A Report on

AGRISCIENCE

February 1996

1995 Agriscience Teacher of the Year

Dale Gruis

St. Ansgar, Iowa

Advisor Dale Gruis (left) instructs students Brian Pitzen and Amy Sponheim as they observe a Gram stain slide of bacteria cultures. This test is used to identify specific bacteria strains.

A Little Goes A Long Way

The 1995 Agriscience Teacher of the Year stretched a small budget into an award-winning program

If you want to know how far a $1,500 agriculture department budget can stretch, ask Dale Gruis, advisor of the St. Ansgar, Iowa, FFA Chapter. Its elasticity amazed even him when he was named the 1995 Agriscience Teacher of the Year at the 68th National FFA Convention Nov. 9-11 in Kansas City, Mo.

Gruis, who has taught at St. Ansgar for half of his 10-year teaching career, dispels the myth that agriscience instruction is only for wealthy, multi-teacher programs. "The trick is to come up with activities that are not very expensive," Gruis notes. Some of his most effective teaching tools cost little to nothing, and he budgets more costly experiments to maximize learning while minimizing expenses.

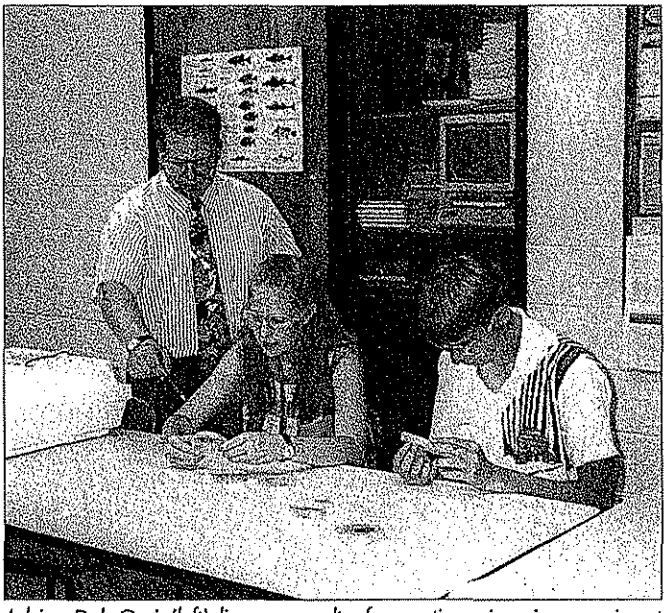
"When I spend money on an experiment that is fairly pricey, I use it in more than one class. For example, maybe both freshmen and sophomores will do the experiment, so I won't have to purchase the materials for two more years," Gruis says. Tissue culture and conjugative plasma transfer experiments fall under this heading. Gruis notes that it's cheaper to buy larger quantities, making his alternating-year plan even more cost-effective.

Building Cows and Racing Bacteria

Low-cost and free materials can capture students' interest and imaginations just as well as $100 tissue cultures, Gruis has learned. For example, his students

Continued on Page 2

Continued from Page 1



Advisor Dale Gruis (left) discusses results of a genetic engineering experiment with students Julie Rosenberg and Erik Goodale. The students are conducting conjugative plasma transfer, which shows how a strain of bacteria can transmit resistance to an antibiotic to another strain of bacteria.

research newspaper and magazine articles on current scientific topics such as genetic engineering or biotechnology. Gruis then gets the students' creativity flowing through activities such as the "Design the Perfect Dairy Cow" contest.

"The wilder and more creative they get, the better," Gruis says. "They'll recommend chopping off the head and installing a computer, or getting rid of the udder to put a stainless steel tank in its place."

Such lessons have wider applications than the activity itself. "It gets them thinking about the important physiological parts of the animal, plus they also have to think about what makes it work, and what are its weaknesses," Gruis notes. "Then they can understand why, through genetic engineering, scientists can change certain characteristics."

This also provides Gruis a forum for teaching his concept of agriculture as a "money science." "If you're in agriculture, you're applying science: growing plants and animals *is* science," he says. The development of bovine somatotropin to increase dairy production triggered this idea. "Companies develop these technologies to try to make a profit," Gruis says. "Without economic incentive, a lot of these developments wouldn't happen."

Micro-organism Olympics is another low-cost activity that grabs students' interest. Gruis groups his Agricultural Education I students in teams, and gives each team a petri dish filled with nutrient agar, a substance in which bacteria can grow. Each team scours the dark corners of the school—locker rooms, bathrooms, etc.—to try to find the largest population of bacteria.

Students collect the sample by touching tape on the surface of the area they've chosen to test. They dab the tape on the surface of the agar, cover the petri dish and watch the races. The team with the fastest and greatest degree of microorganism growth wins.

"There's a shock value there, to realize how fast they grow and reproduce," Gruis says.

Activities such as the Micro-organism Olympics also teach students to work together and learn from each other. Gruis emphasizes cooperative learning techniques in his classes and uses them almost every day. He finds that creating groups of three to five students works well for many activities.

"Especially when we're trying to brainstorm, it works better in a small group than by yourself," Gruis notes. The group work can last anywhere from several minutes to most of the period, if the class is working on a more involved lesson or experiment.

Fishing for a Diverse Program

One of the school's biggest cooperative learning applications is the aquaculture program that started three years ago. Rather than purchasing a pre-built system, Gruis let the students design and develop the operation from the ground up. Now, the FFA chapter owns and operates the project, and the agricultural education program benefits from any proceeds. Students raise about 200 tilapia to eating size every year, but it's more of an educational benefit than a money-maker. "It usually costs more to operate than we get back from it," Gruis says.

Aquaculture continues to be one of Gruis' main teaching tools. He offers a separate semester-long course in aquaculture, that has captured the interest of 38 students in the past two years. In addition to raising the tilapia, students conduct a number of experiments on water quality, feeding, lighting, pH, dissolved oxygen and even Pavlov's response theory. It provides a constant supply of fish for dissection, and even becomes a valuable learning tool in his animal science class. "The fish have done more to help students understand feeding efficiencies in cattle and hogs than any other activity we have done," Gruis notes.

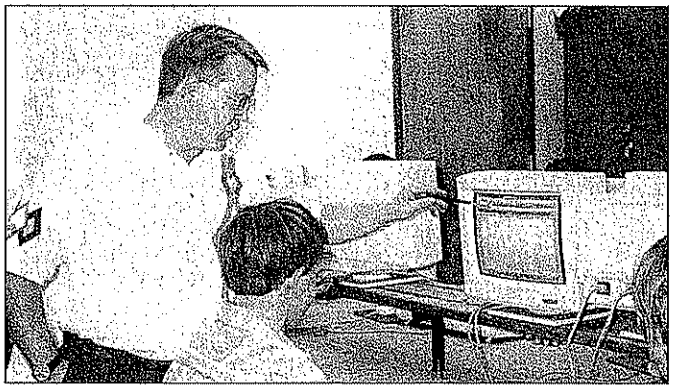
Five years ago, a fish tank would have been unheard of in the St. Ansgar agricultural education program. Before Gruis arrived, the program was predominantly production agriculture and agricultural mechanics, reflecting the area's economic mainstays of cash grain, hog and dairy operations. However, Gruis found no opposition to his proposal to shift the emphasis toward a more scientific and business-based approach—in fact, the changes have garnered nearly a three-fold membership increase, and incredible support from the community.

"We realized the need to revamp the curriculum by exposing students to more agriscience and agribusiness concepts," Gruis says. Though 75 percent of his students are from farms, he estimates only 10 percent of those young people will ever have a chance to farm. "Though it's a strong production area, a lot of students realize they'll go into other areas of agriculture," Gruis notes.

The metamorphosis began with a meeting with the high school principal and science teacher to discuss the complements between agriculture, biology, chemistry and earth science. Gruis then gathered his advisory committee to get their input. Their assessment: incorporate computer instruction, biology concepts, food processing and marketing, financial management and agribusiness.

Today, students work extensively on computers, becoming literate in both IBM and Macintosh platforms by the time they graduate. The school offers four agriculture classes, one for each grade level, in addition to four specialized courses in horticulture, mechanical systems, computer applications in agriculture and aquaculture.

St. Ansgar aquaculture students designed, maintain and manage a 1,000 gallon aquaculture system. The project helps students learn about physiology, feed efficiency factors and business management. Advisor Dale Gruis (center) examines one of the 200 tilapia students raised to eating size in 1995 with students Greg Stone (left) and Rob Huffman.



St. Ansgar agricultural education students use the department's computer lab to maintain records, perform record analysis and create research presentations. Advisor Dale Gruis (left) discusses a project with student Sam Kofoot.

Attracting Students With Applied Learning

The result has been tremendous. Not only is enrollment up, but some of the top academic students in the school are enrolled in agricultural education. However, Gruis also makes sure that the more academically challenged students have a place in his program.

"I receive the greatest joy from teaching students who struggle in other classes but who excel in ag ed with a little encouragement and hands-on learning," Gruis says. "Many students who struggle with book-based learning excel in an environment which emphasizes practical application and common sense."

Gruis has watched his enrollment soar from 36 in 1991 to 81 this year, and demand outpaces supply. In one recent semester, students signed up for 10 different classes, but there are only enough hours in the day to teach seven. It's a big change from when he started—one semester he only had enough student interest to teach five courses. He credits the scientific emphasis and increased FFA activities as the primary magnets.

"If students have respect for the program, they'll want to be in it more," Gruis says. "We're doing things that aren't being done in many schools' science departments, and students are proud of that."

Continued on Page 4

Continued from Page 3

The chapter has also increased its calendar of FFA activities, and in 1995 advanced more career development event teams to the state level than any other chapter in Iowa.

"There's such a close link between career development events in FFA and the things we teach in class," he says. "Once students get a taste of it and see the opportunities, they're really excited about it."

> *"If students have respect for the program, they'll want to be in it more. We're doing things that aren't being done in many schools' science departments, and students are proud of that."*
>
> —Dale Gruis

Because of that symbiotic link, Gruis allows the classroom and FFA activities to have financial ties in some cases—another way he stretches his budget. "There's such a strong link between them, I don't have a problem using FFA funds to enhance the school program—FFA members will be the recipients of the program." Gruis adds that students make the decision on whether to use FFA funds to sponsor classroom activities.

Gruis' program has attracted the attention of other teachers in the school. Gruis says the science teachers have commented that many agricultural education students have a real advantage in science classes, especially with regard to genetics. They're able to contribute real-world examples that enhance the understanding for the whole class.

In addition to his already busy schedule teaching agriscience, Gruis has just taken on an additional responsibility—teaching applied biology. Interest among his students runs high: the entire enrollment is made up of his sophomore agriculture class. "The key is that it's applied biology—90 percent is the same as a biology class, and 10 percent tries to emphasize practical applications of biology, like agriculture, medicine and food technology," Gruis comments.

Tapping Great Ideas

Though obviously successful and creative in his teaching methods, Gruis refuses to take credit for the ideas. "My best resources are other ag teachers," he says. He advises learning as much as possible from other teachers. "I have no shame in stealing an idea from another teacher if my students will benefit from it," he admits.

Gruis, who minored in biology as he pursued his agricultural education degree at Iowa State University, also uses ISU as a resource. He attended a biotechnology workshop that was aimed at science teachers, and benefits from free teaching materials from the ISU biotech lab.

Considering the strong science focus of Gruis' program, one might think he had set a goal of winning the Agriscience Teacher of the Year award. Not true—in fact, he never intended to apply until a fellow agriculture teacher and the school principal encouraged him.

"It's an interesting note that ag teachers are quick to push kids to try for awards, but don't want to do it themselves." Gruis says. The process has been an educational one for him, and his students will probably benefit from what he's discovered.

"If I could share some ideas with others in the process, that's great, but I probably learned more ideas from others through this than I've given away," Gruis notes. •••

The FFA Mission
FFA makes a positive difference in the lives of students by developing their potential for **premier leadership, personal growth and career success** through agricultural education.

Micro-organism Olympics

Description:
Students will collect and grow cultures of microorganisms. Their goal will be to produce the fastest growing culture.

Objectives:
To demonstrate how rapidly microorganisms reproduce.
To help students understand microorganisms' impact on agriculture.

Interest Approach:
- Write the number, 76 trillion (76,000,000,000,000), on the overhead or chalk board.
- Ask students to brainstorm what this number represents.
  Answer: The number of bacteria which one bacterium can generate in 24 hours.
- Brainstorm ways in which bacteria affect our lives positively and negatively.
- Provide flavored yogurt as an example of beneficial applications of bacteria.

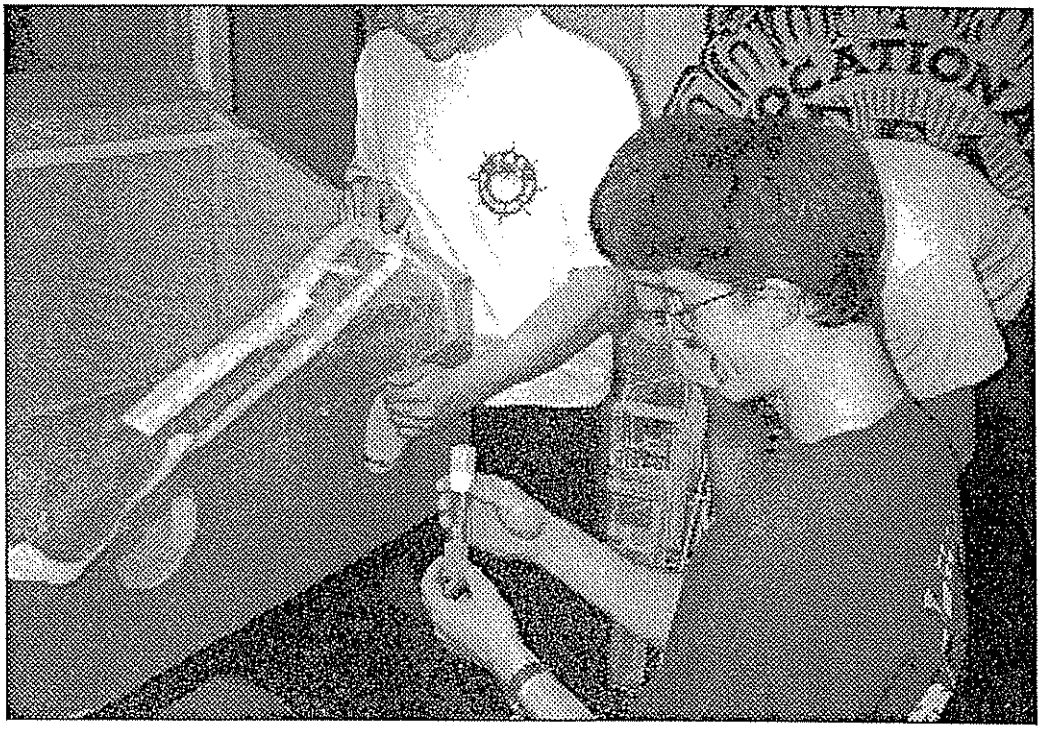
Equipment and Supplies Needed:
- nutrient agar plates–one per student
  (Petri dishes containing nutrient agar. Purchase ready-made or pour your own.)
- propane torch or bunsen burner
- paper clips or inoculating loops
- scotch tape or masking tape
- razor blades
- filter paper or coffee filter (cut into strips approximately 1 cm wide and 4 cm long)
- beakers (100 ml work well, however any size will work)
- forceps
- permanent markers

Continued...

Notes:

"Green Pigs and Biocookies"

Dale Gruis
St. Ansgar High School
St. Ansgar, IA 50472
Phone: 515-736-2402



Important Resources and References:

Office of Biotechnology
Iowa State University
Lori Miller
1-800-262-0015 ext. 9818

Iowa Biotech Educator

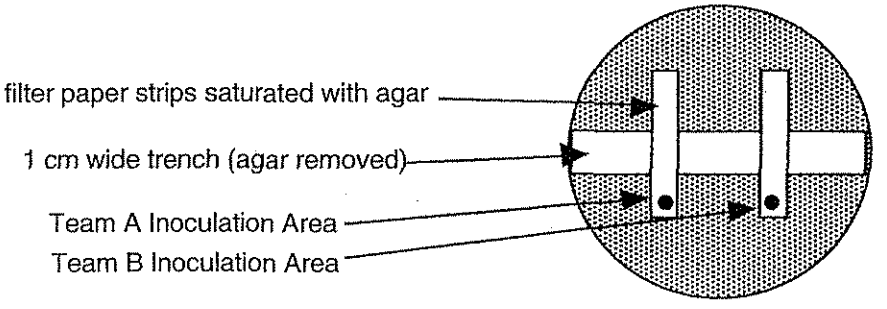
The AGBIOTECH Infosource

Flinn Scientific Supply

Carolina Biological Supply

Long Jump Competition: This event is designed to give students the opportunity to isolate and grow a specific bacteria culture. The event is a race against another group.

1. Combine groups from the 100 Meter Dash into two teams. (Label them teams A and B.)
2. Give each team a sterile nutrient agar plate, a razor blade, a beaker, forceps, two paper clips and two strips of filter paper.
3. Use a propane torch or bunsen burner to sterilize the razor blades and the forceps by passing them through the flame.
4. Use the sterilized razor blade to cut a 1 cm wide trench across the middle of the agar in the sterile nutrient agar plate. Remove the agar with a sterile forceps.
5. Place this agar in a sterile beaker and heat or microwave to melt the agar.
6. Sterilize the forceps by flaming.
7. *Use the forceps to dip two strips of filter paper in the molten agar.*
8. Place the saturated strips on the sterile nutrient agar plate. Place the strips so they form two separate bridges across the trench. Place the strips at least 1 inch apart.



9. Label the strips A and B. (Label on the half of the petri dish which contains the agar.)
10. Each team selects one bacteria culture from the 100 Meter Dash Plate, and uses a straightened paper clip to gently scrape the culture from the plate.
11. Gently touch the paper clip on one end of the filter paper (race track) to transfer the cells to the agar surface.
12. One team gets lane A and the other gets lane B. Inoculate only one end of each strip.
13. Close the plates and tape shut to prevent accidental opening or contamination.
14. Examine the plates after 24 hours, 48 hours, etc. The first culture to grow across the race track to the other side of the trench wins the event.

Note: *Never touch contaminated agar (microorganism cultures) with your hands. Sterilize contaminated petri dishes with bleach and water before discarding or incinerate. They should be handled as a biohazard material.*

Continued...

Procedure:

100 Meter Dash: This event is a competition to see which group can find and grow the fastest-growing microorganism culture. (The nastier the better.)

1. Divide the class into groups. (2-3 students per group works best)
2. Each group is to search the school to find an area which they feel will give the greatest potential for microbial growth.
3. Each group takes one piece of tape approximately two inches long. Hold the tape on one end, being careful not to contaminate the other end.
4. Upon deciding where to obtain their sample, students will stick the tape on the surface they wish to sample. The microorganisms will stick to the tape.
5. The tape is then placed on the nutrient agar, sticky side down, and lightly rubbed with a finger to transfer the microorganisms to the agar surface. The plates are now inoculated.
6. Tape the nutrient agar plates shut to prevent accidental opening.
7. Label the plates with a permanent marker. (Always label the agar side of the plate.)
8. Place in a warm place to incubate. The plates will grow without an incubator, however the results will take slightly longer. (A chicken egg incubator speeds growth. Incubate at approximately 90 degrees F.)
9. Place the plates agar side up to prevent excess moisture from condensing on the agar.
10. Check after 24 hours, 48 hours, 72 hours, etc. You may crown the champion when you have enough growth to see a definite difference.
11. Do not discard the plates.

Notes:

Items for Discussion:
Why is the tremendous rate of bacteria reproduction important?

Where can microorganisms be found in our environment?

What are pathogens?

What are mutations?

What is cloning?

Can bacteria develop resistance to antibiotics?

What are the beneficial applications of bacterial growth?

How are bacteria utilized in biotechnology applications?

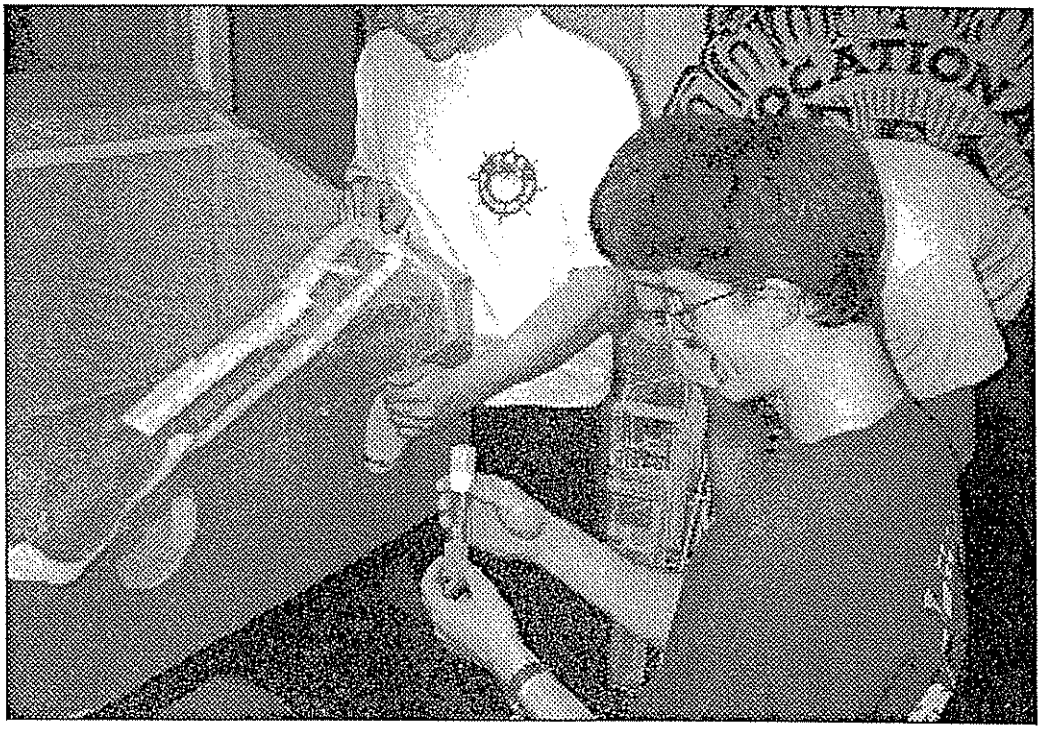
Are bacteria and microorganisms important to agriculture?

Suggested Follow-up Activities:
- Use the bacteria cultures to conduct Antibiotic Sensitivity Tests.
- Perform a Gram Stain to observe the bacteria under a microscope.
- Culture yogurt using active bacteria cultures from plain yogurt.

AGRISCIENCE

"Green Pigs and Biocookies"

Dale Gruis
St. Ansgar High School
St. Ansgar, IA 50472
Phone: 515-736-2402



Important Resources and References:

Office of Biotechnology
Iowa State University
Lori Miller
1-800-262-0015 ext. 9818

Iowa Biotech Educator

The AGBIOTECH Infosource

Flinn Scientific Supply

Carolina Biological Supply

WHY BIOTECHNOLOGY?!#@!

The following includes several scenarios that an instructor could use to introduce a biotechnology unit in an attempt to make this information relevant to your students. Each student should select a scenario at the beginning of the unit. At the end of the unit, students should answer the question posed by the scenario by writing a one page paper.

Scenario #1
Many scientists currently believe that our current level of food production will not keep pace with increases in world population. Past increases in food production utilizing selective breeding techniques has been called the "Green Revolution". Over the next 30 years, increases in world population may exceed our increases in food production. How might biotechnology be utilized to solve this dilemma?

Scenario #2
Assume you are interested in a career in biotechnology, what career skills and biotechnology knowledge would you need to have?

Scenario #3
You are interested in attending a community college or university to major in Animal Science. Why would you need to have an understanding of biotechnology?

Scenario #4
Assume you plan to stay in your home community and farm with your parents. You plan to raise corn, soybeans, and hogs. Why would you need to have a working knowledge of biotechnology?

Scenario #5
You have grown up on a farm and are familiar with agriculture; however, you plan to attend college and major in nursing. Why would you need to have an understanding of biotechnology?

Scenario #6
You are in the agriculture class the hour before lunch. You eat school lunch everyday, and you actually like it. Why would you need to have an understanding of biotechnology?

Scenario #7
You are a redneck farm kid who only comes to town for school. Your hobbies are pigeon shooting and gopher trapping. Why would you need to have an understanding of biotechnology?

Biotechnology Terminology

DNA: deoxyribonucleic acid

Chromosome: structures found in the cell nucleus which contain genes

Gene: specific site on a chromosome which controls the heredity of trait(s)
Example: eye color

Allele: variations of a specific gene
Example: Gene= Eye Color; Alleles: Blue eyes, green eyes, brown eyes

Transgenic: (Transgenic plants, Transgenic animals) organisms which have been genetically engineered.

Gene Pool: All traits which an organism can inherit.
Selective Breeding: Only traits within the same species are available.
Swine Gene Pool: Hampshire breeding, Yorkshire breeding, etc.

Genetic Engineering: It may be possible to utilize traits from other species. For example: firefly genes in a tobacco plant.

Mutation: A new variation of a gene. Random mutations can occur in nature or may be caused by mutagens such as: chemicals or radiation.

Plasmid: A free-floating ring of DNA found in some bacteria and viruses. Commonly utilized in genetic engineering to transfer genes from one organization to another.

Gene Gun: Equipment used to blast genes into cells.

Clone: A genetically identical copy of an organism.

Genetic Engineering: Transferring genes from one organism to another.

Gene Mapping: Processing of mapping the locations of genes on chromosomes.

Human Genome Project: Project to map the locations and functions of all genes on human chromosomes.

Gel Electrophoresis: Process of seperating the chemical components of a substance using agarose gel and electricity. (Genetic fingerprint)

Bioreactor: Utilizing a living organism to produce a substance.
Example: Genetically engineering bacteria to produce insulin.
Genetically engineering soybeans to produce pharmaceuticals.

GMO: Genetically modified organism. (Some countries have concerns about purchasing GMO's.)

Bacillus thuringiensis: Bacteria which contains a crystalline protein structure which is harmful to some insects if ingested.

Agrobacterium tumefaciens: Bacteria which is commonly used to transfer genetic material into organisms. (Injects its DNA into plant cells.)

Lab Safety and Material Handling:

All bacteria cultures should be handled as biohazards. Soak waste materials in a 10 % bleach solution for 24 hours, and dispose of in a biohazard waste receptacle.

Resources:

Websites: biotech.iastate.edu
project.bio.iastate.edu
biotech.wisc.edu
signat.com

Office of Biotechnology
Iowa State University
1-800-643-9504 (ask for Lori Miller)

Carolina Biological Supply Catalog (see your science teacher)

Flinn Scientific (see your science teacher)

THE AGBIOTECH INFOSOURCE

Issue 29 June, 1997 Published by AG-WEST BIOTECH INC.

Biotechnology in Cyberspace:

Your Guide to Biotech Resources on the Internet

Biotechnology —the leading edge science that is revolutionizing agriculture — is developing at an amazing pace. Traditional educational resources may have difficulty keeping up with biotech research breakthroughs and technical achievements.

Not to worry. The Internet offers a better way to access the most up-to-date information available every day. Dozens of sites on the World Wide Web offer students and teachers opportunities to learn the latest on biotechnology. From technical, how-to information to debates about the ɔrality of genetic engineering, it's all out there in ˌberspace waiting to be explored. We've prepared a list of sites which offer good material for students.

Educational Sites

Biotech Educational Resources (Indiana University)

http://biotech.chem.indiana.edu/pages/education.html

This may be the top web site for students interested in biotechnology, not because of the information it contains, but because of the dozens of active links it offers to other educational sites. (The site is also of interest to students in other branches of science, especially chemistry.) Links are provided to sites offering graphic-rich guidebooks, bioscience video and on-line biotech courses.

Several links offer actual courses with a/v supports that can be used as a supplement to classroom materials. (You'll need video plug-ins to take full advantage of these sites.) Examples include:

• ***Cells Alive!*** http://www.cellsalive.com

A very lively site about bacteriology and cell biology intended for beginning biology students. Lots of animations and images.

• ***HHMI Virtual Lab*** http://www.telefusion.com/ɔctures/hiband/neat/index.html

An interactive site which gives access to a "virtual lab" as well as to lectures and exhibitions.

• ***UCI Life Science Education Guide*** http://www-sci.lib.uci.edu/SEP/life.html

A comprehensive, annotated list of life-science-related instructional Webresources. The entries are broken down by category and then by estimated grade level ranging from kindergarten to university graduates.

Access Excellence

http://www.gene.com:80/ae/

Called "A Place in Cyberspace for Biology Learning and Teaching", this is another excellent educational site for biotech and other biosciences. Interest areas include:

• Bioethics in the Classroom;
• Weekly science reports, interviews with news-making scientists and funfactoids;
• Online seminars, projects, and discussions hosted by scientists and teachers; and
• Activities Exchange - Biology-related activities and classroom projects developed by teachers.

Ag-Biotech Industry Sites

Ag-West Biotech

http://www.lights.com/agwest/

Ag-West Biotech Inc. is a non-profit company located at Innovation Place, north of the University of Saskatchewan in Saskatoon, Saskatchewan. It promotes Saskatchewan's involvement in ag-biotech. Among other resources, the site contains all issues of *Ag-Biotech Infosource* and the monthly *Ag-Biotech Bulletin*. It also provides links to many of the biotech organizations in Saskatchewan.

Global Agricultural Biotechnology Association (GABA)

http://www.lights.com/gaba/tech/index.html

This page is intended as a clearing house of news,

information and opportunities. Though only GABA members have full access, students are welcome to browse the collection of Current News and Opportunities Articles. Articles on the development of health, environmental and safety regulations are also available.

National Research Council / Plant Biotechnology Institute

http://www.pbi.nrc.ca/pbiintro.html

Located in Saskatoon, the Plant Biotechnology Institute (PBI) is one of five NRC institutes involved in biotechnology. PBI is primarily focused on the improvement of Canadian crops, specifically canola, cereals and grain legumes. All issues of the PBI Bulletin are archived.

InfoAgbiotech

http://aceis.agr.ca/fpi/agbiotec/english.html

Maintained by The Biotechnology Strategies and Coordination Office of Agriculture Canada, this site includes detailed information on:

- Regulating products of biotechnology;
- Information Bulletins on a dozen key biotech topics; and
- Information on commodity areas such as Microbial FertilizerSupplements; Novel Feeds; Plants with Novel Traits; and Veterinary Biologics.

Food Biotechnology Centre

http://www.biotech.ca/fbc/

This site contains copies of the Centre's bulletin, and an interesting chronological history of food biotechnology.

Food and Agriculture Organization of the United Nations

http://www.fao.org/

Called the World Agricultural Information Centre, this site is not restricted to biotech themes, but provides an interesting and accessible source for general information on the world food and agricultural situation. The site also includes FAO's digital photo archive; FactFile; and a site search engine.

General Biotech Sites

InfoBiotech Canada

http://www.ibc.nrc.ca/ibc/

InfoBiotech Canada (IBC) is a partnership of government, private and academic sectors with the goal of providing enhanced access to information on Biotechnology in Canada and worldwide. Access areas include: Canadian, global, organizational and corporate sites; biotechnology events; research activity and others.

Biotechnology Industry Organization Library

http://www.bio.org/bio/library.html

This site includes dozens of electronic publications on topics ranging from *Agricultural Biotechnology: the Future of the World's Food Supply* to *Bioremediation, a Natural Answer to Environmental Reclamation.* Other topics of interest include resources such as *Real Life Problems: Biotech Answers, 1996 High School Essay Contest Winner.* and *Tools for Teaching Biotechnology: A Bibliography of Resources.*

Strategis

http://strategis.ic.gc.ca

Strategis makes the information resources of Industry Canada, the federal government's economic department, available to the public. Information on consumer and business developments in Canada and world-wide are featured. Use the site's search tool to find sites and documents related to biotechnology.

Other Science News Sites

Newswire

http://www.ari.net/newswire/nwhome.htm

Newswire maintains a comprehensive database of news releases from top institutions engaged in scientific, medical and business research. The friendly interface allows you to flexibly search, browse or download any article or abstract. Many articles are biotech-related.

New Scientist Planet Science

http://www.newscientist.com/

This colourful site is chock-full of frequently updated science news. The on-line version of the leading popular scientific journal in Europe, "Planet Science" includes such features as answers to seemingly wacky scientific questions, ideas for experiments, interviews and news tidbits. Although the award winning site covers all kinds of science stories, some of the best coverage is of biotechnology.

If you would like to receive future issues of this agbiotechnology information publication for schools, please contact:

Ag-West Biotech Inc., 101-111 Research Drive
Saskatoon, Sask., S7N 3R2 Canada
(306) 975-1939 Fax: (306) 975-1966
E-mail: agwest@agwest.sk.ca
Web: http://www.lights.com/agwest

Published by
Westcross House Publications, 608 Duchess Street
Saskatoon, Sask., S7K 0R1 Canada
(306) 934-1772 Fax: (306) 664-6615
E-mail: signatur@eagle.wbm.ca

Funding assistance provided by
Saskatchewan Agriculture and Food

To BST or Not to BST

Objectives:

1. To develop an understanding of how bST is used and why.
2. To develop an understanding of bST effects milk production and milk quality.
3. To discuss some of the pros and cons of utilizing bST.

Interest Approach:

Take the Pre-Quiz

Background Information:

Hormone: chemical secreted by glands which affect the way a body operates; bST must be injected it cannot be fed or it would be broken down in the gut

E. coli: a naturally occurring intestinal bacterium, has been genetically engineered to produce bST

Milk Composition and Safety: All milk contains natural bST that is produced by the cow. Milk from cows treated with bST contains the same levels of bST as natural milk.

Assignment:

Upon reading and reviewing the information about bST each student will write an answer to the following scenario.

Scenario:

Assume you are a dairy farmer who milks 100 cows. Would you use bST in your herd? Why or Why not? (Explain with as much detail as possible.)

Name _____

Pre Quiz on bST

1. T F bST is a hormone which is produced and secreted in cattle.

2. T F bST is only in milk from cows injected with bST.

3. T F Cows treated with bST produce more milk with greater efficiency.

4. T F bST was the first FDA approved hormone for livestock.

5. T F Feeding bST will increase milk production but not as much as injecting bST.

6. T F Milk can be tested to see if it is from cow's that have been injected with bST.

7. T F bST in milk is absorbed into the blood stream of humans who consume milk.

8. T F Small dairy farmers cannot get the same production increases by using bST.

9. T F bST is a protein.

10. T F Levels of insulin like growth factor I are lower in milk from cows injected with bST than in milk from non-injected cows.

Bovine Somatotropin (bST)

-Pre-test Answer Key-

1. T bST is a protein hormone produced in cattle by the pituitary gland located at the base of the animal's brain.

2. F All milk contains bST whether injected or naturally occurring.

3. T Milk yields are significantly increased when cows are injected with bST. Feed efficiency is increased because more milk is produced.

4. T bST was approved by the FDA on November 5, 1993 for increasing milk production in dairy cows.

5. F Feeding bST will not work. The hormone bST is a complex protein which is rendered ineffective when it enters a cow's digestive system.

