is essentially the same except for the base pair sequence it contains. This similarity of DNA makes the manipulation and transfer of DNA between different life-forms possible. If the structure or function of plant DNA was different from animal DNA, then DNA from a plant could not be spliced into the DNA of an animal. A clear understanding of the makeup of cells and a working knowledge of the structure and function of DNA is necessary to understand genetic manipulation.

H. Answers to the Activity Sheet

Student pictures will vary, but they should show that the students observed some parts of the cells.

I. Answers to the Evaluation

1. j
2. k
3. g
4. e
5. c
6. f
7. l
8. a
9. b
10. h
11. i
12. d
13. a
14. d
15. b

16. The steps in the replication of DNA are as follows:

- A protein binds to a place on the DNA called the origin.
- An enzyme begins to break the hydrogen bonds that hold the two strands of DNA together, unzipping the double helix.
- As the DNA strands are being unzipped, a complex enzyme (DNA polymerase) binds to each DNA strand segment and begins to add a new base unit to the strand. The added base must be compatible with the base on the parent DNA strand.
- Another enzyme then bonds the new nucleotides with the parent DNA strand.

UNIT IV: FOUNDATIONS OF GENETIC ENGINEERING Name _____

Lesson 1: The Mechanics of Cells and DNA Date _____

EVALUATION

Match the correct function on the right to the cell part on the left by writing the letters in the blanks.

1. _____ Cell wall
2. _____ Cell membrane
3. _____ Cytoplasm
4. _____ Mitochondria
5. _____ Endoplasmic reticulum
6. _____ Ribosomes
7. _____ Golgi apparatus
8. _____ Vacuole
9. _____ Plasmid
10. _____ Nucleus
11. _____ Chromosome
12. _____ Gene

a. Stores water, enzymes, pigments and other substances
b. Small circular piece of DNA that contains a few genes
c. A membrane that transports molecules
d. Segment of DNA that is responsible for the expression of a trait
e. Powerhouse of the cell
f. Primary location for protein synthesis
g. Contents of the cell, excluding the nucleus
h. Control center for the cell
i. Location of genes
j. Provides support for plant cells
k. Controls the movement of materials into and out of the cell
l. Packages protein molecules for movement within and outside the cell

Circle the letter that corresponds to the best answer.

13. The unit of a DNA molecule that contains the code for building proteins is the:

    a. Nitrogen base unit.
    b. Phosphate unit.
    c. Sugar unit.
    d. Potassium unit.

14. When examining the structure of DNA, which of the following bonding arrangements is found in the DNA molecule?

    a. Guanine bonded to thymine
    b. Cytosine bonded to thymine
    c. Adenine bonded to cytosine
    d. Guanine bonded to cytosine

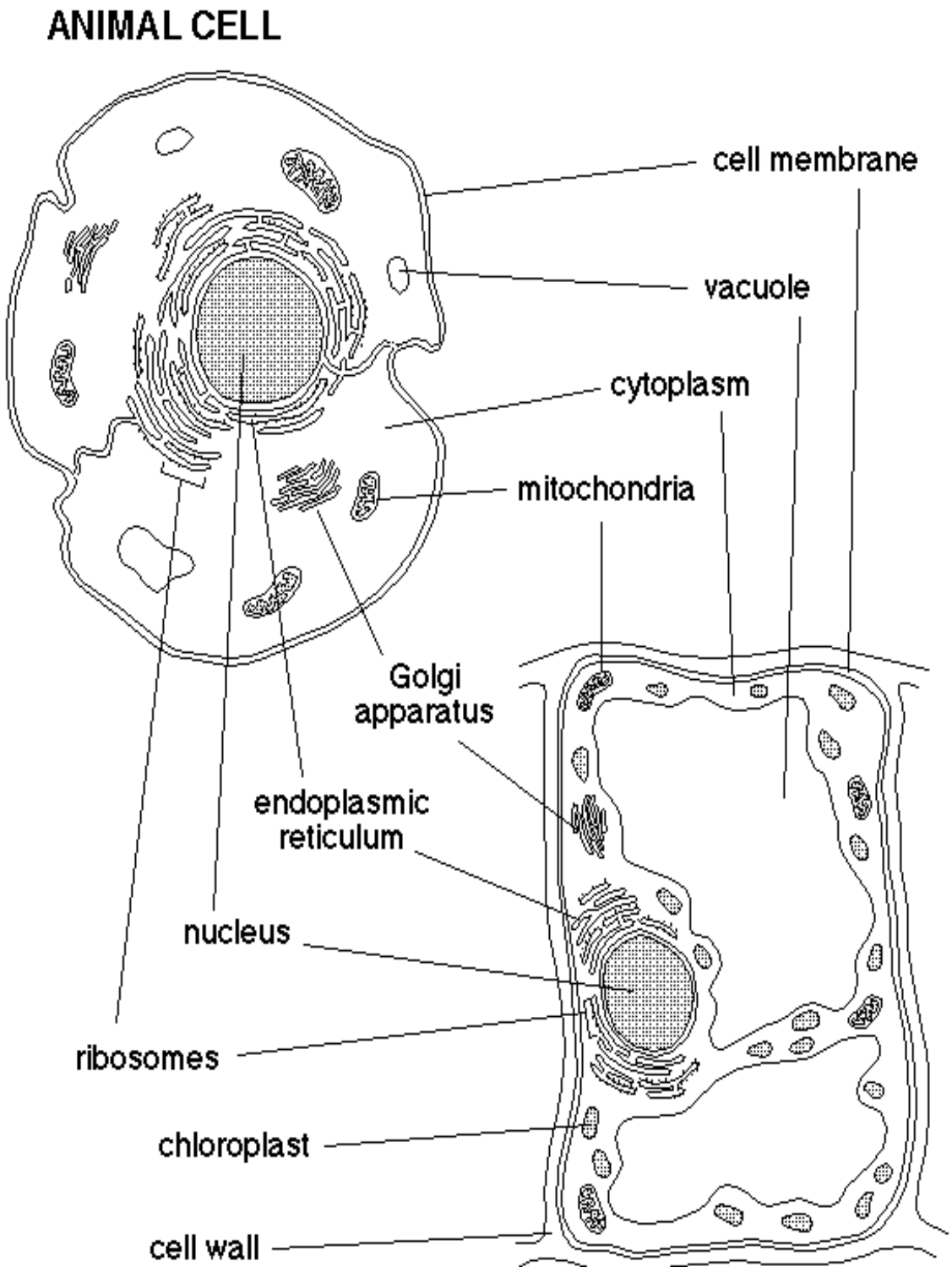
15. A codon is a:

a. Segment of DNA that is responsible for the expression of a trait.
b. Segment of DNA that is three base pairs long and codes for a specific amino acid.
c. Segment of DNA that codes for one of twenty polypeptides.
d. Segment of DNA that contains no base units.

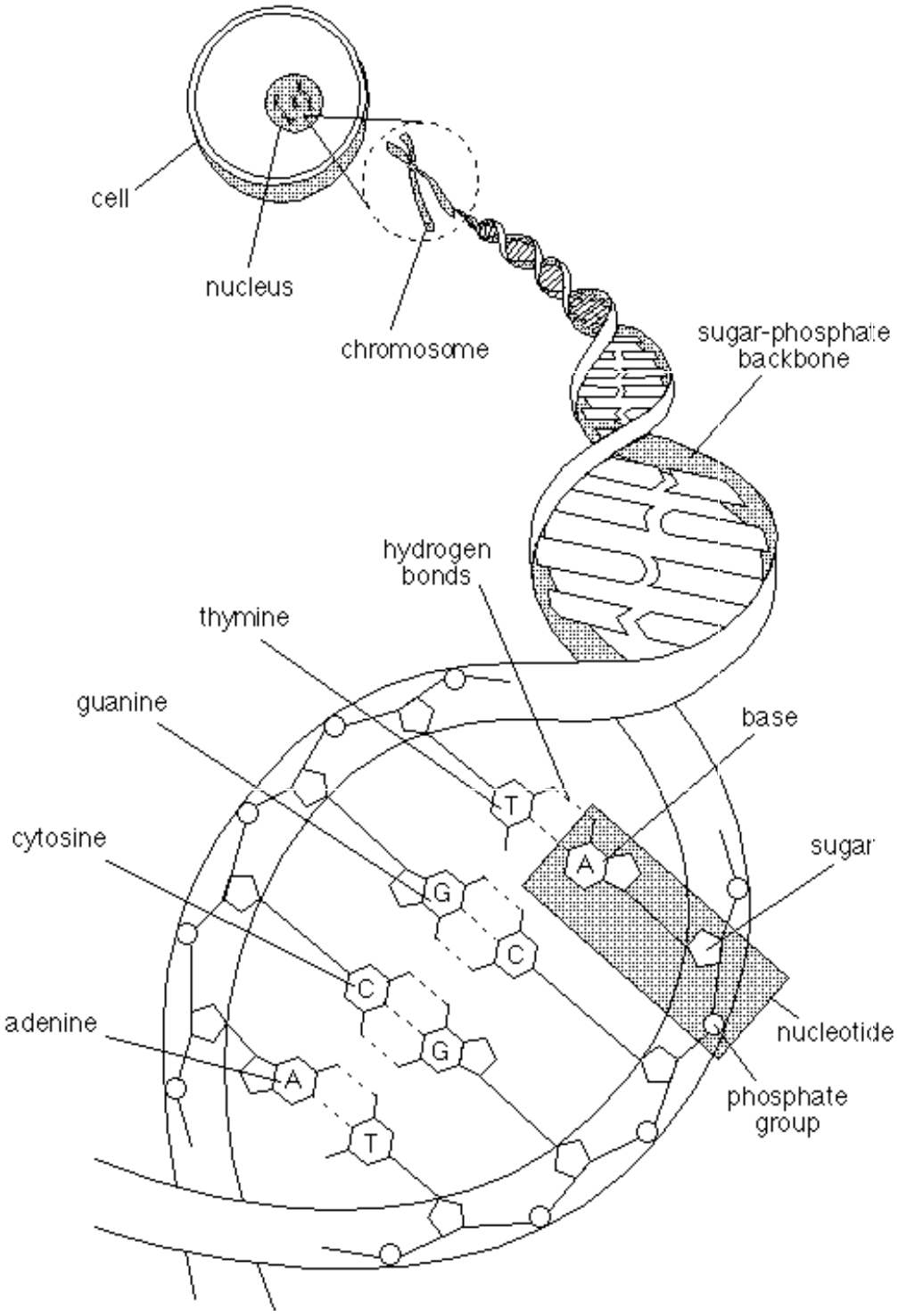
Complete the following short answer question.

16. What are the steps in DNA replication?

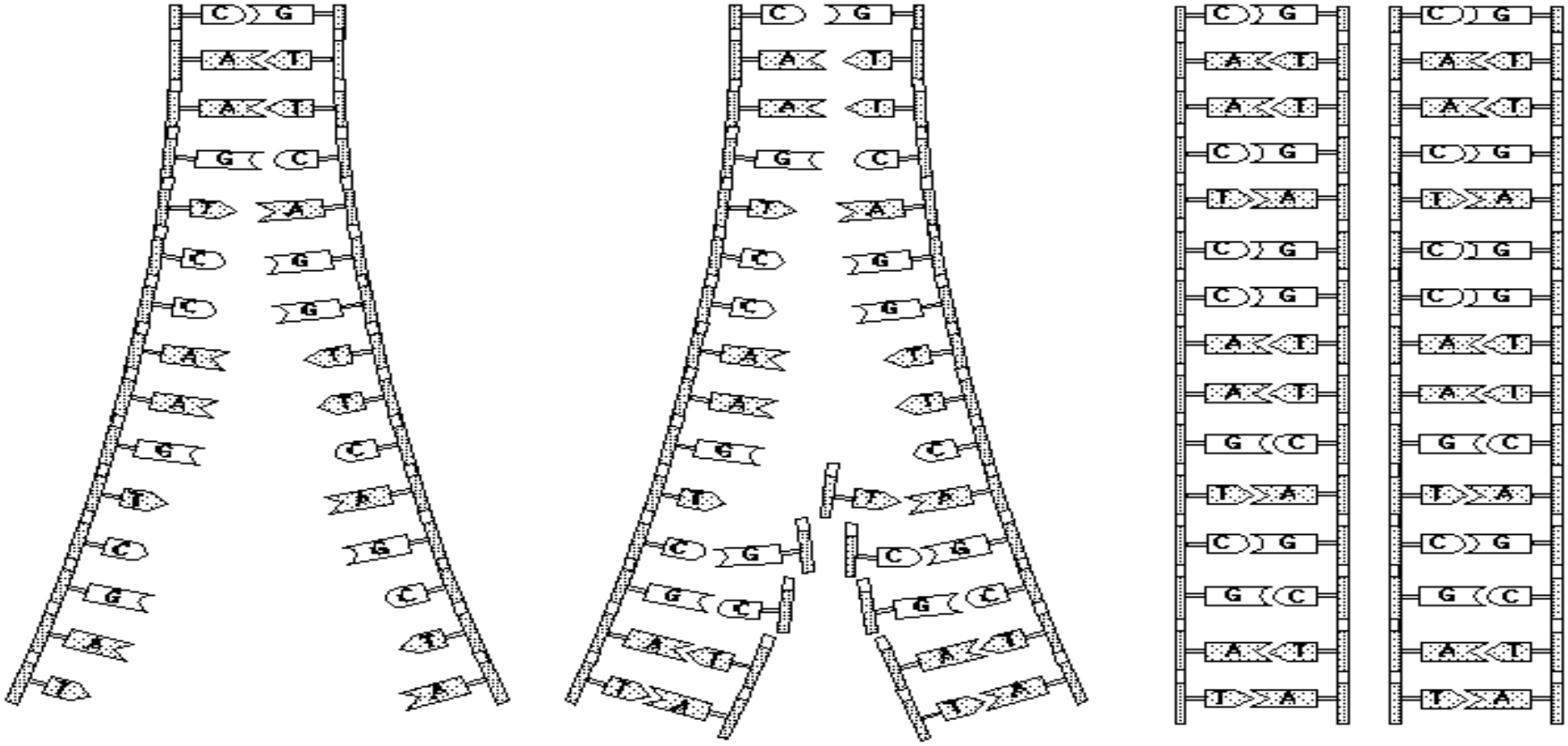
The Parts of a Cell



The Cellular Chain of Command



DNA Replication



Comparing Plant and Animal Cells

Objective: Identify the parts of plant and animal cells.

Materials and Equipment:

Microscope
2 glass slides
2 cover slips
Onion
Toothpicks
0.9 percent NaCl
Methylene blue

Procedure:

A. Red or Purple Onion Cells

1. Remove a paper thin section of an onion peel. Cut out a small piece about the size of a penny. Place this tissue sample on a clean glass slide. Add a drop of water and carefully place a cover slip over the specimen. **Gently** press out any air bubbles.

2. Examine the tissue using the low-power objective and then the high-power objective. Look for the nucleus, nuclear membrane, cytoplasm, and cell wall.

3. Draw a picture of one of the onion cells and label the cell parts that you observed.

B. Human Epithelial Cells

1. Carefully scrape the inside of your mouth with the flattened end of a toothpick. Place the scrapings in a drop of 0.9 percent NaCl on a clean glass slide. Repeat the scraping procedure four times and then place a cover slip over the specimens.

2. Add a drop of methylene blue to one edge of the cover slip. To pull the stain across the specimen, use a paper towel to begin absorbing liquid at the edge of the cover slip opposite the stain. Continue until the excess stain has been removed.

3. Examine the cells using the low- and high-power objectives. Draw and label the parts of the cells that you observe.

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 2: Cell Reproduction and Genetics

Competency/Objective: Explain how cells reproduce.

Study Questions

1. **What is mitosis?**
2. **What is meiosis?**
3. **How do mitosis and meiosis differ?**
4. **What are dominant and recessive genes?**
5. **What are homozygous and heterozygous gene pairs?**
6. **What are genotypes and phenotypes?**
7. **What are mutations?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit IV.
2. Transparency Masters
   a) TM 2.1: Mitosis
   b) TM 2.2: Meiosis
3. Activity Sheet
   a) AS 2.1: Mitosis and Meiosis

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 2: Cell Reproduction and Genetics

TEACHING PROCEDURES

A. Review

In the last lesson, the cell and its components were examined in some detail. This lesson focuses on the two ways in which cells reproduce and how this reproduction can pass on genetic information and the traits seen in the organism's offspring.

B. Motivation

When discussing cell reproduction, the obvious question to ask is why body cells need to reproduce at all. If a body cell can grow and get bigger, why does it need to reproduce itself? Think for a moment about a large car factory. Why do manufacturers like General Motors or Ford have different factories in the Midwest? Why not one big factory?