6. F All milk contains bST whether it occurs naturally or from bST that is injected in a cow.

7. F bST is a protein which is digested in the stomach; therefore, it will not be absorbed into the bloodstream.

8. F All dairy cows injected with bST will increase milk yields significantly.

9. T bST is a hormone which is a complex protein.

10. F Insulin-like growth factor I increases by up to two-fold in milk from treated cows, but it is still well within the range for both bovine and human milk.

Biotechnology Information Series

Bovine Somatotropin (bST)

What is bovine somatotropin (bST)?

Bovine somatotropin is a growth hormone found in cattle. The word "bovine" refers to cattle, and the word "somatotropin" refers to the name of the hormone. Hormones are chemicals that are secreted by glands within the body. They are natural substances that affect the way the body operates. Bovine somatotropin, abbreviated as bST, is a protein hormone produced in cattle by the pituitary gland located at the base of the animal's brain.

A hormone similar to bST is produced in all species of animals. This hormone is important for growth, development, and other bodily functions of all animals. In the 1930s, it was discovered that injecting bST into lactating (milk-producing) cows significantly increased milk production.

How did scientists develop bST?

Until recently, the only source of bST was from the pituitary glands of slaughtered cattle. There were only small quantities of bST available, and it was very expensive.

Now, the new science of biotechnology makes it possible to work with DNA, the part of a cell that contains the genetic information for an animal or a plant. Scientists have determined which gene in cattle controls or "codes" for the production of bST. They have removed this gene from cattle and inserted it into a bacterium called *Escherichia coli*. This bacterium, which is found in the intestinal tract of humans and animals, acts like a tiny factory and produces large amounts of bST in controlled laboratory conditions. The bST produced by the bacteria is purified and then injected into cattle (figure 1).

The movement of a gene from one organism to another, in this case from the pituitary gland of a cow to a bacterial organism, is called "recombinant DNA technology." Several Food and Drug Administration (FDA) approved drugs, including insulin for the treatment of diabetes and tissue plasminogen activator (TPA) for the treatment of heart attacks in people, are produced in a similar way.

How does bST affect milk production?

To affect a cow's milk production, bST must be injected into the animal on a regular basis, similar to the way insulin must be regularly injected into people who have certain types of diabetes. Feeding bST to cows will not work. Amino acids and peptides are the building blocks of proteins. The hormone bST is a complex protein that is immediately broken down into small, inactive amino acids and peptides and rendered ineffective when it enters a cow's digestive system. How often a cow must be injected with bST will depend on whether a bST product can be developed that releases the hormone gradually over a long period of time.

Milk yields are significantly increased when cows are injected with bST, although not as much as some reports in popular newspapers and magazines suggest. The exact details of how bST increases milk production are not known, but it is thought that blood flow to the cow's mammary (milk-producing) gland is increased. The blood carries an increased amount of nutrients available for milk production. More nutrients are extracted from the blood by the mammary gland, which improves efficiency of milk production. Feed efficiency (pounds of milk produced per pound of feed consumed) is improved because more milk is produced and the proportion of feed used for body maintenance is decreased. The actual amount of feed consumed by bST-treated cows increases, helping the cow meet the increased nutrient demands.

North Central Regional
Extension Publication
Bio-3 (pre-print) Revised

Milk production in bST-treated cows increases from 4.8 to 11.2 pounds per day. Feed efficiency improves from 2.7 to 9.3 percent (Peel, et al.). Table 1 summarizes the results of 32-week treatments of cows injected with bST in several states and foreign countries.

Misinformation provided by some groups gives the impression that there is controversy about the biology of somatotropin. However, 800 reports on 20,000 treated cows have yielded remarkably consistent results worldwide (Bauman).

Researchers have summarized several bST trials and found a milk production increase of 8.4 pounds per day (Bauman). They estimated that, depending on how the dairy operation is managed, average increased milk production is expected to range from 8.5 to 17.6 percent.

It is difficult to predict how individual cows will respond to bST. A higher response is seen when treatment is started after the cow has been producing milk for 101 days, rather than when treatment is started on days 57-100 after calving. The response of cows treated in early lactation is less (Bauman). Cows that have had more than one calf show a greater increase in milk production than do first lactation heifers (Peel, et al.). Milk yield gradually increases for the first few days after bST treatment begins. A maximum increase is seen in about six days. To meet the needs for this increased milk production, treated cows consume from 10 to 20 percent more grain and forage.

Normally, cows reach their peak milk production 7-9 weeks after lactation begins. Milk quantity then slowly declines throughout the remainder of lactation. The ability of cows to maintain relatively high levels of milk production throughout lactation is called "persistency." The major response of cows treated with bST is a significant improvement in persistency. The normal decrease in milk yield as lactation progresses is markedly reduced. Quality of management, including health programs, milking practices, nutrition, cow condition, and environmental conditions will be major factors in the response to bST.

What are the benefits and risks of bST?

The commercial use of bST in dairy cattle is controversial and has stirred heated debate among the dairy industy, activist groups, and consumers.

Effects on cow health

The physiological effects of bST treatment are the same as those seen in any high-producing cow. Nutrition, health programs, environment, and milking technique must be appropriate for the use of bST or results will be disappointing. On many farms, the management changes instituted by producers as they are preparing to use bST will probably cause a greater increase in milk production, efficiency, and profitability than actual use of bST. In the initial stages of use, producers will be encouraged to use bST on cows that have been in lactation for at least 100 days, are in good physical condition, pregnant, and are free from health problems such as mastitis or infertility.

Concern has been expressed regarding the effect of bST on reproduction. The optimum calving interval of 12-13 months may lengthen because bST can extend the time that cows efficiently produce milk. Dairy Herd Improvement Association (DHIA) records show that higher milk-producing herds have lower conception rates than lower producing herds (Ferguson and Skidmore). This negative effect on reproduction is seen in cows treated with bST and is associated with increased milk production. However, some people believe that a longer calving interval could benefit the health of bST- treated cows, since many health problems of dairy cows are associated with calving and rebreeding. The ability of a cow to reproduce is affected by her physical condition, nutrition, health, and level of milk production.

Few research studies have investigated the physiological effects of bST on the functioning of the ovaries and pituitary gland. Cows receiving dosages of bST far beyond what will be used in practice have shown an adverse

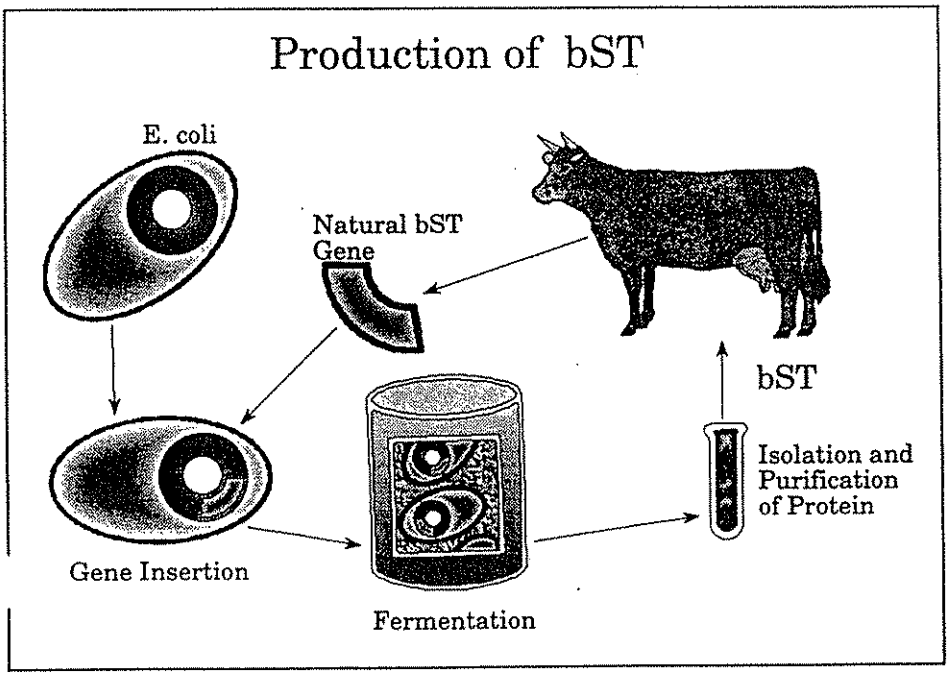


Figure 1. bST production

Table 1. Increases in milk production and feed efficiency of bST-treated cows (Peel, et al.)

Location	Increase in Milk Yield (%)	Increase in Feed Efficiency (%)
Arizona	8.3	2.7
Cornell University	11.5	5.3
Missouri/Monsanto	21.8	8.2
Utah/Utah State U.	14.6	5.3
France	17.8	9.3
Germany	16.6	4.9
Netherlands	18.5	7.6
United Kingdom	19.2	5.4

effect on estrous activity (the time when an animal is capable of being bred). This effect is not seen when cows receive low to average dosages of bST. High dosages of bST are reported to increase the death rate of calf embryos, so starting a cow on bST during early pregnancy should probably be avoided (Ferguson and Skidmore). This effect is not seen at recommended dosages. The effect of bST on reproduction will have to be monitored closely in individual herds.

Several research studies have shown that bST is not associated with increased mammary infections (mastitis) (Ferguson and Skidmore). Other studies have shown an increase in mammary gland infections when bST is used, but the increase is what would be expected with increased production. The length of a cow's gestation (pregnancy), calf birth weight, calf survival rate, and calf growth are not influenced by using the product. Some early reports indicated an increased incidence of twins, but later reports failed to confirm this.

Milk composition and safety

Consumer advocates and others have expressed concern about the safety of milk from bST-treated cows. All milk contains natural bST that is produced by the cow. Milk from bST-treated cows also contains the same amounts of injected bST and no differences can be measured compared to untreated cows. There are four forms of natural bST, and each has a chain of either 190 or 191 amino acids. The recombinant bST that is injected into cows has 191 amino acids. The biological activity of commercial bST is identical to naturally produced bST.

Studies indicate that both natural bST produced by the cow and bST produced by recombinant DNA techniques are immediately broken down into inactive amino acids and peptides in the digestive tract when they are consumed by humans. In contrast, steroid hormones such as estrogens, progesterones, and anabolic steroids are smaller, ring-like structures that are absorbed from the digestive tract and are biologically active in humans. This is not the case with bST in milk, whether it is produced naturally by the cow or by recombinant DNA technology (Barbano and Lynch).

Studies show that bovine somatotropin is inactive in humans. During the 1950s, natural bST produced by cows was injected into children with growth defects in an attempt to encourage growth. There was no effect, probably because the bovine somatotropin protein molecule differs from human somatotropin (human growth hormone) by about 30 percent of the amino acid sequences.

Milk composition from bST-treated cows has been thoroughly investigated (Barbano and Lynch). The characteristics of milk from bST-treated cows are within the normal range of variation of milk from untreated cows. During the first 28 days of treatment, milk fat increases and milk protein decreases slightly. After longer treatment, cows adjust their nutrient intake and the normal balance is re-established. An increase in non-protein nitrogen and whey protein and a decrease in casein have been observed after long-term bST administration. This difference is not always significant, and the effect on cheese yield would probably be minor, if any. One study showed a slight increase in unsaturated compared to saturated fat. The difference was small, but suggested a healthier product from bST treatment. No differences in free fatty acids have been observed. Cholesterol levels are in the range of normal milk composition. Insulin-like growth factor I increases by up to two-fold in milk from treated cows, but it is still well within the range for both bovine and human milk. No differences in flavor have been found.

The National Institute of Health has concluded that milk from bST-treated cows is essentially the same as from untreated cows, and there is no difference in safety of the products.

Table 1. Increases in milk production and feed efficiency of bST-treated cows (Peel, et al.)

Location	Increase in Milk Yield (%)	Increase in Feed Efficiency (%)
Arizona	8.3	2.7
Cornell University	11.5	5.3
Missouri/Monsanto	21.8	8.2
Utah/Utah State U.	14.6	5.3
France	17.8	9.3
Germany	16.6	4.9
Netherlands	18.5	7.6
United Kingdom	19.2	5.4

effect on estrous activity (the time when an animal is capable of being bred). This effect is not seen when cows receive low to average dosages of bST. High dosages of bST are reported to increase the death rate of calf embryos, so starting a cow on bST during early pregnancy should probably be avoided (Ferguson and Skidmore). This effect is not seen at recommended dosages. The effect of bST on reproduction will have to be monitored closely in individual herds.

Several research studies have shown that bST is not associated with increased mammary infections (mastitis) (Ferguson and Skidmore). Other studies have shown an increase in mammary gland infections when bST is used, but the increase is what would be expected with increased production. The length of a cow's gestation (pregnancy), calf birth weight, calf survival rate, and calf growth are not influenced by using the product. Some early reports indicated an increased incidence of twins, but later reports failed to confirm this.

Milk composition and safety

Consumer advocates and others have expressed concern about the safety of milk from bST-treated cows. All milk contains natural bST that is produced by the cow. Milk from bST-treated cows also contains the same amounts of injected bST and no differences can be measured compared to untreated cows. There are four forms of natural bST, and each has a chain of either 190 or 191 amino acids. The recombinant bST that is injected into cows has 191 amino acids. The biological activity of commercial bST is identical to naturally produced bST.

Studies indicate that both natural bST produced by the cow and bST produced by recombinant DNA techniques are immediately broken down into inactive amino acids and peptides in the digestive tract when they are consumed by humans. In contrast, steroid hormones such as estrogens, progesterones, and anabolic steroids are smaller, ring-like structures that are absorbed from the digestive tract and are biologically active in humans. This is not the case with bST in milk, whether it is produced naturally by the cow or by recombinant DNA technology (Barbano and Lynch).

Studies show that bovine somatotropin is inactive in humans. During the 1950s, natural bST produced by cows was injected into children with growth defects in an attempt to encourage growth. There was no effect, probably because the bovine somatotropin protein molecule differs from human somatotropin (human growth hormone) by about 30 percent of the amino acid sequences.

Milk composition from bST-treated cows has been thoroughly investigated (Barbano and Lynch). The characteristics of milk from bST-treated cows are within the normal range of variation of milk from untreated cows. During the first 28 days of treatment, milk fat increases and milk protein decreases slightly. After longer treatment, cows adjust their nutrient intake and the normal balance is re-established. An increase in non-protein nitrogen and whey protein and a decrease in casein have been observed after long-term bST administration. This difference is not always significant, and the effect on cheese yield would probably be minor, if any. One study showed a slight increase in unsaturated compared to saturated fat. The difference was small, but suggested a healthier product from bST treatment. No differences in free fatty acids have been observed. Cholesterol levels are in the range of normal milk composition. Insulin-like growth factor I increases by up to two-fold in milk from treated cows, but it is still well within the range for both bovine and human milk. No differences in flavor have been found.

The National Institute of Health has concluded that milk from bST-treated cows is essentially the same as from untreated cows, and there is no difference in safety of the products.

Economics

The potential economic effect of bST on the family dairy farm has generated heated debate. The nimal Health Institute, an organization of drug and vaccine manufacturers, maintains that the use of bST will be of equal value to any size farm (Milligan). They contend that use of the product will favor the good dairy manager, regardless of farm size.

Estimates of the effect of bST on dairy production have probably been exaggerated. The United States Department of Agriculture estimates that the use of bST could lead to a 2 to 5 percent increase in national milk production within five years, or about the increase seen yearly without the use of bST. This increase would be in addition to the normal milk production increase per cow.

In most dairy herds, bST will not be used in cows until they have been in lactation for about 100 days. It will not be used in cows with chronic health or fertility roblems. It is expected that bST ill be used less in heifers than in adult cows. If 50 percent of farmers adopt the use of bST, and it is used in 60 percent of the lactation days per user herd, milk production will increase about 3.5 percent (assuming an average per cow production increase of 15 percent). Many well-managed dairy herds increase per cow production more than this on an annual basis by using improved management and genetics. For most herds, a farmer who requests a thorough herd analysis by a competent nutritionist and veterinarian and then follows their recommendations will achieve a larger increase in milk production than by using bST alone.

Failure to adopt proven technology is a problem throughout the dairy industry. Almost 60 percent of cows are bred by mating to a bull, rather than by artificial insemination from proven sires ith superior genetic performance. Only 50 percent of U.S. dairy producers use DHIA management information and records to improve production.

The government milk price support system tends to make prediction of the effect of bST on milk prices difficult. It is true, however, that efficient managers in areas of the country with higher milk prices benefit more from application of technology and increased production.

It is argued that large commercial dairy operations can begin using new technologies such as bST more easily, rapidly, and efficiently than smaller operations. Sophisticated record keeping and division of labor may make timely injection of cows with bST more feasible for these larger operations. Other demands on the time and management skills of typical Midwest dairy producers who have diversified farming operations may make new technology more difficult to implement.

Others argue that smaller producers with direct owner control of the herd can manage individual cows better and will see a greater production increase from the use of bST. It is not automatically true that larger herds are better managed and, therefore, will benefit more from bST.

There is no question that consumer loss of confidence in the quality of milk produced by using bST, whether the reasons are logical or not, would reduce milk consumption and have a negative economic impact on the dairy industry. This is a major concern of dairy producers. Relative to milk quality, bST appears to be neutral. It neither improves nor harms quality. Consumers would gain with bST technology since milk production costs may decline due to improved efficiency. The ultimate effect of use of bST on consumption is unknown.

How is bST regulated?

The United States Food and Drug Administration (FDA) is responsible for regulating the use of bST since it is an animal drug and because milk and meat are food products. Several commercial companies have submitted data to the FDA, asking for approval to use bST in dairy cows to increase milk production.

Before approval of bST for use in dairy herds, the FDA allowed the consumption of milk and meat from animals that received bST as part of the experimental testing process. Such approval is often granted during the process of license approval of animal products. Milk from treated cows has been judged safe because bST is biologically inactive in humans and is a protein hormone that is digested and destroyed by gastric enzymes when it is consumed. Each company seeking approval for bST has to demonstrate that bST has zero biological activity in milk when it is consumed. "The FDA has found no pertinent information indicating that food derived from bST-treated cows is unsafe." (Review). It is not required that producers withhold milk from the market for a certain period of time after test herd cows have been treated with bST.

Federal law prohibits the social and economic effects of a product from affecting the FDA's decision whether to approve its use or not. The FDA must determine if a product is safe, pure, potent, and effective. Producers can decide whether a product is economical or useful. Approval by the FDA does not mean that a product must be used, but only that it can be used, if desired.

Testing required by the FDA

Before any new product can be approved, companies must demonstrate its effectiveness under actual use conditions in several geographic locations. Fifty cows per herd are required for bST approval. Three dosages of bST were used for the studies submitted to the FDA. The quality control of bST used in the test herds was monitored and all procedures to be used were approved by the FDA before the

testing began. The majority of the tests in the approval process were performed by independent scientists at university laboratories and farms or in commercial herds.

Cows were injected with bST at various times during the lactation period. The effectiveness of the drug and its safety for the first and later lactation periods were monitored. Milk yield was calculated on a 3.5 percent fat basis. Milk composition, including fat, crude protein, lactose, calcium, and phosphorus, were measured about once per week. Daily feed intake was measured in the test herds. Body condition and health were monitored throughout the studies. The effect of bST treatment on reproduction was evaluated, including breeding cycles, conception rates, number of breedings per conception, length of time from calving to the next conception, abortions, incidence of twins, calving difficulties, and stillbirths. The weight, growth, and health of calves during the first four weeks of life were monitored. Monthly somatic cell counts, as a measure of mastitis, were required. The sites where bST was injected were monitored for any signs of adverse reactions.

To evaluate safety, companies had to use one, three, and five times the expected dosage level of bST for two consecutive lactations in one of their test herds. Heifers born to treated cows were raised through breeding age and monitored for abnormalities. Companies seeking approval for bST were also required to prove that its use was not harmful to the environment.

First bST product approval granted by FDA

On November 5, 1993, the FDA announced approval of a bST product, the animal drug sometribove, for increasing milk production in dairy cows. The Monsanto Company of St. Louis, Missouri, developed the drug. However, the drug could not be used immediately due to a 90-day moratorium imposed by Congress during the summer of 1993. The moratorium was designed to give the White House Office of Management and Budget time to study possible consumer reaction and the drug's impact on the dairy industry.

The FDA approval also carried with it some provisions to deal with antibiotic residue concerns. In September 1992, the General Accounting Office reported that the FDA had found evidence in submitted clinical trials that bST-treated cows have a slightly increased incidence of mastitis. This report raised concerns that antibiotic treatments for mastitis could lead to increased antibiotic residues in milk. States require milk to be tested for drug residues. Milk found to have unsafe levels of residues must be discarded.

Although an FDA advisory committee concluded in March 1993 that adequate safeguards exist to prevent unsafe levels of antibiotic residues from entering the milk supply, additional steps were taken to ensure that any unsafe residues in the milk of bST-treated cows are detected before the milk or its products are marketed.

According to a news release issued by the U.S. Department of Health and Human Services (HHS News), Monsanto agreed to a post-approval monitoring program that includes:

- A two-year tracking system of milk production and drug residues in 21 top dairy states that will periodically compare the amount of milk discarded after bST is marketed to the amount discarded prior to approval.
- A 12-month comparison of the proportion of milk discarded due to positive drug tests between bST-treated and untreated herds.
- A reporting system to monitor all bST use and follow up on all complaints.
- The use of sometribove in 24 commercial dairy herds will be specifically monitored for mastitis, animal drug use, and the resulting loss of milk.

The FDA has concluded that it has no legal basis to require special labeling of food products derived from bST-treated cows. Food companies may voluntarily label their products, provided the information is truthful and not misleading to consumers.

What are the controversies concerning the use of bST?

The most intense controversy surrounding approval of bST for use in dairy cows has occurred in major dairy producing states in the Great Lakes and New England areas. Representatives of the dairy industry are concerned about the ultimate economic effect on producers.

Consumer and environmental advocacy groups have expressed opposition based on concerns about milk quality and the use of biotechnology in general.

Dairy producers

Some producers are afraid that they will not be able to keep up with new technologies and they will suffer economically as a result. Others feel that a product such as bST will work to the disadvantage of producers in the Great Lakes States and the Northeast. Natural resistance to new technology adoption and a fear of genetic engineering techniques cause some producers to resist the approval and use of bST.

Special interest groups

Activist groups with a variety of agendas and motives have addressed the bST issue. Some have stated that milk from treated cows may not be safe after all, and more testing is needed. Others see this as a scare tactic to delay or block the use of bST and undermine consumer confidence in milk from bST-treated cows. Some animal rights groups see the use of animals for food, under any circumstances, as inhumane or a violation of those animals' "rights."

testing began. The majority of the tests in the approval process were performed by independent scientists at university laboratories and farms or in commercial herds.

Cows were injected with bST at various times during the lactation period. The effectiveness of the drug and its safety for the first and later lactation periods were monitored. Milk yield was calculated on a 3.5 percent fat basis. Milk composition, including fat, crude protein, lactose, calcium, and phosphorus, were measured about once per week. Daily feed intake was measured in the test herds. Body condition and health were monitored throughout the studies. The effect of bST treatment on reproduction was evaluated, including breeding cycles, conception rates, number of breedings per conception, length of time from calving to the next conception, abortions, incidence of twins, calving difficulties, and stillbirths. The weight, growth, and health of calves during the first four weeks of life were monitored. Monthly somatic cell counts, as a measure of mastitis, were required. The sites where bST was injected were monitored for any signs of adverse reactions.

To evaluate safety, companies had to use one, three, and five times the expected dosage level of bST for two consecutive lactations in one of their test herds. Heifers born to treated cows were raised through breeding age and monitored for abnormalities. Companies seeking approval for bST were also required to prove that its use was not harmful to the environment.

First bST product approval granted by FDA

On November 5, 1993, the FDA announced approval of a bST product, the animal drug sometribove, for increasing milk production in dairy cows. The Monsanto Company of St. Louis, Missouri, developed the drug. However, the drug could not be used immediately due to a 90-day moratorium imposed by Congress during the summer of 1993. The moratorium was designed to give the White House Office of Management and Budget time to study possible consumer reaction and the drug's impact on the dairy industry.

The FDA approval also carried with it some provisions to deal with antibiotic residue concerns. In September 1992, the General Accounting Office reported that the FDA had found evidence in submitted clinical trials that bST-treated cows have a slightly increased incidence of mastitis. This report raised concerns that antibiotic treatments for mastitis could lead to increased antibiotic residues in milk. States require milk to be tested for drug residues. Milk found to have unsafe levels of residues must be discarded.

Although an FDA advisory committee concluded in March 1993 that adequate safeguards exist to prevent unsafe levels of antibiotic residues from entering the milk supply, additional steps were taken to ensure that any unsafe residues in the milk of bST-treated cows are detected before the milk or its products are marketed.

According to a news release issued by the U.S. Department of Health and Human Services (HHS News), Monsanto agreed to a post-approval monitoring program that includes:

- A two-year tracking system of milk production and drug residues in 21 top dairy states that will periodically compare the amount of milk discarded after bST is marketed to the amount discarded prior to approval.
- A 12-month comparison of the proportion of milk discarded due to positive drug tests between bST-treated and untreated herds.
- A reporting system to monitor all bST use and follow up on all complaints.
- The use of sometribove in 24 commercial dairy herds will be specifically monitored for mastitis, animal drug use, and the resulting loss of milk.

The FDA has concluded that it has no legal basis to require special labeling of food products derived from bST-treated cows. Food companies may voluntarily label their products, provided the information is truthful and not misleading to consumers.

What are the controversies concerning the use of bST?

The most intense controversy surrounding approval of bST for use in dairy cows has occurred in major dairy producing states in the Great Lakes and New England areas. Representatives of the dairy industry are concerned about the ultimate economic effect on producers.

Consumer and environmental advocacy groups have expressed opposition based on concerns about milk quality and the use of biotechnology in general.

Dairy producers

Some producers are afraid that they will not be able to keep up with new technologies and they will suffer economically as a result. Others feel that a product such as bST will work to the disadvantage of producers in the Great Lakes States and the Northeast. Natural resistance to new technology adoption and a fear of genetic engineering techniques cause some producers to resist the approval and use of bST.

Special interest groups

Activist groups with a variety of agendas and motives have addressed the bST issue. Some have stated that milk from treated cows may not be safe after all, and more testing is needed. Others see this as a scare tactic to delay or block the use of bST and undermine consumer confidence in milk from bST-treated cows. Some animal rights groups see the use of animals for food, under any circumstances, as inhumane or a violation of those animals' "rights."

Others have stated that cows have a right not to be injected with bST.

Others

Other opposing arguments state that the FDA does no independent testing of its own, but only monitors the studies of the companies seeking approval. The persistent oversupply of milk and dairy products has also been cited as a reason to block the use of bST. Some dairy farmers oppose the use of bST but feel they would have no choice but to use the product in their own herd in order to stay competitive if bST came into general use (McDermott).

Table 2 summarizes arguments for and against the use of bST in the categories of food safety and its effect on the number and size of farms.

What lies ahead?

Use of bST will have a significant effect on the research and development investment in agricultural biotechnology by commercial firms. Universities will be expected to provide unbiased scientific information.

Patience, tolerance, and understanding will be required by educators, extension workers, and other professionals in agriculture who work with groups that either support or oppose implementation of technology such as bST.

For more information

Dairy News and Information Center, 2233 Wisconsin Avenue, N.W., Suite 500, Washington, D. C. 20007. Tel. toll-free 1-800-343-2479.

Nolan R. Hartwig, D.V.M. Extension Veterinarian, 2270E Veterinary Medicine Complex, Iowa State University, Ames, Iowa 50011. Tel. (515) 294-8790.

Agricultural Biotechnology: Issues and Choices. Copyright 1991 by Purdue Research Foundation. Available from Agricultural Communication Service, Media Distribution Center, Purdue University, West Lafayette, Indiana 47907.

Written by Nolan R. Hartwig, D.V.M. Iowa State University Extension Veterinarian, and Glenda D. Webber, Office of Biotechnology, Iowa State University.

References

Barbano, David M. and Joanna M. Lynch. "Milk from bST Treated Cows: Composition and Manufacturing Properties." *Advanced Technologies Facing the Dairy Industry: bST*. Cornell University. Nov. 10-11, 1989.

Bauman, Dale E. "Biology of Bovine Somatotropin." *Advanced Technologies Facing the Dairy Industry: bST*. Cornell University. Nov. 10-11, 1989. p. 1-8.

Ferguson, James D., and Andrew Skidmore. "Bovine Somatotropin — Reproduction and Health." *Advanced Technologies Facing the Dairy Industry: bST*. Cornell University. Nov. 10-11, 1989. p. 57-66.

HHS News. U.S. Department of Health and Human Services. Nov. 5, 1993.

McDermott, Keyron. Editorial, *The Des Moines Register*, Des Moines, Iowa, May 3, 1990.

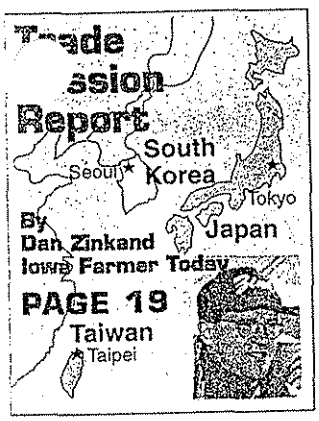
Milligan, Robert A. "Profitability of bST Technology." *Advanced Technologies Facing the Dairy Industry: bST*. Cornell University. Nov. 10-11, 1989. p. 36-48.

Peel, C. J.; D. L. Hurd; K. S. Madsen; and G. de Kerchove. Monsanto Agricultural Company. In *Proceedings, Monsanto Technical Symposium*, Oct. 24, 1989. The Monsanto Company, St. Louis, Missouri.

Review of Bovine Somatotropin. *FDA Veterinarian*. March/April 1990, Vol. V, No. II.

Stanton, B. F., and A. M. Novalovic. "The Impact of bST Technologies: The Pros and Cons." *Advanced Technologies Facing the Dairy Industry: bST*. Cornell University. Nov. 10-11, 1989. p. 142-148.

PRINTED WITH SOY INK ■ COPYRIGHT 1997 ■ PERIODICALS



IOWA FARMER TODAY®

VOL. 13, NO. 39 ■ JUNE 7, 1997 ■ CIRCULATION 72,000 ■ 1 SECTION

Farmers search for profit from CRP land

Signup in brief ~

USDA Secretary of Agriculture Dan Glickman recently announced the national signup for CRP is 16.1 million acres and 522,000 acres in Iowa.

CRP SPECIAL REPORT:

- Iowa farm leaders are not surprised by the latest CRP figures, but they are curious what the change will mean. **PAGE 13**

- With many acres coming out of CRP this fall many producers face decisions about how to return that land into profitable production. **PAGE 16**

IFT photo by Jeff DeYoung

Mills County farmer Paul Speck prepares to plant soybeans on what used to be CRP ground. Speck, who farms near Mineola, will no-till corn and beans. The land came out of the CRP program this year. Many terraces define slopes in this hilly region of Southwest Iowa.

Update: BST quietly accepted at some dairies

By **Jeff DeYoung**

Iowa Farmer Today

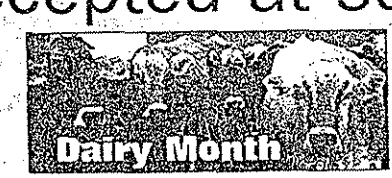
WOOD — Darren Davelaar isn't the type to jump into something with both feet.

Davelaar, who milks 240 Holsteins with his father, Garrett, near here in Lyon County, started using the synthetic hormone bovine somatotropin (BST) in November 1995.

Ten months earlier, the Davelaars started milking three times (3X) a day after adding 200 cows to their Northwest Iowa operation.

"We wanted to just try one thing at a time," Darren says.

After the 3X milking started working well, the Davelaars decided to



give BST a try.

"We had heard it worked real well with heifers, and at that time 80 percent of herd was 2-year-olds," Darren says. "We gave it a try and were satisfied. Now, we use it on our whole herd."

The Davelaars are averaging 6 to 8 pounds more milk daily per cow by using BST.

"We're expecting a lot more from them, so we do all we can to make

See page 4: BST ➡➡➡

IOWA FARMER TODAY

Vice President/Publisher
Steve DeWitt
Publications Editor
Lori Leonard Shellady
Managing Editor
Bob Davis
Business Development Mgr.
Terry Reilly

EDITORIAL
Assistant Editor
Myron Williams
Copy Editor
Ron De Christopher
Crops Field Editor
Dan Zinkand
Contributing Editor
Kevin Blind, Iowa Pork Today
FIELD OFFICES
Gene Lucht
515-964-5501
Joyce Vogelman
515-756-3356
Jeff DeYoung
Livestock Field Editor
712-527-3311

CIRCULATION
Mary Stein 800-475-6655

MAIN OFFICE
Local number
319-398-8461
Nationwide WATS
800-475-6655
Classified nationwide WATS
800-475-4692
FAX number
319-398-8482
E-mail address
ift@fyiowa.com
World Wide Web
http://www.IowaFarmer.com/

Mailing address:
Iowa Farmer Today
P.O. Box 5279
Cedar Rapids, Iowa
52406-5279

PRINTED WITH SOY INK

ABA BPA INTERNATIONAL

Established in 1984, Iowa Farmer Today (USPS 002141) is published by The Gazette Co., 501 Second Ave., S.E., Cedar Rapids, Iowa 52401.
Qualified farm operators receive this publication without charge. Subscription rates to Iowa Farmer Today is $28.00 per year. Iowa Farmer Today is published weekly. Individuals subscribe by calling 1-800-655. Periodicals postage at Cedar Rapids, Iowa, and additional mailing offices.
POSTMASTER: Send address changes to Iowa Farmer Today, P.O. Box 5279, Cedar Rapids, Iowa 52406-5279.

➡➡➡ BST: Producers find BST not a cure-all for all woes

From page 1

the cows more comfortable," Darren says. "We have not had any increase in problems from using BST."

The furor over the use of the growth hormone has subsided considerably in the last year, says Leo Timms, Extension dairy specialist at Iowa State University in Ames. Because of that, BST use in Iowa's dairy herd has increased.

"All the things they talked about, from bad milk to burned-out cows, hasn't happened," he says.

"Some of the processors are taking the milk when they first refused it, and producers are more open to telling you that they use it. We have really seen this increase in the last six months."

Producers also are learning the use of BST is not a cure-all for all their woes. Timms says BST cannot overcome poor management.

"Producers saw others use it early, and at first they were cautious. Now, they're aggressive, and you can do that if your management is in place," he says. "For example, when we had the heat stress problems in 1995, the cows were not eating and people saw that was not the time to use it. They realized those cows had to be in better shape."

After the cows were in better condition, Timms says, producers started looking at BST to boost milk production.

He says BST will work for any size operation. Timms knows of 20- to 30-cow dairies and much larger operations using BST.

Iowa is experiencing an increase in the number of dairy cows. Timms says much of the expansion is coming from smaller producers, particularly in South Central and Northern Iowa. Iowa's dairy industry is at a crossroads.

"We have a lot of people who are asking themselves if they want to be in the dairy business," Timms says.

"We are seeing some expansion, and I don't know if that will lead to more BST use. People view it now as just another management tool."

Darren says it is essential producers contemplating the use of BST understand it will require more management.

"If those things aren't there it probably isn't going to work for you."

He believes BST is being used more frequently in Northwest Iowa, but it's not something dairy producers talk about.

"It's not because people are afraid to talk about it. It's just more accepted," Darren says.

"When it first came out, it was the worst thing in the world. Now, you don't hear much about it." ■

Introduction to Biotechnology

Objectives:

1. To develop a basic understanding of biotechnology.
2. To brainstorm ways in which biotechnology can be utilized to solve problems and improve productivity.
3. To define genetic engineering.
4. To introduce the theory behind the development of the Flav'r Sav'r® tomato.
   (Note: No longer in production?)

Strategies:

Utilize a brainstorming activity to generate interest and develop a basic understanding of genetic engineering.

Activity (Interest Approach):

- Divide the class into groups of 2 to 3 students.
- Provide each group with a clean piece of paper.
- Read the following statement:

> *"Each group will have 3 minutes to design the perfect hog. Before you start designing you may want to generate a list of problems associated with hogs and hog production."*
>
> *"Draw a picture of your hog and select one person from your group who will explain its features."*
>
> (Note: You may substitute the word hog with... dairy cow, corn plant, etc.)

Evaluation:

- Have each group report back and explain the features of their design.
- Reward for the best design.

Discussion Points:

What is biotechnology?
What is genetic engineering?
How does genetic engineering differ from traditional selective breeding?
Would it be possible to make a hog which could photosynthesize?
What would be the possible benefits of producing a hog which could photosynthesize?
How does modern agriculture compare to 100 years ago?
What agricultural developments might we have 100 years in the future?

Assignment:

Read the article about the Flav'r Sav'r® tomato.

FLAVR SAVR™ TOMATOES

We Like Tomatoes

Whether we toss them in salads or slip them onto sandwiches, Americans eat a lot of tomatoes. Each year, an estimated 85 percent of U.S. households purchase tomatoes. And each month, some 55 million of us purchase three pounds of fresh tomatoes from our local grocery store. Tomatoes rank third in vegetable consumption among Americans, behind only potatoes and green salad.

Yet, despite high consumption levels, we are very dissatisfied with the quality of tomatoes we buy. In a 1993 survey, tomatoes ranked #1 in produce items most likely to leave us dissatisfied.

The FLAVR SAVR™ Tomato vs. Other Tomatoes

Today, most fresh tomatoes are picked green, prior to reaching their full flavor potential, in order to be sure they will survive the long journey from the farm to the grocery store. The tomatoes are then transported in refrigerated trucks – often at temperatures below 55 degrees (colder temperatures dramatically reduce flavor). The typical result – tomatoes that look red, but taste green.

The FLAVR SAVR tomato is developed by isolating the polygalacturonase (PG) gene, an enzyme in all tomatoes which causes them to soften and eventually spoil. By putting a copy of this tomato gene into the tomato plant backwards, Calgene Fresh has discovered a way to slow down the tomato's softening process. Thus, FLAVR SAVR tomatoes spend more time on the vine for extra flavor.

FLAVR SAVR tomato seeds are planted and grown just like other tomato seeds. But because FLAVR SAVR tomatoes are slower to soften than other tomatoes, they hold their peak flavor longer.

Giving Consumers A Choice

Because Calgene Fresh wants to provide consumers with the opportunity to make informed choices, the company will voluntarily label each tomato: "MacGregor's, Grown from Flavr Savr Seeds." In addition, Calgene Fresh will provide information at the point of purchase that clearly identifies the tomato as genetically engineered. This consumer information brochure explains how and why the FLAVR SAVR was developed, offers a more technical discussion of the technology, a complete nutritional profile and an "800" phone number to call for more information.

MOST FREQUENTLY CONSUMED VEGETABLES

Vegetable	*Numbers consuming* (per 10,000)
1. Potatoes	4171
2. Green Salad	4030
3. Tomatoes (raw & cooked)	2552
4. Dried peas and beans	1070
5. Green beans	992
6. Cole slaw, cabbage	944
7. Corn	852
8. Carrots	811
9. Green peas	553
10. Onions	385
11. Broccoli	249
12. Greens (collards, etc.)	244
13. Spinach	237
14. Sweet potatoes	158
15. Cooked green peppers	129

Source: **National Cancer Institute**

• • • • • • • • • • • • • • • • • •

Tomatoes rank #1 in produce items most likely to leave consumers dissatisfied.

1. **Tomatoes**
2. Lettuce
3. Apples
4. Bananas
5. Oranges
6. Grapes
7. Cantaloupe
8. Peaches

Source: **The Packer's 1993 Fresh Trends Consumer Profile Study**

The FLAVR SAVR Tomato: A Nutritional Snapshot

Tomatoes are considered a significant source of vitamin A and vitamin C. And, because tomatoes are the third most consumed vegetable among Americans, they rank higher than most other vegetables for U.S. dietary intake of these nutrients. In fact, next to potatoes, Americans consume more vitamin C from tomatoes than from any other vegetable. (Source: National Cancer Institute)

In scientific studies, Calgene Fresh researchers compared the FLAVR SAVR tomato's nutritional profile to that of traditionally bred tomatoes and found no significant differences. The FLAVR SAVR tomato's nutritional profile closely matches that of other tomatoes and, for all nutritional values, measures well within the published range.

HOW BLOCKING THE SOFTENING GENE CHANGES THE FLAVR SAVR TOMATO

Component	*Changed*	*Unchanged*
Nutritional Profile		✔
Potential Toxins		✔
Horticulture traits		✔
Color (pigmentation)		✔
Softening rate	✔	

Safety and Nutritional Tests Reviewed By Expert Panel

Calgene Fresh's safety and nutritional data were reviewed by an external panel of experts, which included Dr. Ian Munro, former Director General for the Food Directorate in Canada's Department of Health and Welfare. Munro summarized the panel's conclusions by saying, "FLAVR SAVR tomatoes are as safe for human consumption as other tomatoes that are currently a part of the human diet."

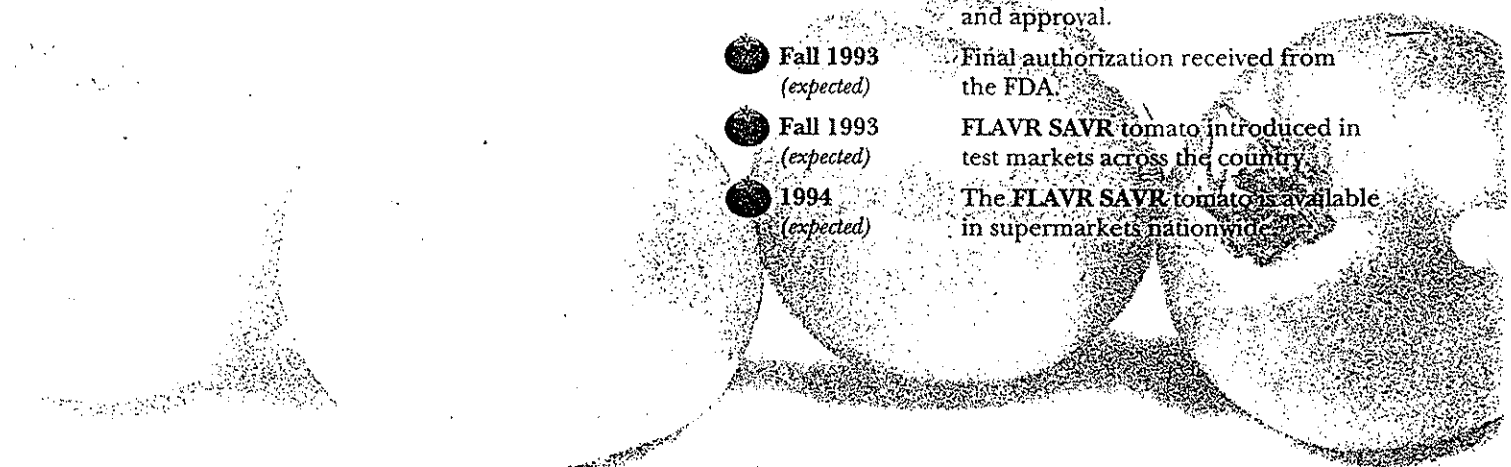
HOW FLAVR SAVR TOMATOES STACK UP ON NUTRITION

Nutritional Component	*Normal Range For All Tomatoes*	*Flavr Savr Ranges*	*Within Normal Range*
Protein	0.85 g – (015 se)	0.75 g – 1.143 se	yes
Vitamin A	192 – 1667 IU	330 – 1600 IU	yes
Vitamin B1 (Thiamin)	16 – 80 µg	38 – 72 µg	yes
Vit. B2 (Riboflavin)	20 – 78 µg	24 – 36 µg	yes
Vitamin B6	50 – 150 µg	86 – 150 µg	yes
Vitamin C	8.4 – 59 mg	15.3 – 29.2 mg	yes
Nicotinic acid	0.3 – 0.855 mg	0.43 – 0.70 mg	yes
Calcium	4.0 – 21 mg	9 – 13 mg	yes
Magnesium	5.2 – 20.4 mg	7 – 12 mg	yes
Phosphorus	7.7 – 53 mg	25 – 37 mg	yes
Sodium	1.2 – 32.7 mg	2 – 5 mg	yes
Iron	0.2 – 0.95 mg	0.2 – 0.41 mg	yes

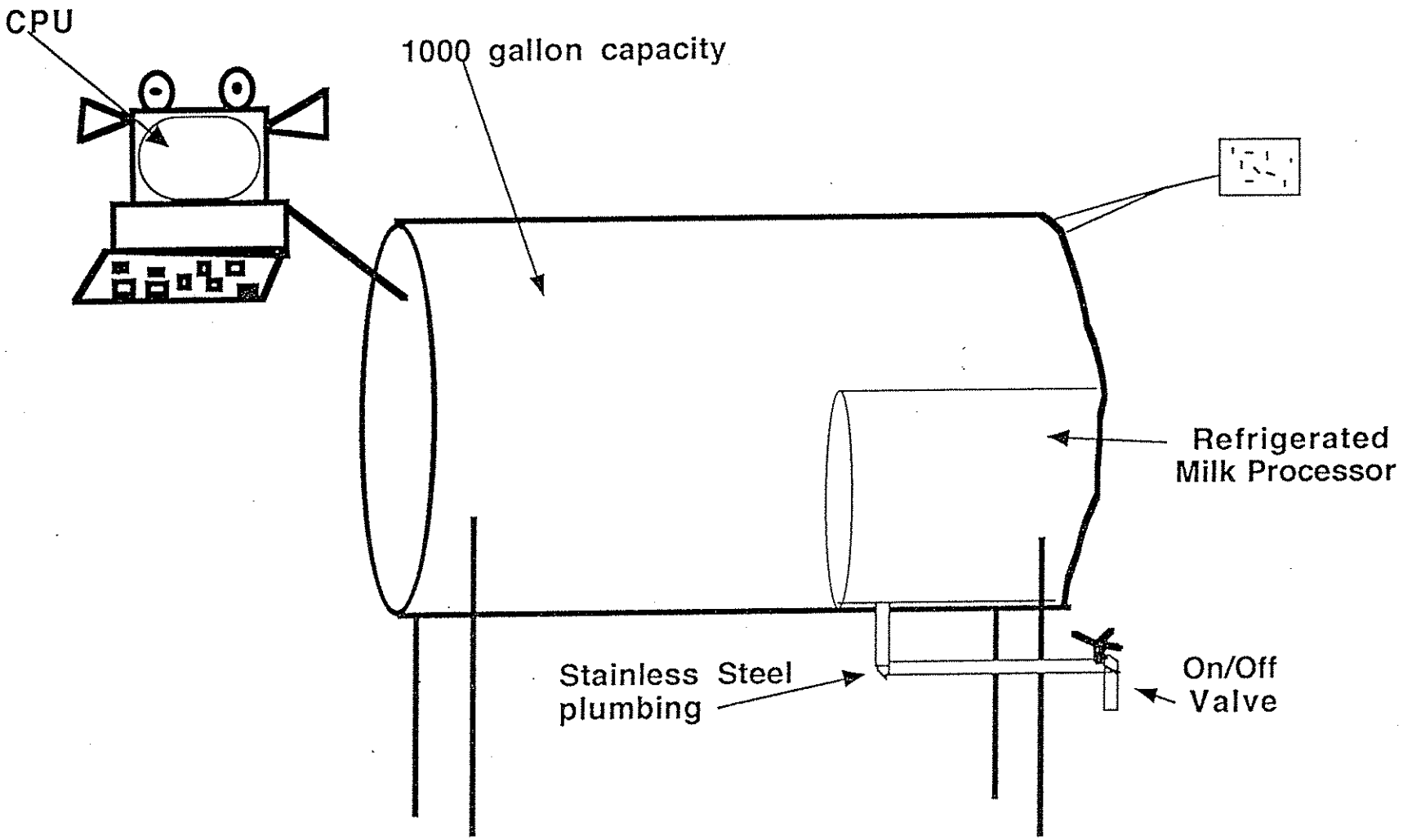
* Measurements based on 100g fresh tomato

DEVELOPMENT OF THE FLAVR SAVR TOMATO

1982-1989	Pioneering research conducted to solve an age old problem – how to supply an abundance of great tasting tomatoes throughout the year.
1989	Fresh tomato varieties selected meeting FLAVR SAVR tomato specifications.
October 1992	U.S. Department of Agriculture determines the FLAVR SAVR tomato does not present a plant pest risk and therefore field trials need not be regulated.
February 1993	Nationally recognized panel of food safety experts reviews data and concludes the FLAVR SAVR tomato is as safe as any other tomato currently part of the human diet.
March 1993	Pre-market testing completed on the FLAVR SAVR tomato and data submitted to the U.S. Food & Drug Administration (FDA) for its review and approval.
Fall 1993 *(expected)*	Final authorization received from the FDA.
Fall 1993 *(expected)*	FLAVR SAVR tomato introduced in test markets across the country.
1994 *(expected)*	The FLAVR SAVR tomato is available in supermarkets nationwide.



The Perfect Dairy Cow



"DOWN on the PHARM"

Objective: To understand medicines of the past, present, and future.

Materials: Donuts, knives, handout, internet or magazines

Interest Approach: Write the words "farm" and "pharm" on the board. In groups of two, the students should come up with a definition for each word, then discuss what the differences between the definitions of the two words might be as a large group.

Instruction: Begin with a discussion of how pharmaceuticals are developed today. Ask students about alternative pharmaceutical production.

Provide students with the two handouts. One handout is an article ("Using Transgenic Plants to Make Medicines"); the other has the terms to be defined listed on it. Have the students define the words using the article. After the students have wrote down the definitions, discuss the words and their meanings in class.

Following this, the students should read the article, and a discussion should take place following the silent reading session. It is suggested that you introduce the three areas of research concerning the use of transgenic tobacco plants. 1) Transgenic tobacco plants containing human genes that control blood clotting. 2) Transgenic seeds containing antiviral drugs. 3) Anti-freeze proteins used to preserve the quality of frozen cells, sperm, and embryos.

Biopharmaceuticals - drugs produced in living organisms

Genes - the living blueprints that control inherited traits

Genetic Engineering - modification of organisms by "cutting" specific genes from one plant, animal, or bacteria and "pasting" them into another organism

Niche - Small, specialized

Nutraceuticals or Functional Foods - foods with high levels of specific nutrients that are useful in health care

Pharm - Biopharmaceuticals are grown here

Phytochemicals - chemicals in plants that can be used in making drugs, health foods, and cosmetics

Transgenic - genetically modified

Activity: Plasmids (Genetic Engineering). This activity is designed to help students visualize the concept of plasmid transfer with regard to genetic engineering. A copy of the activity is provided.

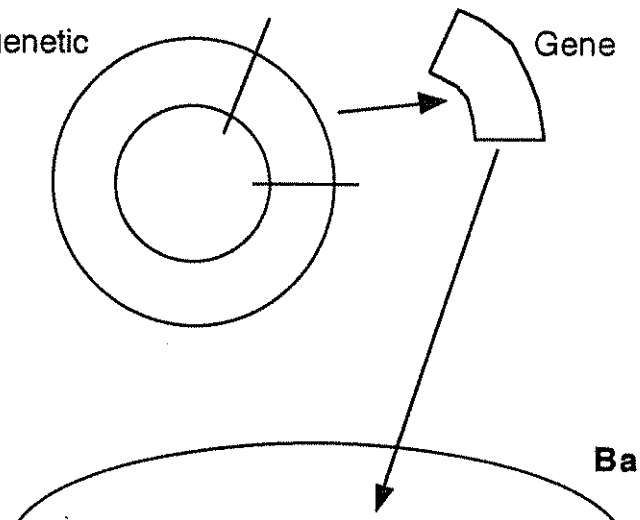
Plasmids
(Genetic Engineering)

Description:
An activity to help students visualize the concept of plasmid transfer with regard to genetic engineering.

Objectives:
To understand plasmid transfer.
To identify applications of genetic engineering for agricuture.

Materials Needed:
- Donuts
- Snip a piece of donut. This represents a "chunk" of genetic material which can be released by using "scissor enzymes".

Plasmid
Ring of genetic material



Bacteria: plasmid inserted into bacterium which then replicates the plasmid and injects into a plant cell.

Plant Cell

The plant cell then incorporates the plasmid into its DNA.

THE AGBIOTECH INFOSOURCE

Issue 22 July, 1996

Published by AG-WEST BIOTECH INC.

Using Transgenic Plants to Make Medicines

Producing Medicines down on the "Pharm"

Plants: Medicines of the Past, Present, and Future

Plants have been an important source of medicine for thousands of years. Even today, the World Health Organization of the United Nations estimates that up to 80 per cent of people still rely mainly on traditional remedies such as herbs for their medicines.

Plants are also the source of many modern *pharmaceuticals* (drugs). It is estimated that approximately one quarter of prescribed drugs contain plant extracts or active ingredients obtained from or modeled on plant substances. Some of our ·t known medicines fit into this category; aspirin, for mple, is a synthetic version of a traditional pain remedy derived from the bark of willow trees.

In recent years, pharmaceutical companies have intensified the screening of plants for substances that may be useful in making new or improved medicines. Several Saskatchewan companies are actively involved in the research and development of pharmaceuticals derived from plants, as well as *nutraceuticals* or *functional foods* (foods with high levels of specific nutrients that are useful in health care).

Fytokem Inc. of Saskatoon is involved in the preparation of plant extracts and *phytochemicals* (chemicals in plants that can be used in making drugs, health foods, and cosmetics.) Saskatoon's *Bioriginal Food and Science Corp.* derives health products from specialty crops that are grown in Saskatchewan. For example, *Bioriginal* markets a high-potency *gama linolenic acid - GLA (*a fatty acid that is useful in controlling inflammation) derived from the borage plant.

What Are Biopharmaceuticals?

Researchers are now exploring the potential of biotechnologies such as genetic engineering to extend the range of products, including medicines, that can be obtained from plants.

Genetic engineering involves the modification of organisms by "cutting" specific *genes* (the living blueprints that control inherited traits) from one plant, animal, or bacteria and "pasting" them into another organism. This biotechnology has many uses, including the production of "non-plant" products in plants. Scientists are, for example, attempting to add genes to canola plants that will make them produce a type of biodegradable plastic.

Biotechnology can also be used to make *biopharmaceuticals* (drugs produced in living organisms). While the small number of biopharmaceuticals currently available are all produced in mammalian cell and tissue cultures, researchers have now developed genetic modification techniques that can be used to transform animals and plants into living "factories" capable of producing drugs.

The technology to produce biopharmaceuticals in plants is still experimental and no drugs from this technique are currently available. However, research is starting to yield results:

- Cooperative research by the University of Ottawa, Health Canada, and the Canadian Red Cross Society has succeeded in producing *transgenic* (genetically modified) tobacco plants containing human genes that control blood clotting. These substances can be used to treat immune system disorders that often follow bone marrow transplants.

- The same consortium is developing a vaccine useful against a virus called CMZ. This virus is harmful to people whose immune systems are weak. The researchers have succeeded in expressing the vaccine in tobacco seeds, and are working on its expression in rice. Ultimately, they believe it may be possible for people to take their medicine simply by eating transgenic seeds containing the antiviral drug.

- A researcher at Queen's University in Ontario has used genetic engineering to transfer the genes controlling the proteins that keep fish from freezing into tobacco plants. Although these "anti-freeze" proteins are not used in drugs, the researchers anticipate that they will be useful in the medical field to preserve the quality of frozen cells, sperm, and embryos.

Making Biopharmaceuticals Using Transgenic Plants

One interesting research project on biopharmaceuticals is taking place in Western Canada. A Calgary company called *SemBioSys Genetics Inc.* has developed a transgenic canola variety which contains an *anti-coagulant* (a substance that reduces blood clotting and helps prevent heart attacks). The substance, called *hirudin*, was originally found in the saliva of leeches.

Using genetic engineering techniques, the genes responsible for producing the hirudin were cut from the cells of the leeches and pasted into canola cells. When plants were grown from the genetically engineered cells they contained hirudin.

One major advantage of using plants to "grow" substances such as hirudin may be reduced cost. Building the facilities to produce biopharmaceuticals from tissue culture can cost up to $50 million. In the case of plant production, once the research and development is completed, growing the drug- producing plants can be relatively inexpensive. For instance, that plant-derived hirudin may soon be produced at about one tenth its present cost.

However, there are technical problems to be overcome before drug production in plants becomes practical. For instance, although plants are relatively inexpensive to cultivate, the costs of extracting and purifying biopharmaceutical substances can be high. Because plants must compete with various emerging methods of drug production, including other biotechnologies such as yeast fermentation, it is critical that costs are kept modest.

Production companies are working to develop new systems which will control costs. *SemBioSys*, for example, has also developed procedures that deal with the problem of separation and purification of hirudin from the canola. Researchers found a way to attach the hirudin genes to the *oleosins* in canola during the genetic modification process. Oleosins are highly *lipophilic* proteins (substances that promotes the dissolvability of a fat) located on the surface of oil bodies found in high quantities in a variety of seeds, including canola.

The oleosins (with the attached biopharmaceuticals) are embedded in the oil and can be easily separated from the other seed proteins through water extraction. The oil and the oleosin/biopharmaceutical float to the surface, effectively purifying these proteins. Once the oil is separated, additional purification processes yield a 99% pure hirudin molecule. This results in a relatively low cost separation process, and the canola's hirudin activity compares well with a similar product produced in a strain of yeast.

New Opportunities...Down on the "Pharm"

From an agricultural perspective, turning a standard farm into a *pharm* (a newly coined term for a specialized farm where biopharmaceuticals are grown) has the potential to be very lucrative. It has been estimated, for example, that the potential value of canola seed containing the pharmaceutical hirudin could be $120,000 per tonne, a huge jump from the normal value of canola seed, which currently sells at $250-300 per tonne.

Of course, only small amounts of a drug are needed in comparison to food, so biopharmaceuticals will never be grown over large areas like standard crops. Still, biopharmaceuticals and other alternative products produced in transgenic plants could add important *niche* (small, specialized) markets that contribute to the diversification of prairie agriculture.

When developing transgenic alternatives, it will be important to be selective in choosing the crops that carry biopharmaceutical substances. Alfalfa, potatoes and canola are among the crops being examined. While canola is well suited to genetic modification, *Dr. Maurice Moloney,* the founder of *SemBioSys* and a professor at the *University of Calgary*, believes the best applications of biotechnology to canola will be related to food and feed markets. Most prominent among these applications are improved feed meal, modified edible oils, and food processing enzymes that are already part of the food chain.

However, several relatives of canola that are not presently used as food crops are suitable candidates to produce biopharmaceuticals. From the scientist's viewpoint, these crops can be modified with the same biotechnologies developed for canola, while farmers can use familiar cultivation techniques. These alternative plants, however, will be not be able to cross pollinate with conventional canola, eliminating a potential threat to the traditional uses of canola as a top food crop.

In addition to useful new sources of medicines, biopharmaceutical crops will provide opportunities to diversify the agri-food economy. Smaller scale, specialty seed crushing operations and end-product manufacturing could provide an entirely new type of growth opportunity for the agricultural industry.

*Special thanks to **Dr. Ron Wilen** of the Biochemistry Department at the University of Saskatchewan for his support in producing this Infosource.*

Ω

If you would like to receive future issues of this agbiotechnology information publication for schools, please contact:

Dr. William Riley, President
Ag-West Biotech Inc., 230-111 Research Drive
Saskatoon, Sask., S7N 3R2 Canada
(306) 975-1939 Fax: (306) 975-1966
E-mail: agwest@innovplace.saskatoon.sk.ca
Web: http://www.lights.com/agwest

Published by
Westcross House Publications, 608 Duchess Street
Saskatoon, Sask., S7K 0R1 Canada
(306) 934-1772 Fax: (306) 664-6615
E-mail: signatur@eagle.wbm.ca
Web: http://www.signat.com

Funding assistance provided by
The Saskatchewan Agriculture Development Fund

Bioethics

Description:

Many developments in biotechnology and genetic engineering have been quite controversial.

Flav'r Sav'r® tomato: Initially consumers were concerned about accusations of engineers using a gene from an Arctic Flounder fish in the tomato. This rumor was not true but was one of many controversys surrounding the introduction of the Flav'r Sav'r. (*Gene transfer does occur in nature.*)

bST: Consumers were concerned about health hazards associated with consuming milk produced using this hormone. bST is a naturally occuring substance.Tests have shown that there is no more bST in milk from treated cows than in milk from untreated cows.

Cloning: People are concerned about cloning technology being used to produce a superior race of humans.

Objectives:

1. To develop an understanding of pros and cons associated with utilizing biotechnology.
2. To learn to appreciate both sides of a controversial issue.
3. To understand that their may not be a definite right or wrong.

Activity:

- Divide the class into two groups.
- Assign one group to research and brainstorm pros of utilizing biotechnology. Assign the second group to research and brainstorm cons of utilizing biotechnology.
- Allow time for each group to research their view.
- Allow the two groups to debate their views. You may want to have each group select a spokesperson whom group members can relay their views to, but only the spokesperson will speak. (Depends on how large your class is.)

Debate: (Suggested questions to address.)

Is genetic engineering messing with mother nature? (playing God)
What is your best argument in favor of utilizing genetic engineering?
What is your best argument against utilizing genetic engineering?
What are the long term effects?
Should we be allowed to genetically engineer people to run faster for sports?
Should we be allowed to genetically engineer animals to be used as human organ donors?

Summary:

- Summarize by generating a list of pros and cons.

  Personal Opinion: I don't tell students that genetic engineering is "right", but rather I want them to know what it is and recognize the possibilities.

  Someone will almost always say that genetic engineering is "playing God" because if God wanted you to have it you would have been born with it. My response is... I ask how many of them have ever had a shot of antibiotics or a vaccination? Where you born with a hypodermic needle in your arm? Should we let a 6 year old child die because she was born with a bad heart? Should we let people starve if we know how to produce more food? How can a human play "God"? If I could play "God" I wouldn't be driving a 1987 Ranger.

Evaluation:

Have each student write a one page opinion paper. (Their view pro or con.)

Assignment:

- Read "Natural Gene Transfers: How Nature Engineers Plants"

THE AGBIOTECH INFOSOURCE

ssue 20 April, 1996 Published by AG-WEST BIOTECH INC.

Natural Gene Transfers: How Nature Engineers Plants

Biotechnology: A Natural Process?

The word biotechnology conjures up images of people in hite coats using futuristic science to do things nature can't — ıch as transferring genes from one plant or animal species to nother.

This image is only partially accurate. It's true that scien- ists have learned to modify the genetic code controlling the ıheritance of plant or animal characteristics. Beginning in 973, they discovered how to cut genes out of one plant, animal, r bacteria and paste them into another in such a way that the ıodified organism could reproduce.

These techniques allow genes to be transferred between ompletely different species, or even between bacteria, plants or nimals.

However, genetic transfers between species — or even bacteria and plants — isn't "unnatural." In fact, cientists developed the basic techniques of genetic engineering y mimicking methods of gene transfer that occur all the time in ur natural environment.

Bacteria: Nature's Genetic Engineers

As far back as 1869, the Swiss scientist *Fredrick Meischer* liscovered and isolated DNA, the substance inside the cells of ny organism which contain the genetic "blueprint" controlling ll of its characteristics.

Like his contemporary *Gregor Mendel*, who first estab- ished the principles of heredity, *Meischer's* discovery was largely gnored by the scientific community of his time.

It was in the mid-1920s that the British pathologist *Frederick Griffith* learned that the pneumonia-causing bacterium ıe was studying was capable of transforming its basic characteris- ics. His experiments showed that a harmless strain of bacteria ould transform into a lethal one.

Several decades later, researchers discovered that viruses iving in the bacteria are the agent of its genetic transformation rom one type to another. The scientists observed that bacterial nd viral DNA can integrate, and then "ferry" genes between lifferent kinds of bacteria.

Bacteria and Gene Transfers in Plants

A similar discovery about natural gene transfers in plants was made by agricultural scientists in 1907.

Erwin Smith and *Charles Townsend* discovered that plant traits can be changed in nature in much the same way bacteria are altered by the activity of viruses.

The scientists discovered this when they observed the formation of a plant tumor called a crown gall. Crown galls form on a plant at the site of a fresh wound when the wound is infected by a common soil bacterium.

Although at the time they didn't understand the genetic science involved, the researchers were observing the activity of *Agrobacterium tumefaciens*, which is capable of inserting its genes into plants. The foreign genes can then "hijack" the genetic code of the plant, making it a better host for the bacteria.

What *Smith* and *Townsend* did come to realize was that the cell mechanisms of all living things, whether plant or animal, are fundamentally the same. This discovery later made it possible to apply the process of gene transfer, first observed in the plants changed by *A. tumefaciens*, to the modification and improvement of many plants useful in agriculture.

In time, this was accomplished by finding a way to delete the genes that cause the crown gall disease and substitute other genes that produce desirable traits. Scientists found that they could harness this unusual ability of *A. tumefaciens* to carry out gene transfers in the lab.

How Bacteria Are Used to Modify Plants

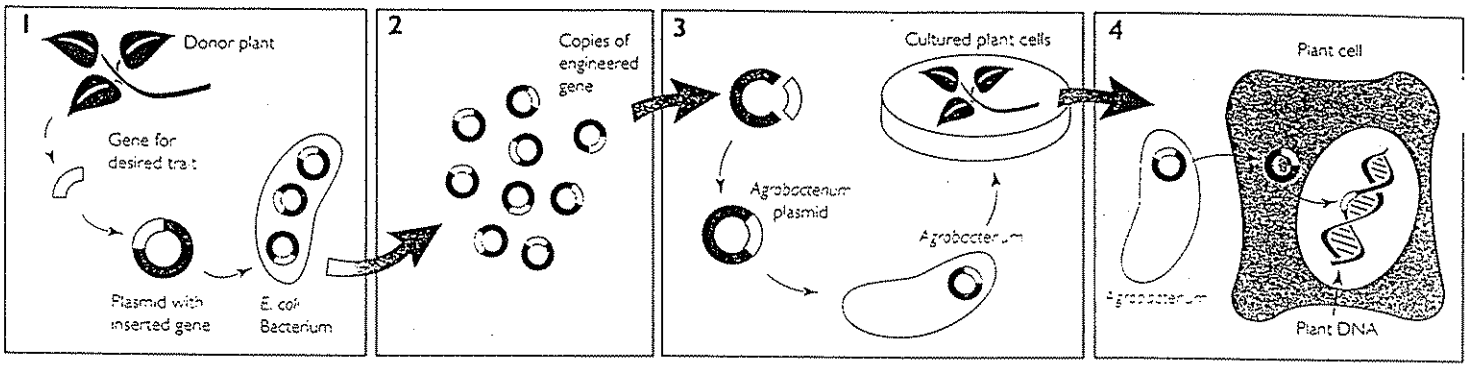
Once scientists have discovered the genes responsible for the trait they want to introduce into another plant, they face several difficult problems in transforming the target plant.

First they must accumulate enough pure DNA needed to genetically alter a number of target plant cells.

A second problem is finding a way to deliver genes through the walls of the cell and into the nucleus. After all, the cell is designed by nature to keep foreign material out.

Several ways have been found to solve these problems, but one of the most useful methods harnesses bacteria to both increase the amount of DNA as well as to "deliver" genes through cell wall and into the nucleus.

Using Bacteria to Move Genes Between Plants



How do they do it?

1. Scientists have discovered that a number of *enzymes*, complex organic substances originating in living cells, can be used as tools to "cut" genes from plants. Some 300-400 enzymes are now available for use in biotechnology. Different enzymes are used to cut and isolate specific genes.

Once scientists have discovered and isolated the genes that control a desired trait in a plant (such as resistance to a disease), they have to find a way to replicate or clone enough exact copies of the genes to transform a large number of cells from the target plants.

Their first step is to take the genes responsible for a desired trait from a plant and insert them, using enzymes, into a *plasmid* taken from a common type of bacterium called *E. coli*.

Plasmids are very important in biotechnology because they are the basis of gene cloning. Plasmids — circular pieces of DNA that are found in bacteria — can reproduce or replicate themselves quickly.

2. Once a gene is inserted into a plasmid, the plasmid can be reintroduced into the bacterial cell. When the altered bacteria is grown in a culture (a medium that promotes rapid growth), the plasmid containing the desired gene is copied or cloned in every cell.

Because bacteria grow quickly, this method makes it possible to make millions of copies of the desired gene in a short period.

3. Using enzymes, the plant genes are now removed from the *E. coli* plasmids and inserted into the plasmid of *A. tumefaciens*, the soil microorganism that can move foreign genes into plant cells.

4. Finally, the altered *A. tumefaciens* is mixed with the target plant cells. The bacteria ferry the engineered plasmid into the target plant cells. The "foreign" plant gene is then incorporated into the plant cell's DNA. New plants can be grown directly from these modified cells in a special growth chamber.

Some of the plants grown from these cells will have the trait specified by the new gene. By growing the plants, scientists can now test to see which of the plants have been genetically transformed.

The Goal: Improved Crop Varieties

By harnessing nature's methods of gene transfer, scientists have been able to genetically alter a number of common crops, creating new varieties that are better suited to farmer's needs.

Certain crops respond more readily to biotechnology than others. One of these crops is canola. Already, several new varieties of canola have been developed through genetic engineering.

For example, we now have canolas that are resistant to certain kinds of herbicides that used to kill them. Other canolas have been modified to produce specific kinds of oil suitable for special uses, including enhanced nutrition, medicines, and the production of lubricants.

Grasses, like wheat, or legumes, such as peas, are more difficult to modify. Recently, scientists at the National Research Council's Plant Biotechnology Institute in Saskatoon have used *A. tumefaciens* biotechnology to produce their first genetically modified peas.

Although there are many new biotechnologies available to solve basic problems in plant transformation, scientists continue to use nature's method of genetic modification to further their research.

Special thanks to Dr. John D. Mahon, of the National Research Council, Plant Biotechnology Institute, for his support in producing this Infosource.

Ω

If you would like to receive future issues of this agbiotechnology information publication for schools, please contact:

Mr. Ron Kehrig, Interim Manager
Ag-West Biotech Inc.
230-111 Research Drive
Saskatoon, Sask., S7N 3R2 Canada
(306) 975-1939 fax: (306) 975-1966
e-mail: agwest@innovplace.saskatoon.sk.ca

Funding assistance provided by
The Saskatchewan Agriculture Development Fund

Published by
Westcross House Publications
608 Duchess Street
Saskatoon, Sask., S7K 0R1
(306) 934-1772 fax: (306) 664-6615
e-mail: signatur@eagle.wbm.ca

Genetic Diversity

Description:
Students will taste pieces of paper saturated with 3 different substances. The ability to taste each of these substances is genetically linked. Some students will lack the genetic ability to taste one, two, or all of the substances. The data can then be used to estimate genotypes for all students in the class.