Several reasons exist for having many factories or many cells. First, the managers of the factory (the nucleus of the cell) can only control a limited workload. The operations of the factory (the making of proteins in the cell) cannot increase above the capacity that the management (cell nucleus) can handle. Another reason for having more than one is so that the supply and export of products is not slowed. The larger a factory gets the more raw materials it demands (just as the larger a cell gets the more nutrients, oxygen, and other raw materials it demands). At the same time, the export of products also increases, and these two factors slow the movement of raw materials and products into and out of the factory (cell).

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students if they know how hair, fingernails, skin, or muscles grow. Use TM 2.1 to show the stages of mitosis and how tissues grow.

What is mitosis?

a) Mitosis is a type of cell division in which somatic cells divide and form two new cells; each new cell contains the same number of paired chromosomes as the parent cell, or two complete sets of chromosomes (a diploid number of chromosomes).
b) Stages of mitosis (Hint: Remember PMAT.)
    1) Prophase
        (a) Chromosomes coil and condense to form a double-stranded structure consisting of two paired chromatids connected at a body called a centromere.
        (b) The nuclear membrane dissolves gradually.
        (c) A network of microtubules begins forming around centrioles, which start to move to opposite ends of the cell; the network of microtubules is called a spindle.
        (d) Spindle fibers extend out from the centrioles toward the center of the cell.
    2) Metaphase
        (a) Chromosomal units move to the center of the cell and form a line between the two poles.

(b) Each spindle fiber attaches to a centromere.

3) Anaphase
   (a) The centromeres break, allowing the spindle fibers to pull apart the chromatids.
   (b) The chromosomes move toward opposite poles of the cell.
   (c) The poles move farther apart, elongating the cell.
   (d) At the end of anaphase, the two poles each have a complete set of chromosomes.
4) Telophase
   (a) In animal cells, the cell membrane pinches together, dividing the cell into two cells.
   (b) In plant cells, a cell plate forms in the middle of the cell and begins to divide it into two cells; a cell membrane forms on both sides of the cell plate, and the cell plate changes to a cell wall.
   (c) Nuclear membranes develop in the daughter cells.
   (d) The chromosomes uncoil and lose their distinct outlines.

2. Ask students how sex cells divide. Use TM 2.2 to show the stages of meiosis. Have students complete AS 2.1. When doing the activity, make sure to observe each phase before allowing students to move on to the next one. The instructor may want to make up a poster showing the different phases so that students can use it as a model.

What is meiosis?

a) Meiosis is a type of cell division that produces gametes (sex cells). It has two phases of cell division, producing four gametes. The gametes contain half the number of chromosomes found in the parent cell, or a single set of chromosomes, and are referred to as haploid cells.

b) Meiosis I
   1) Prophase I
      (a) Homologous chromosomes pair together and form a tetrad, a grouping of four chromatids side by side.
      (b) Nonpaired chromatids may exchange segments in a process called "crossing over."
      (c) The centrioles move apart and the spindle forms.
      (d) The nuclear membrane dissolves.
   2) Metaphase I
      (a) Homologous chromosomes line up in the center of the cell.
      (b) The spindle fiber ends attach to centromeres.
   3) Anaphase I - Homologous chromosomes separate and are pulled to different poles.
   4) Telophase I
      (a) The cell plate and/or cell membrane forms, creating two haploid daughter cells.
      (b) Nuclear membranes form.

c) Meiosis II
   1) Prophase II
      (a) The spindle fibers develop.
      (b) Paired chromatids move to the center of the cell.
   2) Metaphase II
      (a) The chromosomal units line up in a row between the two poles.
      (b) They become attached to the spindle fibers.
   3) Anaphase II - Chromatids separate and move toward opposite poles.
   4) Telophase II
      (a) The center of each cell closes off with the formation of a cell membrane or cell plate.
      (b) Nuclei form.

(c) Chromosomes uncoil.

3. Have students compare mitosis and meiosis and list the differences.
How do mitosis and meiosis differ?

a) Mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell.
b) Mitosis produces diploid somatic cells, while meiosis produces haploid gametes.
c) Mitosis produces two identical cells, and meiosis produces four nonidentical cells.
    1) During mitosis, chromosomes contribute an identical chromosome to each daughter cell.
    2) In meiosis, homologous chromosomes split and contribute nonidentical chromosomes to each daughter cell.
d) Meiosis allows genes to cross over, while mitosis does not.

4. Ask students to define the word dominant. Relate this definition to dominant and recessive genes.

What are dominant and recessive genes?

a) Chromosomes work in pairs.
b) Each chromosome has a homologous chromosome that has genes that code for the same information but somewhat differently.
c) Each gene in a gene pair is either dominant or recessive.
d) Dominant genes are expressed; they mask the expression of a recessive gene.
e) Recessive genes are genes that are not expressed, or apparent in the traits of the animal.

5. Ask students to define the terms homozygous and heterozygous.

What are homozygous and heterozygous gene pairs?

a) Either of the two possible expressions of a gene or multiple genes that code for a specific trait is called an allele.
b) An organism with two dominant alleles or two recessive alleles is homozygous for that specific trait; they are either homozygous dominant or homozygous recessive.
c) An organism with one dominant allele and one recessive allele is heterozygous for that trait.

6. Have students explain and give examples of a genotype and a phenotype.

What are genotypes and phenotypes?

a) Genotype - The specific combination of alleles for a trait.
b) Phenotype - The appearance or expression of a trait as determined by the genotype.

7. Ask student if they believe that all mutations are bad. Point out that mutations such as seedless grapes and oranges are not harmful.

What are mutations?

a) Mutations are alterations in the nucleotide sequence found in a DNA molecule; they may be from the insertion, deletion, or miscoding of a base unit during replication.
b) Mutations can occur during replication in mitosis or meiosis.
    1) Mutations during mitosis are not inheritable; they affect the daughter cell and any cells descending from it.

2) Mutations prior to meiosis are passed on to an organism's offspring if the mutant gamete is fertilized.

F. Other Activities

Review the use of Punnet squares to further discuss genotype and phenotype.

G. Conclusion

An understanding of cell reproduction and the basic genetic concepts discussed in this lesson suggests how genetic manipulation must be done. To add a gene to an entire plant or animal, genetic manipulation must be done before or during meiosis. Gene interaction is quite complex, and genetic manipulation is even more complex.

H. Answers to Activity Sheet

AS 2.1

1. a. Mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell.
   b. Mitosis produces diploid somatic cells, while meiosis produces haploid gametes.
   c. Mitosis produces two identical cells, and meiosis produces four nonidentical cells.
   d. Meiosis allows genes to cross over, while mitosis does not.

2. In meiosis I, homologous chromosomes are separated, and a double-stranded chromosomal unit is passed on to the new cells. In meiosis II, the chromatids split apart, with each new cell receiving one chromosome.

I. Answers to the Evaluation

1. a
2. d
3. b
4. a
5. c

6. Mutations are alterations in the nucleotide sequence found in a DNA molecule; they may be from the insertion, deletion, or miscoding of a base unit during replication.

7. a) Prophase
   b) Metaphase
   c) Anaphase
   d) Telophase

8. Students may list any two of the following:

   - Mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell.
   - Mitosis produces diploid somatic cells, while meiosis produces haploid gametes.
   - Mitosis produces two identical cells, and meiosis produces four nonidentical cells.
   - Meiosis allows genes to cross over, while mitosis does not.

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING Name _____

Lesson 2: Cell Reproduction and Genetics Date _____

EVALUATION

Circle the letter that corresponds with the best answer.

1. Meiosis can be defined as a type of cell division in which:

    a. Gametes are produced.
    b. Somatic cells are produced.
    c. Two identical cells are produced.
    d. Diploid cells are produced.

2. One difference between animal and plant cells during the last phase of mitosis is that in animal cells the cell membrane pinches in to divide the cell, while in plant cells:

    a. Cell membranes do not exist.
    b. The cell membrane grows out of the center of the cell, dividing it.
    c. The nuclear wall grows to divide the cell.
    d. The cell plate grows to divide the cell.

3. What is the term used to describe when chromosomes exchange segments during meiosis?

    a. Haploid exchange
    b. Crossing over
    c. Centromere replication
    d. Mutation

4. If a plant has a recessive allele for a dwarf plant and a dominant allele for a tall plant, how tall would the plant be?

    a. Tall
    b. Short
    c. Medium height
    d. It is impossible to tell how tall it will be.

5. What is the appearance or expression of a trait in an organism called?

    a. Chromotype
    b. Genotype
    c. Phenotype
    d. Heterozygous

Complete the following short answer questions.

6. What are mutations?

7. What are the four stages of mitosis, in the order in which they occur?

   a.

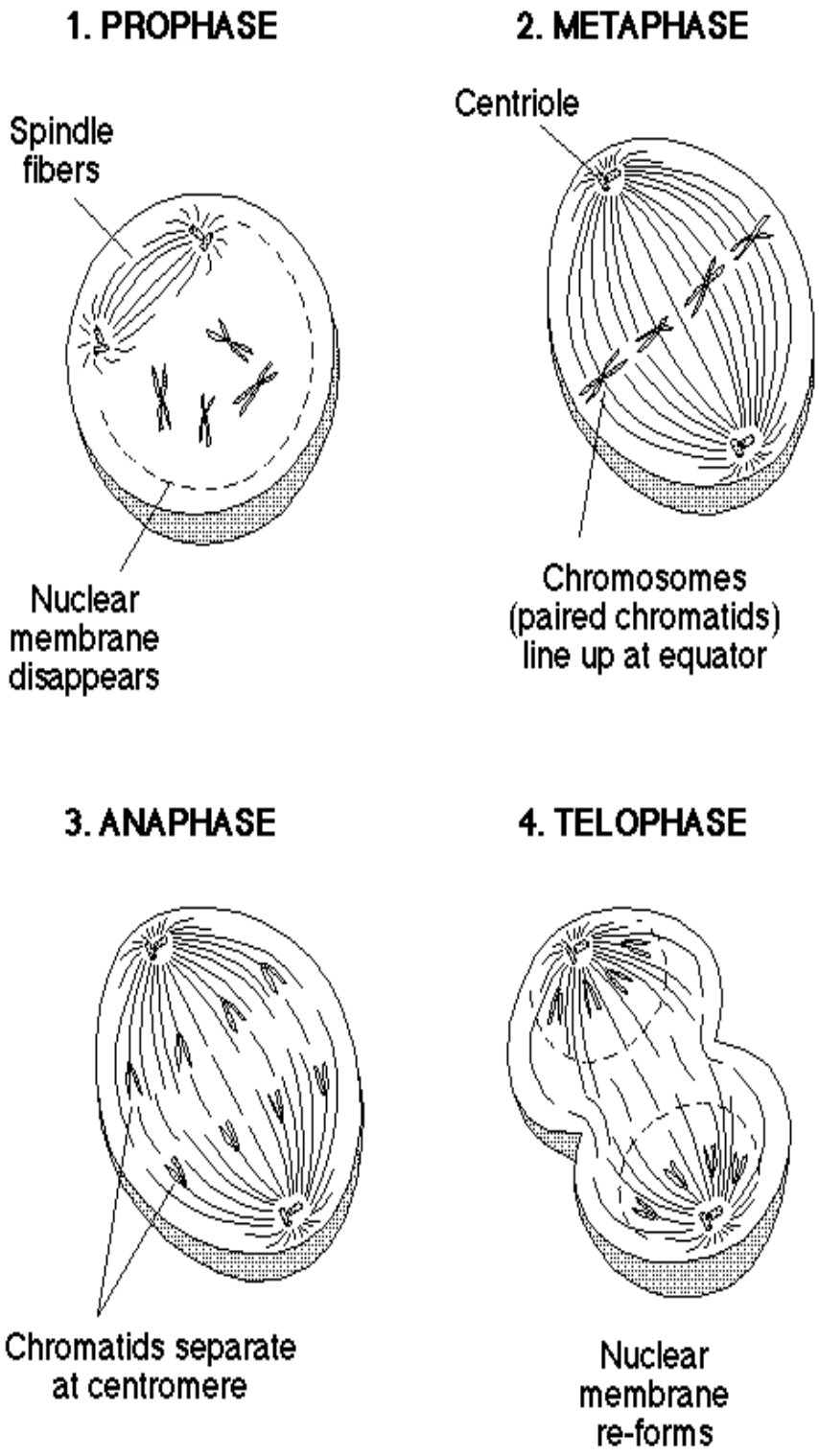
   b.

   c.

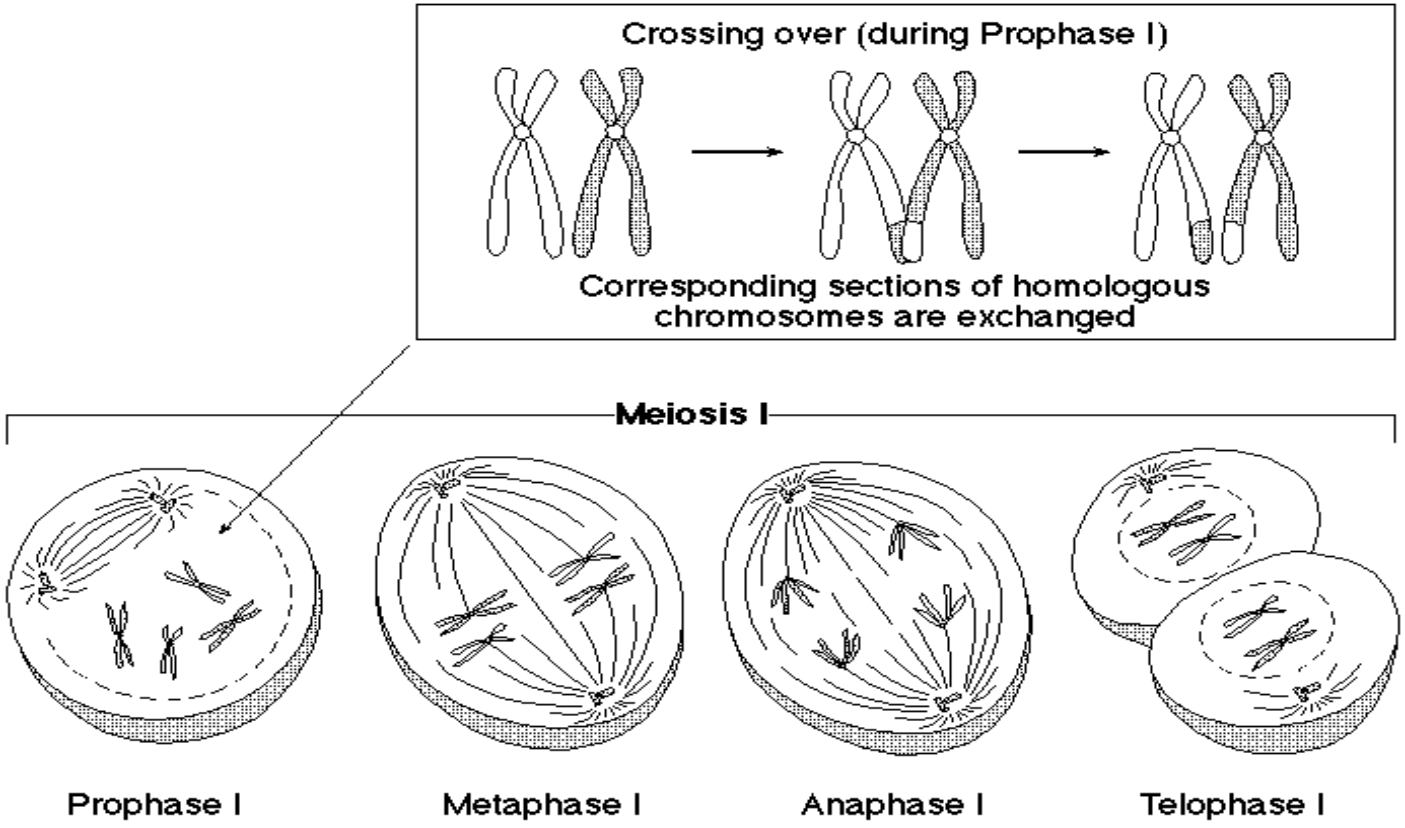
   d.

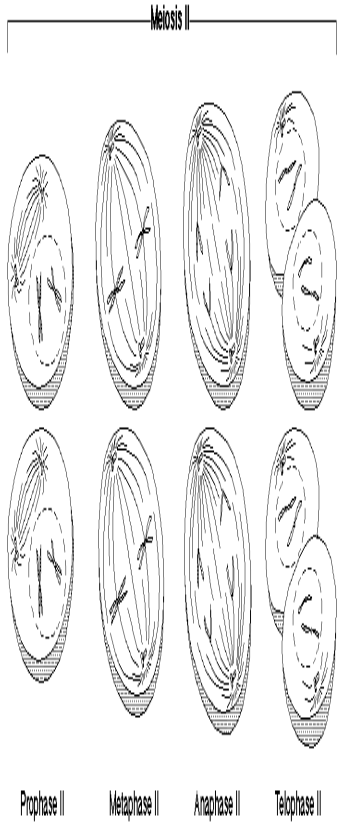
8. What are two ways in which mitosis and meiosis differ?