Objectives:
To develop an understanding of genotype and inheritance.
To show genetic diversity.
To diagram genotype using the Punnet Square.

Interest Approach:
Are any of you related to each other ? (cousins, etc.)
Do you have any similar traits ? (height, hair color, etc.)
Why don't look exactly the same ?

Equipment and Supplies Needed:
Genetic Taste Papers (avail. from science catalogs...Carolina Biological, Flinn, etc.)
- Control
- PTC
- Thiourea
- Sodium Benzoate

Procedure:
- Give each student one of each taste paper.
- Taste the control, first, to familiarize them with the taste of the paper.
- Taste each of the other taste papers. Have students records either a Yes or a No for each paper. Record a "Yes" if they detect a definite taste. Record a "No" if they do not detect a definite taste. (Record only definite tastes. An "I think I taste it..." should be considered a "No.")

Ag. 1 **Genotype and Genetic Diversity** Name_____

Record either a "Yes" or a "No" in under each substance. "Yes" if you detect a definite taste. "No" if you do not taste it, or if you are not sure. (Be careful not to confuse the taste of the substance with the taste of the filter paper. Re-taste the control paper if necessary.)

	Y or N	Genotype
PTC		
Sodium Benzoate		
Thiourea		

You have gathered information about your genetic make-up.

Assume that each trait is **complete dominance**.

PTC:

If you tasted the PTC, record a "PP" in the genotype box.
If you did not taste the PTC, record a "pp" in the genotype box.

Sodium Benzoate:

If you tasted the Sodium Benzoate, record a "PP" in the genotype box.
If you did not taste the Sodium Benzoate, record a "pp" in the genotype box.

Thiourea:

If you tasted the Thiourea, record a "tt" in the genotype box.
If you did not taste the Thiourea, record a "TT" in the genotype box.

Note: Assume that the ability to taste Thiourea is homozygous recessive. Only "tt" can taste Thiourea.

Questions:

Could somone who has the genes "Pp" taste the PTC ?

Could someone who has the genes "Ss" taste the Sodium Benzoate ?

Could someone who has the genes "Tt" taste the Thiourea ?

What is meant by homozygous recessive ?

Ag. 1 **Punnett Square** Name_____

One of the major advantages of sexual reproduction is genetic diversity. Complete a square to show the genotypes of the following cross.

George's Genotypes: Pp Ss Tt

Gertrude's Genotypes: Pp Ss Tt

List all of the possible gene combinations which the male's sperm could have.

List all of the possible gene combinations which the female's egg could have.

Using these gene combinations complete the square.

Analysis:

Lightly shade the individuals who can taste all three substances.

Circle the individuals who cannot taste any of the substances.

If we could reproduce George, asexually, what genotype(s) would the offspring have ?

Value Added Products
(Soybean Flavor/Soymilk)

Objectives:

1. To identify the economic value of grain production to Iowa's economy.
2. To learn alternative uses for crops. (Other than feed.)
3. To estimate the economic impact of adding value to Iowa products.

Interest Approach:

Cut up cubes of tofu and see if they can identify it. Taste it.
(Caution: most of your students will not like it plain.)

Strategies: (What will the teacher do?)

Questions:

- How does Iowa rank nationally in corn production?
  see "Iowa's Rank in Agriculture"
- How does Iowa rank nationally in soybean production?
  see "Iowa's Rank in Agriculture"
- How do we use corn?
  We most commonly think of feed.
- How do we use soybeans?
  We most commonly think of feed.
- Can you list some alternative uses of corn and soybeans?
  see Dept. of Ag Publication on Crop uses
- What is tofu?

Activities: (What will the learner do?)

Soybean Flavor Demonstration (ISU)

Soymilk Lab (see lab procedure)

Evaluation:

Scenario:

Assume that a quart of soymilk sells for $1.50 per quart.

- Calculate the value of last year's soybean crop if sold for $7 per bushel.
- Calculate the value of last year's soybean crop if processed and sold as soymilk.
- Work in groups of 3-4 to brainstorm possible uses for the soymilk by-product.

References/Resources:

Iowa's Rank in Agriculture
Iowa Census Report

SOYBEAN FLAVOR DEMONSTRATION

Prepared by the Office of Biotechnology, Iowa State University

The soybean grain commonly produced by farmers has a grassy or beany flavor. This flavor is not a problem when the grain is used as animal feed, but it can be objectionable to some persons when soybeans are used in food products.

The beany flavor is the result of the action of an enzyme called lipoxygenase. As the name implies, the enzyme is involved in the oxidation of lipids or fat, which results in the beany flavor. There are three forms of the enzyme, commonly referred to as lipoxygenase 1, 2, and 3. The three forms occur in common soybean varieties grown by farmers.

To eliminate the beany flavor, soybean scientists evaluated varieties from throughout the world in an attempt to find those that did not have one or more of the lipoxygenase enzymes. They found a few varieties that lacked 1, 2, or 3, but no variety lacked more than one of the three forms. By hybridization, mutation, and selection, soybean breeders were able to combine the genes that control the three forms of the enzyme. Soybeans are now available that lack one, two, or three of the lipoxygenase enzymes. These soybeans are being used to produce soymilk and other food products that no longer have the beany flavor of common soybeans.

The soybeans with and without the lipoxygenase enzymes provides a tangible illustration of the action of a gene. The soybeans needed for the demonstration can be obtained without charge from the Office of Biotechnology, Iowa State University, 1210 Molecular Biology Building, Ames, IA 50011, 1/800-262-0015 x9818 or FAX: 515/294-4629.

Procedure:

1. Distribute to each student a seed of the soybean variety that lacks the lipoxygenase enzymes. It is important to taste the seeds without the enzymes first because those seeds with the enzymes will leave such a strong aftertaste that it is impossible to know if any later samples do or do not have the beany flavor.

   The students should be advised to be careful when chewing on the seeds to avoid damage to their teeth. After they have chewed on the seed, they should record the flavor they perceive.

2. Distribute to each student a seed of the soybean variety that has the lipoxygenase enzymes. The students should chew on the seed and record the flavor they perceive.

Note: The soybeans that lack the beany flavor were developed by classical plant breeding methods. Biotechnologists are using molecular techniques to modify the flavor of crop products. The FlavrSavr tomato is the first commercial product developed by molecular techniques to have improved flavor.

revised 6/94

MODIFICATION OF SOYBEAN OIL TO IMPROVE ITS NUTRITIONAL QUALITIES

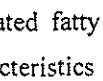
Prepared by the Office of Biotechnology, Iowa State University

Nutritionists recommend that consumers minimize the amount of saturated fat in their diets. There also is evidence that the consumption of hydrogenated products should be minimized because of the possible negative effects of the trans fatty acids produced by the process.

In 1994, the first commercial soybean varieties were grown that had changes in their oil characteristics with respect to reduced saturated fat content and reduction of a fatty acid that may eliminate the need for hydrogenation in some oil products. These varieties will significantly alter the manner in which soybeans are produced and marketed by farmers and the products that will be available to consumers.

COMPOSITION AND CHARACTERISTICS OF SOYBEAN OIL

The five major fatty acids in soybean oil are palmitate, stearate, oleate, linolenate, and linoleate. The fatty acids differ in the number of carbon and hydrogen atoms they contain, which causes differences in the nutritional value of each and their influence on the characteristics of food products.

* Palmitate: It is made up of 16 carbon atoms and a full set of hydrogen atoms, which makes it a saturated fatty acid  . Palmitate has a negative impact on human nutrition. It has desirable characteristics for making margarine and shortening.

* Stearate: It is made up of 18 carbon atoms and a full set of hydrogen atoms. Stearate is a saturated fatty acid that does not have the same negative effect on human nutrition as does palmitate. It has desirable characteristics for making margarine and shortening.

* Oleate: It is made up of 18 carbon atoms, two of which each lack a hydrogen atom. The absence of a full set of hydrogen atoms make it an unsaturated fatty acid  . Oleate is referred to as a monounsaturate. It is desirable for human nutrition and for frying oils.

* Linoleate: It is made up of 18 carbon atoms, four of which each lack a hydrogen atom. Linoleate is an unsaturated fatty acid that is referred to as a polyunsaturate. It is desirable for nutrition, but can lead to off-flavors in food products that are not hydrogenated.

* Linolenate: It is made up of 18 carbon atoms, six of which each lack a hydrogen atom. Linolenate is an unsaturated fatty acid that is described as a polyunsaturate. It is desirable for nutrition, but it is the fatty acid most responsible for the off-flavors in food products that are not hydrogenated.

To improve the nutritional characteristics of soybean oil, it is desirable to reduce the content of the saturated fatty acids, particularly palmitate, and lower the content of linolenate to eliminate the need for hydrogenation. Both of these changes have been accomplished in soybeans by developing genes that alter the fatty acid content.

Hydrogenation

Hydrogenation is a chemical process used to add hydrogen atoms to the unsaturated fatty acids, particularly linolenate. The addition of hydrogen reduces the development of off-flavors in oil products. During hydrogenation, hydrogen atoms in oleate, linoleate, and linolenate may change from the cis form $-\overset{H}{C}=\overset{H}{C}-$ to the trans form $-\overset{H}{C}=C-$. Research indicates that the cis form does not have a negative effect on nutrition, but the trans form is not desirable.

Development of new genes

The genes needed to markedly change the composition of soybean oil were not available in soybean varieties grown throughout the world. To develop the necessary genes, soybean scientists treated seeds with chemicals called mutagens. The mutagens alter the DNA in the cells, which results in the formation of new genes. Scientists cannot control what genes are changed by the mutagens, so they evaluate thousands of plants from the treated seeds to try and find the ones that have been changed for the genes they need.

The mutagen treatment of soybean seeds was successful and new genes were found that reduce the palmitate or the linolenate content of the oil. By combining the new genes from different plants, the scientists were able to reduce saturated fat content of the oil by more than 50% and the linolenate content by more than 75%. These genes have been put in varieties that can be grown by farmers.

Production of the new varieties by farmers

The soybean varieties with the new oil characteristics must be kept separate from conventional varieties during planting, harvest, and marketing. If grain of the new oil varieties and grain of the conventional varieties are accidentally mixed, the oil obtained from it will not have the desired fatty acid content.

When soybean farmers grow the new oil varieties, they make a contract with a company that wants the oil. In the contract, the farmers agree to keep the new oil varieties separate from the other varieties they are growing. The company agrees to pay the farmer for the extra work required to keep them separate.

Marketing of the new soybean oil to consumers

The first soybean oil with reduced saturate content or reduced linolenate content will be obtained from the new varieties grown by farmers in 1994. No information is available on the way in which the new oils will be marketed to consumers.

U.S.
SOYFOODS
DIRECTORY

Soyfoods Nutrition Information

Although soyfoods are widely recognized for their nutritional qualities, interest in soyfoods has risen recently because scientists have discovered that a soy component called isoflavones appears to reduce the risk of cancer. More research needs to be done to determine exactly how isoflavones work, but it appears that as little as one serving of soyfoods a day may be enough to obtain the benefits of this anticancer phytochemical.

The calcium content of fortified soymilks which may be found in retail stores can be found in our Soymilk Calcium Chart.

It is important, though, to understand the entire nutritional value of specific soyfoods so that dietetic decisions can be made. For instance, soy protein has been found to be effective in reducing cholesterol, in treating kidney disease, and may cause calcium to be better utilized, helping to ward off osteoporosis. Some soyfoods such as miso contain high amounts of sodium, and should be avoided by people who need to minimize their sodium intake. A single serving of tempeh contains twice as much fiber as the average American eats in a day.

Composition and nutrient content of selected soyfoods can be found at the USDA Nutrient Database for Standard Reference.

For more information about soyfoods, please refer to our book list.

. . .

MODIFICATION OF SOYBEAN OIL TO IMPROVE ITS NUTRITIONAL QUALITIES

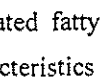
Prepared by the Office of Biotechnology, Iowa State University

Nutritionists recommend that consumers minimize the amount of saturated fat in their diets. There also is evidence that the consumption of hydrogenated products should be minimized because of the possible negative effects of the trans fatty acids produced by the process.

In 1994, the first commercial soybean varieties were grown that had changes in their oil characteristics with respect to reduced saturated fat content and reduction of a fatty acid that may eliminate the need for hydrogenation in some oil products. These varieties will significantly alter the manner in which soybeans are produced and marketed by farmers and the products that will be available to consumers.

COMPOSITION AND CHARACTERISTICS OF SOYBEAN OIL

The five major fatty acids in soybean oil are palmitate, stearate, oleate, linolenate, and linoleate. The fatty acids differ in the number of carbon and hydrogen atoms they contain, which causes differences in the nutritional value of each and their influence on the characteristics of food products.

* Palmitate: It is made up of 16 carbon atoms and a full set of hydrogen atoms, which makes it a saturated fatty acid  . Palmitate has a negative impact on human nutrition. It has desirable characteristics for making margarine and shortening.

* Stearate: It is made up of 18 carbon atoms and a full set of hydrogen atoms. Stearate is a saturated fatty acid that does not have the same negative effect on human nutrition as does palmitate. It has desirable characteristics for making margarine and shortening.

* Oleate: It is made up of 18 carbon atoms, two of which each lack a hydrogen atom. The absence of a full set of hydrogen atoms make it an unsaturated fatty acid  . Oleate is referred to as a monounsaturate. It is desirable for human nutrition and for frying oils.

* Linoleate: It is made up of 18 carbon atoms, four of which each lack a hydrogen atom. Linoleate is an unsaturated fatty acid that is referred to as a polyunsaturate. It is desirable for nutrition, but can lead to off-flavors in food products that are not hydrogenated.

* Linolenate: It is made up of 18 carbon atoms, six of which each lack a hydrogen atom. Linolenate is an unsaturated fatty acid that is described as a polyunsaturate. It is desirable for nutrition, but it is the fatty acid most responsible for the off-flavors in food products that are not hydrogenated.

To improve the nutritional characteristics of soybean oil, it is desirable to reduce the content of the saturated fatty acids, particularly palmitate, and lower the content of linolenate to eliminate the need for hydrogenation. Both of these changes have been accomplished in soybeans by developing genes that alter the fatty acid content.

Hydrogenation

Hydrogenation is a chemical process used to add hydrogen atoms to the unsaturated fatty acids, particularly linolenate. The addition of hydrogen reduces the development of off-flavors in oil products. During hydrogenation, hydrogen atoms in oleate, linoleate, and linolenate may change from the cis form $-\overset{H}{C}=\overset{H}{C}-$ to the trans form $-\overset{H}{C}=C-$. Research indicates that the cis form does not have a negative effect on nutrition, but the trans form is not desirable.

Development of new genes

The genes needed to markedly change the composition of soybean oil were not available in soybean varieties grown throughout the world. To develop the necessary genes, soybean scientists treated seeds with chemicals called mutagens. The mutagens alter the DNA in the cells, which results in the formation of new genes. Scientists cannot control what genes are changed by the mutagens, so they evaluate thousands of plants from the treated seeds to try and find the ones that have been changed for the genes they need.

The mutagen treatment of soybean seeds was successful and new genes were found that reduce the palmitate or the linolenate content of the oil. By combining the new genes from different plants, the scientists were able to reduce saturated fat content of the oil by more than 50% and the linolenate content by more than 75%. These genes have been put in varieties that can be grown by farmers.

Production of the new varieties by farmers

The soybean varieties with the new oil characteristics must be kept separate from conventional varieties during planting, harvest, and marketing. If grain of the new oil varieties and grain of the conventional varieties are accidentally mixed, the oil obtained from it will not have the desired fatty acid content.

When soybean farmers grow the new oil varieties, they make a contract with a company that wants the oil. In the contract, the farmers agree to keep the new oil varieties separate from the other varieties they are growing. The company agrees to pay the farmer for the extra work required to keep them separate.

Marketing of the new soybean oil to consumers

The first soybean oil with reduced saturate content or reduced linolenate content will be obtained from the new varieties grown by farmers in 1994. No information is available on the way in which the new oils will be marketed to consumers.

Stop Cloning Around

Objectives:

1. To analyze the pros and cons of cloning orgnisms.
2. To understand the meaning of cloning.
3. To understand the meaning of the term "bioreactor".

Assignment:

- Read the articles about cloning and answer the questions.
- Review the questions.

Discussion:

Should we allow the cloning of humans?
Would a cloned human be identical to the original?
- probably not, remember P=G+E

Should cloning of plants, animals and bacteria be legal?
What potential benefits do you see from cloning plants, animals and bacteria?
What potential problems do you see from cloning plants, animals and bacteria?
What types of cloning are widely used already?
- tissue culture
- plant cuttings

What is the genetic significance of a clone?
- genetically identical - less chance of losing a valuable trait

What is a "bioreactor"?
- an organism genetically altered to produce a valued result or product

Example: bacteria engineered to produce insulin
cows engineered to produce pharmaceuticals

What are the benefits of sexual production?
- **genetic diversity**
- hybrid vigor

What are the benefits of asexual reproduction?
- **genetically identical**
- less chance to lose or mask a valuable trait
- fast way of increasing populations of unique, valuable organisms

Analyze:

- **Read this statement and allow students to work in pairs to develop their answer.**

"Assume you found a very rare, one-of-a-kind orchid, black orchid. You have been offered $1000 a piece for each one you can produce. You only have one. Would you reproduce this orchid sexually or asexually? Why?"

Study Guide **Stop Cloning Around** Name_____

Read the attached articles and answer the following questions.

1. Who are George and Charlie?

2. Why are they unique?

3. Who is Dolly?

4. Why was she named Dolly?

5. What is unique about the female fetuses being carried by research cows?

6. Who is Richard Seed, and why is he significant?

7. What is the title on the cover of the March 10, 1997 Business Week?

8. Where did the DNA used to produce Dolly come from?

9. How many microorganisms already have fully mapped genomes?

10. By 2003, farmers may be...

11. What is a genome?

12. What is a mutation?

13. What is a genetic map?

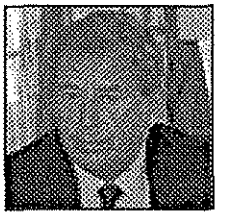
14. George, Charlie, and Dolly are all examples of scientists' efforts to produce bioreactors. How would you define "bioreactor"?

15. What is meant by the term "pharming"?

1-20-98

- **Article From The Associated Press**

Havel Re-Elected Czech President



Czech President Vaclav Havel was re-elected for a second five-year term Tuesday, but only after being forced to go to a second round of voting by deputies, the speaker of the Czech parliament announced.

The 61-year-old former dissident playwright was returned to office with 99 votes from the 197 deputies present, and 47 out of the 81 senators, giving him the majority needed in the two houses of parliament, said Milos Zeman.

Earlier Havel, who led the 1989 Velvet Revolution in Czechoslovakia, had failed to garner the majority required in a first round of voting, winning 91 votes in the 200-member lower house and 39 in the 80-seat Senate, Agence France-Presse reported. He had been widely expected to be re-elected, five years after he became president of the Czech republic following its split from Slovakia at the end of 1992.

Two marginal candidates were standing against him: a far-right leader, Miroslav Sladek, currently in jail charged with inciting racial hatred, and Stanislav Fischer, a 62-year-old astrophysicist supported by communists. The vote, by secret ballot, was preceded by a debate in the ornate Spanish Hall of Prague Castle. A minority of speakers opposed.

Havel's re-election was seen as aimed at keeping the country on track to join the European mainstream, despite political and economic turmoil at home. The vote comes amid political turmoil after the collapse of former premier -- and long-term Havel rival -- Vaclav Klaus's government last month. Havel was standing for re-election only months after fighting lung cancer and pneumonia.

N A T I O N A L

Researchers Say Cow Cloning May Lead to Medicine Production in Milk

Researchers announced Tuesday that they have successfully cloned two identical, genetically engineered calves, a step that could lead to the mass production of drugs for humans in cows' milk.

Named George and Charlie, the male calves born last week were created through a combination of cloning and genetic engineering by Dr. James Robl at the University of Massachusetts and Dr. Steven Stice of Advanced Cell Technology Inc. The findings were discussed at an International Embryo Transfer Society meeting in Boston.

The UMass researchers haven't produced a cow that can produce a drug, but that next step could be coming soon. The researchers said they have pregnant

cows carrying female fetuses that have been altered to produce milk with the human serum albumin, a protein essential to the blood that is widely used by hospitals.

Advanced Cell Technology, the company founded by the researchers, already has a deal with Genzyme Transgenics Corp. of Framingham, Mass., to produce albumin. ``We've taken a significant step toward making this commercially viable," Robl said.

The calves were born at a ranch in Texas. ``It's a big deal," said Mark Westhusin, a researcher at Texas A&M University. ``This technology has the potential to be a lot more efficient than the technology that we have now."

The calves aren't the first animal clones with altered genes -- lambs Molly and Polly have a human gene expected to make them produce a protein helpful in blood clotting. But even Dr. Ian Wilmut, the Scottish researcher who genetically engineered the lambs and the now-famous Dolly, acknowledged that drug-making cows could be more valuable because cows produce much more milk than sheep.

George and Charlie contain two genetic alterations -- a ``marker" gene and one that made cells resistant to an antibiotic. Those markers have shown up everywhere, from the blood to the spleen to the bones.

Robl said the technique his team used to clone the calves was a variation on the nuclear transfer process Wilmut used last year to clone Dolly the sheep, the first mammal cloned from an adult cell. But Stice said unlike the method used with sheep, cloning the calves did not require surgery and was relatively quick.

On Monday, the Food and Drug Administration said it has the authority to regulate human cloning. ``We're not only able to move, we're prepared to move," said Dr. Michael Friedman, the FDA's acting commissioner, noting the agency can go to court to stop unauthorized cloning attempts.

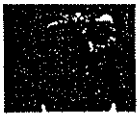
The FDA's decision, which had been widely expected, means it would be a violation of federal law to try the procedure without the agency's approval. The news follows an announcement earlier this month by a Chicago-area physicist Richard Seed who said he was ready to set up a clinic to clone human babies and predicted that as many as 200,000 human clones a year would be produced once his process was perfected.

``The scientific issues are far from clear and ... there are some significant ethical concerns that have to be dealt with," added Friedman, noting that the first cloning success -- the Scottish sheep Dolly -- took 277 tries. For safety reasons, he said, ``we're more interested in the 277 failures than in the success."

Seed did not return a call for comment, but says he plans to clone a person within 18 months. A physicist, Seed has no medical degree, no laboratory backing and little money. He and a brother, Randolph, a Chicago surgeon, did pioneer a human embryo transfer technique during the 1980s, but their for-profit company fizzled.

- **Article From The Associated Press**

BOB RUBIN'S AGENDA



AT&T'S GAME PLAN

BusinessWeek

MARCH 10, 1997 A PUBLICATION OF THE McGRAW-HILL COMPANIES $3.50

THE BIOTECH CENTURY

Cloning animals is just the beginning. Thanks to fundamental advances in genetics, biology will define scientific progress in the 21st century. It's all happening faster than anyone expected.

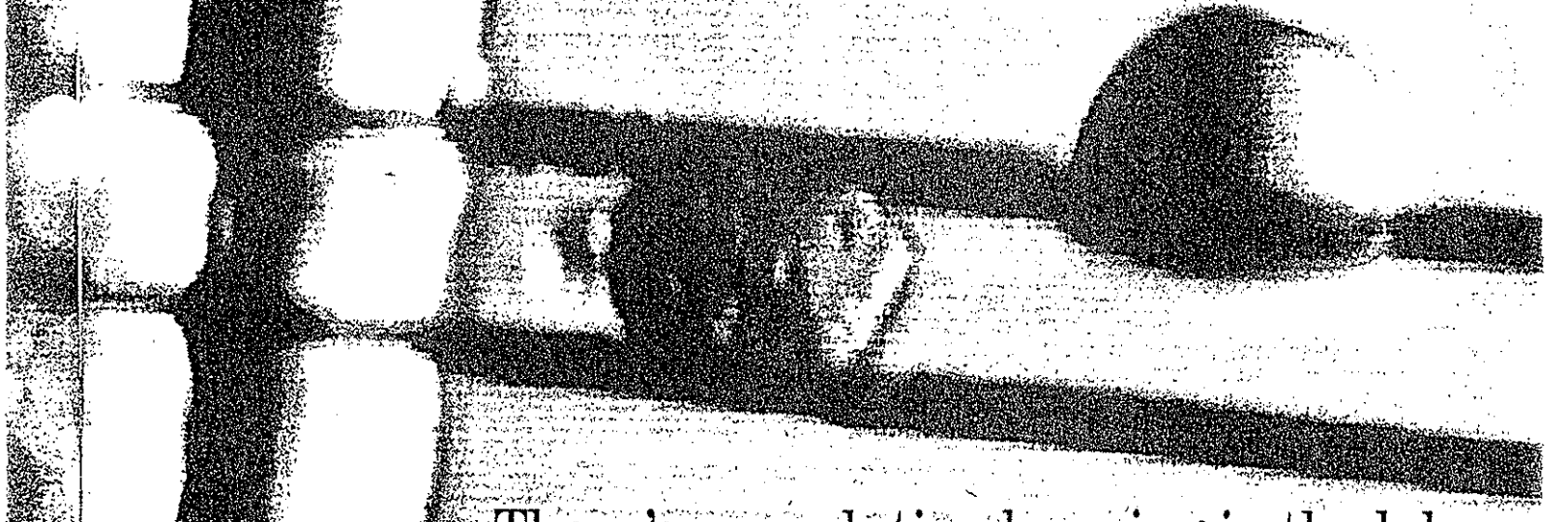
PORT

There's a revolution brewing in the lab, and the payoff will be breathtaking

THE NEW CENTURY

The grand, tumultuous pageant of human history is, in a large part, propelled by technology. Metalworking and improved agriculture carried civilization out of the Stone Age. In the 19th century, the Industrial Revolution gave rise to mighty machines and sprawling cities. In the 20th century, physics became king. Physicists split the atom, explored the bizarre worlds of relativity and quantum theory, and harnessed the power of tiny chips of silicon. Along the way, they transformed the world with the atom bomb, the transistor, the laser, and the microchip. But now, many experts believe, humankind is poised to ride a new wave of scientific knowledge in the headlong rush to the future. "This was the century of physics and chemistry," proclaims 1996 Nobel prize-winning chemist Robert F. Curl of Rice University. "But it is clear that the next century will be the century of biology."

On Feb. 22, that century was suddenly upon us—arriving years sooner than anyone expected, not like a lion but in the guise of a lamb. A previously obscure 52-year-old Scottish embryologist, Ian Wilmut, stunned the world by announcing that he and his team at the Roslin Institute outside Edinburgh had created an exact copy—a clone—of an adult Dorset sheep. The historic lamb, created from DNA extracted from the sheep's mammary gland, was named Dolly. "We couldn't think of



JAMES KING-HOLMES/SCIENCE PHOTO LIBRARY/PHOTO RESEARCHERS

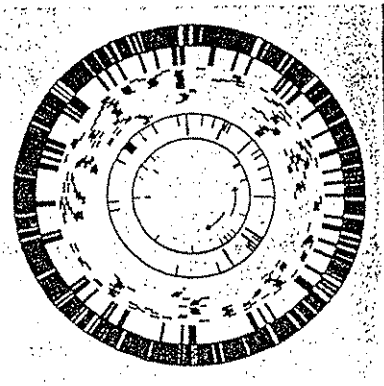
SCIENCE OF THE LAMBS: *A sheep ovum is injected with an embryonic cell*

CONTENTS

Special Report
THE BIOTECH CENTURY

A ROADMAP FOR BIOTECH RESEARCH

The new biotechnology allows scientists to get at the most basic functions of life, deep inside the complex interactions of genes. Here are some key developments.



HEMOPHILUS This bacterium, which causes meningitis and childhood ear infections, was the first organism for which researchers identified the entire genome—the complete set of genes. One goal: pointing the way toward new drugs and vaccines.

anyone with a more impressive set of mammary glands than Dolly Parton," says Wilmut.

Wilmut's trick was to replace the genes in a normal sheep oocyte, or egg, with DNA from an adult sheep mammary gland. He prodded the egg to grow and inserted it into the womb of another sheep. Last July, Dolly was born—an exact genetic copy of the adult whose mammary gland was tapped for DNA.

Wilmut and other scientists say that in principle, the same technique should work for any other mammal—including humans. Dr. Jon W. Gordon, an obstetrics researcher at the Mount Sinai Medical Center in New York, notes that cloning a human might not be so simple. Some genetic experiments that work in mice don't work in rats, and vice versa—suggesting that all mammals are not quite the same. And the first step, he said, will be for others to repeat Wilmut's dazzling experiment—to be certain that the results are correct.

If Wilmut's work is confirmed, it suddenly becomes possible to imagine some mind-bending consequences. Improvements in sheep and cattle ranching would be only the beginning. If the cloning of humans ever became practical, grieving parents might conceivably choose to clone a dying child. Some individuals might make a desperate grab for immortality by trying to clone themselves. Already, scientists are joking that the richest and most egotistical among them are hopping the next plane to Scotland. "It's an incredible development," says Arthur L. Caplan, director of the Center for Bioethics at the University of Pennsylvania. "Unfortunately, we don't have the legal and ethical basis to handle it yet." Two days after the cloning was announced, President Clinton asked for a national commission to review what the White House called the "troubling" implications of cloning.

DOLLY Dr. Ian Wilmut and his colleagues at the Roslin Institute added new genes to 277 eggs before they got one to grow into the world's most famous sheep. Researchers elsewhere will now be rushing to duplicate the feat.

And yet, the headline-grabbing lamb represents only a tiny slice of what's just around the corner in biology during the coming century. Science is on the brink of an unprecedented explosion in its ability to understand and manipulate life. Until recently, researchers were forced to painstakingly search for genes one by one. The effort to nab the cystic fibrosis gene took 10 years and cost more than $150 million, for example. To isolate one obesity gene required a decade of work.

Now, however, gene sleuths are approaching from the other direction. They are deciphering the entire genetic code—known as the genome—of a wide variety of organisms, from humans to microbes. As these genomes are being decoded, or "sequenced," researchers are separating the individual genes and beginning to discover what each of them does.

Already, the fully sequenced genomes of six microorganisms have been published, and the cost is now as low as $300 per gene. Some 50 more, including those of the devastating malaria parasite and other disease-causing organisms, will be finished by the end of the 1990s. And thanks to the ambitious Human Genome Project and similar efforts in plants and animals, scientists will hold in their hands the complete blueprints of everything from nematodes and mustard plants to mice and men by the first decade of the 21st century—all neatly catalogued in computer databases.

Eric Lander at the Whitehead Institute for Biomedical Research in Cambridge, Mass. likens these complete genomes to the periodic table of elements, the basis for 20th-century research in chemistry. Stanford University geneticist Richard M. Myers says having the genomes "is expanding people's imaginations, allowing them to think on a grand scale, asking and answering questions they would never have dreamed of before." Adds Monica Riley, senior scientist at the Marine Biological Laboratory in Woods Hole, Mass: "In the near future, we will know everything that goes into making up a living cell. It's an exhilarating time to be doing science."

No one doubts that the payoff will be immense. By 2003, farmers

(CLOCKWISE FROM TOP) PHOTOGRAPHS BY THE INSTITUTE FOR GENOMIC RESEARCH; DR. JEAN... BURGESS/SCIENCE PHOTO LIBRARY/PHOTO RESEARCHERS; JEFF J. MITCHELL/REUTERS

may be growing plants that make enough plastic to reduce our dependence on oil. The massive amount of information holds the promise of a slew of new drugs and treatments—and a far deeper understanding of human behavior, health, and disease. "It gives us tremendous hope we can finally win the battle against bacteria," says J. Craig Venter, president of the Institute for Genomic Research (TIGR), a pioneer in gene sequencing.

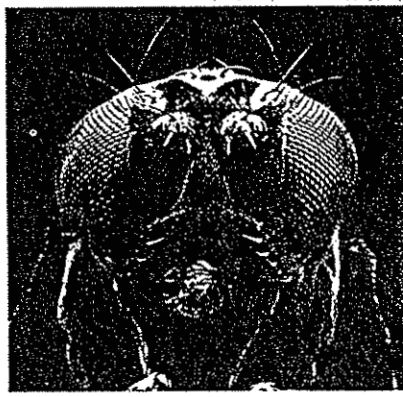
Moreover, the spillovers could reach outside biology. Motorola has a team of researchers exploring the potential of gene splicing and genome engineering for computing. The idea is to use the DNA molecule as the basis for computers vastly more powerful, for some calculations, than today's digital machines. University scientists have already built primitive DNA computers. Even further afield, the genome information will illuminate previously dim corners of history—by analyzing genetic variations among populations. "We can ask: 'Where did we come from? How many migrations did our ancestors make out of Africa?'" explains Mary-Claire King, a gene hunter at the University of Washington.

Of course, none of this will be easy. The discovery of a gene or the elucidation of a complicated biological pathway may be only a small step toward a cure or useful medicine. The gene for sickle-cell anemia is one example. It was identified 20 years ago, but there still are no cures. Now, with thousands of new genes being discovered every year, pharmaceutical and biotech companies are awash in potential targets for drugs. "But drug discovery has turned out to be a bear," says Larry M. Gold, chief scientist of NeXstar Pharmaceuticals Inc.

What's more, the biological century will bring myriad moral and legal conundrums. Should doctors, for example, test for genetic conditions or predispositions they can do virtually nothing about? Will employers and insurance companies get access to the results of those tests? Should they be able to use that information to deny employment or insurance coverage? Already, British companies say they have been using genetic information to set rates and eligibility criteria for buyers of life insurance (page 84).

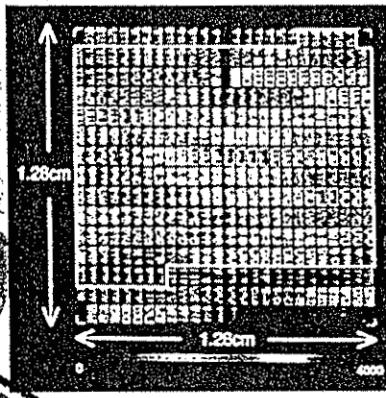
These hurdles and dilemmas, however, are far from the minds of many scientists toiling in university and company labs to understand the biology laid bare by the new genetic information. What they see instead is the chance to transform not just science but the world of the next century, just as the microchip changed this one. And the story really starts with one of the simplest forms of life—bacteria.

In July, 1995, Venter's team made history by completing the first full gene sequence of a living organism other than a virus. The bacterium was *Hemophilus influenzae*, which causes meningitis and children's ear infections. In the two

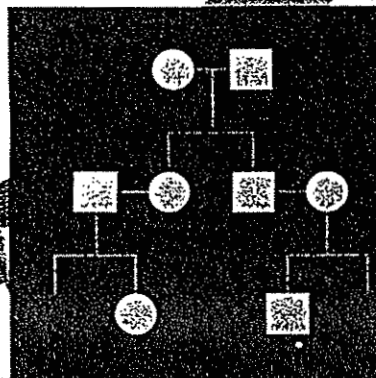


YEAST, DROSOPHILA, C. ELEGANS Two of these simple organisms—fruit flies and tiny round worms—are very close to being sequenced; yeast has been done. Many genes are remarkably similar to ours, offering new clues to fight disease.