Mitosis


1. PROPHASE
Spindle fibers
Nuclear membrane disappears
2. METAPHASE
Centriole
Chromosomes (paired chromatids) line up at equator
3. ANAPHASE
Chromatids separate at centromere
4. TELOPHASE
Nuclear membrane re-forms

Meiosis


Crossing over (during Prophase I)
Corresponding sections of homologous chromosomes are exchanged
Meiosis I
Prophase I
Metaphase I
Anaphase I
Telophase I


Meiosis II
Prophase II
Metaphase II
Anaphase II
Telophase II

Lesson 2: Cell Reproduction and Genetics Name _____

Mitosis and Meiosis

Objective: Simulate the stages of mitosis and meiosis.

Materials and Equipment:

Pipe cleaners
Beads
Pieces of yarn

Procedure:

1. Using pipe cleaners, beads, and pieces of yarn, illustrate the four stages of mitosis. The pipe cleaners and beads should represent the chromosomes. The pieces of yarn can illustrate the nucleus, centrioles, and spindle fibers. Be ready to explain what happens in each of these four stages.

2. Use the pipe cleaners, beads, and yarn to illustrate the four stages of meiosis I. Be sure to show the differences that distinguish meiosis I from mitosis. Be ready to explain each stage of meiosis I.

3. Use the pipe cleaners, beads, and yarn to illustrate the four stages of meiosis II. Be sure to illustrate the crossing over of genes. Be ready to explain each stage of meiosis II.

Key Questions:

1. What are four differences that exist between mitosis and meiosis?

   a.

   b.

   c.

   d.

2. How does meiosis I differ from meiosis II in terms of the genetic material passed on to the new cells?

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 3: Genetic Modification

Objective/Competence: Describe the processes of genetic modification.

Study Questions

1. **What are gene mapping and gene sequencing?**
2. **How is DNA extracted?**
3. **What is restriction digestion?**
4. **What is gel electrophoresis?**
5. **What is gene splicing, and how is it accomplished?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit IV.
2. Transparency Master
   a) TM 3.1: Gel Electrophoresis
3. Activity Sheet
   a) AS 3.1: DNA Extraction

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 3: Genetic Modification

TEACHING PROCEDURES

A. Review

Lesson 2 discussed how cells reproduce and pass on genetic information. A spontaneous change in the genetic code of a cell or organism is called a mutation. Recombinant DNA technology provides researchers with the tools necessary to intentionally alter specific parts of the genetic code of a cell. This lesson will describe some of these tools.

B. Motivation

Gel electrophoresis can be dramatized by the use of an obstacle course. Configure student chairs or desks to form three obstacle courses. Divide the students into three groups, with two to four students in the first group, four to eight in the second group, and eight to twelve in the third group. All groups should start the obstacle course at the same time and should be instructed not to touch any chair or desk. When the winning team reaches the finish line, all teams must freeze. Explain that the obstacle course represents the agarose gel through which the DNA fragments must pass in gel electrophoresis. The longer the fragment, the slower it will move across the gel.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to describe gene mapping and gene sequencing.

What are gene mapping and gene sequencing?

a) Gene mapping is the process of finding the location of genes for specific traits on the chromosomes of an organism. Researchers use gene mapping to select specific genes for modification.
b) Gene sequencing is a process that shows the order of all the base units (A, T, C, G) as they line up on a particular gene. It allows scientists to recognize how to cut out a particular gene or gene fragment.

2. Ask students if DNA is a chemical substance. Because it is a chemical substance, it can be extracted chemically. Use AS 3.1 to allow students to perform a DNA extraction.

How is DNA extracted?

a) The cell membrane or cell wall must be broken down to release the cytoplasm, and the nuclear membrane must also be broken to release the chromosomes.
    1) This can be accomplished with a surfactant, which is a fatty acid compound like detergent.
    2) Heat accelerates this process.
b) Next, a protease must be used to split the protein contents of the cell, including protein molecules called Histones, around which the DNA strands are wrapped.
c) The last step involves separating the DNA from the other cell components. Cold alcohol is added to the cellular solution; the DNA clumps together and rises to the top of the alcohol.

3. Ask students what scissors are used for. Discuss how restriction digestion works.

What is restriction digestion?

a) Restriction digestion is the process of cutting DNA into smaller fragments with restriction enzymes.
b) Restriction enzymes are essentially biochemical scissors; each restriction enzyme cuts DNA at a different sequence of base pairs.
c) Researchers use restriction enzymes to cut genes or DNA fragments out of extracted DNA strands.

4. Ask students to recall the lesson in which DNA fingerprinting was discussed. Explain that the bands that make up the DNA fingerprint are a result of gel electrophoresis. Discuss the process of gel electrophoresis. Use TM 3.1 to illustrate how gel electrophoresis works.

What is gel electrophoresis?

a) Gel electrophoresis is a process in which an electric current is applied to a gel to separate different lengths of DNA fragments into groups; researchers can then recover a desired gene or gene fragment.
b) It requires an electrophoresis box, a buffer solution, a special power supply, and a gel made from agarose or another agent.
c) One end of the electrophoresis box has a positive pole and the other a negative pole.
d) DNA fragments to which a dye has been added are placed in small wells or pockets at the end of gel nearest the negative pole, and an electric current is applied to the gel.
e) Since DNA fragments are negatively charged, they will be repelled away from the negative pole and attracted to the positive pole.
f) Short lengths of DNA will move through the gel faster than long lengths.
g) When the electric current is removed, the fragments of DNA of the same size will be grouped at a one spot on the gel, which is called a band.

5. Ask students to define the term splicing. Explain that gene splicing is like splicing two pieces of rope together using a third piece of rope.

What is gene-splicing, and how is it accomplished?

a) Gene-splicing is the process of inserting a piece of DNA into a chromosome of a cell.
b) Gene-splicing is also called ligation because the enzyme ligase is the biochemical glue that joins the pieces of DNA.
c) Gene-splicing requires several steps.
    1) The researcher cuts out a piece of DNA with a restriction enzyme; the correct enzyme must be used so that the DNA contains complementary bases.
    2) Gel electrophoresis must be performed to separate the DNA fragments by size and isolate the appropriate fragment.
    3) The researcher joins the ends of the selected fragment to the DNA being transformed through a chemical reaction called a ligase reaction.
    4) The result is a cell containing DNA from two different sources, which is therefore called recombinant DNA.

F. Other Activities

1. Use pop beads to show how restriction digestion works.

2. If possible, use restriction analysis and gel electrophoresis experiments such as those found in the curriculum guide *An Introduction to Biotechnology: A Unit for High School Students (Book Three)* published by Kendall/Hunt.

G. Conclusion

This lesson describes some of the most common techniques used by molecular biologists involved in biotechnology research. Knowledge of these techniques will provide a basic understanding of exactly how DNA is manipulated.

H. Answers to Activity Sheet

AS 4.1

1. The soap helped break down the cell membranes and release the chromosomes.

2. Heating the solution accelerated the breakdown of the membranes. Most of the lipids and proteins precipitated out of the solution. However, the solution needed to be cooled after heating to avoid the soap breaking down the DNA.

3. The meat tenderizer contains the enzyme papain, which breaks down proteins.

4. DNA is the only component of the cell that is not soluble in alcohol and therefore precipitates out.

5. (Students should speculate on this question but may not be able to come up with this answer.) The DNA was not pure because some of the other cellular components could have clung to the DNA. It must be washed in alcohol several times to be pure.

I. Answers to the Evaluation

1. d
2. b
3. a
4. c
5. d

6. a) The cell membrane or cell wall and nuclear membranes are broken down with the use of a surfactant.
   b) Protease is used to break down the protein contents of the cell, including histones, around which the DNA is wrapped.
   c) DNA is separated from the other cell components by adding cold alcohol to the cellular solution, which causes the DNA to clump together and rise to the top of the alcohol.

7. Gene sequencing is a process that shows the order of all the base units (A, T, C, G) as they line up on a particular gene.

8. Restriction digestion is the process of cutting DNA into smaller fragments with restriction enzymes.

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is considered to be a type of biochemical scissors?

   a. Agarose gel
   b. Histones
   c. Ligase
   d. Restriction enzymes

2. When a researcher does gel electrophoresis, what causes the DNA fragments to move across the gel?

   a. Buffer solution flows across the gel, moving the DNA fragments.
   b. Negatively charged DNA is repelled away from the negative pole and attracted toward the positive pole of the electrophoresis box.
   c. Positively charged DNA is repelled away from the positive pole and attracted toward the negative pole of the electrophoresis box.
   d. A chemical reaction involving ligase causes the movement of the DNA.

3. Ligase is an enzyme that:

   a. Chemically joins two DNA fragments.
   b. Acts as a restriction enzyme.
   c. Is used in the gel electrophoresis buffer solution.
   d. Is used in DNA extractions to break down the lipid components of the cell.

4. Surfactants, which are similar to detergents:

   a. Break down the protein contents of the cell.
   b. Cause DNA to float to the top of a cellular solution.
   c. Break down the cellular membranes.
   d. Speed up the process of DNA extraction.

5. Gene mapping can be defined as the:

   a. Process that allows researchers to separate different lengths of DNA fragments into groups.
   b. Process of inserting a piece of DNA into a chromosome of a cell.
   c. Process that finds the order of all the base units as they line up on a particular gene.
   d. Process of finding the location of genes on the chromosomes of an organism.

Complete the following short answer questions.

6. What are the three major steps of the DNA extraction process?

   a.

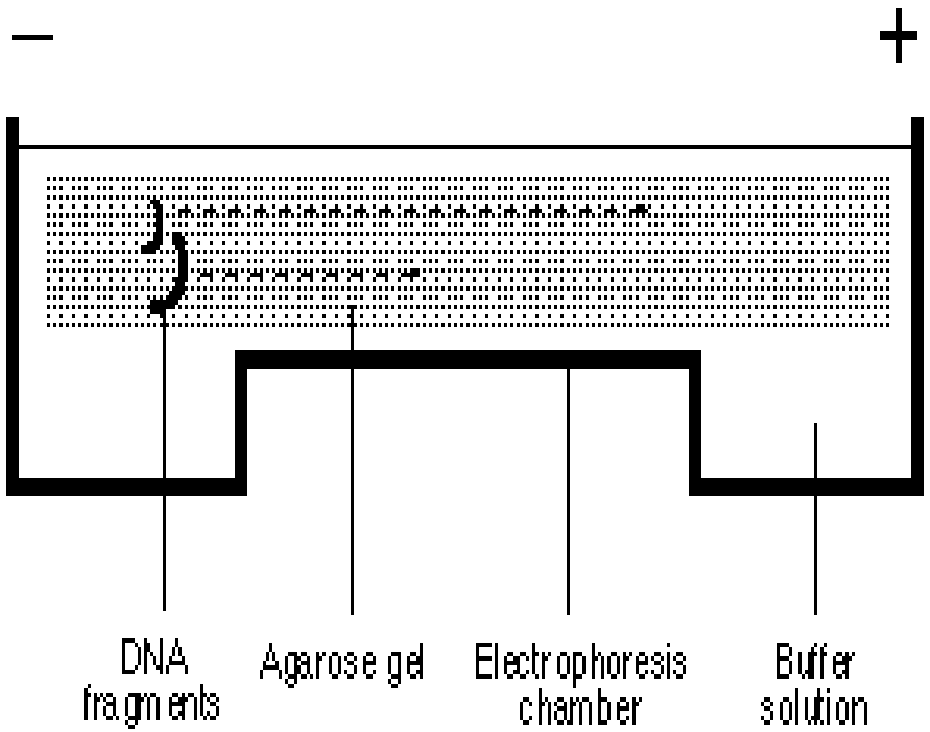
   b.

   c.

7. What is gene sequencing?

8. What is restriction digestion?

Gel Electrophoresis



Lesson 3: Genetic Modification Name _____

DNA Extraction

Objective: Perform DNA extraction.

Materials and Equipment:

1 hot water bath or hot plate set at 55 to 60 degrees Celsius
1 candy or laboratory thermometer (to regulate the hot water bath)
1 cold water bath (ice water in a large bowl)

Materials needed for each group of students:

1 glass or plastic graduated cylinder (100 ml)
1 plastic teaspoon
1 Pyrex glass or heat-resistant plastic beaker or flask (500 ml or larger)
1 piece of glass tubing bent to a 90 degree angle at the end
1 funnel or strainer with a coffee filter
2 flat toothpicks
1 medicine dropper or pipette
1 container of liquid soap (Woolite, laundry soap, or dish soap)
1 test tube for each student
½ medium onion, chopped (should not be finely chopped)
Refrigerated alcohol
Meat tenderizer

Procedure:

1. Observe the instructor as he or she performs steps 2-6.

2. Measure out 5 ml of soap and leave it in the graduated cylinder. Add ¼ teaspoon of salt to the soap. Next, add water to the soap until a total volume of 50 ml is reached. Set the cylinder aside. Place the onion in the beaker or flask. Pour the soap and salt water solution over the chopped onion.

3. Put the beaker or flask containing the onion solution into the hot water bath or onto the hot plate. Check to make sure that the temperature is approximately 55 to 60 degrees Celsius. The onion solution should be heated for 10 to 12 minutes. If the solution is heated for more than 15 minutes, the DNA will break down. Slowly stir the mixture periodically but not so much as to create foam. Make sure to record the time you placed the beaker or flask in the heating environment.

4. After 10 to 12 minutes, remove the solution from the hot water bath or hot plate and place it in the ice water bath for five minutes. Stir the solution slowly while it is cooling.

5. Filter the solution into a plastic cup using the funnel or strainer and coffee filter. Try to avoid getting any foam into the filtered mixture. This filtering procedure may be a slow process; if needed, it can be left to filter overnight in a refrigerator.

6. Divide the filtered solution into the test tubes, placing about one teaspoon in each. Stir the filtered solution while dividing it. The test tubes can be stored in the refrigerator overnight.

7. Add two toothpicks full of meat tenderizer to the solution in the test tubes and **gently** mix. Next, add **cold** alcohol to the solution until a 1 cm layer of alcohol forms on top of the solution. This can be done by using a medicine dropper or pipette. **Do not mix the solution!** Watch as the DNA begins to precipitate out into the alcohol. The bent piece of glass tubing can be used to spool the DNA. The DNA will look like white mucus.

Key Questions:

1. What did the soap do to aid in the extraction of the DNA?

2. Why was the onion solution heated and then cooled?

3. Why was meat tenderizer used? (Hint: Look at the ingredients in the meat tenderizer.)

4. Why did the DNA precipitate out in the alcohol?

5. Do you think the DNA obtained was pure? Why or why not?

UNIT V - ANIMAL TECHNOLOGIES

Lesson 1: Artificial Insemination

Objective/Competency: Describe the process of artificial insemination.

Study Questions

1. **What is artificial insemination?**
2. **What are the benefits of artificial insemination compared to natural breeding?**
3. **What equipment is needed for artificial insemination?**
4. **What steps are involved in artificial insemination?**
5. **How can the estrous cycle be manipulated to aid in artificial insemination?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.
2. Activity Sheet
   a) AS 1.1: Evaluating Semen

UNIT V - ANIMAL TECHNOLOGIES

Lesson 1: Artificial Insemination

TEACHING PROCEDURES

A. Introduction

Biotechnology has been used in the animal industry for many years. Animal biotechnology has its foundation in selective breeding practices. In the early twentieth century, animal biotechnology included artificial insemination. In the late 1970s, embryo transfer technology emerged in the animal industry. In 1997 animal cloning was performed using an adult sheep, and biotechnology continues to open new opportunities in animal production. This lesson will examine the technology of artificial insemination.

B. Motivation

The livestock industry is becoming an industry that demands a more uniform product. How does a producer achieve this improved level of product quality? Many producers are using artificial insemination to accomplish this goal. Purebred producers who want exceptional breeding stock but view buying superior male animals as too expensive commonly use artificial insemination. Artificial insemination technology has also made the international exchange of breeding stock economically feasible.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to define artificial insemination in their own words.

What is artificial insemination?

Artificial insemination is the process of collecting semen from a male animal and placing it in the reproductive tract of a female animal.

2. Ask students what the benefits of artificial insemination are.

What are the benefits of artificial insemination compared to natural breeding?

a) AI allows for the selection and use of male animals regardless of where the animals are physically located.
b) AI helps reduce the spread of reproductive or venereal diseases.
c) AI reduces or eliminates the cost of owning and maintaining a male animal.
d) The genetic improvement of livestock through the use of superior animals occurs more quickly due to a dramatic increase in the number of offspring a male animal can produce (sire) per year.

3. Show students the actual equipment used in AI or pictures of the equipment.

What equipment is needed for artificial insemination?

a) Dummy - female replica mounted by male so that semen can be collected
b) Artificial vagina - water-filled plastic sheath used to collect the semen
c) Microscope - to check the quality of the semen

d) Semen straw - thin plastic tube used to store the amount of semen needed to inseminate one female
e) Semen tank - aluminum tank used to store semen in liquid nitrogen
f) Insemination instrument - syringe-like tool that holds the straw and deposits the semen into the reproductive tract

4. Ask students to describe the process of artificial insemination. Have students complete AS 1.1. Students must be given pictures of primary, secondary, and tertiary sperm abnormalities to complete the activity. These pictures may be available in reproductive physiology or veterinary husbandry textbooks. Point out that the activity only addresses a few factors that affect the quality of sperm and does not provide an absolute measure of fertility.

What steps are involved in artificial insemination?

a) Semen is collected using an artificial vagina.
b) The semen is tested for quality, which is determined by the motility, shape, and quantity of the sperm.
c) Extenders are added to increase the volume. The extenders that are most commonly used are citrate, egg-yolk phosphate, and homogenized milk.
d) The semen is placed in straws and frozen in liquid nitrogen at -320 degrees Fahrenheit.
e) The timing of insemination must be carefully managed; generally, insemination should occur shortly before ovulation.
f) The semen must be properly thawed.
g) A trained technician should inseminate the female by placing the straw in the inseminating instrument, which is inserted into the vagina and guided through the cervix; the semen is placed at the end of the cervix or the beginning of the uterus.

5. Ask students why one would want to manipulate the estrous cycle of animals. Explain that if producers can breed all of the animals at once management costs will be reduced and the resulting offspring will be more uniform in age.

How can the estrous cycle be manipulated to aid in artificial insemination?

a) Through the injection of certain hormones that affect the estrous cycle, a producer can cause females to begin estrous as a group.
b) This process, which is called estrous synchronization, simplifies the management of an artificial insemination program because animals in the group can all be bred within one or two days of each other.

F. Other Activities

1. Obtain a cow's reproductive tract from a slaughterhouse and demonstrate the insemination process.

2. Invite a local AI technician to bring AI equipment and talk to the class.

3. Arrange a field trip to observe a technician performing AI.

G. Conclusion

Artificial insemination is an important management practice for livestock producers. The availability of a wide selection of animals for breeding and accurate performance records motivates producers to use artificial insemination. The dairy industry most commonly uses AI. However, beef cattle producers, dog breeders, horse breeders, and swine producers are using AI more frequently.

H. Answers to the Activity Sheet

AS 1.1

Answers will vary.

I. Answers to the Evaluation

1. b
2. d

3. Based on the motility, shape, and quantity of the sperm

4. Students may list any three of the following: dummy, artificial vagina, microscope, semen straws, semen tank, or insemination instrument.

5. Students may list any of two of the following.

- AI allows for the selection and use of male animals regardless of where the animals are physically located.
- AI helps reduce the spread of reproductive and venereal diseases.
- AI reduces or eliminates the cost of owning and maintaining a male animal.
- The genetic improvement of livestock through the use of superior animals occurs more quickly due to a dramatic increase in the number of offspring a male animal can have per year.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 1: Artificial Insemination Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Artificial insemination (AI) can be defined as the:

   a. Process of depositing sperm.
   b. Process of collecting sperm from a male animal and placing it in the female reproductive tract.
   c. Process of collecting an egg from a female animal, fertilizing it, and placing it in the reproductive tract of another female animal.
   d. Process of fusing a sperm and an egg.

2. How is the estrous cycle manipulated?

   a. Through the injection of vitamins
   b. By using artificial insemination
   c. By placing a group of females together
   d. Through the injection of hormones

Complete the following short answer questions.

3. How is the quality of semen evaluated?

4. What are three pieces of equipment used in artificial insemination?

   a.

   b.

   c.

5. What are two benefits of artificial insemination?

   a.

   b.

Lesson 1: Artificial Insemination Name _____

Evaluating Semen

Objective: Visually examine semen to evaluate semen quality.

Materials and Equipment:

Microscope with a 100x oil immersion objective
Small amount of immersion oil
Hot water bath (at approximately 98°F)
Several glass test tubes
Microscope slides and cover slips
Frozen semen samples
Semen stain (Blom's Esin-Nigrosin stain)
Several eye droppers

Procedure:

1. Place the semen sample in test tubes in the water bath.

2. Place the microscope slides and cover slips in the water bath; they should be warm when used.

Evaluation of Individual Motility

3. Place one drop of semen on a slide and place a cover slip over it. Using a 40x objective, focus the microscope and observe the sample. Select an individual sperm cell and observe the speed at which it moves. Observe ten different sperm cells and use the chart below to find the score for each of these sperm cells based on how long it takes for each of them to move across the viewing field. Total the scores and divide by ten to calculate the individual motility score for the semen sample.

Observed Behavior	Points
Very rapid forward motion that may be hard to follow	5
Rapid forward progression	4
Steady forward progression at a moderate speed	3
Slow progression or slightly erratic (stop and start) motion	2
Weak rocking movement without forward motion	1
No motion	0

Average score _____

Evaluation of Sperm Morphology (Sperm Structure)

4. Place one drop of semen on a slide and add one drop of semen stain. Mix the semen and stain together and place the cover slip on the solution.

5. Using oil immersion, focus the microscope. Next, search for an area that has at least five sperm cells in the viewing field. Count and record the number of sperm in the field. Use the pictures of sperm abnormalities provided by your instructor to help you identify abnormal sperm cells. Count and record the number of abnormal cells that have primary abnormalities (those relating to the sperm head and the caplike structure at its tip) and the number with secondary (involving droplets on the tail) or tertiary

(other defects of the tail) abnormalities. Select a new group of sperm cells and repeat this process until 100 cells have been observed.

6. Score the morphology of the semen sample.

Primary Abnormalities	Points
less than 10	20
10 to 19	15
20 to 29	10
more than 29	5

Secondary and Tertiary Abnormalities	Points
less than 25	20
26 to 39	15
40 to 59	10
more than 59	5

7. Calculate the average morphology by finding the sum of the primary abnormalities and the secondary and tertiary abnormalities and dividing by two.

Primary abnormalities score _____

Secondary and tertiary abnormalities score _____

Total _____ ÷ 2

Average score _____

UNIT V - ANIMAL TECHNOLOGIES

Lesson 2: Embryo Transfer Technologies

Objective/Competency: Describe the process of embryo transfer.

Study Questions

1. **What is embryo transfer?**
2. **What are the advantages of embryo transfer?**
3. **What equipment is needed for embryo transfer?**
4. **How is the donor managed for superovulation?**
5. **What are the steps in the embryo flush process?**
6. **What are the steps in transferring the embryo to the recipient?**
7. **What is cloning, and how is it accomplished?**
8. **What are the benefits of cloning?**
9. **What is in vitro fertilization (IVF)?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.
2. Transparency Master
   a) TM 2.1: Catheter
3. Activity Sheets
   a) AS 2.1: Examining Embryos (Instructor)
   b) AS 2.1: Examining Embryos (Student)

UNIT V - ANIMAL TECHNOLOGIES

Lesson 2: Embryo Transfer Technologies

TEACHING PROCEDURES

A. Review

As discussed in Lesson 1, the use of artificial insemination in the livestock industry has enabled livestock producers to select highly desirable male animals for their breeding programs. However, producers must own many high quality female animals to improve a herd's genetic potential rapidly. Through the development of embryo transfer technologies, producers can obtain high quality embryos and improve the genetic potential of their herds more quickly.

B. Motivation

Congratulations! Your two-year-old heifer has been named Grand Champion at four major Angus shows across the country. You have put a great deal of hard work and money into this animal, and now you have the opportunity to make money by raising or selling calves. You could use embryo transfer. If semen from a prizewinning bull is used in the embryo transfer process and three or four live births are predicted, would you choose to use embryo transfer technology? What are the factors that might influence your decision?

C. Assignment

D. Supervised Study

E. Discussion

1. Remind students that an embryo is a fertilized egg. Ask them to explain what embryo transfer is.

What is embryo transfer?

a) Embryo transfer (ET) is the process of transplanting embryos from a donor female to a recipient female.
b) Embryo transfer has six basic steps.
    1) Synchronization of estrous in donor and recipient
    2) Superovulation of the donor
    3) Breeding the donor
    4) Recovering the embryos from the donor through flushing
    5) Isolating and examining the embryos
    6) Transferring embryos to the recipients or freezing the embryos

2. Ask students to identify when embryo transfer might be of the greatest benefit.

What are the advantages of embryo transfer?

a) Increases the reproductive potential of superior females
b) Increases the rate of genetic improvement in a herd
c) Allows female animals to be progeny tested more easily and accurately
d) Provides a way to use breeding stock from other countries

3. Point out to students that some of the equipment used in embryo transfer is similar to the equipment used in AI. Show students a semen straw and an embryo straw as examples. Discuss the equipment used in ET.

What equipment is needed for embryo transfer?

a) Equipment needed to flush a donor
   1) Catheter
   2) Stylet
   3) Collection cylinder
   4) Shoulder-length glove
   5) Lubricant
   6) Syringes
b) Equipment needed to examine the embryos
   1) Microscope
   2) Pipette embryo-handling tool
   3) Gridded search dish
c) Equipment needed to transfer the embryo to a recipient
   1) Embryo straw
   2) Embryo transfer gun

4. Ask students to recall the name of the hormone that causes the follicle (egg or ovum) to be released at ovulation. Tell students that if large amounts of this hormone (FSH) are given, multiple eggs will be released.

How is the donor managed for superovulation?

a) If prostaglandin is used to manipulate the heat cycle, preparation of the donor cow begins ten days after she is in standing heat with an injection of the hormone FSH.
b) FSH injections are given once in the morning and once in the evening until a total of seven injections have been given.
c) Prostaglandin is injected in the morning and evening on the third day of the procedure, which causes the donor to come into estrus in 48 hours.
d) When estrus begins, the donor is bred naturally or through AI.

5. Ask students where the egg cells (ova) are produced. Explain that each female animal has thousands of immature ova in their ovaries. Review the reproductive cycle of the female, focusing on ovulation. Have students complete AS 2.1.

What are the steps in the embryo flush process?

a) The embryo flush process is performed seven days after breeding.
b) An epidural anesthesia is injected into the space between two cervical vertebrae.
c) With the aid of the stylet, the catheter is inserted into the vagina, through the cervix, and into the right uterine horn.
d) The technician must palpate the donor carefully to guide the catheter into the right location.
e) The inflatable bulb near the end of the catheter is inflated to block off the uterine horn while it is being flushed.
f) The sterile flushing solution is allowed to flow into the uterine horn under the force of gravity until 500 milliliters of the solution is in the uterine horn, and the horn is then massaged to loosen the embryos.
g) When the fluid has filled the uterine horn, the outlet tube of the catheter is opened and the fluid and embryos are collected in a collection cylinder.
h) This process is repeated in the left uterine horn.
i) The embryos settle to the bottom of the collected fluid, and the fluid is siphoned off so the embryos can be counted and characterized, or examined for quality.

6. Describe the procedure for transplanting the collected embryo into the recipient.

What are the steps in transferring the embryo to the recipient?

a) Embryos that are to be transferred to recipients are loaded into plastic embryo straws.
b) They are then prepared to be either transferred into recipient cows or frozen in a container of liquid nitrogen at -320 degrees Fahrenheit.
c) The embryo transfer gun is loaded with a straw and inserted into the vagina.
d) It is guided through the cervix and into the uterus, where the embryo is expelled.

7. Ask students to give examples of animals that have been cloned. Explain that sheep, cattle, and goats have all been cloned.

What is cloning, and how is it accomplished?

a) Cloning - the asexual reproduction of an organism in which the resulting organisms are identical
b) Two methods of cloning
    1) Splitting an embryo
        (a) A researcher physically splits the embryo into two halves as it is dividing.
        (b) Each half is transferred to a recipient and develops normally.
    2) Nuclear transfer
        (a) A cell is extracted from a parent organism, and an electrical pulse is used to fuse it to an unfertilized ovum that has had its nucleus removed.
        (b) The new cell has a diploid number of chromosomes and will develop as if it were a natural embryo; however, it must be stimulated to act like a fertilized ovum and begin dividing.

8. Ask students to list some reasons why a group of genetically identical animals could be useful.

What are the benefits of cloning?

a) Cloning can increase the number of highly prized animals produced.
b) Fewer animals could be used in live animal tests because all of the animals--control animals and experimental animals--would be identical.
c) Animals genetically altered to produce pharmaceuticals could be cloned, which would reduce the cost of producing the animals.

9. Ask students to recall what in vitro means (“in glass”). Explain that IVF is one of the newest biotechnologies. A few dairy producers have begun to use it.

What is in vitro fertilization (IVF)?

a) IVF is a process in which immature follicles are collected from the ovaries of a female animal, stimulated to mature, and fertilized outside the female reproductive tract.
b) The fertilized embryos can be transferred to recipient animals.

F. Other Activities

1. Using a female reproductive tract from a slaughterhouse, simulate the embryo transfer process.

2. Show the video “Embryo Transfer” from Creative Educational Video (CEV), which is available from MVRC.

3. Contact an ET technician or veterinarian and ask if he or she would bring the ET equipment to class or if the class could borrow the equipment for a day so students could do an equipment identification activity.

4. Take students to a farm or veterinarian's office to observe an actual or simulated nonsurgical flush.

G. Conclusion

In the early 1980s, embryo transfer was an expensive and difficult process involving the surgical removal of embryos. Today, more and more producers, particularly those who produce breeding animals, are looking to embryo transfer to give them more progeny from their high performing animals.

H. Answers to Activity Sheet

AS 2.1

Answers will vary.

I. Answers to the Evaluation

1. d
2. b
3. d
4. c
5. b
6. d
7. 3
8. 2
9. 4
10. 1

11. Students may list any two of the following.
    - Cloning can increase the number of highly prized animals produced.
    - Fewer animals could be used in live animal tests because all of the animals--control animals and experimental animals--would be identical.
    - Animals genetically altered to produce pharmaceuticals could be cloned, which would reduce the cost of producing the animals.

12. Embryo transfer (ET) is the process of transplanting embryos from a donor female to a recipient female.

13. IVF is a process in which immature follicles are collected from the ovaries of a female animal, stimulated to mature, and fertilized outside the female reproductive tract. The fertilized embryos can be transferred to recipient animals.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 2: Embryo Transfer Technologies Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is not an advantage of embryo transfer technology?

   a. Embryo transfer allows for easier and more accurate progeny testing of female animals.
   b. Embryo transfer provides a way to use breeding stock from other countries.
   c. Embryo transfer increases the rate of genetic improvement in a herd.
   d. Embryo transfer reduces the management needed for breeding programs.

2. A stylet is used to:

   a. Insert the embryo into the recipient.
   b. Insert the catheter into the donor for the flushing procedure.
   c. Manipulate the embryos when counting and grading them.
   d. Collect the embryos after they have been flushed.

3. The hormone that causes a cow to superovulate is:

   a. Prostaglandin.
   b. Syncromate-B.
   c. Progesterone.
   d. Follicle stimulating hormone.

4. How many days after a donor cow has been superovulated and bred is the flush procedure done?

   a. 2
   b. 3
   c. 7
   d. 11

5. The process in which a cell is extracted from a parent organism and fused into an ovum that has had its nucleus removed is called:

   a. In vitro fertilization.
   b. Nuclear transfer.
   c. Embryo splitting.
   d. Embryo flushing.

6. Which of the following is not equipment required for embryo transfer?

   a. Catheter
   b. Straw
   c. Collection cylinder
   d. Surgical supplies

Superovulation involves several steps. Put the following steps in the correct order by placing "1" by the first step, "2" by the second step, etc.

7. Prostaglandin is injected into the donor cow.

8. The donor cow is injected with FSH.

9. The donor cow is bred.

10. Ten days pass after estrous is detected in the donor cow.

Complete the following short answer questions.