MUSTARD WEED Researchers have begun to decipher the complete genome of one plant—the mustard weed, known scientifically as *Arabidopsis*. The eventual result could be supercrops or trees that would yield such products as plastics and drugs.



DNA CHIPS The marriage of microchips and DNA is a natural. Researchers are using chips to rapidly identify genetic variations in specific tissues. Comparing diseased and healthy tissue can reveal causes of disease.



FAMILY TREES Researchers are now using large families, often from genetically isolated communities, together with powerful computer technology, to identify genes involved in more complex disorders such as diabetes and heart disease.

(TOP) PHOTOGRAPH BY OLIVER MECKES/PHOTO RESEARCHERS; ILLUSTRATION BY LISA KNOUSE BRAIMAN

years since, researchers have used the sequence to uncover what Venter calls a "remarkable biological mechanism that could totally change the basis of vaccine and drug development."

Geneticist Richard Moxon of Oxford University discovered that the bug is essentially preprogrammed for constant evolution. Like all cells, its genes contain the information to make proteins. But special sequences tucked in its genome cause the process to go awry periodically, creating new forms of key proteins. That enables *H. influenzae* to evolve on an hourly basis, evading the human immune system. Standard vaccines also target these proteins, which is why they don't work very well. The trick will be mining the genome to dig out more obscure proteins that the bug can't change so rapidly. Researchers at MedImmune Inc. in Gaithersburg, Md., are using this strategy to develop better vaccines.

Special Report
THE BIOTECH CENTURY

PINCH OF YEAST. Drug companies are also interested in searching the genome for places to attack with new types of antibiotics. To help put a price tag on this sort of genetic information, Genome Therapeutics Corp. in Waltham, Mass., recently sold the sequence of *Helicobacter pylori*, the bug that causes ulcers and possibly stomach cancer, to Swedish pharmaceutical giant Astra for a cool $22 million.

Higher up the evolutionary ladder, sequencing the genomes of creatures like yeast, nematodes, and fruit flies is leading to advances. Once nature finds a biological pathway that works, she tends to use it over and over. As a result, "the majority of human disease genes that have been found have counterparts in yeast" and other simple organisms, explains S. Michal Jazwinski, professor of biochemistry and molecular biology at Louisiana State University in New Orleans. Just as important, the animals can be experimented on to understand these shared genes and biological pathways, something that can't be done in people. Geneticist Michael Wigler of Cold Spring Harbor Laboratory in New York used yeast to figure out the biology of a gene, called *ras*, that when mutated causes human cancers.

Scientists at NemaPharm, in Cambridge, Mass., are using the nematode *C. elegans* in a similar fashion. One target: Alzheimer's disease. Researchers have found a human gene, dubbed presenilin, that is linked to the disease. The gene is also present in the worm. So NemaPharm scientists are now disabling the worm's gene to figure out what it was doing—and how it interacts with other genes. "We're looking for suppressors of the gene," explains Timothy J. Harris, research and development chief at Sequana Therapeutics Inc., which recently bought NemaPharm. And when the entire *C. elegans* genome is sequenced by early 1998, says Harris, the worm "will be helping us in all our internal R&D programs at Sequana." That includes searching for the human

DNA FOR DUMMIES: THE BASICS YOU NEED TO KNOW

The blueprint of life is **DNA.** Its famous double helix is a long, long chain built by linking together four simple molecules. The order in which those molecules are linked determines the information contained in the DNA. It is the **SEQUENCE** of those molecules that molecular biologists are now busily decoding. All of the DNA in an organism is referred to as the organism's **GENOME.**

GENES are DNA chains made up of hundreds or thousands of simple molecules. Each gene contains instructions to make another type of crucial molecule, a **PROTEIN.** Proteins include everything from hormones such as insulin—which regulates blood-sugar levels—to enzymes that help digest the food we eat. Some proteins turn other genes on and off, which then affect still other genes, creating complicated feedback loops.

Individual proteins are but tiny cogs in incredibly complex biological systems. Consider the immune system, in which thousands of genes and proteins work together to field an

COMMENTARY

WHEN SCIENCE FICTION BECOMES SOCIAL REALITY

Of all the worrisome scenarios the genetic age has conjured, none is more deeply embedded in the popular psyche than the Frankenstein myth, with its moral that dire consequences await the scientist who dares to play God. For at least 20 years, scientists and biotech entrepreneurs have dismissed the fears of man-made life as science fiction, saying that whole-mammal cloning was impossible and would be until well into the 21st century.

But when Dolly, the cloned sheep, preened for her first photographs last week, the public learned that all sorts of genetic mischief, including mammal cloning, in fact is quite possible. "The symbolic significance is greater than the real significance," says Barbara A. Koenig, director of the program on Genomics, Ethics & Society at Stanford University.

Koenig believes Dolly's near-term impact could be significant for couples unable to bear children. Many couples have shown how far they will go to get genetically related offspring rather than adopt an unrelated child. Some seem willing to bear any expense and undergo the most difficult and risky medical procedures. Given that desperation, they may try to find a scientist willing to experiment with cloning.

AMBIGUOUS RESULTS. For ethicists, this will only add to a plate already full of issues that biotechnology has already raised. In the biotech century, those questions will become even more urgent. Perhaps the most fundamental questions right now are these: Exactly what kind of medical knowledge can be gleaned from genetic information today? And what can be done with it?

The truth is that most genetic tests are inconclusive. The diagnoses they yield often show no more than a slightly increased or decreased risk of someone's getting a particular illness. A perfect example is breast cancer. A gene that increases the risk of breast cancer was recently identified, marking an important scientific breakthrough.

One of Koenig's current projects is to study the ethical implications of testing women for mutations in this gene, which appear in some breast cancer patients. "My main fear is the overuse and commercialization of diagnostic tests before we have enough information," she says. Finding mutations could

army of cells and antibodies (another type of protein) against intruders. The DNA in each of the body's cells contains all the genetic information to produce a person. But in any given cell, only some of the genes are switched on; the rest are dormant. That's what makes a liver cell, say, different from a skin cell—different sets of genes are turned on in each.

Scientists despair of understanding exactly how humanity's 80,000 genes flip on and off in the amazing molecular dance that leads to a human being. But they are uncovering the genes and proteins that underlie small pieces of this grand puzzle—so-called **BIOLOGICAL PATHWAYS.** One famous pathway is the process by which cells turn the sugar glucose into enough energy to run a marathon.

But genes can also go horribly wrong. A "misspelling" in just one letter—an improper or missing link in the DNA chain—is a **MUTATION.** A change in a single link of the thousands in a gene can produce disease. Sickle-cell anemia, for instance. Other diseases are more complex. Heart disease, cancer, and Alzheimer's are due to mutations in several genes.

Much of the effort in genetics today is directed at finding these faulty genes—and then figuring out how their flawed proteins make biological pathways go awry. Aiding the search is something called a **GENETIC MAP.** Much like an atlas, a genetic map shows the locations of genes and fragments that have been identified. Each of these can be used as a signpost, or **MARKER,** to help identify genes that might be related to disease.

Just as it's easier to get to Evanston if you know it's near Chicago, it's easier to find a gene if you start from a marker nearby. When gene sleuths are tracking an inherited disease in a family, they look for markers present only in family members with the disease. When they find those markers, they know they are close to the genes.

Finding genes this way is costly and time-consuming. That's why researchers have begun blindly sequencing the entire genome, link by link. That way they will find thousands of new genes and all of the extra genetic information that sits between genes. This vast amount of new information opens the door to the most basic understanding of life.

By John Carey in Washington

genes that code for conditions from asthma to obesity.

The new genomics also is having a more direct impact on the diagnosis and treatment of human disease. One tack, used by companies like Human Genome Sciences Inc. (HGS) in Rockville, Md., is to pluck out all the genes that are actually turned on in a cell. Many of them are unknown. By figuring out their function, researchers may stumble across potential new drugs and drug targets. HGS, for instance, is about to begin clinical trials with previously unknown proteins that help heal wounds or fight arthritis. And HGS partner SmithKline Beecham has used the method to find promising new drugs against osteoporosis and other diseases.

Meanwhile, other companies are using technology to create what are known as DNA arrays, or DNA chips. The basic idea is to put thousands of different pieces of DNA onto a silicon chip, each at a different spot. The chips are designed in such a way that they can find the genetic differences between, say, a cancer cell and its noncancerous precursor. Using this method, Darwin Molecular Corp. researchers in Bothell, Wash., have found some 500 genes that are altered when prostate cells turn cancerous. Those genes may hold the clues to better diagnostic tests or to biological processes that could be blocked to stop the cancer.

On a lower-tech level, the expansion of genetic knowledge also is aiding more traditional searches for human disease genes. In an approach called positional cloning, scientists first search for large families that suffer from an inherited disease. Then they look for bits of genetic material shared by the

lead women who aren't actually at high risk for breast cancer to seek mastectomies without proper medical justification, for example.

Right now, controversy is raging in Britain, where an association of insurers has announced that applicants for life insurance must disclose the results of any genetic tests they've taken. The association has also said that those results will affect premium costs and underwriting decisions. There have been calls for government intervention and fears that high-risk individuals who really should take these tests to help doctors plan their treatments will now avoid them.

It all hit home for Brit Stephen Frost, who not only must live with the unnerving knowledge that he has a 50-50 chance of developing Huntington's chorea—the best accuracy a test currently can provide—but who says his former employer, an insurer, made life so miserable for him that he had to quit his job once his diagnosis became known.

It doesn't help that on the research side the consideration of the bioethical questions has been spotty and half-hearted for years. President Clinton's call for a new group to study the ethics of cloning could lead to consideration of other research projects—such as research with viable human embryos.

At the more practical implementation level, insurance companies are at the front line today of the ethics controversy over genetic testing. But employers are close behind them. As biology tells us more and more about who we are and how we work, employers will want to know which of their workers are carrying genetic time bombs.

The problem is the genetic information available so far is incomplete and difficult to interpret. But even when much better information is avaliable, its misuse could pose a far greater threat than Frankenstein ever did.

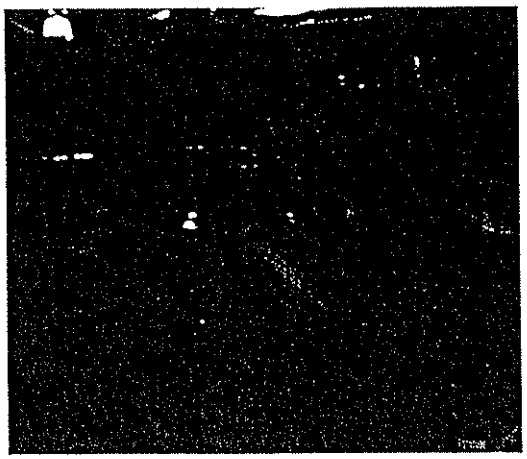
By Joan O'C. Hamilton in San Francisco, with Julie Flynn in London

(BOTTOM) ILLUSTRATION BY JORDIN ISIP

family members carrying the disease. When they find those "markers," they know the gene must be nearby.

Until recently, these searches have been hampered by a dearth of markers. But in the past few years, researchers have been mapping new markers by the thousands. "We used to say, 'We can't find the disease genes because there are not enough markers,'" says Howard Jacob of the Medical College of Wisconsin. "We fixed that. We used to say, 'It's too expensive.' And we fixed that."

That's why researchers are scouring the world, searching for families or isolated groups with rare inherited diseases. At the University of Washington, for instance, King is closing in on a gene that causes deafness in families from Costa Rica. Sequana scientists are using people from Tristan da Cunha to nab genes for asthma. A group of Germans who used to live in Russia have a unique gene for Alzheimer's. Such family lineages may soon help scientists find not just the genes for diseases caused by single defects, but for more complicated conditions like manic depression, high blood pressure, or heart disease. "We're making progress toward the real frontier of the more complex disorders," says Dr. Francis Collins, director of the Human Genome Project at the National Institutes of Health.



Gene research promises new drugs, new treatments—and a far deeper understanding of human health and behavior

CRAIG VENTER'S TEAM COMPLETED THE FIRST DNA SEQUENCE OF A BACTERIUM

CANCER HELP? While all these disease-causing genes are rare, elucidating their mechanisms may have widespread usefulness. In the case of the breast cancer gene called BRCA-1, only a small portion of breast cancer victims actually inherit mutations. But the protein encoded by the gene may play a major role in noninherited forms of breast and ovarian cancer. Dr. Jeffrey Holt, professor of cell biology at Vanderbilt University in Nashville, Tenn., has shown that mice with ovarian cancer live much longer when given a normal version of the gene. Washington's King now wants to start a clinical trial in ovarian cancer patients to see whether the technique works in people. "This shows how we can use the gene to develop a therapy," she says.

Special Report
THE BIOTECH CENTURY

In addition to new medicines, this information offers a new window into human history. "As people move around the world, their genes move with them," explains King. Geneticists have shown, for instance, that one breast-cancer mutation predates the destruction of the second temple of Israel. Another mutation moved from the Baltic to America to Israel in Jewish migrations.

Yet the explosion of genetic knowledge will reverberate far beyond new drugs or history. "The biological century will arrive on three fronts—medicine, environmental remediation, and agriculture," predicts TIGR's Venter.

Take pollution cleanups. New studies show that, during the course of evolution, nature has repeatedly added or excised clumps of genes from microorganisms, much like an engineer adding and deleting software routines while fine-tuning a computer. But if nature can do it, so can today's gene jockeys, creating a new field dubbed "genome engineering." One bug now being sequenced at TIGR can withstand astonishing amounts of radiation. By inserting the string of genes coding for the uranium-gobbling pathway, scientists might fashion a cell that can clean up highly radioactive waste.

Venter and other visionaries have dreams of a greener, more productive economy created with the help of organisms capable of doing everything from cleaning up waste to making methane—natural gas—from inorganic fuel, solving our pressing pollution problems. Genome engineering "isn't science fiction anymore," says Venter.

Indeed, the first steps are already being taken. Four years ago, Chris Somerville, head of plant biology at the Carnegie Institution of Washington, slipped a gene for making plastic into *Arabidopsis*, a type of mustard plant. The gene turned the plant into a biological plastics factory. Now, Monsanto Co. scientists are turning the concept into commercial reality. "We're expecting to see it planted in thousands of acres by 2003," says Somerville.

Just as exciting is a recent discovery by Calgene scientists of the gene for the enzyme controlling the formation of cellulose in plants. After 30 years of fruitless biochemical search for the enzyme, "this is our first break in understanding how to control biomass," Somerville explains. Genetically boosting the enzyme could make it possible to create trees with much higher proportions of cellulose—the plant kingdom's structural fiber—and less than the normal amounts of other cell wall components. Because these secondary components are what make the pulp-and papermaking process polluting and inefficient, scientists say, the engineered trees could help clean up a major industry. Beyond that, "there is a mad scramble in plant biology to find the most useful genetic sequences," says Somerville. "The world hasn't even seen the tip of the iceberg."

DOLLY'S DEBUT. Of course, the world did get a stunning glimpse of a bold new future in agriculture with Ian Wilmut's Dolly. According to biological dogma, the feat was unlikely at best. The reason: All cells possess a full complement of genes, and thus the basic instructions to create an entire organism. But during the delicate dance of development, when embryonic cells become skin, or heart, or brain, all the genes not needed for these new specialized functions are turned off. And most textbooks say they can't be turned back on again.

Wilmut and his team found a way. They extracted cells from the mammary glands of an adult sheep. Then they starved the cells. That apparently changed the complicated protein scaffolding around the cells' DNA, which plays a key role in determining which genes are active or inactive. In essence, he coerced the specialized cells into believing they had returned to a stage in which all things are possible. The genes that had been turned off were primed to turn on again.

From there, it was a simple matter of using standard high-tech methods. Wilmut took the nuclei, and thus all the genes, out of sheep oocytes. Then he placed each oocyte next to one of the treated mammary gland cells. One pulse of electricity caused the two cells to fuse, dumping the adult

PETER

sheep's genes into the egg. Another pulse prodded the oocyte to embark on the journey to make Dolly, the clone.

The process still has plenty of bugs. It took no less than 277 tries to make Dolly. "They killed a lot of embryos and made a lot of malformed sheep," says Pennsylvania's Caplan.

Special Report
THE BIOTECH CENTURY

DNA CHIPS. But the feat does help pave the way to barnyards filled with new types of livestock. Companies like Alexion Pharmaceuticals Inc. in New Haven and PPL Therapeutics PLC in Scotland already have altered pig genes to make hearts, kidneys, and other organs that could be transplanted into humans, and they have engineered cows that make drugs in their milk. The cloning process will enable these so-called transgenic animals to be duplicated much faster than by traditional breeding. "It's not an overnight revolution, but there is significant potential for research and improvement of domestic animals," says Christopher Bidwell, an animal geneticist at Purdue University.

Some scientists believe that the biological century will usher in a new era in electronics as well. The lure of genes as the basis of computation is that the twisting helixes are jam-packed with information—millions of times more than on the densest microchip. True, performing a mathematical calculation might take an hour using DNA, compared with a fraction of a second for silicon, said Dan Boneh of Princeton University at a recent meeting on DNA computing. Chips can do only one thing at a time, compared with a DNA computer, which can theoretically do 100 million billion things at once. But DNA still has a long way to go before it can hope to challenge silicon.

Already, the world is racing headlong into the biotech century. And not even the scientists leading the way know where it all might lead. TIGR's Venter wonders whether we even possess the intellect to understand how humanity's 80,000 genes can work together in intricate harmony to produce a being that is capable of contemplating its own origins and destiny. But it is clear that as we enter the new millennium, biotechnology is about to weave its own threads into the great tapestry of human history.

By John Carey in Washington, Naomi Freundlich in New York, and Julia Flynn in Roslin, Scotland, with Neil Gross in New York

WANT TO LEARN MORE?
University of Pennsylvania bioethicist Arthur Caplan and BW's John Carey will answer questions about this Special Report on America Online in the Globe on Sunday, Mar. 2, at 9 p.m. EST.

FINDING A CURE IN DNA?

Biotech companies embrace projects that examine links between genes and disease

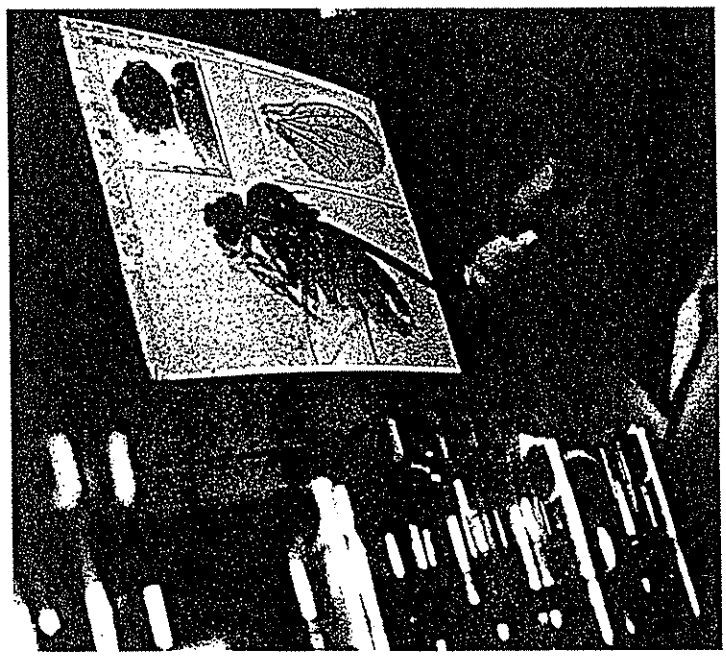
The British company PPL Therapeutics PLC, which holds the rights to the controversial sheep-cloning technology, saw its stock jump with the arrival of Dolly on the world stage. But it is far from clear whether PPL will profit from its technology. Researchers say it is too early to know exactly what the commercial applications will be.

Some of the young companies embracing and driving the biotech revolution may, however, ultimately produce huge rewards for their backers. These are the companies working in the field of genomics, delving into the mystery of the human genome and trying to pull out clues to what causes human disease. They have become darlings of Wall Street and of large pharmaceutical companies hungry for new drugs. Cynthia Robbins-Roth, a biotech industry consultant, estimates that the six largest genomics companies have deals worth up to $1 billion with their bigger pharmaceutical brethren. Many are locked in fierce competition to find genes involved in diabetes, cancer, Alzheimer's disease, schizophrenia, and other disorders.

"CHALLENGE." The key hurdle for these companies is to go beyond genome sequencing to so-called functional genomics—using a variety of laboratory techniques to identify how particular genes work—and how they go wrong. "If you're not doing this, then you're not going to be competitive," says Wole M. Fayemi, an analyst at Genesis Merchant Group Securities in San Francisco.

The race to find function is not an easy one. "It's a tremendous challenge," says David Galas, chief scientist at Darwin Molecular Corp. in Bothell, Wash. Daniel Cohen, the founder of Genset in Paris, says his company has found 100 mutated genes "and none are good targets for drugs."

In the process of hunting down those targets—places where drugs could be used to correct disorders—researchers are discovering that computer technology is a crucial tool. But some classical biological experiments with the likes



At Exelixis, researchers put nine human disease genes into fruit flies; seven led to a visible change in the insects' appearance

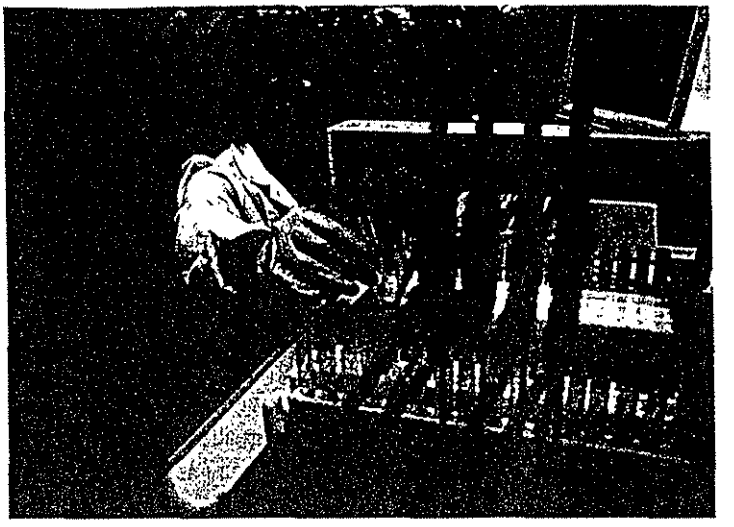
JAY REED

A TECHNICIAN PERFORMS RESEARCH ON FRUIT FLY GENES AT EXELIXIS IN CAMBRIDGE, MASS.

of fruit flies, yeast, and other simple organisms are also moving back to the refront.

To identify which genes e worthy of further study, researchers try to determine which are related to human disease. In the past, this kind of experiment involved meticulously studying one biological pathway at a time. Now, companies such as Affymetrix in Santa Clara, Calif., InCyte in La Jolla, Calif., and others are designing so-called DNA chip arrays that let researchers look at thousands of genes simultaneously and pinpoint which ones are turned on or off in a disease.

The information coming out of these arrays is powerful, but it doesn't get at the biological underpinnings of disease. That's where simple organisms come in.



DNA SAMPLES FROM DIABETIC PATIENTS ARE REVIEWED BY A SEQUANA THERAPEUTICS SCIENTIST

Rising from sellers of research to providers of product is the trick

For example, Exelixis in Cambridge, Mass., is studying fruit flies. Scientists there have inserted nine human disease genes—including one for cancer and another for obesity—into fruit flies and found that seven of them lead to a visible change in the flies' appearance. By identifying other fruit fly genes that also produce this change, researchers can begin reconstructing biological pathways that lead to disease. The hope is to find a key step in a disease pathway that can be interrupted by a drug.

Special Report
THE BIOTECH CENTURY

Other companies use baker's yeast to determine gene function. Yeast genes have far more in common with human genes than side-by-side photographs of the two might suggest. With this in mind, Cadus Pharmaceutical Corp. in Tarrytown, N. Y., is using yeast to determine the function of some 400 genes that code for so-called receptors—molecules on the outside of cells where the cells receive messages. Many disorders are related to improper working of these receptors, making them good targets for drug development. On Feb. 27, the public company announced that it is signing a deal worth up to $68 million with SmithKline Beecham for access to its yeast work.

The larger genomics companies are beefing up their functional side—often by striking deals with startups. Last October, Sequana Therapeutics Inc., a genomics firm in La Jolla, Calif. bought NemaPharm, a startup that specializes in nematodes. According to Timothy J. Harris, Sequana's vice-president for research and development, Glaxo was so excited by this purchase that they cut a second deal with Sequana for access to the nematode work. The worms are especially helpful in the study of Alzheimer's disease and other neurological ills. Sequana also has made forays into fruit flies, yeast, and other organisms.

Dr. Robert Tepper, vice-president of biology at Millenium Pharmaceuticals, has experiments running in flies, yeast, and mice. But he's excited about Millenium's work involving human disease via population studies and the growing integration of mammalian cells with microchips. "Given a choice, I'd rather rely on these," he says. He shares the worry with Genset's Cohen that there's no guarantee treatments for a fly will be applicable to a human being.

PROMISES. Although companies may disagree about the best strategy for divining the workings of genes, they agree that the range of new technologies—from the fruit flies to complex arrays of DNA-studded computer chips—are the wave of the future. "A gene sequence doesn't do squat to cure patients," says Remi Barbier, chief financial officer at Exelixis.

Questions remain on whether genomics companies can rise from sellers of research data to providers of product. But by integrating technologies into their programs, they have taken the first step. "The outlook remains extremely promising," for functional genomics companies, says Elizabeth Silverman, a biotech analyst at Punk, Ziegel & Knoell in New York. "It's a technology that's at the bottom of its curve in terms of its contribution to drug discovery and development."

By Naomi Freundlich in New York

THE SEARCH FOR FUNCTION

Much of the promising work on commercial applications of genetics is occurring at small companies. Some are already publicly traded; others might help their larger partners strike it rich.

AFFYMETRIX* SANTA CLARA, CALIF. DNA chips. Deals with Hoffmann-La Roche, Merck, and Glaxo.

CADUS* TARRYTOWN, N.Y. Studying yeast. Deals with SmithKline Beecham, Bristol-Myers Squibb, and Solvay.

EXELIXIS CAMBRIDGE, MASS. Fruit flies. Private co. raised $16 million, IPO expected next year. No announced deals yet.

GENSET* PARIS Strength is in finding regulatory regions for genes. Deals with Synthelabo, Johnson & Johnson.

HUMAN GENOME SCIENCES* ROCKVILLE, MD. Strong sequencing company. Deals with SKB and Merck DGaA.

INCYTE* PALO ALTO, CALIF. Combines huge DNA database with chips. Deals with Pfizer, Upjohn, and 8 others.

MILLENNIUM* CAMBRIDGE, MASS. Gene hunters plus strong functional capabilities. Deals with Hoffmann-LaRoche, Lilly.

NEMAPHARM CAMBRIDGE, MASS. Studying nematodes, now owned by Sequana. Deal with Glaxo.

*PUBLICLY TRADED

DATA: BW

JHS

ROBER

History of Biotechnology

Objectives:

1. To explain the basic history of biotechnology in agriculture.
2. To identify important applications of biotechnology.
3. To research ways that biotechnology may affect the future of agriculture

Strategies: (What will the teacher do?)

Assign the study guide and essay prior to class.
Review the study guide and individual essays.
Review the Biotechnology Timeline
Introduce and prepare students to do the DNA Extraction lab.

Activities: (What will the learner do?)

Read the entire publication
Study Guide
Essay
Read the DNA extraction lab and perform the lab.

Evaluation:

Study Guide
Essay
DNA Extraction lab

References/Resources:

"Farmers Discovered Biotechnology 10,000 Years Ago..."
DNA Extraction Lab Handout
Study Guide Handout
Essay Handout
Biotechnology Timeline Handout

History of Biotechnology

- 10,000 years ago- People used microbes to produce wine, bread and cheese

-1865 Gregor Mendel's Theory of Heredity

Friedrich Miescher 1867-
discovers nucleic acid or DNA

-1900 Chemical composition of DNA was determined

Oswald Avery 1944-
Discovers genes are made of DNA

- 1953 Watson & Crick-discover the double-helix structure of DNA

Discovery of ligating 1967-
enzyme that join fragments of DNA

-1970 H. Smith- Isolated restrictive enzymes which cut DNA fragments

Boyer & Cohen 1973-
Recombine human DNA with bacteria DNA to produce human protein

- 1983 Gene from an E.Coli was transferred into a plant cell

Ag 1 Unit: **Biotechnology in Ag**

History of Biotechnology Study Guide

1. Why did agriculture begin?

2. What was one of the earliest "biotechnology" techniques used by farmers? W was the major goal of this process?

3. When did scientists first recognize hybrid plants?

4. What *is a hybrid*?

5. What major biotechnology event occurred in the 1930's?

6. How much have corn yields increased in the past 100 years?

7. Around 1800, people began to use...

8. Why are bacteria used to process foods?

9. List three examples of foods which are produced by utilizing bacteria, and ex the role of the bacteria.

Extra Credit:
What two scientists are credited with discovering how DNA is constructed.

Ag 1 Unit: **Biotechnology in Ag**

History of Biotechnology Study Guide

1. Why did agriculture begin?

   -about 8000 B.C., when people began to settle in one spot and raise plants

2. What was one of the earliest "biotechnology" techniques used by farmers? W was the major goal of this process?

   -Selective breeding of plants and animals: to produce better plants and an (improved the genetics)

3. When did scientists first recognize hybrid plants?

   -early 1700's

4. What is a hybrid?

   -the offspring of breeding two varieties

5. What major biotechnology event occurred in the 1930's?

   -hybrid crop seed dramatically increased crop yields

6. How much have corn yields increased in the past 100 years?

   -tripled

7. Around 1800, people began to use _____ to create new foods.

   -bacteria

8. Why are bacteria used to process foods?

   -produce desireable flavors and textures; can also preserve food by preventing the growth of <u>pathogenic</u> microorganisms

9. List two examples of foods which are produced by utilizing bacteria, and explain the role of the bacteria.
   -Cheese: produces desired flavors ; Yogurt: ferments the milk
   (Note: Soy sauce and Yeasts are fungi <u>not</u> bacteria)

<u>Extra Credit:</u>
What two scientists are credited with discovering how DNA is constructed.
-Watson and Crick

Ag 1 Unit: **Biotechnology in Ag**

History of Biotechnology Essay

Choose <u>one</u> of the following articles:

Making the World's Food Better
Cut and Paste: Molecular Scissors Make New Products Possible
Guess Who's Coming to Dinner? 10 Billion by 2030
Sweet Success With Sweet Potatoes

- In one paragraph, explain the major idea presented in this article.
- In a seperate paragraph, explain how this idea could affect agriculture in Iowa.

DNA Extraction from ~~Onion~~ Banana / Kiwi

DNA is present in the cells of all living organisms. This procedure is designed to extract DNA from onion in sufficient quantity to be seen and spooled. It is based on the use of household equipment and supplies. ~~Onion~~ Banana is used because of its low starch content which allows the DNA to be clearly seen.

Materials:

- two 4-cup measuring cups (1000 ml) with ml markings
- one 10 cup measuring cup (250 ml) with ml markings
- measuring spoons
- sharp knife for cutting ~~onion~~ banana
- large spoon for mixing and crushing ~~onion~~ banana
- thermometer that will measure 60 degrees C (140 degrees F)
- strainer or funnel
- # 6 coffee filter or cheese cloth
- hot water bath (60 degrees C) saucepan and hot plate works well
- ice water bath (a large mixing bowl works well)
- distilled water
- light-colored dish washing liquid or shampoo (Dawn works well)
- large onion
- table salt, either iodized or non-iodized
- meat tenderizer that contains papain, such as Adolph's
- one small test tube per student (preferably with cap)
- medicine droppers or Pasteur pipettes
- 95 % ethanol (grain alcohol)
- flat toothpicks

Procedure:

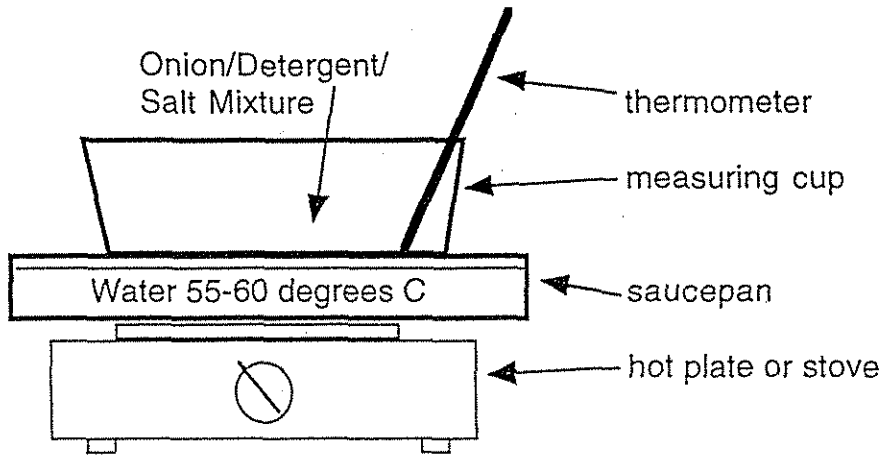
1. Set up hot water bath at 55 to 60 degrees C and an ice water bath.

2. Prepare ~~Onion~~ Banana Solution: Mix one tablespoon dish washing liquid, and one level 1/4 teaspoon of table salt. Add distilled water until the total volume is 100 ml. Dissolve the salt by stirring slowly to avoid foaming.

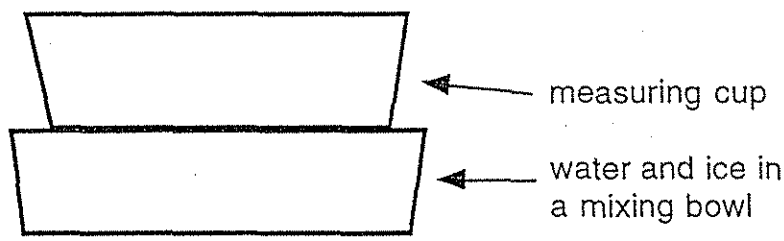
3. Coarsely chop the ~~onion~~ banana and place into a 4-cup measuring cup.

4. Cover chopped ~~onion~~ banana with the 100 ml. solution from step 2.
   Liquid detergent causes the cell membrane to breakdown and dissolves the lipids and proteins of the cell by disrupting the bonds that hold the cell membrane together. The detergent causes lipids and proteins to precipitate out of the solution. NaCl enables nucleic acids to precipitate out of an alcohol solution because it shields the negative phosphate end of DNA, causing the DNA strands to come closer together and coalesce.

5. Place the 4-cup measuring cup into the hot water bath for 10-12 minutes. **Caution:** Do not heat longer than 15 minutes because the DNA will begin to break down.



6. Cool the mixture in the ice water bath for 5 minutes. (Caution if you are not using Pyrex the glass measuring-cup may shatter.) During this step press the chopped onion against the sides of the measuring cup with the back of the spoon. *T(his step slows the breakdown of DNA.)*



7. Filter the mixture through a #6 coffee filter or four layers of cheese cloth placed in a strainer over a 4-cup mixing bowl. (Strain in a refrigerator overnight.)