11. What are two reasons cloning may be useful?

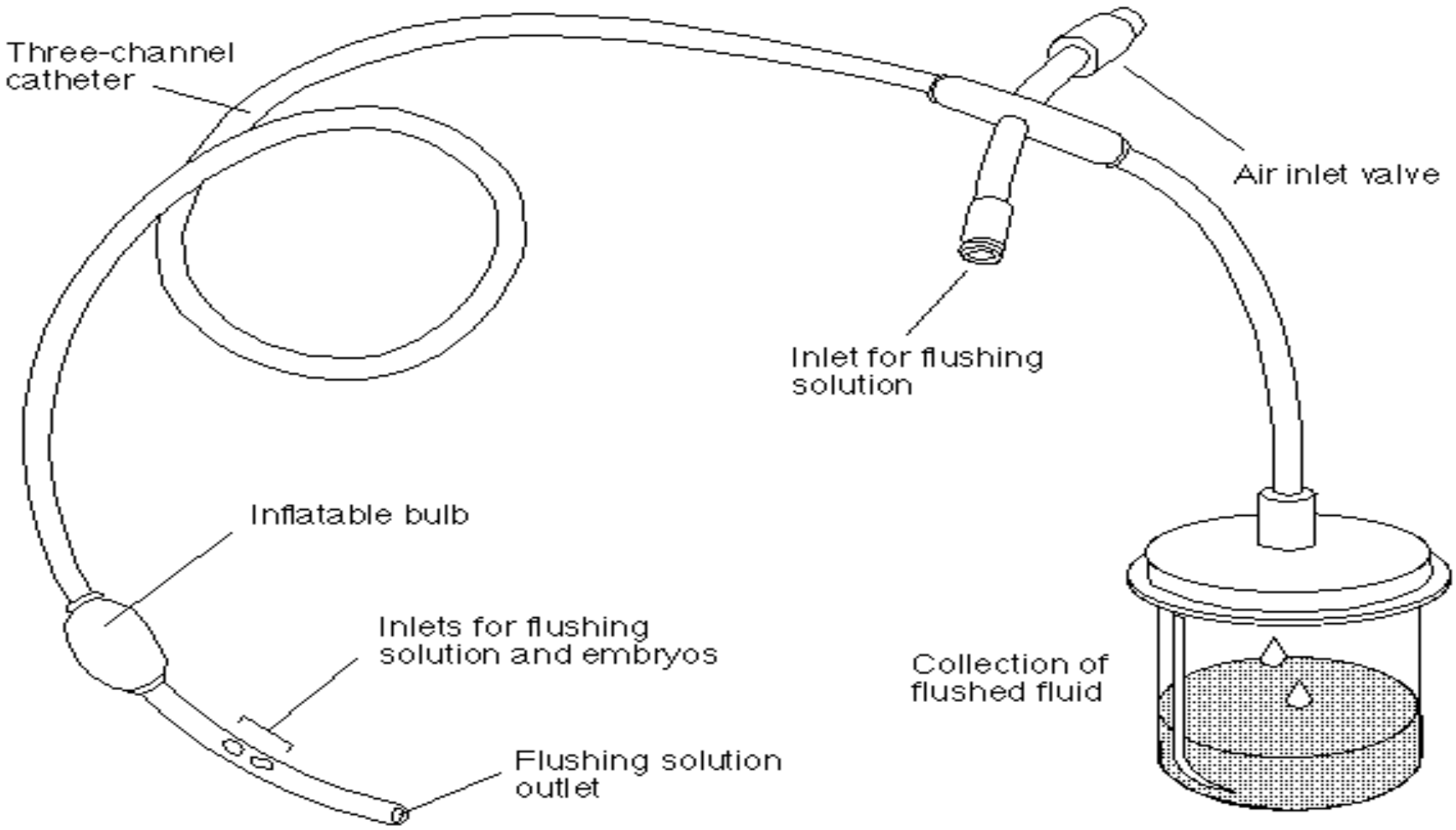
    a.

    b.

12. What is embryo transfer?

13. What is in vitro fertilization?

Catheter


Three-channel catheter
Air inlet valve
Inlet for flushing solution
Inflatable bulb
Inlets for flushing solution and embryos
Collection of flushed fluid
Flushing solution outlet

Lesson 2: Embryo Transfer Technologies

Examining Embryos

Objective: Examine and grade embryos.

Materials and Equipment:

1-5 microscopes (magnifying **less** than 100x, preferably 10x and 50x)
4-6 petri dishes (preferably gridded dishes)
500 ml of embryo-holding media or flushing fluid
Liquid nitrogen tank
Warm water bath

Procedure:

Before conducting this activity, frozen cattle embryos must be obtained from a local breeding service or veterinarian. Embryos can also be obtained from ABS (American Breeders Service) for a fee; the price charged for these embryos will vary.

Obtain a tank containing liquid nitrogen from a local veterinarian or livestock breeder to store the embryos correctly. Remember to thaw the embryos properly by first allowing them to warm in the air for 10 to 15 seconds and then placing them in a warm water bath. Place a known number of embryos in a gridded petri dish containing holding solution and label it "A." Place a single Grade 1, Grade 2, or Grade 3 embryo in each of the other petri dishes and label them "B," "C," and "D"; these dishes should contain holding media and have a lid.

Note: It can sometimes be difficult to find Grade 3 embryos, since they are not often frozen.

Divide students into groups. The number of groups will depend on the number of microscope observation stations. Place one or more of the petri dishes containing embryos at each station. Demonstrate how to remove the cover and focus the microscope so that the embryos in the dish are visible. Have the students examine the embryos and complete the activity.

Lesson 2: Embryo Transfer Technologies Name_____

Examining Embryos

Objective: Examine and grade embryos.

Materials and Equipment:

1-5 microscopes (magnifying **less** than 100x, preferably 10x and 50x)
4-6 petri dishes (preferably gridded dishes)
500 ml of embryo-holding media or flushing fluid
Liquid nitrogen tank
Warm water bath

Procedure:

1. Use the microscope to observe each of the petri dishes prepared by your instructor.

2. Count the embryos in dish "A" and record the number in the space provided. _____

3. Grade the embryos in dishes "B," "C," and "D." The different classifications used when grading embryos are described below.

   Grade 1: The embryo is nearly perfect. More than 98 percent of the cells in the embryo are apparently active. It is rounded in appearance.

   Grade 2: The cell mass of the embryo is apparently 70 to 98 percent active. Some cells are extruded from the surface of the embryo, so it may not be rounded in appearance.

   Grade 3: Less than 70 percent of the cell mass of these embryos is apparently active. Several cells are extruded from the surface of the embryo, which may be severely malformed.

   Degenerate: None of the cell mass of the embryo appears active. It may be flat or concave in shape.

4. Answer the following questions.

   a. What is the grade of the embryo in dish "B"?

   b. What is the grade of the embryo in dish "C"?

   c. What is the grade of the embryo in dish "D"?

UNIT V - ANIMAL TECHNOLOGIES

Lesson 3: Applications of Biotechnology in Animal Agriculture

Objective/Competency: Identify other applications of biotechnology in animals.

Study Questions

1. **What are supplemental hormones?**

2. **How is biotechnology used to produce supplemental hormones and animal health products?**

3. **How is DNA fingerprinting used in the livestock industry?**

4. **What are the emerging applications of biotechnology in the animal industry?**

References

1. *Biotechnology: Application in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.

2. Transparency Master

   a) TM 3.1: Producing BST

3. Activity Sheet

   a) AS 3.1: Emerging Applications of Biotechnology

UNIT V - ANIMAL TECHNOLOGIES

Lesson 3: Applications of Biotechnology in Animal Agriculture

TEACHING PROCEDURES

A. Review

Livestock producers have benefited from advances in biotechnology like artificial insemination and embryo transfer. Biotechnology is now having an impact on livestock performance in ways not directly related to breeding. The development of economical growth hormones, genetically engineered vaccines, and other products has begun to affect animal agriculture substantially.

B. Motivation

A swine producer annually markets approximately 800 hogs weighing an average of 220 pounds each and receives an average price of $0.49 per pound for them. If the producer could increase production by 12 percent by using a biotechnology product, how much is the product worth to the producer? Assume that the biotechnology product costs $3.50 per pig. The animals would produce 21,120 additional pounds of pork, worth $10,348.80. Subtracting $2,800 for buying the product leaves the producer with $7,548.80 in extra income. A hormone supplement that can increase pork production is nearing the marketing stage.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to recall what hormones are. Explain that hormones are complex proteins that trigger certain chemical changes in an animal's body. Discuss the use of supplemental hormones.

   What are supplemental hormones?

   a) Supplemental hormones are chemical messengers administered to animals to stimulate them to grow, produce more milk, or improve their performance in another way.
   b) Bovine somatotropin (BST) - When injected into a cow, BST causes a secondary hormone to be released that increases blood flow in the mammary glands, thus increasing the amount of milk produced.
   c) Porcine somatotropin (PST) - When injected into a pig, the hormone causes the pig to grow about 15 percent faster and consume 20 percent less feed; muscle mass increases, while backfat is reduced.
   d) Growth hormone releasing factor (GHRF) - GHRF is not itself a hormone, but it stimulates the pituitary gland to release larger amounts of growth hormones.
   e) Chicken growth hormone and chicken molting hormone - The growth hormone shortens the time needed for broilers to reach market size by 15 percent, while the molting hormone increases egg production.

2. Use TM 3.1 to show the process of producing BST by genetically modifying bacteria. Discuss other applications of biotechnology in producing animal health products.

   How is biotechnology used to produce supplemental hormones and animal health products?

a) Supplemental hormones
   1) The gene responsible for the production of somatotropin was inserted into a plasmid taken from a bacterium; the plasmid ring was opened with a restriction enzyme, and the gene was spliced into the opening.
   2) The plasmid was reinserted into the bacterium.
   3) Modified bacteria are placed in a fermentation tank under ideal conditions for growth and division.
   4) After a substantial number of bacteria are produced, the somatotropin can be purified from the bacteria.

b) Animal health products
   1) Monoclonal antibody technology - Monoclonal antibodies are produced by fusing together a tumor cell and an immune system cell that produces antibodies against a specific antigen, yielding a cell that divides rapidly and produces the desired antibody.
   2) Therapeutic proteins
      (a) When injected, therapeutic proteins like interferon and interleukin-2 attack viruses; they also stimulate the animal's immune system to attack the viruses.
      (b) They are produced by genetically modified bacteria.
   3) Genetically engineered vaccines - These vaccines produced by genetically modified bacteria contain only the antigen of the disease-causing organism, which triggers the immune system to produce antibodies against the antigen.

3. Ask students to recall what a DNA fingerprint is and how it is made. Ask students how DNA fingerprinting is used in the livestock industry.

   How is DNA fingerprinting used in the livestock industry?

   DNA fingerprinting is used in the livestock industry to positively identify individual animals, such as stolen animals, offspring for breed registration, and transgenic animals for patent purposes.

4. Ask students to speculate about the possible benefits of cloning adult livestock. Explain that possible applications of a technology play an important part in driving research efforts. Discuss other emerging applications of biotechnology. Have students complete AS 3.1.

   What are the emerging applications of biotechnology in the animal industry?

   a) New vaccines, such as vaccines for foot rot in cattle and strangles in horses
   b) Protein for livestock feeds that are produced by genetically modified bacteria
   c) Engineered rumen bacteria that allow animals to better use feedstuffs that are normally hard to digest
   d) Cloning of adult animals

F. Other Activities

1. Show the class a simulated DNA fingerprint to have students match an animal to its parents. A mock DNA fingerprint can be created by drawing in lines representing bands for different animals. Refer to Lesson 3 in Unit 2.

2. Have students search the Internet for current biotechnologies being developed that would affect animal agriculture.

G. Conclusion

Research in biotechnology is very expensive, but if the potential income for products is high enough, someone will do the research. The actual application of biotechnology to the livestock industry is very

slow. However, biotechnology products are now being used on a daily basis. Livestock producers will use these tools if they prove to be both effective and economical.

H. Answers to the Activity Sheet

AS 3.1

Answers will vary with the sources used.

I. Answers to the Evaluation

1. c
2. b
3. d
4. b
5. a

6. Monoclonal antibodies are produced by fusing together a tumor cell and an immune system cell that produces antibodies against a specific antigen, yielding a cell that divides rapidly and produces the desired antibody.

7. The livestock feed industry is developing genetically modified bacteria that produce protein for feeds and engineered rumen bacteria that allow animals to better use feedstuffs that are hard to digest.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 3: Applications of Biotechnology in Animal Agriculture Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What are supplemental hormones?

   a. Organic substances produced by endocrine glands and carried in the bloodstream to produce a metabolic effect
   b. Genetically modified bacteria that contain the antigen of a disease and trigger the immune system to produce antibodies
   c. Chemical messengers administered to animals to stimulate growth, milk production, or other types of performance
   d. Therapeutic proteins that stimulate an animal's immune system to attack viruses

2. Why is bovine somatotropin (BST) used?

   a. It stimulates the pituitary gland to release larger amounts of growth hormones.
   b. It causes a secondary hormone to be released that increases blood flow in the mammary glands, thus increasing the amount of milk.
   c. It reduces animal fat and increases muscle mass.
   d. It causes the animal to grow about 15 percent faster and consume 20 percent less feed.

3. How are supplemental hormones produced by biotechnology?

   a. By fusing a tumor cell and an immune system cell that produces antibodies against a specific antigen
   b. Drawing the hormone from the endocrine gland with a syringe
   c. Collecting the hormone from the brains of slaughtered animals
   d. Genetically modifying bacteria with the gene responsible for production of the hormone

4. What is <u>not</u> a reason to use DNA fingerprinting in the livestock industry?

   a. To identify individual animals
   b. To prevent the spread of disease
   c. To verify the parentage of an offspring animal
   d. To identify transgenic animals for patenting

5. Which of the following is an example of a currently emerging application of biotechnology in the animal industry?

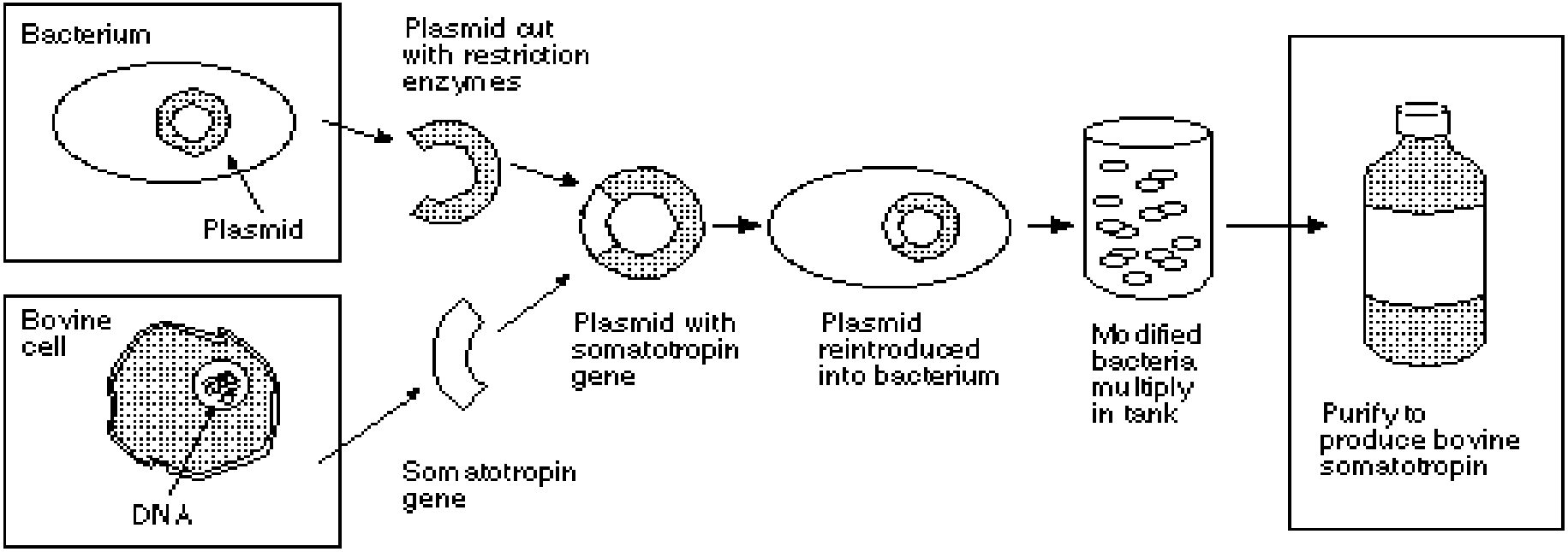
   a. Cloning of adult animals
   b. DNA fingerprinting
   c. Developing tests for diseases
   d. Genetically modifying bacteria

Complete the following short answer questions.

6. How are monoclonal antibodies produced?

7. What two currently emerging applications of biotechnology involve the livestock feed industry?

Producing BST



Lesson 3: Applications of Biotechnology in Animal Agriculture

Name _____

Emerging Applications of Biotechnology

Objective: Research new applications of biotechnology in animal agriculture.

Working in groups assigned by your instructor, answer the following questions using information from magazines, newspapers, and the Internet.

1. What are some developments that have taken place in the last year in livestock vaccines? (Hint: search for information from companies that produce animal vaccines.)

2. What biotechnology products for feed enhancement are currently available or under development? (Hint: search for information on livestock feed companies or genetically engineered livestock feed.)

3. What is the current status of the use of somatotropin in the livestock industry and the predictions for its use in the future?

4. What are the uses and the expected uses of monoclonal antibodies?

5. What are the latest advances in transgenic livestock?

UNIT V - ANIMAL TECHNOLOGIES

Lesson 4: The Impact of Biotechnology in Animal Agriculture

Objective/Competency: Summarize the impact of biotechnology in animal agriculture.

Study Questions

1. **What are some career opportunities in animal biotechnology?**
2. **What are some economic factors of animal biotechnology that affect producers?**
3. **What are health and safety concerns of consumers of animal biotechnology?**
4. **What are the global social impacts of animal biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.
2. Activity Sheet
   a) AS 4.1: Careers in Animal Biotechnology

UNIT V - ANIMAL TECHNOLOGIES

Lesson 4: The Impact of Biotechnology in Animal Agriculture

TEACHING PROCEDURES

A. Review

Animal agriculture is a multibillion dollar industry in the United States. Biotechnology is just beginning to make a substantial impact on this industry. As discussed in the previous lessons, the livestock breeding and animal health sectors of animal agriculture have already felt the impact of biotechnology. As the technology advances, more areas of livestock production will be affected. Advancements in this field will increase the number of career opportunities available. However, the growth of animal biotechnology will bring with it a number of issues that must be resolved, including economic concerns for producers, health and safety concerns for consumers, and global social impacts.

B. Motivation

Some individuals who first entered careers in the computer industry when it was in its infancy in the early 1980s are among the wealthiest people in America today. Bill Gates, the founder of Microsoft, is a good example. Some people have classified biotechnology as the next explosive industry. Career positions in biotechnology are increasing in number between 10 and 20 percent per year. As this industry grows, so will the opportunities for those interested in biotechnology.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to list career opportunities related to animal biotechnology. Group these jobs into the eight categories listed below.

What are some career opportunities in animal biotechnology?

a) Research and development
   1) Glass washer
   2) Laboratory assistant
   3) Research assistant
   4) Postdoctoral fellow
   5) Research director/principle investigator
b) Quality control
   1) Quality control analyst
   2) Environmental health and safety specialist
   3) Equipment validation engineer
   4) Validation technician
c) Clinical research
   1) Clinical coordinator
   2) Clinical data specialist
   3) Clinical research associate
   4) Animal handler/technician
d) Manufacturing and production
   1) Product development engineer
   2) Manufacturing engineer/technician
   3) Instrument calibration technician

4) Packaging operator

e) Regulatory affairs
   1) Regulatory affairs specialist
   2) Documentation specialist

f) Information systems
   1) Scientific programmer analyst
   2) Literature research assistant

g) Marketing and sales
   1) Market research analyst
   2) Sales representative
   3) Customer service representative

h) Administration
   1) Human resources representative
   2) Supply buyer
   3) Patent administrator

2. Ask students to describe how livestock producers decide whether or not to use a new technology. Explain that the economics of using a new product versus not using the product are very important.

What are some economic factors of animal biotechnology that affect producers?

a) Benefit-to-cost ratio of biotechnology products
b) Cost of not using a biotechnology product
c) Reliability of the biotechnology products
d) Cost of additional management or training

3. Ask students to recall the results of the biotechnology opinion survey taken earlier in this course. Have students list some concerns about animal products. Ask students if most people in their community believe that biotechnology is safe.

What are health and safety concerns of consumers of animal biotechnology?

a) Fear of new technology because of a lack of understanding about it
b) Skepticism about safety research
c) Fear about the wholesomeness of foods produced through the use of biotechnology

4. Explain that by the year 2030 the world's population is expected to double to 12 billion people. Ask students to speculate about how food production can be doubled by that year. Ask students to further speculate as to who will be able to obtain food if the demand exceeds the supply.

What are the global social impacts of animal biotechnology?

a) Biotechnology has the potential to increase the global production of meat, dairy products, and eggs.
b) International concerns must be addressed; the international political environment will determine the extent of the use of animal biotechnology.
c) Biotechnology may change the number of livestock producers needed.

F. Other Activities

Have someone with a career in animal biotechnology speak to the class about the job and the field of biotechnology.

G. Conclusion

As biotechnology products such as feed quality enhancers, growth stimulants, protein feeds, and transgenic breeding stock become available to producers, the economic and social impacts of these products will have to be addressed. Career opportunities in animal biotechnology are increasing steadily as the industry expands. Animal biotechnology must, however, address the health and safety concerns of consumers for the products of animal biotechnology to be fully accepted.

H. Answers to Activity Sheet

AS 4.1

Answers will vary.

I. Answers to the Evaluation

1. d
2. c
3. d
4. g
5. b
6. e
7. f
8. a
9. c

10. Consumers are concerned about the new technology because of a lack of understanding about it, skepticism about safety research, and a fear about the healthiness of foods produced through the use of biotechnology.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 4: The Impact of Biotechnology in Animal Agriculture Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is a possible global social impact of biotechnology?

   a. Advancements in biotechnology may decrease the global production of meat, dairy products, and eggs.
   b. Advancements in biotechnology will decrease the costs of management for producers.
   c. Advancements in biotechnology will decrease consumer concerns about the safety of food products.
   d. Advancements in biotechnology may change the number of livestock producers needed.

2. Which of the following is not an economic factor that affects producers?

   a. Reliability of biotechnology products
   b. Cost of not using a biotechnology product
   c. Fear of the new technology
   d. Cost of additional training or management

Match the following positions to the major area of employment by writing the letter from the right-hand column in the correct blank.

3. _____ Research and development	a. Literature research assistant
4. _____ Quality control	b. Animal handler/technician
5. _____ Clinical research	c. Customer service representative
6. _____ Manufacturing and production	d. Postdoctoral fellow
7. _____ Regulatory affairs	e. Product development engineer
8. _____ Information systems	f. Documentation specialist
9. _____ Marketing and sales	g. Equipment validation engineer

Answer the following short answer question.

10. What are health and safety concerns of consumers of animal biotechnology?

Lesson 4: The Impact of Biotechnology in Animal Agriculture Name _____

Careers in Animal Biotechnology

Objective: Investigate a specific career opportunity in animal biotechnology.

Select a specific job title in the field of animal biotechnology. The careers in this lesson can be used, as well as other titles that you might find. The next step is to compile a profile of the career title you have selected by answering the questions below. Be prepared to present your findings to the class.

1. What are the responsibilities of someone with this job?

2. Where are available jobs located?

3. What is the average salary?

4. What personality traits are needed for someone working in this job?

5. What level of education is needed to obtain this position?

6. Where can this education be obtained?

7. What is the job market like for someone looking for a position?

UNIT VI - PLANT TECHNOLOGIES

Lesson 1: Traditional Plant Breeding

Competency/Objective: Describe traditional plant breeding processes.

Study Questions

1. **What is natural crossbreeding?**

2. **What is selective breeding?**

3. **What are the advantages and disadvantages of selective breeding?**

4. **What is a hybrid?**

References:

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.

2. Activity Sheet

   a) AS 1.1: Hybrids and Their Offspring

UNIT VI - PLANT TECHNOLOGIES

Lesson 1: Traditional Plant Breeding

TEACHING PROCEDURES

A. Introduction

The selection of plants based on phenotypes has been going on for thousands of years. When humans stopped roaming the land and settled in one area, plants that were useful were planted in large quantities and allowed to breed naturally. People then began to notice that some plants were more productive than others, so they saved and grew seeds from these plants, beginning the practice of selective breeding. A major advance in selective breeding occurred in 1922 with the introduction of hybrid seed corn. In the mid-1990s, the first genetically modified crops were introduced, and a new era of plant breeding began.

B. Motivation

Pioneer, DeKalb, and CIBA Seeds are well-known companies that have prospered by developing and marketing selected plant crosses. The sale of seed from these crosses, or hybrids, has yielded many billions of dollars over the last fifty years. These companies spent large sums of money in the 1920s and 1930s on plant breeding programs. In the 1990s, companies like Monsanto have invested billions of dollars in purchasing and developing gene patents and gene transfer technology. Why have companies like Monsanto made these investments?

C. Assignment

D. Supervised Study

E. Discussion

1. Review the parts of a flower, and ask students to recall the ways in which plants reproduce.

   What is natural crossbreeding?

   a) Natural crossbreeding is a reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention.
   b) It allows the random mixing of genes within a species.

2. Ask students to define what selective breeding is in the livestock industry. Relate this definition to selective plant breeding.

   What is selective breeding?

   a) Selective breeding is the process of identifying plants with desirable traits and causing them to reproduce.
   b) Selective breeding can be done asexually or sexually.
   c) Plants are selectively bred mainly for two reasons.
      1) To increase the production of the useful parts of the plant
      2) To increase the ability of a plant to withstand harsh environments, disease, and plant pests

3. Compare the advantages and disadvantages of selective animal breeding to those of selective plant breeding.

What are the advantages and disadvantages of selective breeding?

a) Advantages
   1) The occurrence of desired plant traits can be increased, especially traits that can raise crop yields.
   2) The performance of a crop is more predictable since the crop of seeds is more uniform.

b) Disadvantages
   1) The occurrence of undesired traits may be increased.
   2) The genetic diversity of a crop species is reduced.
   3) Crop plant uniformity can increase insect problems.

4. Ask students why nearly every producer who plants corn uses hybrid corn. Have students speculate about what a hybrid plant variety is.

What is a hybrid?

a) A hybrid is a plant produced by crossing two inbred lines of plants that are greatly different genetically.

b) Breeders use three common methods of hybrid development.
   1) Single cross - crossing one inbred plant with another
   2) Three-way cross - crossing a single cross with another unrelated inbred plant
   3) Double cross - two single crosses are crossed

c) A hybrid displays extra growth vigor, or hybrid vigor (heterosis); however, it usually either is sterile or produces offspring that do not perform well.

F. Other Activities

Purchase Wisconsin Fast Plants and use them to show several types of selective breeding. Wisconsin Fast Plants grow and produce seed in a very short time so that several generations can be seen in a matter of a few weeks.

G. Conclusion

Since the mid-1980s, the yields of hybrid crops have not increased significantly, which has led some economic analysts to state that traditional hybrids have reached a limit in production capability. The fact that hybrid seed companies are focusing heavily on gene transfer technology for future profit potential further confirms this analysis. Some people disagree with the rationale of this new focus, but this group seems to be in the minority. Traditional plant breeding processes will undoubtedly be used in the development of new generations of crop seeds, but the real advances in yield and other desirable crop traits will most likely come from recombinant DNA technology.

H. Answers to Activity Sheet

Students will need guidance as they work through the activity sheet questions. The answers to these questions will vary, but some suggested answers are listed below.

1. How do the growth rates of a hybrid compare with the growth rates of the F_2 of a hybrid?

2. This information will vary but should reveal that F_2 generations of hybrids do not perform as well and that plant-to-plant variations are quite high.

3. Answers will vary but the given hypothesis must be measurable.

4. The experimental group should be defined as the F_2 hybrid group and should consist of a stated number of seeds. The control group is the hybrid seed group; it should also consist of a stated number of seeds.

5. Performance can be measured by the growth of the plant in millimeters per day, the change in the circumference of the stem in millimeters per week, germination rate, and nutrient uptake.

6. Examples include light, temperature, humidity, water, wind/chemical/insect stresses, etc.

7. Answers will vary.

I. Answers to the Evaluation

1. c
2. d
3. d

4. The occurrence of undesired traits may be increased, the genetic diversity of a crop plant population is reduced, and crop plant uniformity can increase insect problems.

5. To increase the production of the useful parts of the plant and to increase the ability of a plant to withstand harsh environments, disease, and plant pests

6. Natural crossbreeding is a reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention.

7. A hybrid is a plant produced by crossing two inbred lines of plants that are greatly different genetically.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 1: Traditional Plant Breeding Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Selective breeding can be defined as the:

   a. Process of sexual reproduction of a plant in which pollen from a plant fertilizes the eggs of the same plant.
   b. Crossing of two inbred lines of plants.
   c. Process of identifying plants with desirable traits and causing them to reproduce.
   d. Reproductive process in which two plants with different genotypes reproduce sexually without human intervention.

2. Of the three common methods of producing a hybrid seed, which involves crossing two unrelated inbred plants and then breeding the result with another unrelated inbred plant?

   a. Hybrid cross
   b. Single cross
   c. Double cross
   d. Three-way cross

3. Selective breeding is:

   a. A sexual process.
   b. An asexual process.
   c. Neither a sexual nor an asexual process.
   d. A sexual or an asexual process.

Complete the following short answer questions.

4. What are two disadvantages of selective breeding?

5. Why is selective breeding done?

6. What is natural crossbreeding?

7. What is a hybrid plant?

Lesson 1: Traditional Plant Breeding Name _____

Hybrids and Their Offspring

Objective: Design an experiment that will test the idea that hybrids produce inferior offspring.

For this activity, work in groups assigned by your instructor and design and perform an experiment that will accurately test your hypothesis about the performance of hybrids (F_1) and their offspring (F_2). Use seed collected from a field of hybrid corn and seed from a bag of the same hybrid seed. Whether the offspring of hybrids is "inferior" will be measured by the growth rate of the two groups of plants from emergence to a specified height or length of time as well as the diameter of the stalk, germination rate, and rate of nutrient uptake. The questions below will help guide you through the design of the experiment. Data should be collected periodically until the experiment is completed.

1. What is the problem statement, or what information is desired?

2. List any information that can be collected about the problem. (Hint: check textbooks and the Internet, call a seed salesperson, etc.)

3. State your hypothesis.

4. Define your control and experimental groups. You must consider the size of the groups carefully.

   Experimental group:

   Control group:

5. How will the observations be measured?

6. What environmental controls will be used to ensure that the seed is the only variable in this experiment? (Hint: list the factors that affect the growth rate, and then explain how each factor will be kept the same for the control and experimental group.)

7. What will be the schedule for conducting the experiment? When will observations be made and data be collected?

UNIT VI - PLANT TECHNOLOGIES

Lesson 2: Plant Tissue Culture

Competency/Objective: Explain the process of tissue culture.

Study Questions

1. **What is plant tissue culture?**
2. **What are the advantages and disadvantages of plant tissue culture?**
3. **What equipment is needed for plant tissue culture?**
4. **What steps are involved in plant tissue culture?**
5. **What are the four stages of tissue culture growth?**
6. **How is plant tissue culturing used in genetic engineering?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheets
   a) AS 2.1: Tissue Culturing Strawberries (Instructor)
   b) AS 2.1: Tissue Culturing Strawberries (Student)

Lesson 2: Plant Tissue Culture

TEACHING PROCEDURES

A. Review

Traditional plant breeding techniques, such as selective breeding, have increased plant quality and production. However, a method of propagation called tissue culture is providing plant breeders with new tools for crop improvement. Tissue culture has not replaced traditional breeding practices but rather has enhanced their effectiveness.

B. Motivation

Plant tissue culture was first used in the early 1970s in the propagation of orchids. The orchid seed is very difficult to sow and germinate. It is not only the smallest seed in the world, but it must be exposed to a specific fungus before it will germinate. To produce an orchid from a seed takes an average of seven years. Tissue culture became the solution to the difficulties of orchid propagation. Today, tissue culture is a commonly used and vitally important method of plant reproduction.

Purchase a miniature plant grown from tissue culture. Use this tiny plant to introduce the basic concept of tissue culture. Every plant cell has the entire genetic code and is capable of producing an entire plant.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to define the word tissue. Explain that a tissue is a group of cells that function together for a purpose. Examples of plant tissue include the leaf, stem, root, bud, etc.

   What is plant tissue culture?

   Plant tissue culture can be defined as an asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media where it grows into a new plant.

2. Ask students why tissue culture is done. Have students speculate about the advantages and disadvantages of using tissue culture.

   What are the advantages and disadvantages of plant tissue culture?

   a) Advantages
      1) Allows for mass propagation of clones of a desirable plant
      2) Allows the production of pathogen-free plants
      3) Conserves time through the year-round propagation of plants

4) Conserves growing space

b) Disadvantages
   1) Requires expensive, sophisticated equipment and facilities
   2) Susceptibility to contamination by microorganisms
   3) Requires skilled workers, which adds to the total cost

3. Show students a petri dish and an autoclave or pressure cooker. Ask students to describe how an autoclave works. Explain that an autoclave uses steam under pressure (approximately 15 psi) to heat items above the temperature that microorganisms can survive.

What equipment is needed for plant tissue culture?

a) Preparation
   1) Refrigerator
   2) pH meter
   3) Scale or balance
   4) Heating plate
   5) Autoclave

b) Transfer
   1) Fume or air flow hood
   2) Forceps
   3) Scalpel
   4) Test tubes or petri dishes
   5) Dissecting microscope

c) Growth
   1) Growth chamber - a room that controls exposure to heat and light

4. Ask students to list the steps of the procedure for tissue culturing.

What steps are involved in plant tissue culture?

a) Media preparation
   1) The growing media for tissue culture varies in composition with the species of plant being used.
   2) Generally the media contains plant nutrients, mineral salts with vitamins, hormones, pure water, sugar, and agar (if a semi-solid media is needed)

b) Selecting and collecting an explant to be cultured
   1) Several types of plant tissues are used for explants.
      (a) Shoot tip
      (b) Bud
      (c) Leaf with veins
      (d) Node
      (e) Bud scale
   2) Rapidly growing tissues are usually preferred for the explant.
   3) Tissue must be healthy and disease free.

c) Cleaning the explant
   1) Plant tissue is disinfected
      (a) Alcohol is used on woody plants only.