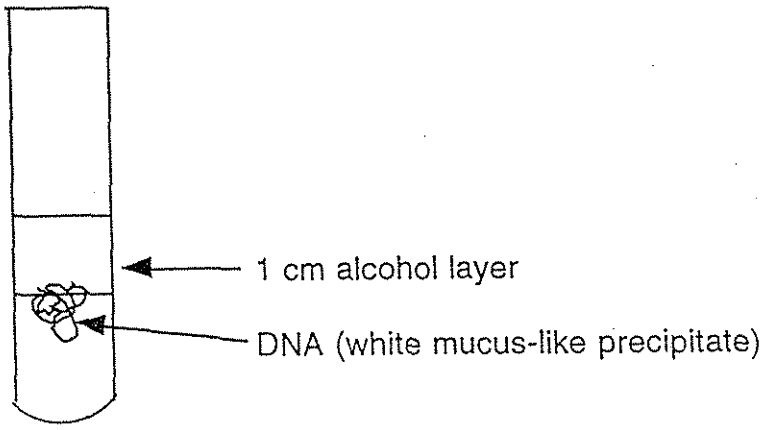
8. Gently mix the onion solution and dispense into test tubes, one for each student. The test tubes should contain about 1 teaspoon of solution or be about 1/3 full. Stir the solution frequently when dispensing into the test tubes.

9. Add two toothpick full of meat tenderizer to the onion solution, cap the tube, and mix gently to avoid foaming. *Meat tenderizer contains papain, an enzyme that will clean extra protein away from the DNA.*

10. Add cold alcohol to each test tube. Slowly poor the alcohol down the side of the test tube to avoid mixing of the solution. Add alcohol until you create a layer of alcohol on top of about 1 cm. For best results the alcohol should be as cold as possible.

11. Allow to sit for 2-3 minutes without disturbing. You can watch the white DNA

precipitate out into the alcohol layer. When good results are obtained, there will be enough DNA to spool onto a glass rod. *DNA has the appearance of white mucus.*



Study Questions:

1. List three other possible sources of DNA. (Sources other than onion.)

2. What is DNA ?

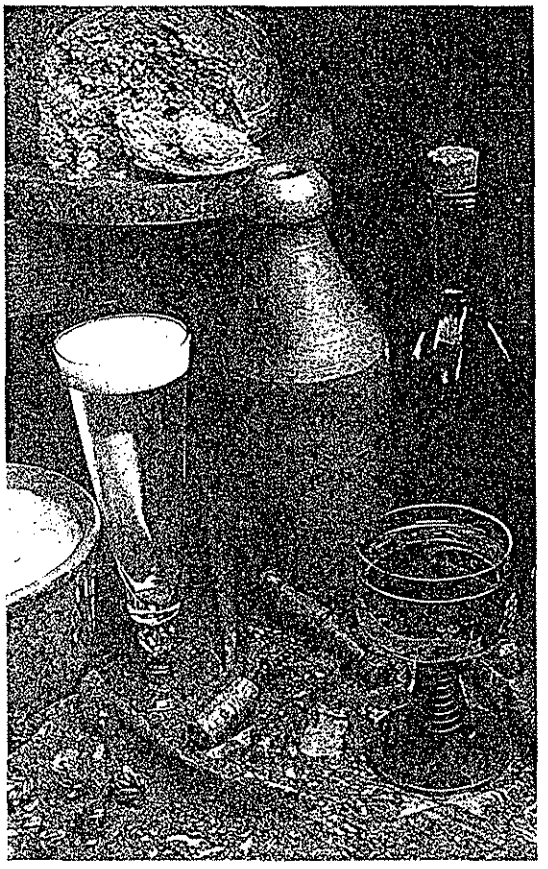
3. Why is an understanding of DNA important to understanding biotechnology ?

4. Why are genetics and genetic advancements important to agriculture ?

Farmers Discovered Biotechnology 10,000 Years Ago: *It's Getting Better With Age*

SEE INSIDE FOR ...

You'll find interesting facts about our planet and its hungry population. You'll learn what Monsanto's researchers can do, and are doing, to prepare farmers around the world to feed more mouths with fewer acres.



Many of the modern tools and techniques we use today to create new foods are not new at all, but merely improved, more precise versions of methods employed throughout history. Even researchers using the latest biotechnology methods, which allow the transfer of a gene from one organism to another, basically are working with the same scientific processes people have used for centuries to increase crop productivity, improve the food supply and produce better foods.

Our long, gradual learning process about foods and food production has spanned several centuries and continues today.

Hundreds of thousands of years ago, people wandered the earth, collecting and eating only what they found growing in nature. By about 8000 B.C., however, the first farmers decided to stay in one place and grow certain plants as crops — creating agriculture and civilization, in that order.

Since that time, people have continued to select, sow and harvest seeds to produce better, safer and larger quantities of foods to sustain themselves. Through crossbreeding and fermentation processes, they moved and modified genes to develop better foods, without understanding the scientific processes behind their actions.

As early as the 1700s, naturalists identified many kinds of hybrid plants — the offspring of breeding between two varieties of plants. By the late 1930s, hybrids accounted for major increases in crop yields. For example, maize/corn hybrids have contributed to tripling maize/corn yields in this century.

Another innovation was employed around 1800, when people first used bacteria to create new and different foods, employing yeast and fermentation processes to make wine, beer and leavened (or soft) bread. When certain bacteria grow in foods, they

Continued on page 4.

NEWBIONEWS
Information On Biotechnology

Making The World's Food Better

For centuries, farmers have made improvements to crop plants through selective breeding and hybridization — the controlled pollination of plants. Plant biotechnology is an extension of this traditional plant breeding with one very important difference — plant biotechnology allows for the transfer of a greater variety of genetic information in a more precise, controlled manner.

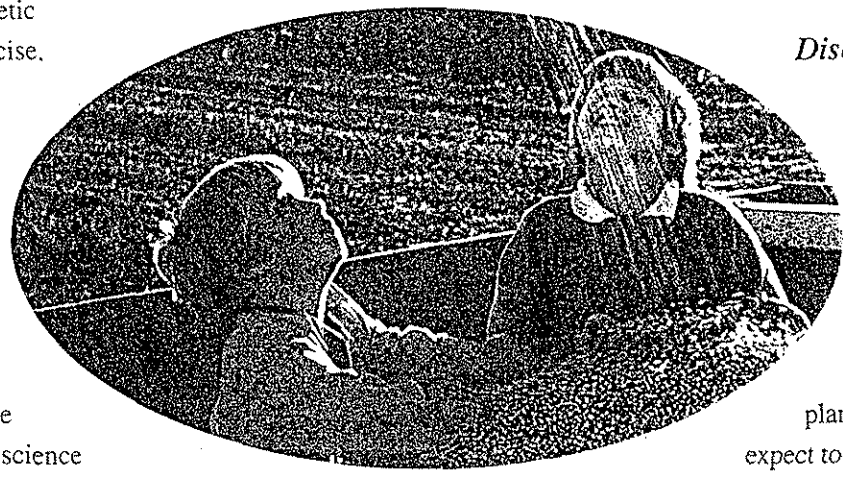
Unlike traditional plant breeding, which involves the crossing of hundreds or thousands of genes, plant biotechnology allows for the transfer of only one or a few desirable genes. This more precise science allows plant breeders to develop crops with specific beneficial traits and without undesirable traits, such as those that would reduce crop yields.

Many of these beneficial traits in new plant varieties fight plant pests — insects, disease and weeds — that can be devastating to crops. Others provide quality improvements, such as tastier fruits and vegetables; processing advantages, such as tomatoes with higher solids content; and nutrition enhancements, such as oil seeds that produce oils with lower saturated fat content. Crop improvements like these can help provide an abundant, healthful food supply and protect our environment for future generations.

Insect Protection

Anyone who has planted a backyard garden is familiar with the potential devastation caused by insect pests. Farmers also face these problems — on a much larger scale.

Bacillus thuringiensis (*B.t.*) — a naturally occurring bacterium present in soil — is known for its ability to control insect pests. Different strains of *B.t.* control different pests. First discovered in 1902, gardeners have been using *B.t.* for decades as a biological insecticide spray. *B.t.* produces a protein that disrupts the digestive system of targeted insects, while remaining harmless to other insects, people, birds and other animals.



Now through biotechnology, researchers are introducing the *B.t.* gene into plants, which allows the plants to protect themselves from certain insect pests. For example, Monsanto's NewLeaf® potato plants are protected from the Colorado potato beetle. Monsanto also has developed cotton with the Bollgard® gene that protects the crop from the tobacco budworm, cotton bollworm and pink bollworm and YieldGard™ maize/corn, which is protected from the European corn borer. These products give today's farmers an alternative to chemical insecticides normally needed to control these pests.

When farmers decrease chemical insecticide use, beneficial insects can survive to help control other harmful insects.

Disease Protection

Plant disease, including fungal and viral diseases, can devastate the yield and quality of crop production. To minimize the economic loss resulting from plant disease, farmers often must plant more acreage than they expect to harvest. This extra acreage increases farmers' planting, fuel, water and fertilizer expenses, which must be passed on to the consumer.

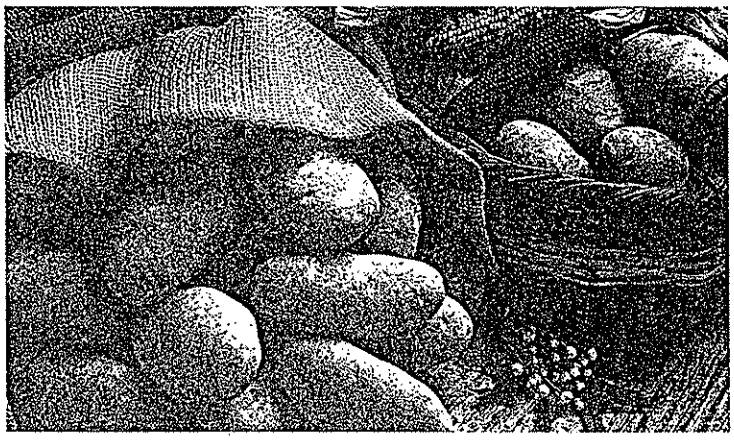
Not all farmers can afford the costs of these traditional methods of disease control. The expense of chemical insecticides is prohibitive in many parts of the world, such as parts of Africa, where, for example, the feathery mottle virus can destroy up to 80 percent of farmers' sweet potato harvests.

Biotechnology makes possible the development of crops protected from certain types of plant viruses. By introducing a small part of the DNA from a virus into the genetic makeup of a plant, researchers have developed crops that have built-in immunity to targeted diseases.

Disease-protected crops offer agricultural, economic and environmental

benefits to farmers. Farmers will be less dependent on chemical insecticides used to control insects that carry viral disease, and they will be able to protect their crop yields. Farmers can reduce resources used, such as the expense of labor, fuel, pesticides, seed and equipment used to plant "extra" acres.

Weed Control



Farmers have battled weeds since the beginning of farming. Weeds not only compete with crops for water, nutrients, sunlight and space, but also harbor insect and disease pests; clog irrigation and drainage systems; undermine crop quality; and deposit weed seeds into crop harvests.

Farmers can fight weeds with tillage, herbicides or, typically, a combination of these techniques. Unfortunately, tillage leaves valuable topsoil exposed to wind and water erosion, a serious long-term consequence for the environment.

Herbicide-tolerant crops offer farmers a vital tool in fighting weeds and are compatible with reduced-tillage methods, which help preserve topsoil. Herbicide-tolerant crops give farmers the flexibility to apply herbicides only when needed, to reduce total herbicide use and to use herbicides with preferred environmental characteristics.

Monsanto researchers have developed herbicide-tolerant crops, such as oilseed rape/canola, maize/corn, cotton and soybean, that can tolerate Roundup® herbicide, known for its favorable environmental characteristics. Roundup effectively controls a broad range of grasses and broadleaf weeds by inhibiting an enzyme essential to plants' growth. In other words, Roundup inhibits growth by establishing a roadblock in plants' metabolic pathways. The gene inserted into these herbicide-tolerant crops — known as Roundup Ready® crops — increases the enzyme in the plants, providing a detour around the roadblock. This detour makes it possible for Roundup Ready crops to thrive even after Roundup is used over the top of the growing crop to control weeds.

Roundup is desirable from an environmental and safety perspective because it binds tightly to soil particles and quickly breaks down in the soil into naturally occurring components, such as carbon dioxide.

Other Crop Improvements

By introducing a gene or genes into a crop plant, many other advantageous features may be possible. Examples include:

• A genetic trait that controls the ripening of tomatoes, peppers and tropical fruits. This trait allows time to ship crops long distances and results in tastier foods far from crops' native regions.

• Potatoes and tomatoes developed with higher solids content. This trait offers decreased processing costs because less energy is needed to extract water when producing potato and tomato products. The higher solids content of potatoes holds the potential to bring consumers lower fat French fries. Because oil replaces water during the frying process, potatoes with higher solids content (and less water) absorb less oil.

• Maize/corn and soybeans with increased essential amino acid content — the building blocks of protein. This trait can improve the quality of protein in food products and animal feed made from these crops.

• Naturally decaffeinated coffee.

• Maize/corn and peas that retain their natural sweetness.

• Crops with modified fatty acid content, allowing for the production of more healthful oils.

benefits to farmers. Farmers will be less dependent on chemical insecticides used to control insects that carry viral disease, and they will be able to protect their crop yields. Farmers can reduce resources used, such as the expense of labor, fuel, pesticides, seed and equipment used to plant "extra" acres.

Weed Control

Farmers have battled weeds since the beginning of farming. Weeds not only compete with crops for water, nutrients, sunlight and space, but also harbor insect and disease pests; clog irrigation and drainage systems; undermine crop quality; and deposit weed seeds into crop harvests.

Farmers can fight weeds with tillage, herbicides or, typically, a combination of these techniques. Unfortunately, tillage leaves valuable topsoil exposed to wind and water erosion, a serious long-term consequence for the environment.

Herbicide-tolerant crops offer farmers a vital tool in fighting weeds and are compatible with reduced-tillage methods, which help preserve topsoil. Herbicide-tolerant crops give farmers the flexibility to apply herbicides only when needed, to reduce total herbicide use and to use herbicides with preferred environmental characteristics.

Monsanto researchers have developed herbicide-tolerant crops, such as oilseed rape/canola, maize/corn, cotton and soybean, that can tolerate Roundup® herbicide, known for its favorable environmental characteristics. Roundup effectively controls a broad range of grasses and broadleaf weeds by inhibiting an enzyme essential to plants' growth. In other words, Roundup inhibits growth by establishing a roadblock in plants' metabolic pathways. The gene inserted into these herbicide-tolerant crops — known as Roundup Ready® crops — increases the enzyme in the plants, providing a detour around the roadblock. This detour makes it possible for Roundup Ready crops to thrive even after Roundup is used over the top of the growing crop to control weeds.

Roundup is desirable from an environmental and safety perspective because it binds tightly to soil particles and quickly breaks down in the soil into naturally occurring components, such as carbon dioxide.

Other Crop Improvements

By introducing a gene or genes into a crop plant, many other advantageous features may be possible. Examples include:

• A genetic trait that controls the ripening of tomatoes, peppers and tropical fruits. This trait allows time to ship crops long distances and results in tastier foods far from crops' native regions.

• Potatoes and tomatoes developed with higher solids content. This trait offers decreased processing costs because less energy is needed to extract water when producing potato and tomato products. The higher solids content of potatoes holds the potential to bring consumers lower fat French fries. Because oil replaces water during the frying process, potatoes with higher solids content (and less water) absorb less oil.

• Maize/corn and soybeans with increased essential amino acid content — the building blocks of protein. This trait can improve the quality of protein in food products and animal feed made from these crops.

• Naturally decaffeinated coffee.

• Maize/corn and peas that retain their natural sweetness.

• Crops with modified fatty acid content, allowing for the production of more healthful oils.

We've Learned A Lot bout DNA In 200 Years

The DNA (deoxrybonucleic acid) from different organisms is essentially the same — simply a set of instructions that direct cells to make the proteins that are the basis of life. Whether the DNA is from a microorganism, a plant, an animal or a human, it is made from the same materials.

As early as the 1800s, researchers understood that all living things are made up of cells that are basically the same. However, it took more than 100 years for researchers to truly understand what was in a cell and how it worked.

At the turn of the century, researchers discovered that all cells ntain a sticky substance called NA. During the 1950s and 1960s, English physicist Francis Crick and American biochemist James Watson learned how DNA was constructed and worked, a discovery that awarded them a Nobel Prize in 1962.

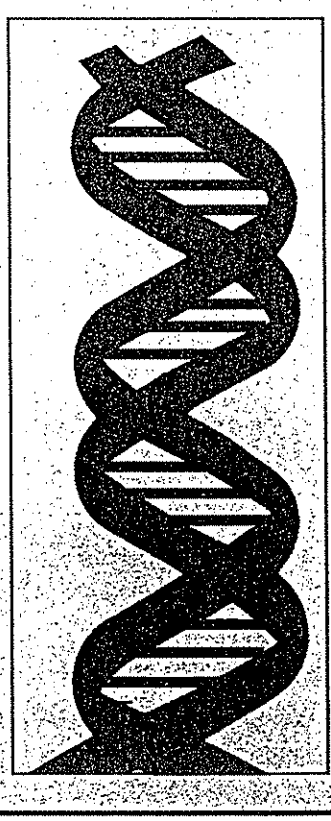
Crick and Watson determined that DNA consists of a double helix structure resembling a spiral ladder. The ladder's legs are composed of two alternating chemicals. These legs are joined by "rungs" made of two nitrogen base chemicals. Crick and Watson also discovered that the sequence of these bases determines the messages or traits passed along by genes. These facts helped researchers determine that DNA directs the development and growth of all living organisms.

Once researchers discovered that all living things understand the same basic DNA code and that genes are interchangeable, they explored transferring a gene, or a specific piece of DNA, from one organism to another.

In late 1973, Dr. Stanley Cohen of Stanford University and Dr. Herbert Boyer of the University of California at San Francisco first applied this theory successfully and transferred the first gene.

This led to the discovery of biotechnology, or genetic modification, which provides the method for new advancements across several industries, including health care, agriculture and environmental protection.

DNA is a double-stranded helix resembling a spiral ladder. The two strands — the ladder's legs — are connected by rungs of two alternating chemicals.



Better With Age

Continued from page 1.

produce desirable flavors and textures. As culinary enhancers, bacteria can be found in many common foods, including:

CHEESE: During the aging of cheese, bacterial enzymes generate characteristic flavors, allowing for wide variations in the end-products. For example, *Penicillium roqueforti*, a mold, gives Roquefort cheese its pungent flavor. Another mold strain, *P. camemberti*, gives Camembert and Brie cheeses their distinctive qualities.

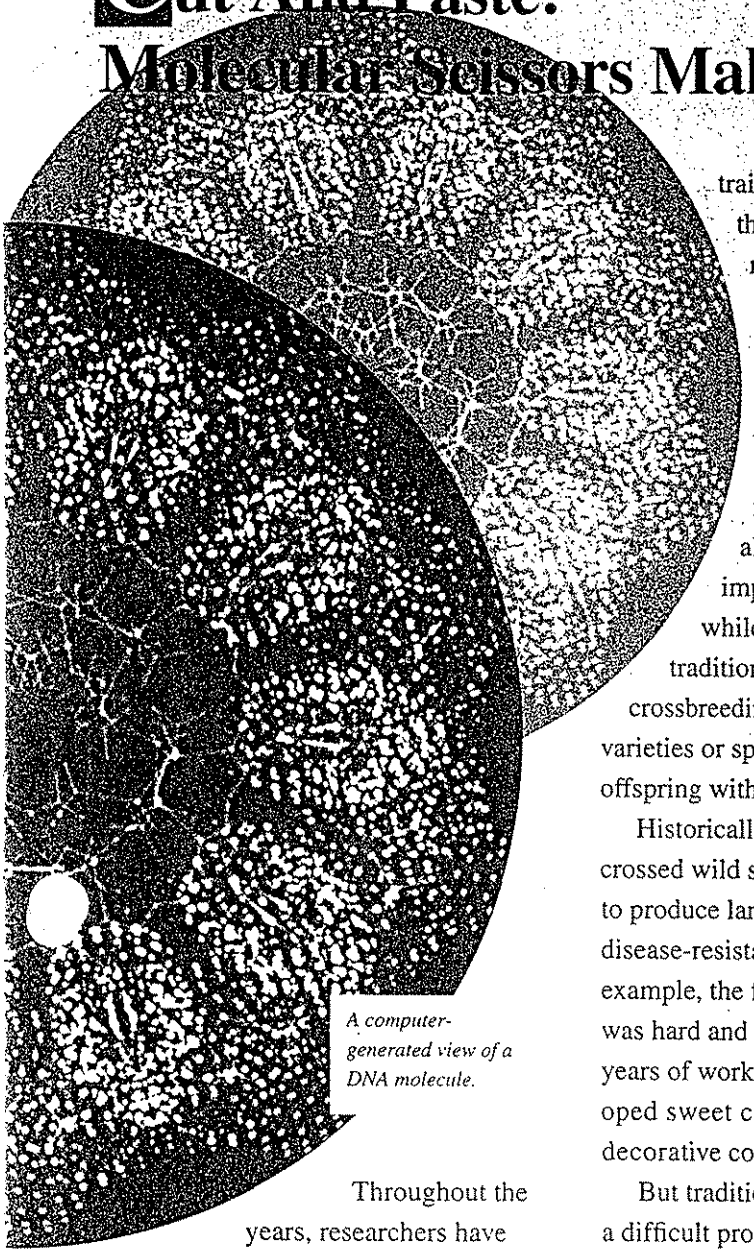
SOY SAUCE: *Aspergillus soyae* and *A. oryzae*, both molds, create soy sauce after sitting a few days in a tank with roasted soybeans, wheat, a salt solution, plus some bacteria and yeast. A similar process produces tofu.

YEAST: Composed of one or more selected strains of *Saccharomyces cerevisiae*, various forms of yeast are used in making bread products and in brewing beer and ale. The use of yeast in baking goes back to 1665, when a baker decided to add some to his leaven. When bakers add yeast to dough, it causes alcoholic fermentation, creating a gas that makes the dough rise.

YOGURT: Food makers produce another fermented product, yogurt, through the combined action of two species of bacteria, *Streptococcus thermophilous* and *Thermobacterium bulgaricum*.

These few examples demonstrate how scientific processes have been making our foods more flavorful for a long time.

Cut And Paste: Molecular Scissors Make New Products Possible



A computer-generated view of a DNA molecule.

Throughout the years, researchers have discovered how to transfer a specific piece of DNA — the basic genetic material in cells of every living organism — from one organism to another. This is important because a cell cannot live outside its own designated environment. A kidney cell, for example, can exist only in the kidney.

So, if researchers want to instruct a cell to produce a specific genetic trait, such as a plant that is virus resistant, researchers must "insert" the instructions for change into the cell — thus, the basis of biotechnology!

These discoveries in biotechnology have allowed researchers to improve many crops while complementing traditional methods, such as crossbreeding plants of different varieties or species to develop offspring with more desirable traits.

Historically, plant breeders crossed wild species with crop plants to produce larger, stronger and more disease-resistant varieties. For example, the first wild maize/corn was hard and inedible. Through years of work, plant breeders developed sweet corn, feed corn, decorative corn and popcorn.

But traditional plant breeding is a difficult process. Growers don't have the luxury of isolating specific genes or traits. They get the bad with the good when they pair plants of different varieties — and then they spend years breeding out undesirable traits. However, with genetic modification — a process that involves modifying a cell so it can perform new functions — today's breeders can transfer a single desired trait into their favorite plant varieties.

A researcher's first step in transferring DNA is to "cut" or remove a gene segment from a chain of DNA using enzyme "scissors" to cut at a specific site along the DNA strand.

The researcher then uses these "scissors" to cut an opening into the plasmid — the ring of DNA often found in bacteria outside of a cell. Next, the researcher "pastes" or places the gene segment into the plasmid. Because the cut ends of both the plasmid and the gene segment are chemically "sticky," they attach to each other, forming a plasmid containing the new gene. To complete the process, researchers use another enzyme to paste or secure the new gene in place.

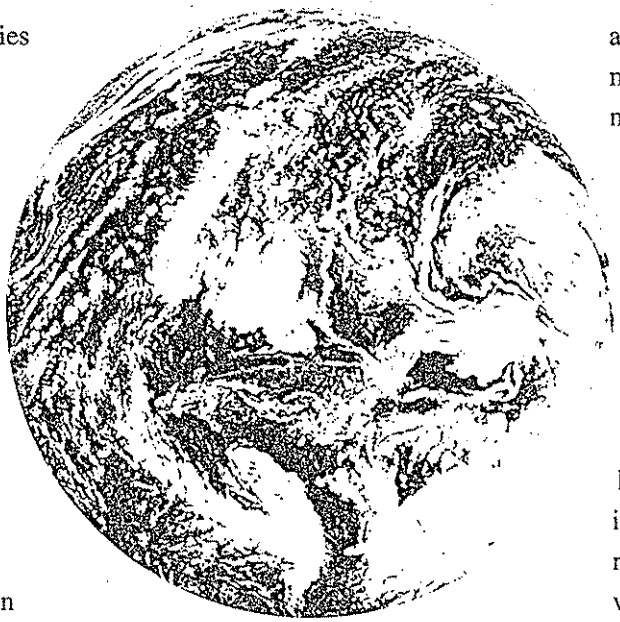
The bacterial plasmid makes biotechnology possible because it can pass between certain cells of bacteria and exchange genetic information. For example, Monsanto researchers use a naturally occurring bacterium called *Agrobacterium* as the means to introduce new genes into plants. Then, they grow whole plants that exhibit the new trait and, finally, produce seeds to grow improved crops.

For some crops, such as maize/corn and wheat, researchers use a particle gun instead of *Agrobacterium* to transfer desirable traits from one plant to another. Researchers bathe microscopic pellets of gold or tungsten in DNA

Continued on page 7.

Guess Who's Coming To Dinner?
10 Billion By 2030

One of the future's few certainties is that the world's population will nearly double, reaching almost 10 billion inhabitants by the year 2030. Humanity must respond to the growing pressures on the Earth's natural resources to feed more people.



Current population growth already is straining the Earth's resources. In the past three decades, world leaders have expended enormous efforts and resources to increase agricultural output. But, because the population has increased almost as rapidly as harvested crops, per capita food production generally has grown modestly.

A lack of suitable farmland due to urban growth, the high cost of fertilizer and irrigation, inadequate transportation and storage methods, and the destruction of topsoil by wind and water erosion also have contributed to food shortages in some parts of the world. As a result, the number of undernourished people still is rising in most developing countries.

Many economists and agricultural experts agree that simply continuing past technological innovation and investment in agricultural infrastructure — basic facilities such as roads, power plants, transportation and communication systems — will not produce sufficient crop yield increases and improvements to feed the world's burgeoning population.

Today's high-yield agriculture is a stunning example of the successes gained through agricultural research. Since 1960, high-yield agriculture has doubled world food production and tripled productivity of the land and water used in agriculture — without any increase in cropland planted globally. Without these strides, farmers would have to plant an additional 10 million square miles — approximately the size of North America — just to meet current food needs.

Traditional breeding programs are still successful, but the success isn't occurring fast enough to be the sole source of solutions to our food production needs. Biotechnology is a science that can complement traditional breeding, and *together* they offer the greatest promise for increasing food productivity.

Biotechnology, which allows the transfer of a gene for a specific trait from one species to another, allows crop improvements that cannot be achieved through traditional breeding methods. Experts assert that biotechnology innovations will triple crop yields without requiring any additional farmland, saving valuable rain forests and animal habitats.

In addition to technical innovations, investments in infrastructure to improve storage, transportation and processing will be vital to reducing crop and post-harvest losses. Development of infrastructure also will help small, resource-poor farmers in the third world utilize local marketplaces.

For example, Brazil, Argentina and Bolivia have some 300 million acres of unplanted land — not rainforests — suitable for crops, such as grain and soybeans. But they lack infrastructure — roads, rails and distribution centers — to support intensive commercial agriculture. Infrastructure improvements not only would allow farmers to transport crops to more people, but also would bring economic benefits to farming communities.

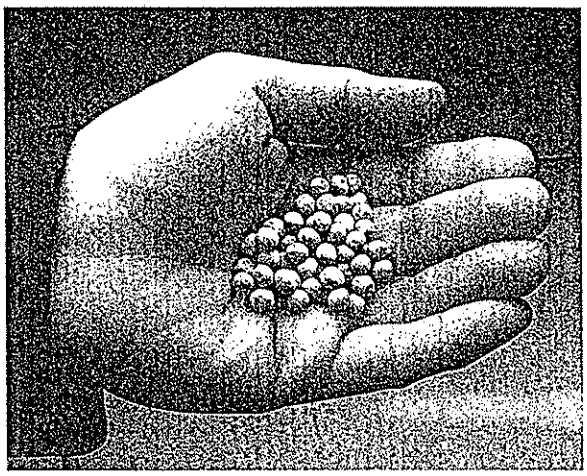
Most experts agree that the world doesn't have the luxury of waiting to act. By working now to put in place the technology and the infrastructure required to meet future food needs, we can feed the world for centuries to come and improve the quality of life for people worldwide.

Gregor Mendel's Pea Plants Lead To Genetic Laws

Why do children often look like their parents? How can children inherit blue eyes from their mothers and brown hair from their fathers? These questions about genetics are similar to the ones monk Gregor Mendel spent his life trying to answer in the 19th century.

Scientists before Mendel dabbled in the area of genetics but were unable to discover how characteristics are passed from one generation to the next. After eight years and thousands of experiments with pea plants, Mendel developed his laws of heredity. Initially, no one recognized the importance of his work. Most historians attribute the lack of interest in Mendel's research to the simultaneous announcement of Darwin's Theory of Evolution.

It wasn't until 1900, 16 years after Mendel's death, that three botanists in different areas of Europe discovered the significance of the information contained in "Proceedings," the document that introduced Mendel's five principles of heredity.



Since then, many researchers have used Mendel's five principles, also known as *Mendelian laws*, to develop more advanced theories of genetics. One of the most remarkable discoveries this century occurred in 1946 when researchers revealed that genes are made up of DNA, the hereditary material present in the cells of living things. This significant advancement ultimately led researchers to develop biotechnology, which allows the transfer of a gene for a specific trait from one organism to another.

This process expands the possibilities of genetic applications across nearly every discipline. From new medical treatments and environmental clean-up, to agricultural production and manufacturing processes, biotechnology promises to bring better answers to important modern-day questions. Gregor Mendel's work not only has stood the test of time, it has established the foundation for today's advancements.

Cut And Paste

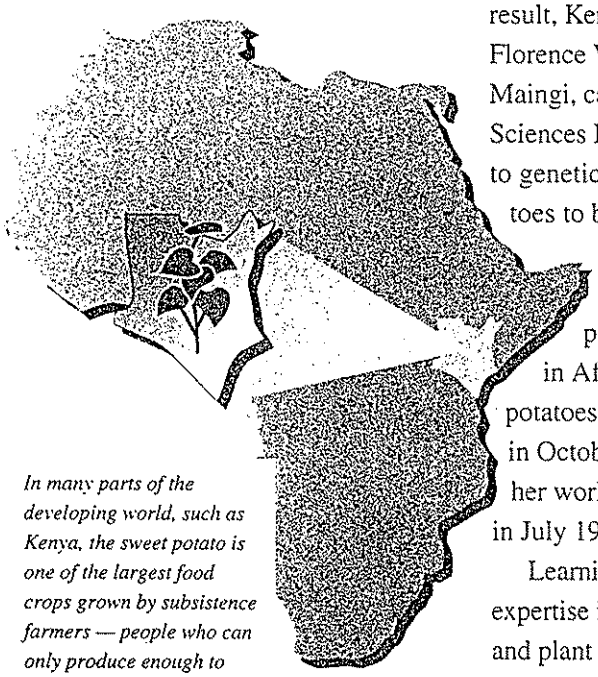
Continued from page 5.

that has the desired trait. The coated pellets are fired through plant cells with a special gun. As they pass through the cells, some of the DNA coating is left behind, mixing with the plant cell's DNA to add a new beneficial trait.

Decades of research have allowed Monsanto specialists to apply their knowledge of genetics to improve various crops, such as maize/corn, soybeans, oilseed rape/canola, cotton and potatoes. These researchers continue to work carefully to ensure that improved crops are the same as current crops, except for the addition of one beneficial trait, such as resistance to a particular insect or virus.

Sweet Success With Sweet Potatoes

Sweet potatoes are one of the largest subsistence food crops in the world, which means they are commonly grown by farmers who can only produce enough to feed their families. Sweet potatoes are high in carbohydrates and vitamin A, and are easy to grow, even in poorly productive soil or during droughts. In addition, harvested sweet potatoes can be stored underground for years, providing a stable food supply for countries like Kenya — a country with 26 million people, 96 percent of whom are starving.



In many parts of the developing world, such as Kenya, the sweet potato is one of the largest food crops grown by subsistence farmers — people who can only produce enough to feed their families.

Unfortunately, sweet potatoes are very susceptible to viral diseases. The feathery mottle virus (FMV) — a degenerative plant disease common in Africa — can reduce crop yields by as much as 50 to 80 percent.

Aphids — small, widespread insects — transfer FMV to plants throughout Africa. Due to economical and technical constraints, African farmers cannot use chemical sprays to control these pests, so the problem persists year after year.

Monsanto is involved in a unique collaborative project with the United States Agency for International Development to accelerate the transfer of technology to less developed countries, so these countries can develop their own agricultural improvements. As a result, Kenyan researchers, Dr. Florence Wambugu and Dr. Daniel Maingi, came to Monsanto's Life Sciences Research Center in St. Louis to genetically improve sweet potatoes to be protected against FMV.

For almost three years, Wambugu developed protection against viruses in African varieties of sweet potatoes. Maingi joined her efforts in October 1993 and has continued her work since her return to Africa in July 1994.

Learning to apply Monsanto's expertise in gene transfer technology and plant regeneration, the researchers are taking tiny portions of the protein coats that surround all FMV and introducing those proteins into African sweet potato plants. Once exposed, the sweet potato plants develop their own protection against full FMV virus.

Plant biotechnology is a perfect fit for the developing world because plant improvements are incorporated in the seed. Crops protected against viruses promise lower input costs and pesticide use for farmers and require no special machinery or special training. Every farmer knows how to plant a seed.

Future generations will feel the significance of Wambugu's and Maingi's work when African farmers are able to protect their crops from FMV.

NewBioNews is published by Monsanto Company. Contents may be reproduced without permission of Monsanto. Comments and suggestions are welcome. Address to:

Biotechnology Communications
Monsanto Europe
Avenue de Tervuren 270-272
1150 Brussels, Belgium
32-2-776-44-13 fax

Biotechnology Communications
Monsanto Company, B2NK
800 N. Lindbergh Boulevard
St. Louis, MO 63167
(314) 694-4228 fax

004-9620R

Printed on recycled paper

Microbiology

Microorganisms and Disease
(Pseudorabies Epidemic)

Description:

To discuss the role of microorganisms in the spread of disease.