(b) For other plants, the explant is soaked in a 10 percent bleach solution for 10 minutes; plant tissue will be damaged if it is soaked too long.
(c) A drop or two of detergent is often added to the bleach solution as a wetting agent.

2) After the tissue is disinfected, it is rinsed in pure water at least three times.

d) Transferring explants to growing media
1) The explant sections are trimmed and transferred to the growing media; some tissue types are divided for growing more plants.
2) A dissecting microscope is sometimes needed for very small explant tissues.
3) This procedure must take place in a sterile environment.

5. Ask students to explain each of the four stages of tissue culture growth.

What are the four stages of tissue culture growth?

a) Initiation and establishment (four to six weeks)
1) A callus, made of rapidly dividing cells, forms and grows in response to the wounding or cutting of the plant tissue.
2) Shoots or immature stems begin to grow.

b) Proliferation or multiplication (one to three months)
1) The shoot multiplies into many shoots.
2) The new shoots can be divided to increase the number of plants produced.
3) This stage uses a slightly different growing media.

c) Pretransplant (three weeks)
1) Roots begin to grow.
2) A slightly different media is used.
3) More light is required.
4) Young plants are stressed slightly in a process called hardening off, in which young plants are exposed to conditions outside the sterile container.

d) Transplanting
1) The growing plants are put in pots and moved to a shady, humid greenhouse.
2) The plants are hardened off again and then moved to a regular greenhouse to receive full sun and less humidity.

6. Have students identify reasons that a person or company working with developing transgenic plants would want to use tissue culture.

How is plant tissue culturing used in genetic engineering?

a) Genetically modified plant tissues can be rapidly grown into plants.
b) A large number of plants can be screened for the presence of a desirable trait.

F. Other Activities

1. Demonstrate media preparation.

2. Tissue culture kits and African violet kits are available for purchase from Carolina Biological or Fisher Scientific. Follow the directions on the kits when preparing them.

3. Show the videos *Plant Tissue Culture Part 1 & 2* (VEP) and *Introduction to Plant Tissue Culture* (CEV), all of which are available from MVRC.

G. Conclusion

More than 50 plant species have been genetically modified. In almost every case, tissue culture played an important role in recovering the modified plant tissues. In 1990, more than 300 commercial plant tissue culture labs were in operation. As plant breeders continue to make use of tissue culture techniques, the use of tissue culture will likely increase.

H. Answers to Activity Sheet

I. Answers to the Evaluation

1. b
2. d
3. c
4. b
5. c
6. c
7. d

8. Plant tissue culture can be defined as an asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media where it grows into a new plant.

9. Tissue culturing is used in genetic engineering to rapidly grow genetically modified plant tissues into plants and to screen a large number of plant tissues for the presence of a desirable trait.

10. Students may list any two of the following: refrigerator, pH meter, scale or balance, heating plate, autoclave, fume or air flow hood, forceps, scalpel, petri dishes or test tubes, dissecting microscope, or growth chamber.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 2: Plant Tissue Culture Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following statements is not an advantage of tissue culture?

   a. Tissue culture allows for the mass propagation of clones.
   b. Plant tissue cultures are susceptible to contamination.
   c. Plant tissue culture allows for the production of pathogen-free plants.
   d. Plant tissue culture allows for the propagation of plants year round.

2. Which of the following substances is not commonly used to make a tissue culture media?

   a. Sugar
   b. Mineral salts with vitamins
   c. Plant hormones
   d. A dilute sodium chloride solution

3. Which of the following is an important criterion to consider when selecting an explant?

   a. The explant should be selected from a young parent plant.
   b. The parent plant should be a monocot because dicot plants do not give good explants.
   c. The explant should be taken from a healthy, rapidly growing part of the parent plant.
   d. The explant is always taken from the shoot tip of the parent plant.

4. If it is not woody plant tissue, the selected explant is disinfected with:

   a. Alcohol.
   b. 10 percent bleach solution.
   c. A detergent.
   d. A very weak acid solution.

5. In which stage of plant tissue growth do the roots begin to form and grow?

   a. Initiation and establishment
   b. Proliferation or multiplication
   c. Pretransplant
   d. Transplanting

6. The stage in which the shoot begins to grow is called the:

   a. Transplanting stage.
   b. Proliferation or multiplication stage.
   c. Initiation and establishment stage.
   d. Pretransplanting stage.

7. A callus is a:

   a. Mass of dead plant cells that accumulate as the tissue culture grows.
   b. Group of cancer cells that can destroy a plant tissue culture.
   c. Group of old cells that forms when the incorrect part of the plant is selected for the explant.
   d. Group of rapidly dividing cells that is a response to the wounding of plant tissue.

Complete the following short answer questions.

8. What is plant tissue culture?

9. How is plant tissue culture used in genetic engineering?

10. What are two pieces of equipment used in tissue culture?

Lesson 2: Plant Tissue Culture Name _____

Tissue Culturing Strawberries

Objective: Perform plant tissue culture.

Materials and Equipment:

1 medium-sized stainless steel pan
1 long-handled spoon
1-2 glass test tubes with caps (25 x 100 mm)
Test tube racks
2 gallons of sterile distilled bottled water
1 glass (Pyrex) quart pitcher or old coffee pot
1 pressure cooker
2-4 eight-inch forceps
1 sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
20 ml of 1N NaOH
20 ml of 1N HCl
2 eyedroppers
1 plastic graduated cylinder
1 small bottle of household bleach
2 packages of premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
1 package of agar
1 package of litmus paper (3.5-6.8) or a pH meter
2-4 medium-sized plastic containers
2-3 sterile paper towels (made by rolling them up in aluminum foil and sterilizing them in the pressure cooker)
1 72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
1 transfer chamber (It can be made from wood or cardboard with a clear plastic sheet or plexiglass over the front and top of the chamber. Holes should be cut in the front so that both hands can be used to work inside the chamber.)
10-20 strawberry runner tips (about 1 inch long)

Procedure for Media Preparation:

1. Follow the directions on the prepackaged shoot multiplication media mix to prepare the media. About one liter of media is enough for the entire class. Make sure that a 2-liter container or larger is used when mixing the media since it can boil up and spill. Add the powder mix to the water (not the reverse). Stir the mixture.

2. Next, the pH of the mixture must be adjusted to 5.7. Measure the pH of the solution with litmus paper. If the solution has a pH higher than 5.7, add one drop of HCl and stir the

solution. If, however, the solution has a pH lower than 5.7, add one drop of NaOH and stir. This process is repeated until the pH is 5.7.

3. Thicken the mix by adding agar. Approximately 5 grams of agar are needed per liter of solution. After the agar is stirred into the solution, heat it and stir until the solution becomes clear. Transfer the hot solution to the glass pitcher and then carefully pour it into the test tubes.

4. Sterilize the medium in a pressure cooker for about 15 minutes. When sterilizing test tubes holding media, place them in a wide-mouth jar or tie them in bundles of ten so that they stand up in the pressure cooker.

Lesson 2: Plant Tissue Culture Name _____

Tissue Culturing Strawberries

Objective: Perform plant tissue culture.

Materials and Equipment:

1 medium-sized stainless steel pan
1 long-handled spoon
1-2 glass test tubes with caps (25 x 100 mm size)
Test tube racks
2 gallons of sterile distilled bottled water
1 glass (Pyrex) quart pitcher or old coffee pot
1 pressure cooker
2-4 eight-inch forceps
1 sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
20 ml of 1N NaOH
20 ml of 1N HCl
2 eyedroppers
1 plastic graduated cylinder
1 small bottle of household bleach
2 packages of premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
1 package of agar
1 package of litmus paper (3.5-6.8) or a pH meter
2-4 medium-sized plastic containers
2-3 sterile paper towels (made by rolling them up in aluminum foil and sterilizing them in the pressure cooker)
1 72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
1 transfer chamber (It can be made from wood or cardboard with a clear plastic sheet or plexiglass over the front and top of the chamber. Holes should be cut in the front so that both hands can be used to work inside the chamber.)
10-20 strawberry runner tips (about 1 inch long)

Procedure:

A. Selecting and Cleaning the Explants

1. Select a healthy-looking strawberry runner tip on which the bud has not yet opened. Cut off 1 to 1 1/2 inches of the tip and place it in a plastic bag containing a damp paper towel.

2. Fill a wide-mouth jar with 1/2 pint of sterile water. Add 2 or 3 drops of liquid dishwashing detergent. Place the runner tips in the jar, put the lid on, and vigorously

shake the jar for 1 minute. Pour out the water and rinse the runner tips 2 or 3 times with sterile water. Repeat this process, or dip the runner tips in 70 percent alcohol for only a few seconds and then rinse 2 to 3 times with sterile water.

3. In another container, add 30 ml of bleach to 270 ml of sterile water to yield a 10 percent bleach solution. Add 2 drops of the detergent and place the explant in the solution. Shake for 10 seconds every minute for ten minutes. Quickly drain the solution; add sterile water and shake the container.

B. Transferring the Explants

1. Spray and wipe down all the inside surfaces of the transfer chamber with a 10 percent bleach solution. Allow them to air dry. Place a small container of 10 percent bleach solution and another container of 1 percent bleach solution in the transfer chamber to use for sterilizing the instruments and gloved hands. Place the forceps and knife in the 10 percent bleach solution and then in the 1 percent solution. Lay the sterilized instruments on a sterile paper towel and allow them to air dry.

2. Using the forceps, unroll another paper towel on the work area inside the transfer chamber. Use the forceps to place the runner tip on the towel. Hold the tip with the forceps while picking up the knife or scalpel and cutting off 1 cm of the stem. Put the knife in the 10 percent bleach solution. Pick up a test tube of medium while holding the explant with the forceps. Remove the test tube cap with the small finger of one hand and hold it firmly in place while putting the cut explant on the medium. Cap the test tube and seal it with Parafilm™ or tape.

C. Growing the Cultures

1. Place the test tube in the planter tray or another holder on a shelf under a florescent light that is 8 to 10 inches away. Continuous light may be used, but if a timer is available, 16 hours of light is normal. Plants may remain at room temperature.

2. Check the cultures every day for signs of contamination. If any fungus or other form of contamination is present, sterilize the contaminated test tubes before discarding.

3. Transfer the explant to new medium every two weeks until it is growing well.

4. In one to two months, the explants should have many shoots and can be divided. When shoots are observed, divide the explant into two pieces about 0.5 cm in diameter. Repeat this process until enough growing plants are produced. Transfer them to a pretransplant medium that has no hormones.

5. After two to four weeks on the medium, the roots should develop. Transplant the plants to an artificial soil mix (greenhouse mix) in a seedling tray. Cover them with transparent plastic and place on a lighted shelf or in a shaded greenhouse.

6. After two or three weeks, uncover the tray daily for a length of time. Gradually increase the time it remains uncovered for a week until they are no longer being covered.

UNIT VI - PLANT TECHNOLOGIES

Lesson 3: Genetically Modified Plants

Competency/Objective: Describe current applications of biotechnology in plants.

Study Questions

1. **How are genetically altered plants developed?**
2. **How do herbicide-tolerant plants function?**
3. **How do insect-resistant plants function?**
4. **How do disease-resistant plants function?**
5. **What effect has biotechnology had on food quality and processing?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
    a) AS 3.1: The Current State of Plant Biotechnology

UNIT VI - PLANT TECHNOLOGIES

Lesson 3: Genetically Modified Plants

TEACHING PROCEDURES

A. Review

Lesson 2 discussed the procedure of plant tissue culture and its use in reproducing plants. This lesson will address producing plants that have been genetically modified. Plant breeders have always searched for healthier and more productive plants. With the development of recombinant DNA technology, plant breeders have been able to select traits from sources outside the plant species with which they are working. As the vast selection of plants, animals, and microbes is examined for potentially helpful genes, researchers will continue discovering and using new genes to increase the world's crop production and decrease the cost of production.

B. Motivation

How valuable is the development of insect- or disease-resistant plants? The global cost of the current chemical control of insects and fungal diseases is $8.7 billion. However, even with the use of these chemical controls, insects and disease cause a 12 to 13 percent reduction in crop production. The chemical insecticide and crop loss costs associated with the Colorado potato beetle and the corn rootworm are over $1 billion in the United States alone. Insect damage costs for cotton exceed $645 million. Obviously, the added costs of genetically modifying a crop to be resistant to one of these pests may be easily offset by the decrease in chemical costs and the increase in yield.

C. Assignment

D. Supervised Study

E. Discussion

1. Review with students the methods of genetically modifying animal cells. Ask students to recall the differences between animal and plant cells, especially the presence of the cell wall. Explain that the cell wall of a plant requires that a forceful method of gene insertion be used.

How are genetically altered plants developed?

a) The desired gene or genes for a trait must be found, isolated, and cloned.
b) A method of genetic transfer is selected.
    1) Bacteria or virus
        (a) The desired gene and a marker gene is inserted into the bacterium or virus, and the microorganism is placed in contact with the plant cell to be modified.
        (b) The organism infects the cell and transfers the desired gene.
    2) Gene gun
        (a) The desired gene and a marker gene are inserted into a plasmid.
        (b) The plasmid is placed on the surface of very small (1 mm in diameter), heavy metal (gold) pellets.
        (c) These pellets are shot into the plant cells with the use of a small high-pressure gun.
    3) Chemicals
        (a) The cell wall is weakened or dissolved.
        (b) The desired gene is physically placed in the cell.
        (c) The plant cell is stimulated to repair the cell wall.

c) Plant cells that incorporate the desired gene into their DNA are selected (by looking for the marker gene) and grown into mature plants through the use of tissue culture.

2. Ask students to list some commonly used herbicides. How do these chemicals kill weeds? The answer lies in the fact that an important chemical process of the plant is disrupted by the herbicide.

How do herbicide-tolerant plants function?

a) Herbicides kill plants by chemically blocking a metabolic pathway.
b) Herbicide-tolerant plants have the ability to bypass the blocked portion of the metabolic pathway; this ability comes from genes that produce certain enzymes that provide a different chemical route around the blocked portion.

3. Explain to students that plants have very little natural resistance to insects and that many insects are becoming increasingly resistant to chemical insecticides. Explain the source of resistance (*Bt*) of insect-resistant plants.

How do insect-resistant plants function?

a) *Bacillus thuringiensis (Bt)* is a soil bacterium that produces a protein that, when eaten by specific insects, dissolves the wall of the gut, causing the insect to be unable to eat and eventually to die.
b) Each *Bt* strain kills a specific type of insect.
c) The genes that cause the production of the protein in specific *Bt* strains have been isolated and transferred to several crop plants, including potatoes, corn, and cotton.

4. Point out that plant diseases are commonly caused by viruses, bacteria, and fungi. Explain how disease-resistant plants combat them.

How do disease-resistant plants function?

a) Virus-resistant plants - A small portion of the DNA from the virus is inserted into the plant DNA, giving the plant an immunity to the virus.
b) Bacteria- and fungus-resistant plants - Current research in this area centers on trying to enhance the plant's natural immune response; plants resistant to bacteria and fungi are not currently available.

5. Ask students if they have heard of or tasted a FlavrSavr™ tomato. Explain that the quality and processing of foods is being advanced by biotechnology.

What effect has biotechnology had on food quality and processing?

a) Tomato
    1) The FlavrSavr™ tomato was developed by Calgene to have a vine-ripened taste and a longer shelf life.
    2) Genes were inserted into the tomato plant that cause the production of an enzyme that slows the breakdown of pectin, which keeps the tomato from getting soft and rotting.
    3) Four other companies have gained approval for similar genetically modified tomatoes.
b) Modified canola and corn plants - These plants yield a grain that is higher in oil content and has a modified oil composition in which the level of saturated and unsaturated oil has been changed to meet different uses.
c) High-starch potatoes
    1) The potatoes are higher in starch and lower in water content.

2) When chips or french fries are made, they will absorb less oil and will therefore be lower in fat.

F. Other Activities

Plant some genetically modified Roundup Ready™ soybeans from Monsanto and some soybean seeds that are the result of a hybrid cross. When the plants reach 8 to 10 inches in height, spray the plants with Roundup. Have the students record daily observations of the effects of the Roundup on both types of plants.

G. Conclusion

The development of transgenic plants by private companies has been fueled by the potential for large profits. Producers are willing to pay companies a premium for crop seed that can lower the costs of raising a crop. The potential of genetically engineered plants is only beginning to be realized.

H. Answers to the Activity Sheet

AS 3.1

Answers will vary based on available information.