Objectives:

1. To understand the differences between bacteria and viruses.
2. To understand pathogens and vectors which can spread disease.
3. To identify and understand steps which can be utilized to decrease or or prevent the spread of disease.

Interest Approach:

Psuedorabies Epidemic Lab (attached)

Background Information:

Viruses: Viruses are not considered living, in fact, scientists are really unsure how to classify them. Viruses infect an organism by injecting their DNA into a host cell such as a plant or an animal. The host cell is 'tricked' into replicating the virus' DNA along with their own DNA. Viruses are so small they are virtually impossible to detect and can be spread very easily. (Some viruses can be carried in a person's lungs from one swine facility to another. Many confinement operations will not let employees enter an operation within 48 hours of working in another swine facility.)

Bacteria: Most bacteria require warm, moist conditions to reproduce. A damp, dirty environment is perfect for promoting bacterial growth. Bacteria can be easily carried from one operation to another via manure, rodents, birds, dogs, humans, etc.

Assignment:

Read the article "Animal Antibiotics: Are They Creating Superdiseases?" and complete the attached study guide.

Conduct **"Microorganism Olympics"** (see attached)

Assessment:

Have each student list 5 steps which could be taken to help reduce the spread of disease causing microorganisms.

Psuedorabies Epidemic

This activity will simulate the spread of pathogenic microoganisms.
Each member of the class must put on safety goggles.
Each member of the class will select a cup with liquid and an eye dropper.
(Caution: Do not drink the liquid !!)

Below is a list of interactions. The interactions must be completed in the order they are listed. Upon contact the two individuals will mix the solutions in their cups with the other person.

Mix as follows:

- Person "A" places two full eye droppers of solution into the cup of person "B". Person "B" then places two full eye droppers of solution into the cup of person "A".

- Repeat this process two more times.

Complete the following interactions in this order:

1. Producers # 5, 6, 7, 8, 9, and 10 all visit the Feeder Pig Auction.
2. Producer #11 purchases feeder pigs from Producer #4.
3. Producer #12 gets puppy from Producer #11.
4. Feed Dealer travels to Producer #1.
5. Producer #1 travels to Vet Clinic.
6. Veterinarian visits Producers #6 and #7.
7. Producer #3 travels to the Vet Clinic
8. Producer #1 shakes hands with Producer #3.
9. Producer #1 travels to the Feeder Pig Auction.
10. Feed Dealer travels to Producer #2.
11. Feed Dealer travels to Producer #3.
12. Feed Dealer travels to Producer #4.
13. Producer #4 travels to Feeder Pig Auction.
14. Producer #9 purchases tractor from #5.
15. Producer #4 travels to the Vet Clinic.
16. Producers #5 and #8 visit the Elevator at the same time.
17. Feed Dealer travels to Producer # 5.
18. Feed Dealer travels to Producer #6, then finally goes home for the day.
19. Producer #10 purchases 5 boars from Producer #6.
20. Elevator delivers feed to Producer #2.

Now add approximately 4 drops of Phenolpthaline indicator into each person's cup.

A color change indicates the person's cup is infected with pseudorabies.

On your map, circle each person who showed contamination. Plot the interactions on the map to determine the source of the contamination. (Only one sample was originally contaminated.)

Who is the source of the contamination ?

Feed Dealer 1 2

Vet Clinic 3

Feeder Pig Auction 4

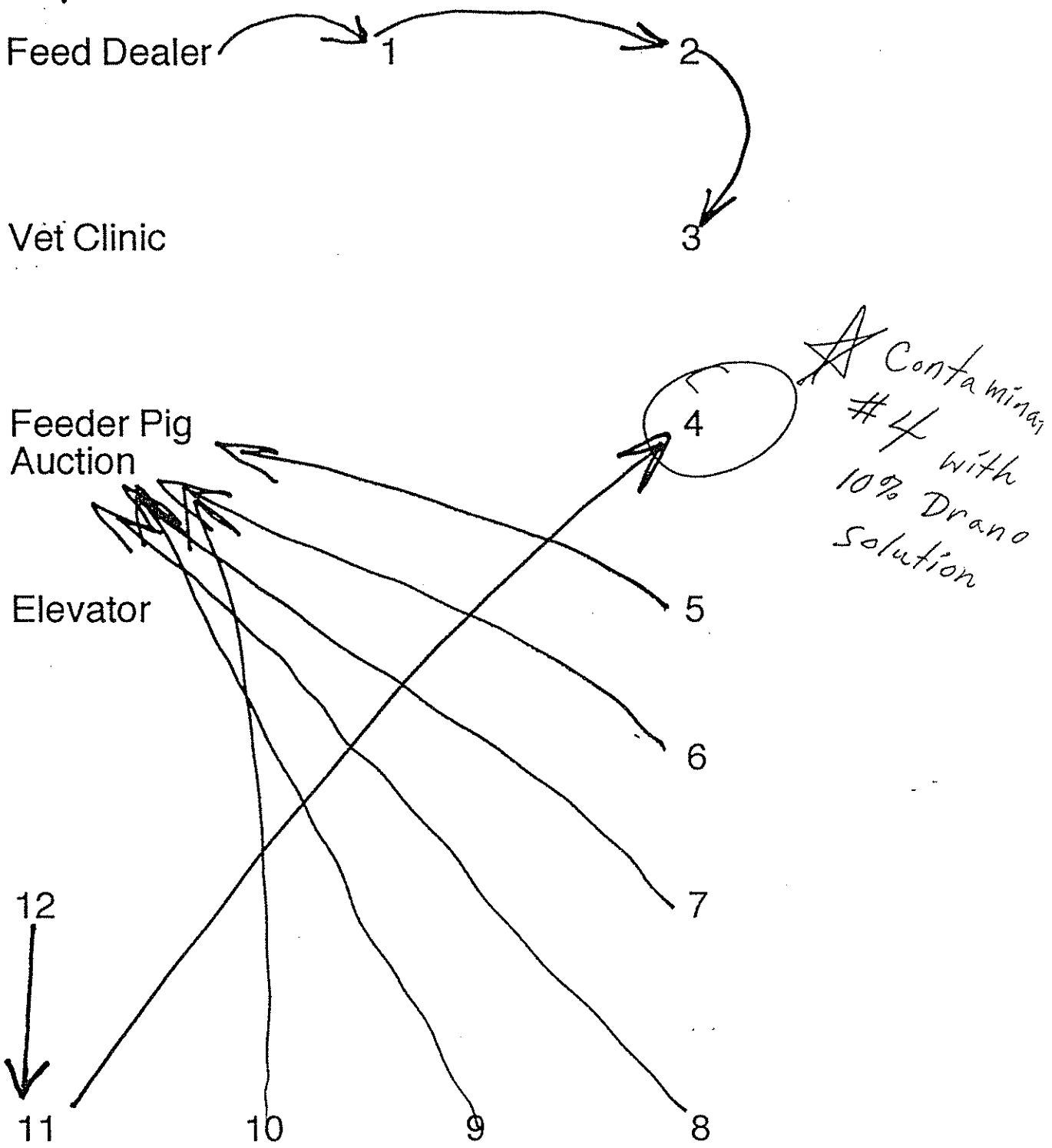
Elevator 5

6

12 7

11 10 9 8

Map Example (Not complete) KEY



☆ Contaminated #4 with 10% Drano Solution

Microorganism Olympics

Objective:

Your goal is to obtain the nastiest, grossest microoganism growth.

Lab Procedure:

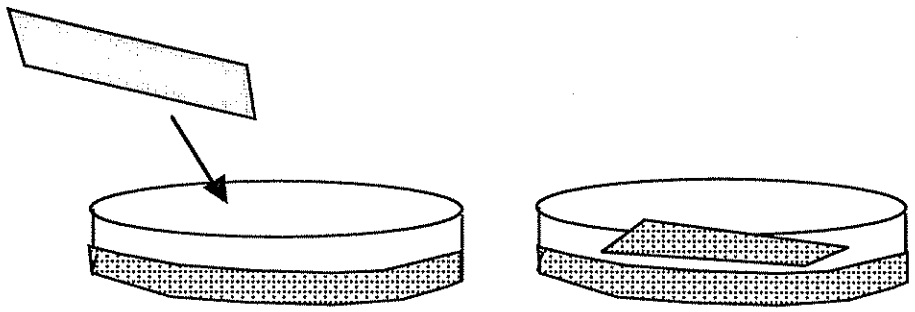
- Give each student a nutrient agar plate to take home.
- Each student will take the plate home and select the most contaminated spot in their home or on their farm. They may sample anywhere or anything.
- Upon selecting a location perform the following steps:

1. Take a piece of 'scotch' tape approximately 2 inches long and stick it to the area you wish to sample. (Example: Stick the tape to the toilet seat.)

2. Gently remove the tape, being careful not to touch the sticky surface with your fingers.

3. Remove the lid and gently place the tape on the surface of the agar. Use a finger lightly press the tape onto the surface of the agar. Any microorganisms should now be transferred from the tape to the agar.

4. Gently lift the tape and discard. Close the petri dish and tape the lid securely onto the plate. Return the plate to school



5. Upon returning the plates to school, label each plate with:
   -the student's name
   -the date and time the sample was taken
   -the location of the sample
6. Incubate in a warm place (such as an egg incubator) or simply place in a warm spot in your room. Allow two to 6 days to incubate. You will probably start to see some growth within the first 24 hours. (85 to 100 degrees F provides faster growth)

7. Pick the winner who found the nastiest, fastiest growing microorganism sample.

8. Discuss why the various locations selected within the class had different levels of contamination.

Animal Antibiotics: Are They Creating Superdiseases?

The truth is that a lack of drugs is forcing livestock producers to manage their animals better. The animals and the entire disease-control system are better for the effort.

Editor's note — *In January,* Progressive Farmer Midwest *published an article about the slowness with which new animal drugs are coming onto the market. (See "Animal Drug Users Fume as FDA Fiddles," Jan. 15, 1995.) The following story discusses the issue of resistance in animals.*

Is there a bacterium or similar pathogen so vile, so defiant of available antibiotics that it threatens an entire animal industry if a cure isn't found or a new medicine isn't approved?

Possibly in poultry, but probably not in hogs or cattle, say scientists and veterinarians. At least not in the U.S.

Antibiotics have never worked against viruses, which is why prevention through vaccinations, quarantine, stress reduction, and other methods of management has always been so critical to stopping their spread.

But scientists have long suspected that constant low-dosage use of antibiotics would eventually lead to strains of bacteria that available drugs couldn't defeat. That fear has proven true in some ways, but not in others.

"On an individual basis where a particular type of bacterium is present, we expect resistance on a particular farm because of improper use of antibiotics," says George D'Andrea, a pathologist and toxicologist at the Alabama Veterinary Diagnostic Lab in Auburn. "But I'm not seeing a trend."

Dr. John Deen, an NC State veterinarian, says: "Resistance to antibiotics is not really a concern in [the hog] industry. To be honest, some of the opposite has been happening."

What's the reason? Producers are cleaning barns better, using all-in-all-out production, and going with three separate sites for sows, nurseries, and finishing floors. The result is lower levels of disease and, in turn, lower levels of antibiotic use. And that helps keep the drugs effective longer.

"What I think is happening is that as we have breaks in production and antibiotic use, the pathogens become sensitive to antibiotics again," Deen says. "For instance, we can now use tetracyclines with good efficacy. We haven't been forced to use some of the second- and third-generation drugs in treatment because we can often use our basic antibiotics."

But there is a relatively new swine disease to worry about. It is a virus, so it can't be halted with antibiotics. Reproductive and Respiratory Syndrome has been recognized for about 10 years, and there's an

Fewer Drugs — *Cattlemen and veterinarians have a declining arsenal of drugs.* PHOTOS: VANN CLEVELAND

"Animal Antibiotics: Are They Creating Superdiseases?"

1. What is a pathogen?

2. Are antibiotics effective in controlling viruses?

3. Scientists are concerned that constant low-dosage use of antibiotics may lead to...

4. Is resistance to antibiotics a major concern in the swine industry?

5. What is your reasoning for the answer you wrote in question #4?

6. What is PRRS?

7. How can resistance strains of bacteria occur?

8. How does stress affect disease?

9. What is BSE?

10. How might the use of "All-in, All-out" management of swine operations affect the development of resistant strains of bacteria?

KEY **"Animal Antibiotics: Are They Creating Superdiseases?"**

1. What is a pathogen?

   a disease causing organism

2. Are antibiotics effective in controlling viruses?

   no

3. Scientists are concerned that constant low-dosage use of antibiotics may lead to...

   increased numbers of antibiotic resistant bacteria

4. Is resistance to antibiotics a major concern in the swine industry?

   not currently

5. What is your reasoning for the answer you wrote in question #4?

   all-in-all-out production, better sanitation, seperate sites

6. What is PRRS?

   Porcine Reproductive and Respiratory Syndrome (a virus)

7. How can resistance strains of bacteria occur?

   Increased exposure to antibiotics allows resistant organisms to grow. (Partially due to decreased competition from non-resistant strains which have been killed. More room to grow.) Low levels may not kill all bacteria.

8. How does stress affect disease?

   Increased stress usually causes an increase in disease

9. What is BSE?

   also known as Mad Cow Disease

10. How might the use of "All-in, All-out" management of swine operations affect the development of resistant strains of bacteria?

    Will likely decrease development of resistant strains because of lower antibiotic usage. If antibiotics are not used the bacteria do have the opportunity to develop resistance.

Jet-Puffed Genetics

Objectives:

1. To review meiosis.
2. To understand the possibilities of genetic engineering.
3. To develop an understanding of gene mapping and its applications.
4. To demonstrate the results of crossing two plants or animals.

Strategies: (What does the teacher need to do?)

- Define and explain each of the following prior to this activity:

Meiosis: Process by which the body produces sex cells.
A cells chromosome pairs split into two seperate chromatids. The chromatids from each pair then migrate to opposite ends of the cell. When the cell divides each "daughter" cell receives one chromatid from each chromosome pair. This is the process by which sperm and egg are produced. A sperm or egg cannot grow and divide by themselves because they are genetically incomplete, containing only half of the needed genetic material.

Example: Humans have 46 chromatids found in 23 chromosome pairs. When the cell divides each "daughter" cell will receive 23 chromatids, but no pairs.

What would happen if you bred a horse with a chicken?
Nothing, they do not have the same number of chromosomes pairs. They could not produce a viable embryo.

Why don't you see 6 foot tall eggs walking around school?
Sperm or egg do not contain the necessary genetic material to grow and divide.
They are 1N (haploid), fertilized eggs are 2N (diploid).

Dominant Genes: A trait which masks a recessive gene.
Recessive Genes: A trait which is masked by a dominant gene.
Complete Dominance: A dominant gene completely masks a recessive gene. The recessive trait cannot be seen.

Example: Cross a Red flower (RR) with a White flower (rr).
RR X rr = Rr Offspring will have Red flowers.

Partial Dominance: A dominant gene partially masks a recessive gene. A mixing of traits.

Example: Cross a Red flower (RR) with a White flower (rr).
RR X rr = Rr Offspring will have Pink flowers.

Strategies cont...

- Define and explain each of the following prior to this activity:

  Genotype: The actual genes present in the chromosomes.
  (Cannot always be seen.)

  Phenotype: The actual physical appearance.
  (Cannot always tell what genes are present.)

  Homozygous: Like genes on each chromatid.
  Example: RR or rr

  Heterozygous: Different genes on each chromatid.
  Example: Rr

  Gene Mapping: The process of identifying genes which control specific traits and mapping their individual locations on the chromosomes. They expect the Human Genome Project to be completed before 2010.

  Gene Splicing: Transferring a gene from one organism to another.

- Obtain the following materials:
  -White miniature marshmallows and Colored miniature marshmallows.
  Colored marshmallows code for specific traits.
  White marshmallows code for extra genes, not identified.
  -Toothpicks

Activities: (What will the student do?)

- Produce one chromosome pair of the mother and one pair of the father.
- Manipulate the chromatids to show all of the possible combinations of the offspring.
- Complete a Punnett Square to show the genotypes and phenotypes.

(See activity sheet.)

Evaluation:

- Observe the results of their crosses.
- Review their Punnett Squares.
- Have students brainstorm applications of gene mapping.
- Have students brainstorm applications of genetic engineering.

Jet-Puffed Genetics

Use the following marshmallow colors:

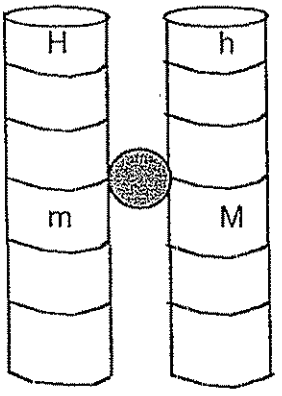
White = extra genes on the chromatid, genes which are not mapped
Green = polled (H)
Orange = horned (h)
Pink = High Milk Protein (M)
Yellow = Low Milk Protein (m)

Assume: Polled exhibits complete dominance over horned.
High Milk Protein exhibits partial dominance over Low Milk Protein

Scenario:

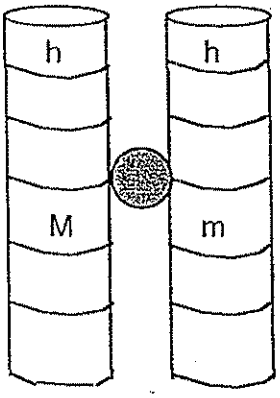
Assume scientists have developed techniques to map specific genes in cattle.
You have a valuable cow which, you have had mapped, and found to be heterozygous for horns and heterozygous for milk protein. (Assume you want polled and high protein.)

Cow

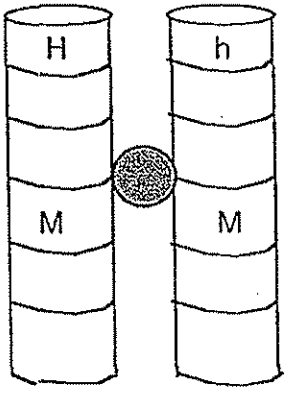


You have a choice of the following two bulls to breed this cow.

Blackstar



Elevator



- Construct each animal's chromosome pair with the corresponding marshmallows.
- Place one dot, with a marker, on Blackstar's chromatids. (So you can tell them apart)
- Place two dots, with a marker, on Elevator's chromatids.
- Manipulate the chromatids to show all possible genetic combinations of these two bulls and the cows. (Remember: Meiosis must happen to produce sperm and egg.) Note: This approach is slightly different than the traditional Punnett Square because you know the specific location of each gene with relation to other genes on that same chromatid.

Summary:

List all the possible genotypes and phenotypes for each of the two crosses:

Cow X Blackstar

Cow X Elevator

Which bull would you use to breed this cow? Why?

If you could use genetic engineering to improve Blackstar what would you do? (Change marshmallows as needed to obtain the desired chromosome pair.)

If you could use genetic engineering to improve Elevator what would you do? (Change marshmallows as needed to obtain the desired chromosome pair.)

If you could genetically splice any other specific trait into cattle what would you choose?

Name _____ Date _____

The Genetic Peril of the Cheetah

The cheetah is truly one of nature's marvels. A virtual running machine, its skull is small and lightweight, its limbs are long and slender, and its spinal column is unusually flexible. The cheetah's heart, lungs, and adrenal glands are all enlarged, enhancing the animal's ability to accelerate during a high-speed chase—a chase often clocked at up to 112 kilometers per hour. Unlike other cats, the cheetah's claws are always extended like cleats, enabling it to grip the ground. These adaptations have made the cheetah an effective hunter on the flat, open savannahs of central and southern Africa.

In spite of the cheetah's skill as a runner and hunter, the species seems to be headed for extinction. While the cheetah's body structure is superbly adapted to a running existence, the cheetah has traits that are considered maladaptive. It is extremely vulnerable to disease, and there is a high infant mortality rate. Although the cheetah is the world's fastest mammal, it can run rapidly for only a few hundred yards before it tires. After a typical chase, the cheetah collapses for half an hour in order to regain its strength. During this time, it is vulnerable to attack by other predators and can lose either its life or its catch. Cheetahs are rather timid creatures, with some 50 percent of their kills snatched away by more aggressive lions, leopards, and hyenas. The cheetah is now limited to a few, small areas in Africa. There are about 20 000 cheetahs left on Earth today.

Research over the last six years suggests that the cheetah has somehow lost most of its genetic variation. Scientific studies have revealed that, genetically, each cheetah is nearly identical to every other cheetah. In other words, the species exhibits genetic uniformity. Genetic uniformity hampers the ability of a species to adapt to environmental changes, such as temperature shifts, drought, glaciation, and even the emergence of new viruses or bacteria. Such uniformity is usually the result of intensive inbreeding.

Scientists have recently puzzled over the causes for the probable inbreeding and resultant genetic uniformity in the cheetah. The most plausible hypothesis to date is that at some point in the past the cheetah went through a severe population reduction. The population reduction was followed by inbreeding, which diminished genetic variability. How severe would the population reduction have to be in order to lead to genetic uniformity? Studies have shown that a population reduced to only seven individuals will retain about 95 percent of its original genetic variation. The population can retain that variation only if the survivors reproduce rapidly enough to expand the size of the population. Slow reproduction in a small population decreases the likelihood that different genetic types will survive. Scientists suspect that at least once in the past the cheetah's population dropped to only a few individuals. What caused the cheetah population to dwindle is not known. The possibilities include catastrophic climatic changes, viral or bacterial plagues, and even hunting by humans.

Several other animals have gone through severe population reductions and seem to be recovering. One example is the northern elephant seal. This population was reduced to about 20 animals. Yet after the passage of protective legislation, the seal population grew. Today the number of elephant seals reaches into the tens of thousands. Can the cheetah have the same good fortune?

Questions:

1. Provide a definition of genetic uniformity _____

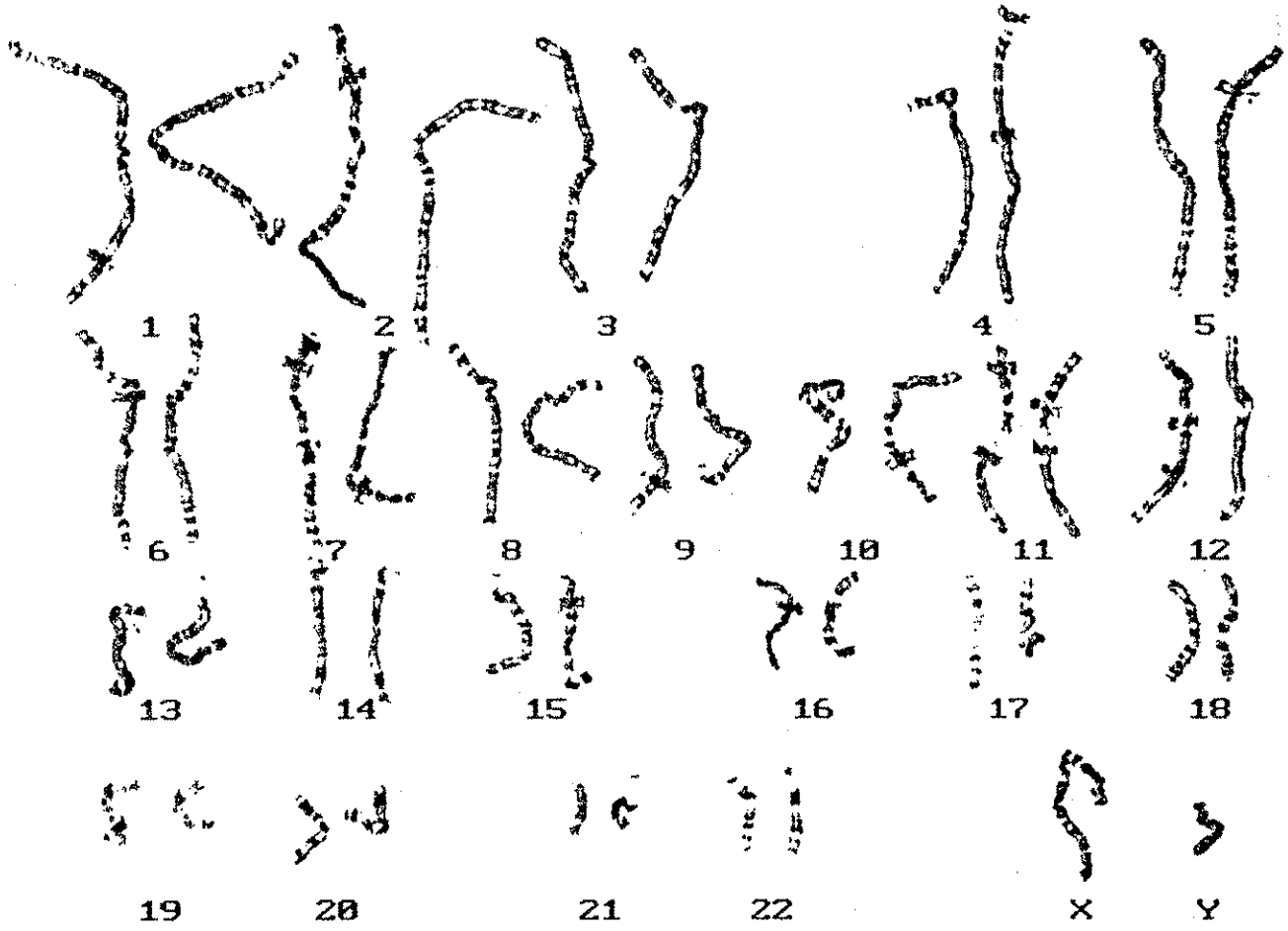
2. How does genetic uniformity occur?

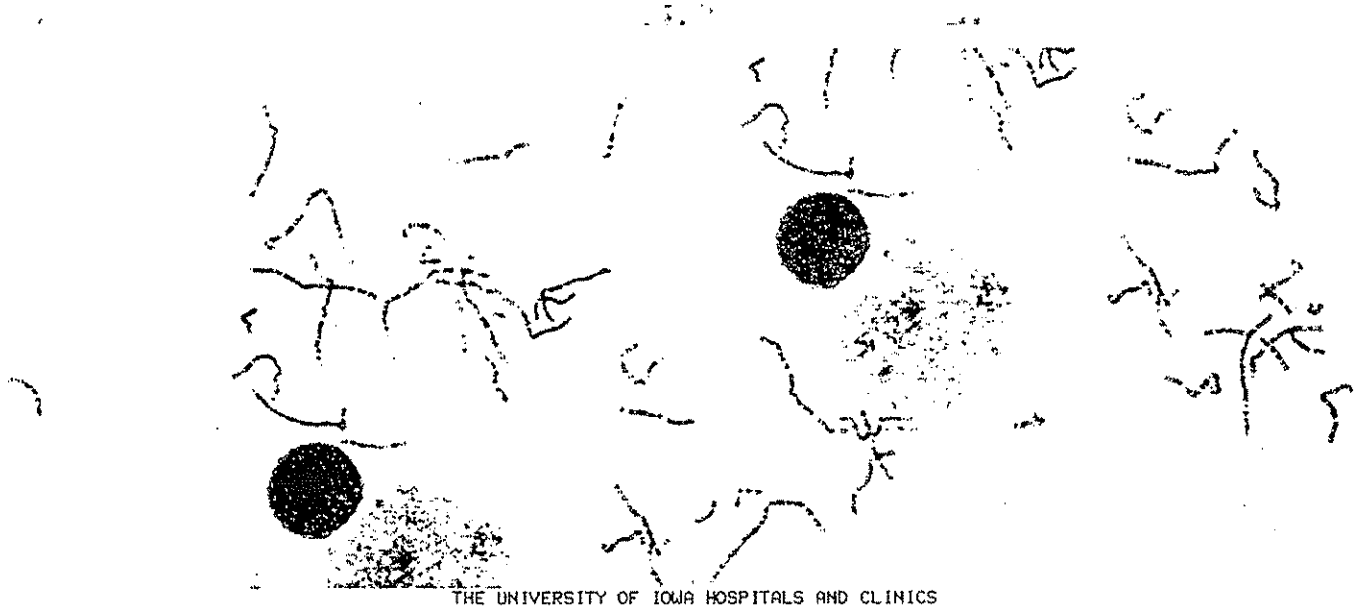
3. How does genetic uniformity hamper the survival of the cheetah? _____

CYTOGENETICS REPORT

Department of Pediatrics

Cytogenetics Laboratory W101 GH





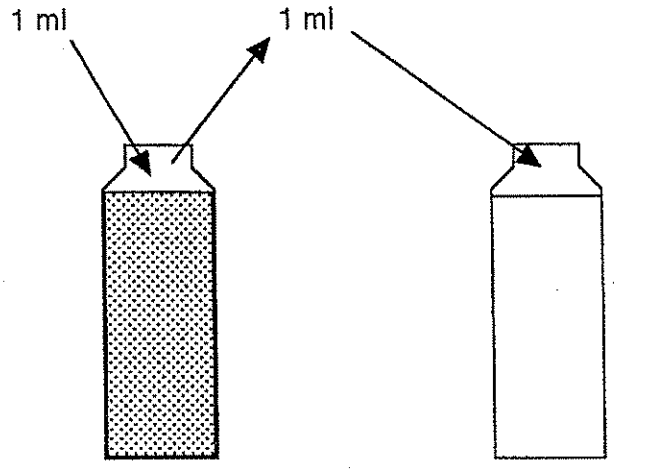
Parts Per Million

Description:
This is an easy way for students to visualize parts per million

Materials Needed:
2 - one liter pop bottles
food coloring
gasoline
syringe to measure 1 ml

Procedure:
- Fill both bottles with water.
- Add one ml of food coloring to one of the bottles of water.
- Shake up. The water will turn a definite color.
- Take one ml out of this bottle and add it to the second bottle.
- The color is typically not visible in the water.

- Repeat the same procedure using gasoline.
- Smell to detect the gasoline. (Gasoline can usually be detected down to 1 PPM.)



Osmotic Regulation
(Osmosis)

Description:
This experiment is designed to help students understand osmosis, and osmotic regulation in fish. Students will demonstrate how salt levels in water affect osmotic balance.

Equipment and Supplies Needed:
Plastic cups (preferably clear)
Sodium Polyacrylate (avail. through science supply catalogs)
Food coloring
Salt

Procedure:
- Fill plastic cup approximately 1/2 full with water.
- Each group should measure and obtain .5 grams of sodium polyacrylate.
- Slowly add the sodium polyacrylate to the cup of water.
- Observe closely.
- Stop adding the sodium polyacrylate when the cup has gelled completely. (It may not be necessary to use all powder.)

Discuss:
- What has happened ?
- What do you think will happen if we add salt to the gel ?

- Slowly sprinkle salt across the surface of the gel.
- Observe closely.
- Continue adding salt until the gel has completely disappeared.

Discuss:
- Why has the gel disappeared ?
- What would happen if we put a freshwater fish in the ocean ?
- What would happen if we put a marine fish in freshwater ?
- Can you think of any practical applications for this substance ?

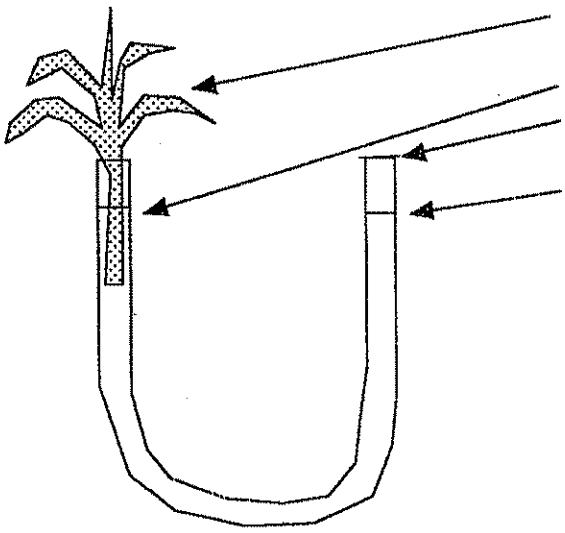
Plant Transpiration

Description:
Students will conduct an experiment which demonstrates plant transpiration.

Objectives:
To demonstrate plant transpiration.
To understand the importance of water to plant growth.
To identify how soil nutrients may affect transpiration.

Equipment and Supplies Needed:
- water
- food coloring
- clear, flexible plastic tubing (two 3' lengths per experiment)
- tape
- two plants per experiment

Procedure:
- Arrange tubing and plant as shown below.



- Insert plant stem into tube. (Roots may be left on.)
- Fill tube with colored water as shown
- Cover the top of the open tube with tape to prevent evaporation
- Mark the initial water level.
- Repeat the steps with a second plant and tubing arrangement. Except, on the second cut the stem shorter so that it **does not** touch the water.

- Observe the change in water levels over the next couple days.

Ag. 1 **Plant Transpiration** Name_____

1 Which tube lost the most water by the end of the experiment ? Why ?

2. What is transpiration ?

3. How do plants control transpiration ?

4. What happens to corn leaves under hot, dry conditions ?

5. Is soil fertility important to helping plants tolerate drought conditions ?

6. Which plant nutrient (NPK) is most important in helping a plant use water more efficiently and manage transpiration rates ?

Ag. 1 **Punnett Square** Name_____

One of the major advantages of sexual reproduction is genetic diversity. Complete a square to show the genotypes of the following cross.

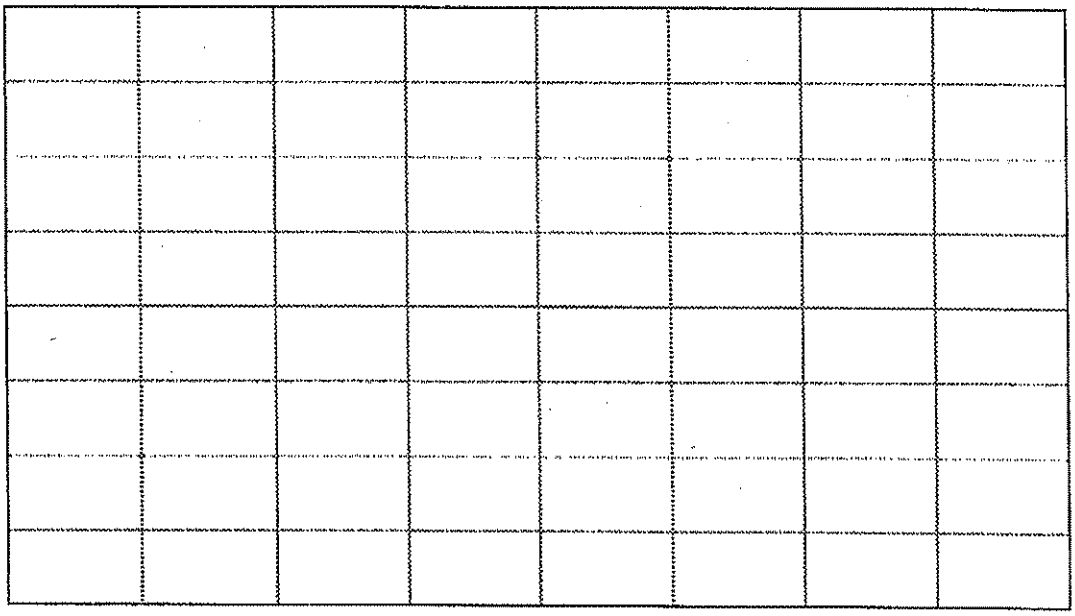
George's Genotypes: Pp Ss Tt

Gertrude's Genotypes: Pp Ss Tt

List all of the possible gene combinations which the male's sperm could have.