I. Answers to the Evaluation

1. a
2. b
3. d
4. a

5. *Bt* or *Bacillus thuringiensis* is a soil bacterium that produces a protein that when eaten by specific insects causes the insect's gut wall to dissolve; it eventually dies. The genes in specific *Bt* strains that cause the production of the protein have been isolated and transferred to several crop plants.

6. Students may list any one of the following: the FlavrSavr™ tomato developed to have a vine-ripened taste and a longer shelf life, modified canola and corn plants that yield a grain that is higher in oil content and has a modified oil composition, and high-starch potatoes that are higher in starch and lower in water content.

7. Students should list the following steps.

   a. The desired gene must be found, isolated, and cloned.
   b. A method of genetic transfer is selected. A bacteria or virus, a gene gun, or a chemical that dissolves or weakens the cell wall is used.
   c. Plant cells that incorporate the desired gene into their DNA are selected by looking for the marker gene and grown into mature plants through the use of tissue culture.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 3: Genetically Modified Plants Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is not a method of transferring DNA into a plant cell?

   a. Using two electrical probes that cause the desired DNA to be forced into the targeted plant cell
   b. Chemically weakening or dissolving the cell wall and inserting the DNA
   c. Using a gene gun that fires heavy metal pellets coated with DNA
   d. Using bacteria and viruses containing the desired gene that attack the targeted cell

2. What is the name of a piece of DNA located or placed near a targeted section of DNA that helps in the identification of the targeted section?

   a. Plasmid DNA
   b. Marker gene
   c. Targeted DNA
   d. Signal gene

3. How do herbicide-tolerant soybeans tolerate the active chemical in a herbicide?

   a. The gene added to the soybeans prevents the absorption of the chemical.
   b. The gene added to the soybeans accelerates the natural immune system of the soybean plant to ward off the toxic effect of the chemical.
   c. The gene added to the soybeans chemically reacts with the substance to neutralize it.
   d. The gene added to the soybeans produces an enzyme that provides a way around the herbicide-caused metabolic pathway block.

4. The common soil bacteria, *Bacillus thuringiensis*, has played a big role in the development of:

   a. Insect-resistant plants.
   b. Disease-resistant plants.
   c. Herbicide-tolerant plants.
   d. High-starch potatoes.

Complete the following short answer questions.

5. How do insect-resistant plants function?

6. What is one example of a biotechnology product that enhances food quality and/or processing? What aspect of the product has been changed through biotechnology?

7. What are the three steps in the development of a genetically modified plant? Briefly describe each step.

   a.

   b.

   c.

Lesson 3: Genetically Modified Plants Name _____

The Current State of Plant Biotechnology

Objective: Describe the current state of plant biotechnology.

Answer the questions below. The Internet would be the best research tool, but newspapers and magazines may also be used. If additional information about plant biotechnology is found, summarize this information on the back of this activity sheet. You will be asked to share some of this information with the class.

1. List at least six companies that are involved developing products in plant biotechnology **and** one of the newest products from each company.

   a.

   b.

   c.

   d.

   e.

   f.

2. Briefly describe how one of these products was developed. (Include information on the source of the transferred gene.)

3. What genetically modified plants have been recently approved by the USDA, FDA, and EPA?

4. What do farm-related magazines have to say about the future of genetically engineered plants/crops?

UNIT VI - PLANT TECHNOLOGIES

Lesson 4: Emerging Applications of Plant Biotechnology

Competency/Objective: Identify emerging applications of biotechnology in plants.

Study Questions

1. **What are biofuels?**

2. **What are biopolymers?**

3. **What are some traits that producers desire in plants?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.

2. Activity Sheet

   a) AS 4.1: Designer Plants--The Agricultural Products of the Future

UNIT VI - PLANT TECHNOLOGIES

Lesson 4: Emerging Applications of Plant Biotechnology

TEACHING PROCEDURES

A. Review

Plants have been cultivated for centuries to provide food for both humans and animals. An increasing number of plants are now grown for industrial and medical uses as well. As discussed in Lesson 3, plants can be genetically modified to improve their usefulness for these purposes. Just as George Washington Carver discovered more than a hundred uses for peanuts, so are today's scientists discovering new uses for plants, especially modified plants. Some emerging applications of plant biotechnology will be examined in this lesson.

B. Motivation

Pass out one soybean-derived crayon, labeled "A," and one traditional crayon, labeled "B," to three or four students. Ask these students to evaluate the two crayons and determine which one is better. List their comments on the board. Ask students if any of them know any young children who play with crayons. Have they ever seen them chew on or simply eat a crayon? Tell the class that one of the crayons is safe to eat. Increase student interest by telling the class that one of the two crayons earned four college students more that $100,000 and prompted many offers of high-paying jobs. Explain that the four college students won a contest sponsored by the United Soybean Board by developing soybean-based crayons. Talk about how a problem relevant to one of those college students (his younger brother eating crayons) sparked a new use for a traditional crop plant.

Pass around a piece of soybean "marble" and explain that a fifth-grader discovered this product. She was trying to come up with a project for her school science fair. She mixed glue and newspaper in a blender and then heated it in the microwave. The mixture formed a hard, granite-like block that could be worked like wood. The formula has been changed slightly, with the glue being replaced by a product made from soy flour, and her discovery is now being marketed as a building material.

Point out that the genetic engineering of plants provides researchers the opportunity to modify a plant so that it is better suited for a particular application. Therefore, more plant-derived products like these will probably be developed, and existing products will likely be enhanced.

C. Assignment

D. Supervised Study

E. Discussion

1. Show a sample of biodiesel to the class and ask students how it is made. Ask students to list other plant-derived fuels.

What are biofuels?

a) Biofuels are combustible substances derived from organic sources. Nearly all biofuels are derived from plants.
b) Several types of biofuels exist.
    1) Alcohol-based fuels
        (a) These fuels are made by fermenting plant materials.
        (b) An example is gasohol, a fuel that is 10 percent alcohol and 90 percent gasoline.

(c) Researchers are searching for plants that they can modify to produce ethanol more economically.

2) Plant oil-based fuels, or biodiesels
   (a) These fuels are made from seeds with a high oil content.
   (b) Most are the result of the addition of methanol to the plant oil and the removal of a sticky substance called glycerin.
   (c) Soybean and rapeseed oils are most commonly used.
   (d) Scientists are looking for ways to engineer plants to produce a larger quantity of oil and to require less extensive processing.
3) Biogas fuels
   (a) Methane gas is derived from the anaerobic (oxygen-free) digestion of plant materials and/or animal waste by microorganisms.
   (b) Researchers are examining the possibility of developing plants that would produce crop residue that is more useful for methane production.

2. Ask a student to look up the definition of a polymer (a natural or synthetic substance that is formed by joining many simple molecules to form large molecules) and read it to the class. Then ask the students to speculate about the definition of a biopolymer.

What are biopolymers?

a) Biopolymers are complex chemical compounds produced by living things; biopolymers from genetically engineered plants may be useful in a variety of industries.
b) Biotechnology is being applied to develop five different types of biopolymers.
   1) Carbohydrates - Researchers are working on the development of a modified corn starch that does not break down when heated in the microwave and genetically engineered potato plants with leaves that have a high sugar content.
   2) Fatty acids - Scientists are working on modifying corn and canola oils to contain a high level of either saturated or unsaturated fatty acids depending on which is needed for a given application.
   3) Pharmaceutical proteins - These biopolymers are used for human health products.
   4) Industrial enzymes - Scientists are trying to modify plants to provide enzymes at a low price for purposes such as fermentation for brewing, processing and bleaching paper, and a feed additive to aid in digestion in livestock.
   5) Bioplastics - Scientists are attempting to develop plants with tissues that contain a higher level of the chemical components of plastic.

3. Ask students to use their imaginations and list the characteristics (other than increased yield) that they think would be valuable plant traits. Some of the traits listed are more than likely being researched as possible crop enhancements. Have students complete AS 4.1. Divide the class into groups of three or four students. Assign two or three sectors of the agricultural industry (based on the FFA proficiency award areas) to each group. Have students use any available resources, including textbooks, magazines, and the Internet. Encourage the group members to pick different questions to research and then compile all of the answers. The answers that the students come up with should be rational, but encourage them to use their imaginations as well as their resources.

What are some traits that producers desire in plants?

a) Environmentally tolerant plants
   1) Drought-tolerant plants
   2) Frost-tolerant plants
   3) Salt-tolerant plants
b) Forestry products
   1) Stronger wood
   2) Fire-resistant wood

3) Trees that grow more quickly

c) Food products with an improved taste
   1) Sweet corn and peas that stay sweet longer
   2) Naturally decaffeinated coffee

d) Fiber crops such as naturally colored and fade-resistant cotton

F. Other Activities

1. Have students search the Internet looking for emerging applications of plant biotechnology.

2. Have students compete in the Missouri Department of Agriculture New Product Contest using products created with biotechnology.

G. Conclusion

Biofuels, biopolymers, and specialized plants with traits desired by producers are three major emerging applications of plant biotechnology. As information about the vast quantity of genes available from microbes, animals, and plants increases, more and more specialty crop plants will be developed. Most of these crops will comprise only a fraction of plant agriculture, and demand will determine which crops are grown.

H. Answers to the Activity Sheet

AS 4.1

Answers will vary.

I. Answers to the Evaluation

1. c
2. d
3. e
4. b
5. a
6. a
7. d
8. Stronger wood, fire-resistant wood, and trees that grow more quickly
9. Drought-tolerant plants, frost-tolerant plants, or salt-tolerant plants

EVALUATION

Match the examples of biopolymers with their descriptions.

1. _____ These biopolymers are used in the bleaching of paper and as additives to animal feeds.
2. _____ This type of biopolymer is found in modified oils from corn or canola.
3. _____ Scientists are attempting to change the chemical components of plants to contain higher levels of substances used for these biopolymers.
4. _____ These biopolymers are used for human health products.
5. _____ This group of biopolymers consists of products like a modified corn starch that does not break down when heated in the microwave.

a. Carbohydrates
b. Pharmaceutical proteins
c. Industrial enzymes
d. Fatty acids
e. Bioplastics

Circle the letter that corresponds to the best answer.

6. Which of the following is <u>not</u> a type of biofuel for which genetically modified plants are being developed?

   a. Petroleum-based fuel
   b. Alcohol-based fuel
   c. Plant oil-based fuel
   d. Biogas fuel

7. Biopolymers are:

   a. Complex carbon compounds that are byproducts of many types of plant biotechnology research.
   b. Combustible substances derived from plants or animals.
   c. Inorganic chemicals that cause plants to mutate.
   d. Complex chemical compounds from genetically engineered plants that are useful in many industries.

Complete the following short answer questions.

8. What are three products that the forestry industry would like biotechnology researchers to develop?

9. What are three types of environmentally tolerant plants that scientists are researching?

Lesson 4: Emerging Applications of Plant Biotechnology Name _____

Designer Plants--The Agricultural Products of the Future

Objective: Describe products of plant biotechnology that could be a part of the future of agriculture.

Answer the following questions to describe a possible plant product produced through biotechnology that might be used in one of the sectors of agriculture assigned to you by your instructor. You will need to use resources like textbooks, magazines and the Internet along with your imagination to complete this assignment.

1. Which sector of agriculture were you assigned?

2. What are the problems or limitations in raising plants used in this sector? (Include anything that costs money or time to control or overcome.)

3. What traits are currently being researched that may help improve the plants used in this agricultural sector?

4. What traits could be added to a plant that would not affect its main use but would improve its secondary uses or byproducts?

5. What are some industrial proteins that could be produced with plants in this sector of agriculture?

6. What are some traits that might enhance the aesthetic appeal (desirability) of plant products in this sector?

7. What is one trait that you feel will be developed in the next ten years?

UNIT VI - PLANT TECHNOLOGIES

Lesson 5: The Impact of Plant Biotechnology

Competency/Objective: Summarize the impact of biotechnology in plant agriculture.

Study Questions

1. **What are the career opportunities in plant biotechnology?**
2. **What are some economic factors of plant biotechnology that affect producers?**
3. **What are health and safety concerns of consumers of plant biotechnology?**
4. **What are the global social impacts of plant biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
   a) AS 5.1: Careers in Plant Biotechnology

UNIT VI - PLANT TECHNOLOGIES

Lesson 5: The Impact of Plant Biotechnology

TEACHING PROCEDURES

A. Review

Plant biotechnology has many applications, not only for food, but for products such as biofuels and biopolymers, as discussed in the last lesson. Many of these products may be on the market soon. What will be the impact of these new products? Will they only be positive? This lesson will provide a look at the economic, health and safety, and social effects of biotechnology on the United States and the world.

B. Motivation

Ask students to imagine this headline "World Price of Sugar Drops to All-Time Low: New Sugar-Producing Tobacco Provides Bumper Crop." Discuss the global effects of this event.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to recall the career areas discussed for animal biotechnology. Relate them to plant biotechnology, pointing out those careers specific to plant biotechnology.

What are career opportunities in plant biotechnology?

a) General areas of biotechnology career opportunities
   1) Research and development
   2) Quality control
   3) Clinical research
   4) Manufacturing and production
   5) Regulatory affairs
   6) Information systems
   7) Marketing and sales
   8) Administration
b) Career opportunities specific to plant biotechnology
   1) Plant scientist
   2) Greenhouse manager
   3) Tissue culture technician

2. Ask students to list the benefits and risks of producing a genetically modified crop.

What are some economic factors of plant biotechnology that affect producers?

a) Benefits
   1) Lower input costs for crops that require less chemicals
   2) Premium price for specialized crops
b) Drawbacks
   1) Higher price of seed
   2) Higher costs associated with the special handling needed to keep crops with a modified composition separate from unmodified crops

3) Limited market for specialized crops

3. Ask students to recall the results of the survey done in Unit 2. Have students list any concerns raised by those who were surveyed.

What are health and safety concerns of consumers of plant biotechnology?

a) Questions about the healthiness of genetically modified foods arise about foods in which the composition of the plant is changed.
b) Some consumers also worry that a plant altered for an industrial purpose will wind up in the food supply.

4. Ask students to speculate about the effect on other countries if a transgenic crop is introduced in the United States. Ask students if the effect would be positive or negative.

What are the global social impacts of plant biotechnology?

a) Positive global impacts
   1) Transgenic plants, such as the sweet potato resistant to the feathery mottle virus (FMV), can greatly benefit developing countries.
   2) The development of environmentally tolerant plants could help reduce the risk of famine in some countries.
   3) The development of edible plant vaccines could make it possible for millions of poor people to receive vaccines.
b) Negative global impacts - The development of some genetically modified crops can destroy the profitability of agricultural cash crops that may be vital to a country's economy.

F. Other Activities

Have students give presentations on the possible social impacts of the introduction of a new transgenic plant.

G. Conclusion

Transgenic crops are just beginning to be planted by producers, and therefore the full impact of these new crops is not quite clear. What transgenic plants will be introduced in the next five to ten years? What will be the long-term impact of the transgenic crops already in commercial production? Will producers, consumers, and developing countries be positively or negatively affected by plant biotechnology? These questions are difficult to answer, but they must be addressed to avoid social and economic pitfalls.

H. Answers to the Activity Sheet

AS 5.1

Answers will vary.

I. Answers to the Evaluation

1. a
2. d

3. Students may list either of the following: the healthiness of genetically modified foods in which the composition of the plant is changed or that a plant altered for an industrial purpose will wind up in the food supply.

4. Reduced input costs for crops that require less chemicals and a premium price for specialized crops

5. Plant scientist, greenhouse manager, tissue culture technician

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 5: The Impact of Plant Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a positive development in plant biotechnology for developing countries?

   a. The development of transgenic plants such as the FMV-resistant sweet potato
   b. The development of corn modified for industrial purposes
   c. The development of modified potatoes with leaves that can produce a large amount of sugar
   d. The development of a modified canola oil that can replace more expensive tropical oils

2. What is a potential drawback for producers raising genetically modified crops?

   a. Some genetically modified crops can reduce input costs for producers.
   b. Most genetically modified crops require more rain to grow than unmodified crops.
   c. Producers can normally obtain a higher price for crops with a modified composition.
   d. Specialized crops produced through genetic modification may have limited markets.

Complete the following short answer questions.

3. What is one health or safety concern that some consumers have about plant biotechnology?

4. What are two economic advantages that modified crops could have for producers?

5. What are three career opportunities <u>specific</u> to the field of plant biotechnology?

Lesson 5: The Impact of Plant Biotechnology Name _____

Careers in Plant Biotechnology

Objective: Investigate a specific career opportunity in plant biotechnology.

Select a specific job title in the field of plant biotechnology. The careers listed in this lesson can be used, as well as other job titles that you might find. Compile a profile of the career by answering the following questions. Then report your findings to the class.

1. What are the responsibilities of someone with this job?

2. Where are available jobs located?

3. What is the average salary?

4. What personality traits are valuable for someone working in this job?

5. What level of education is needed to obtain this position?

6. Where can this education be obtained?

7. What is the future job market outlook like for this position?