List all of the possible gene combinations which the female's egg could have.

Using these gene combinations complete the square.



Analysis:

Lightly shade the individuals who can taste all three substances.

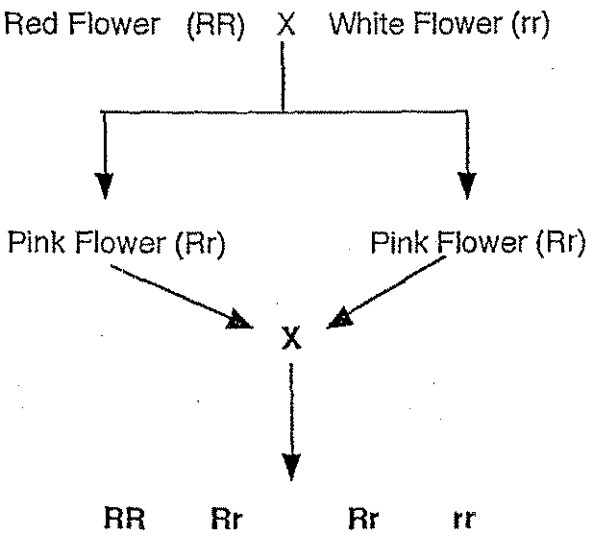
Circle the individuals who cannot taste any of the substances.

If we could reproduce George, asexually, what genotype(s) would the offspring have ?

Monohybrid and Dihybrid Crosses

Terms to Know:
Hybrid: a cross of two pure lines
P_1: the parents (pure lines)
F_1: first generation or first cross of two pure lines
F_2: second generation or crossing two F_1's

Example: **Generation**



Complete a Punnett Squares for the following corn cross through the F_2 generation.

Colored Aleurone (RR) X Colorless Aleurone (rr)

* Colored Aleurone exhibits complete dominance

Complete a Punnett Squares for the following corn cross through the F_2 generation.

Colored Aleurone and Starchy Endosperm (RRSS) X Colorless Aleurone and Sweet Endosperm (rrss)

* Both exhibit complete dominance.

Jet-Puffed Gene Mapping

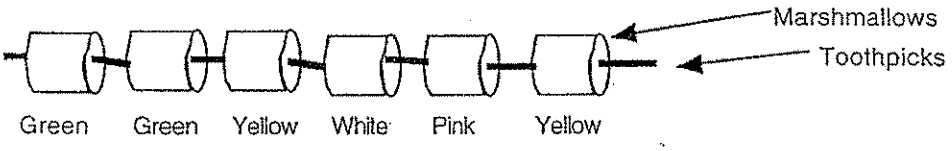
Marshmallow Color Code:

Green = G (Guanine)
Yellow = A (Adenine)
White = T (Thymine
Pink = C (Cytosine)

Step 1

Using toothpicks and marshmallows construct the following strand of DNA.

GGATCAGTACCGTTAACTAT



Step 2

How many Guanines are present in this DNA fragment?

How many Adenines are present in this DNA fragment?

How many Thymines are present in this DNA fragment?

How many Cytosines are present in this DNA fragment?

Step 3

What is the first nucleotide present in your DNA fragment? (Reading from left to right.)

What is the second nucleotide present in your DNA fragment? (Reading from left to right.)

What is the third nucleotide present in your DNA fragment? (Reading from left to right)

What is the fourth nucleotide present in your DNA fragment? (Reading from left to right.)

Step 4

Assume that Green marshmallows are lime, Yellow are lemon, white are vanilla, and pink are cherry-flavored.

Describe the flavor of this strand: 'GAAG'

Describe the flavor of this strand: 'CCCC'

Assuming that these combinations of nucleotides produce specific proteins, do think that 'GGAT' would produce the same protein as 'GCTA'?

Why would scientists like to determine the specific chemical sequence of DNA?

Autoradiomarshmallowgram

Start disassembling your DNA fragment placing each marshmallow on its corresponding color row and corresponding number in the chain. Start placing the marshmallows on the chart. Start at the bottom and work up to the top. You will only have one marshmallow in each row. For example: (The first nucleotide, G, will go in cell G1. The second nucleotide, G, will go in G2 The third nucleotide, A, will go in cell A3.)

Place an "x" in each cell that contains a marshmallow.

	G	A	T	C
20				
19				
18				
17				
16				
15				
14				
13				
12				
11				
10				
9				
8				
7				
6				
5				
4				
3				
2				
1				

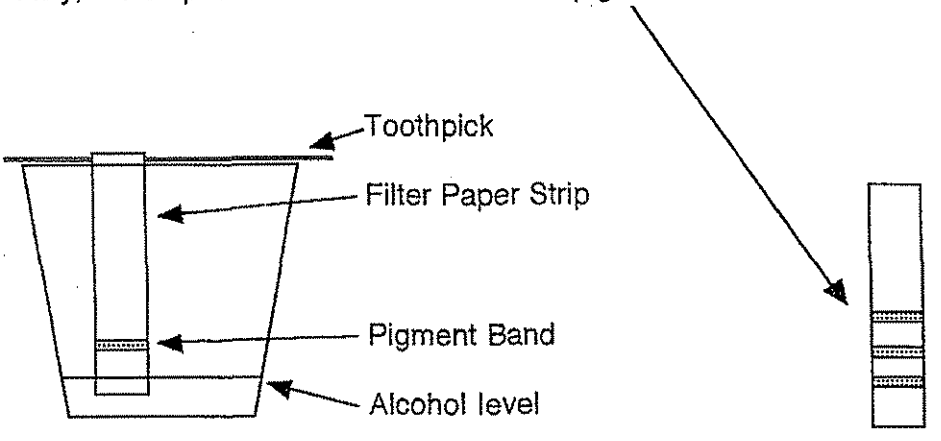
Chromatography

Description:
This experiment will show the different pigments present in plants.

Objectives:
To show the various pigments present in green plants.
To develop an understanding of pigments involved in photosynthesis.
To identify symptoms of nutrient deficiency.

Equipment and Supplies Needed:
Coffee filters
Various plant leaves
Rubbing alcohol
Quarter
Paper clips
Paper cups or glass beakers
Toothpicks

Procedure:
- Cut the coffee filter paper into strips approx. 1 inch wide and 4 inches long.
- Lay plant leaf across the bottom of one of the filter strips.
- Rub a quarter across the leaf to transfer a line of pigment onto the filter strip. Approx. 1/2 inch from one end.
- Hang the filter strip on a toothpick and dangle the strip into a cup with rubbing alcohol. (The filter paper should just touch the alcohol. Do not cover the pigment line.) A paper clip is helpful in securing the filter paper strip.
- Allow to set and observe over the course of the class period.
- Eventually, the strip will show different bands of pigment.



Chromatography Name_____

1. What happened to the initial pigment band ? Why ?

2 What colors did you see in your chromatography strip ?

3. What plant nutrient is largely responsible for green color in plants ?

4. What are the symptoms of nitrogen deficiency in growing corn ?

5. What are the symptoms of phosphorus deficiency in growing corn ?

6. What are the symptoms of potassium deficiency in growing corn ?

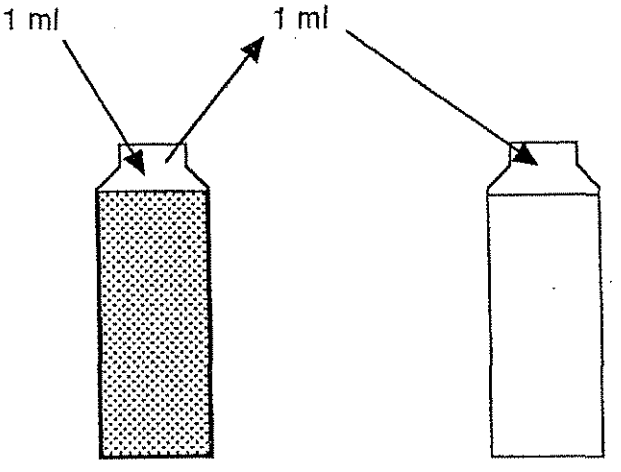
Parts Per Million

Description:
This is an easy way for students to visualize parts per million.

Materials Needed:
2 - one liter pop bottles
food coloring
gasoline
syringe to measure 1 ml

Procedure:
- Fill both bottles with water.
- Add one ml of food coloring to one of the bottles of water.
- Shake up. The water will turn a definite color.
- Take one ml out of this bottle and add it to the second bottle.
- The color is typically not visible in the water.

- Repeat the same procedure using gasoline.
- Smell to detect the gasoline. (Gasoline can usually be detected down to 1 PPM.)



1 / 1000

1 / 1,000,000

Osmotic Regulation
(Osmosis)

Description:
This experiment is designed to help students understand osmosis, and osmotic regulation in fish. Students will demonstrate how salt levels in water affect osmotic balance.

Equipment and Supplies Needed:
Plastic cups (preferably clear)
Sodium Polyacrylate (avail. through science supply catalogs)
Food coloring
Salt

Procedure:
- Fill plastic cup approximately 1/2 full with water.
- Each group should measure and obtain .5 grams of sodium polyacrylate.
- Slowly add the sodium polyacrylate to the cup of water.
- Observe closely.
- Stop adding the sodium polyacrylate when the cup has gelled completely. (It may not be necessary to use all powder.)

Discuss:
- What has happened ?
- What do you think will happen if we add salt to the gel ?

- Slowly sprinkle salt across the surface of the gel.
- Observe closely.
- Continue adding salt until the gel has completely disappeared.

Discuss:
- Why has the gel disappeared ?
- What would happen if we put a freshwater fish in the ocean ?
- What would happen if we put a marine fish in freshwater ?
- Can you think of any practical applications for this substance ?

Osmotic Regulation
(Osmosis)

Description:
This experiment is designed to help students understand osmosis, and osmotic regulation in fish. Students will demonstrate how salt levels in water affect osmotic balance.

Equipment and Supplies Needed:
Plastic cups (preferably clear)
Sodium Polyacrylate (avail. through science supply catalogs)
Food coloring
Salt

Procedure:
- Fill plastic cup approximately 1/2 full with water.
- Each group should measure and obtain .5 grams of sodium polyacrylate.
- Slowly add the sodium polyacrylate to the cup of water.
- Observe closely.
- Stop adding the sodium polyacrylate when the cup has gelled completely. (It may not be necessary to use all powder.)

Discuss:
- What has happened ?
- What do you think will happen if we add salt to the gel ?

- Slowly sprinkle salt across the surface of the gel.
- Observe closely.
- Continue adding salt until the gel has completely disappeared.

Discuss:
- Why has the gel disappeared ?
- What would happen if we put a freshwater fish in the ocean ?
- What would happen if we put a marine fish in freshwater ?
- Can you think of any practical applications for this substance ?

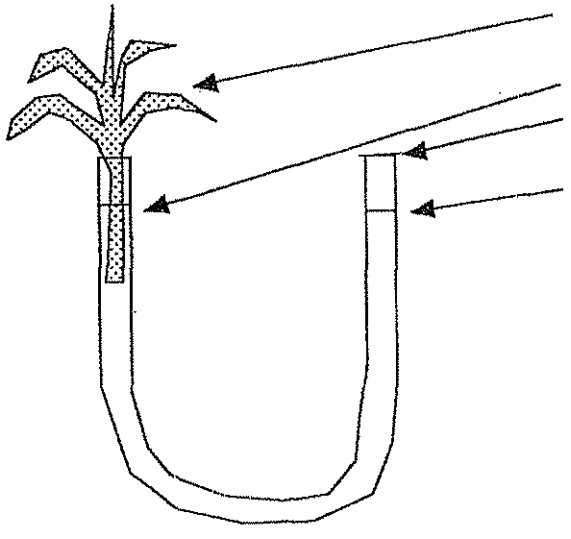
Plant Transpiration

Description:
Students will conduct an experiment which demonstrates plant transpiration.

Objectives:
To demonstrate plant transpiration.
To understand the importance of water to plant growth.
To identify how soil nutrients may affect transpiration.

Equipment and Supplies Needed:
- water
- food coloring
- clear, flexible plastic tubing (two 3' lengths per experiment)
- tape
- two plants per experiment

Procedure:
- Arrange tubing and plant as shown below.



- Insert plant stem into tube. (Roots may be left on.)
- Fill tube with colored water as shown
- Cover the top of the open tube with tape to prevent evaporation
- Mark the initial water level.
- Repeat the steps with a second plant and tubing arrangement. Except, on the second cut the stem shorter so that it **does not** touch the water.

- Observe the change in water levels over the next couple days.

Ag. 1 **Plant Transpiration** Name_____

1 Which tube lost the most water by the end of the experiment ? Why ?

2 What is transpiration ?

3. How do plants control transpiration ?

4. What happens to corn leaves under hot, dry conditions ?

5. Is soil fertility important to helping plants tolerate drought conditions ?

6. Which plant nutrient (NPK) is most important in helping a plant use water more efficiently and manage transpiration rates ?

Jet-Puffed Gene Mapping

Marshmallow Color Code:

Green = G (Guanine)

Yellow = A (Adenine)

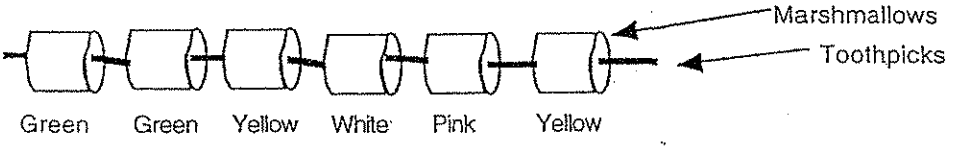
White = T (Thymine

Pink = C (Cytosine)

Step 1

Using toothpicks and marshmallows construct the following strand of DNA.

GGATCAGTACCGTTAACTAT



Step 2

How many Guanines are present in this DNA fragment?

How many Adenines are present in this DNA fragment?

How many Thymines are present in this DNA fragment?

How many Cytosines are present in this DNA fragment?

Step 3

What is the first nucleotide present in your DNA fragment? (Reading from left to right.)

What is the second nucleotide present in your DNA fragment? (Reading from left to right.)

What is the third nucleotide present in your DNA fragment? (Reading from left to right)

What is the fourth nucleotide present in your DNA fragment? (Reading from left to right.)

Step 4

Assume that Green marshmallows are lime, Yellow are lemon, white are vanilla, and pink are cherry-flavored.

Describe the flavor of this strand: 'GAAG'

Describe the flavor of this strand: 'CCCC'

Assuming that these combinations of nucleotides produce specific proteins, do think that 'GGAT' would produce the same protein as 'GCTA'?

Why would scientists like to determine the specific chemical sequence of DNA?

Autoradiomarshmallowgram

Start disassembling your DNA fragment placing each marshmallow on its corresponding color row and corresponding number in the chain. Start placing the marshmallows on the chart. Start at the bottom and work up to the top. You will only have one marshmallow in each row. For example: (The first nucleotide, G, will go in cell G1. The second nucleotide, G, will go in G2 The third nucleotide, A, will go in cell A3.)

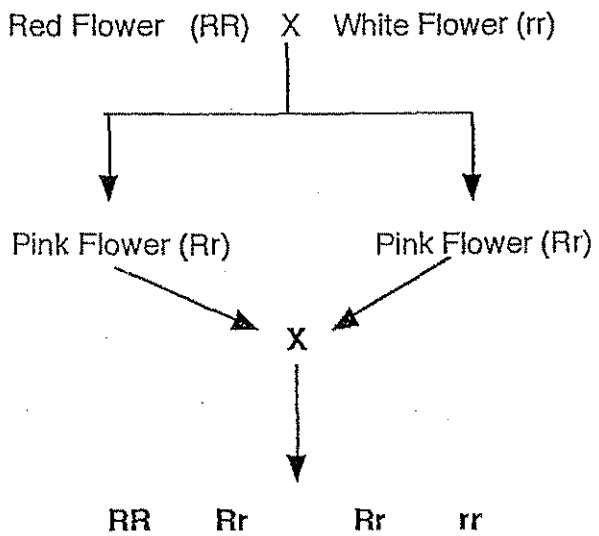
Place an "x" in each cell that contains a marshmallow.

	G	A	T	C
20				
19				
18				
17				
16				
15				
14				
13				
12				
11				
10				
9				
8				
7				
6				
5				
4				
3				
2				
1				

Monohybrid and Dihybrid Crosses

Terms to Know:
Hybrid: a cross of two pure lines
P_1: the parents (pure lines)
F_1: first generation or first cross of two pure lines
F_2: second generation or crossing two F_1's

Example:



Generation

P_1

F_1 (100 % Rr or Pink)

F_2
(1 Red, 2 Pink, 1 White)

Complete a Punnett Squares for the following corn cross through the F_2 generation.

Colored Aleurone (RR) X Colorless Aleurone (rr)

* Colored Aleurone exhibits complete dominance

Complete a Punnett Squares for the following corn cross through the F_2 generation.

Colored Aleurone and Starchy Endosperm (RRSS) X Colorless Aleurone and Sweet Endosperm (rrss)

* Both exhibit complete dominance.

Ag. 1 **Punnett Square** Name_____

One of the major advantages of sexual reproduction is genetic diversity. Complete a square to show the genotypes of the following cross.

George's Genotypes: Pp Ss Tt

Gertrude's Genotypes: Pp Ss Tt

List all of the possible gene combinations which the male's sperm could have.

List all of the possible gene combinations which the female's egg could have.

Using these gene combinations complete the square.

Analysis:

Lightly shade the individuals who can taste all three substances.

Circle the individuals who cannot taste any of the substances.

If we could reproduce George, asexually, what genotype(s) would the offspring have ?

Animal Reproductive System

THE reproductive system is the only system in animals that is different between genders. Breeders and others in the animal industry need a thorough understanding of the female and male reproductive tracts.

Objective:

Explain the functions of the female reproductive tract and the male reproductive tract.

Key Terms:

accessory glands
cervix
clitoris
Cowper's gland
ejaculation
fallopian tubes
infundibulum
ovary
oviducts
penis
prostate gland
scrotum
testicle
testosterone
urethra
uterus
vulva

Female Reproductive Tract

The reproductive system of the female produces egg cells, is the site of fertilization, and develops the fetus. Its structures are significantly different from those of the male reproductive system.

The **vulva** is the external opening of the female reproductive and urinary tracts. Inside the vulva is the **clitoris**, which is the sensory organ of the female. Anterior to the vulva is the vagina. The act of copulation, or mating, occurs in the vagina. During natural mating, semen from the male is deposited in the vagina. The vagina is part of the birth canal. The fetus passes through the vagina during birth.

The **cervix** is a muscular structure between the vagina and the uterus. The annular rings and gel-like mucus substance seal the uterus during pregnancy to protect the developing fetus from infection. During birth, hormones cause the cervix to relax, allowing the young to pass through.

The **uterus** is the location where the embryo develops. The uterus is a Y-shaped structure with two uterine horns. The size of the uterine horns is dependent upon the typical number of offspring produced in one pregnancy. An animal such as the horse that usually has only one offspring per pregnancy has small uterine horns and a large uterine body. An animal such as the pig that has large litters has large uterine horns and a small uterine body.

The **oviducts**, or **fallopian tubes**, are tubular structures that connect the ovaries and the uterus. The reproductive tract has two oviducts, one joining each ovary to a uterine horn. The union of the sperm and the egg cell occurs in one of the oviducts. The resulting zygote travels through the oviduct for implantation into the uterine wall. The **infundibulum** is the funnel-

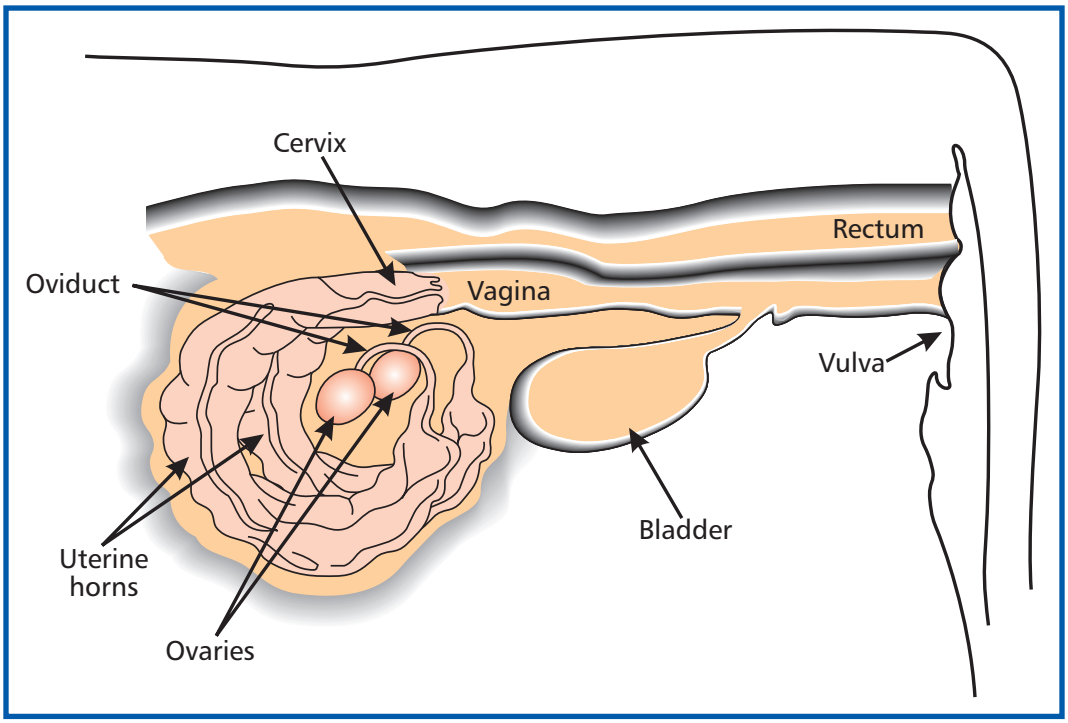


FIGURE 1. Cow reproductive system.

shaped opening of the oviduct. As the ovary releases an egg cell, it is directed into the oviduct by the infundibulum.

The **ovary** is the structure that produces the egg cell. It is also responsible for the production of the hormone progesterone. Each female mammal has two ovaries. In some animals, like chickens, only one ovary functions. Each ovary contains a predetermined number of follicles

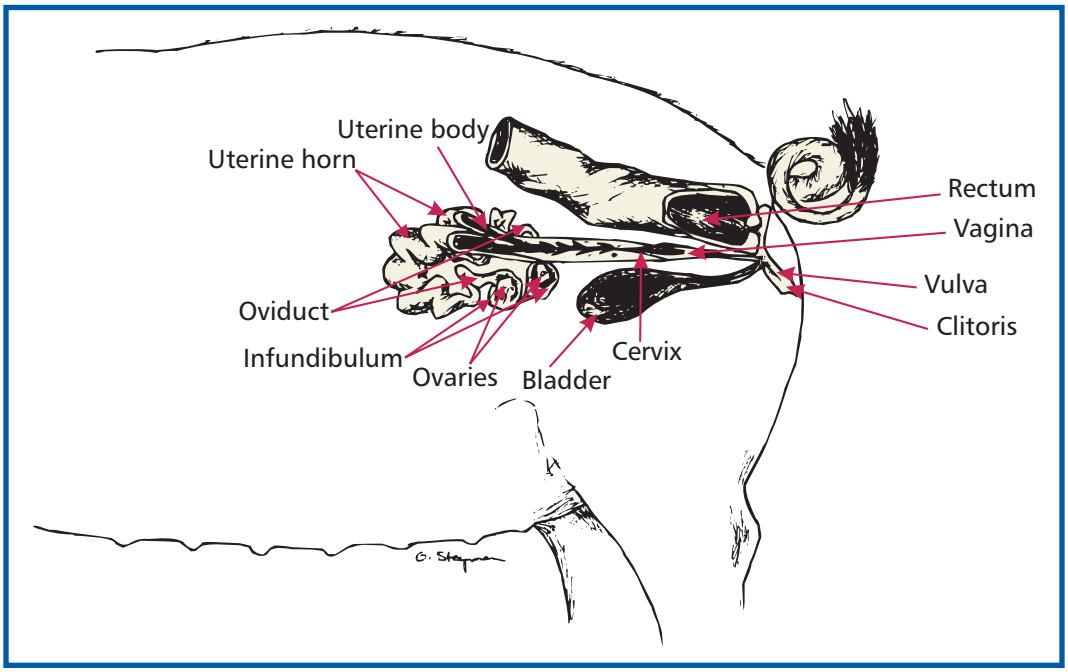


FIGURE 2. Sow reproductive system. (Courtesy, Gary Stegman, Crookston, MN)

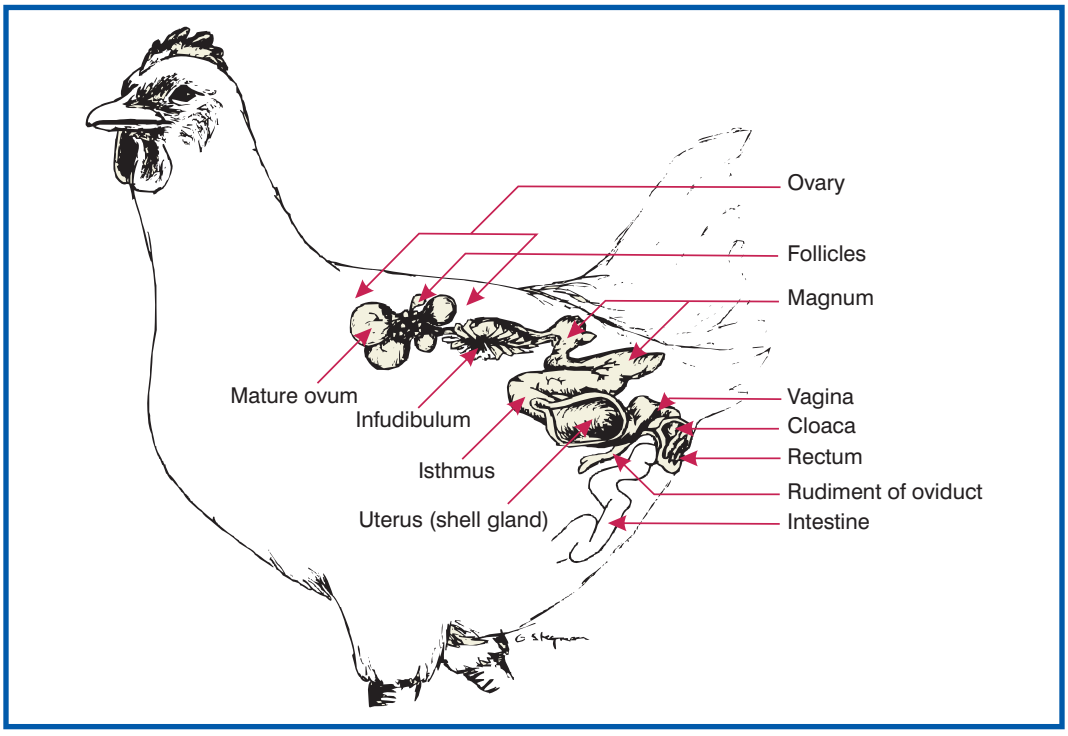


FIGURE 3. Hen reproductive system. (Courtesy, Gary Stegman, Crookston, MN)

when the animal is born or hatched. For instance, a female chick normally has around 4,000 immature follicles, while a heifer has 75,000 immature follicles.

Male Reproductive Tract

The reproductive system of the male produces and stores semen and deposits it into the female reproductive tract.

The **penis** is the organ that deposits semen, the fluid containing sperm cells, in the female reproductive tract. During copulation, the natural act of mating, **ejaculation** occurs, expelling the semen. The end of the penis serves as the sensory organ, which stimulates ejaculation. The penis is normally relaxed and housed in a protective sheath. However, when stimulated, the retractor muscle relaxes, and the sigmoid flexure allows the penis to extend from the sheath. The penises of different species are physiologically different. The penis of the stallion contains erectile tissue, while the penises of most other species do not. The boar has a uniquely shaped penis that resembles a corkscrew but fits the sow's reproductive tract perfectly. The **urethra** is the tube that extends through the penis and allows for the excretion of urine. A male fowl has no penis; instead, it has an undeveloped copulatory organ to deposit semen in the oviduct of the hen. A fish expels semen through the urogenital pore.

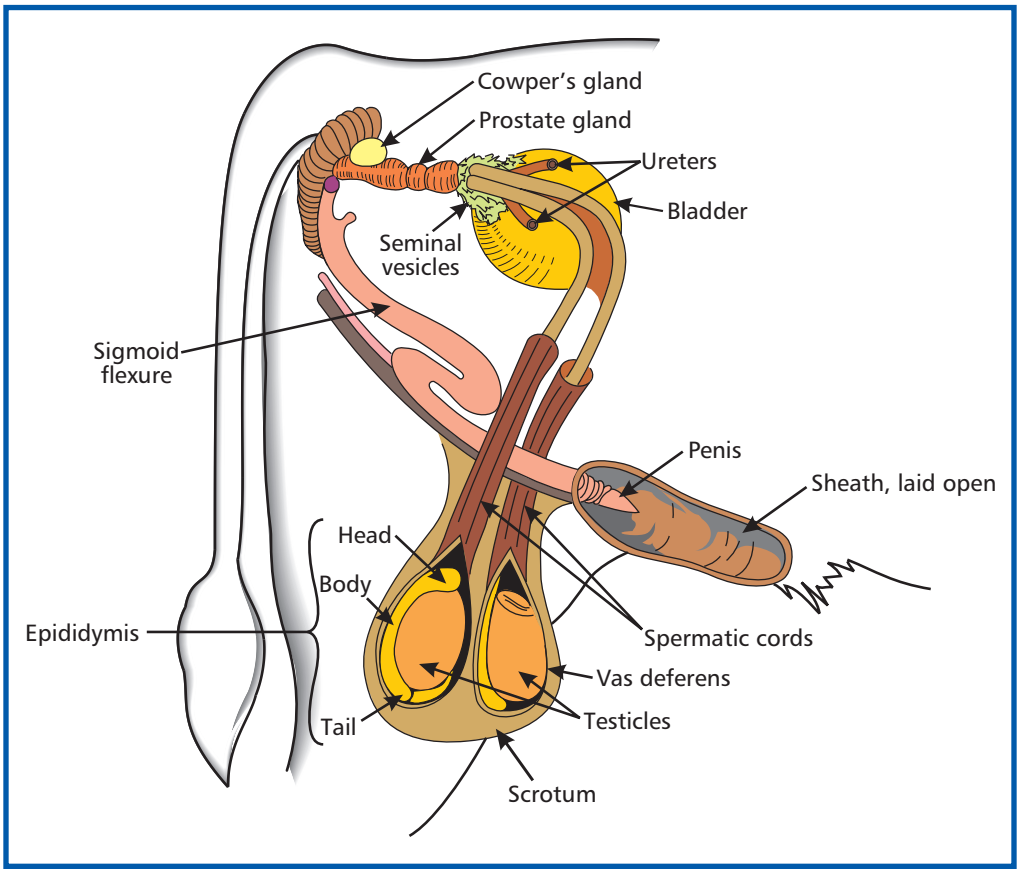


FIGURE 4. Bull reproductive system.

The **accessory glands** produce fluids that benefit the sperm cells. The **Cowper's gland** creates a fluid that cleans and neutralizes the urethra prior to ejaculation. The **prostate gland** secretes a fluid that provides the transportation medium for sperm. A fluid secreted by the seminal vesicles provides nourishment for the sperm.

The **testicle** produces the male gametes and the male hormone **testosterone**. The two testicles of a male mammal are held in the **scrotum**, while in fish and poultry the testicles are held internally. Cryptorchidism is the condition in which one or both of a mammal's testicles do not descend into the scrotum but are instead held in the body cavity. This causes sterility in the affected testicle(s). In a mammal, the scrotum is necessary to provide an environment that encourages sperm production, since its temperature is slightly below the body temperature of the animal.

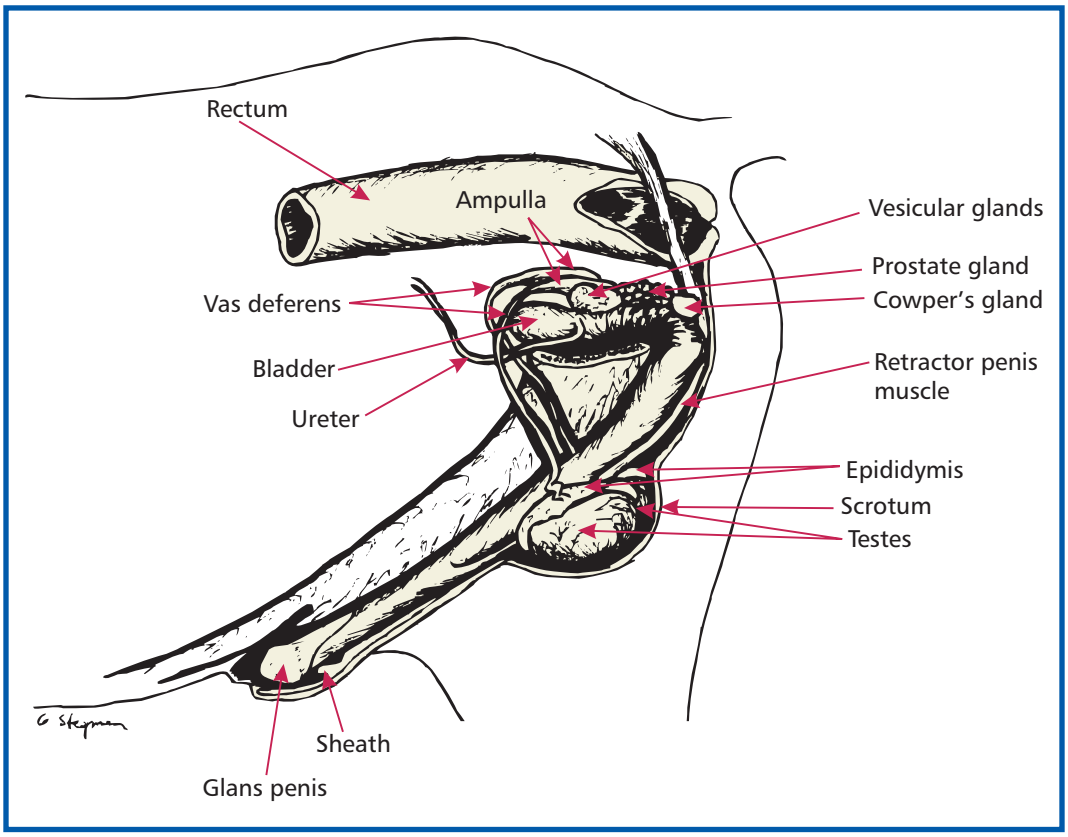


FIGURE 5. Stallion reproductive system. (Courtesy, Gary Stegman, Crookston, MN)

Summary:

The female reproductive tract includes the vulva, vagina, cervix, uterus, fallopian tubes, and ovaries. The male reproductive tract includes the penis, urethra, accessory glands, testicles, and scrotum. Copulation is the natural act of mating.

Checking Your Knowledge:

1. List the structures of the female reproductive tract. Explain the function of each.
2. List the structures of the male reproductive tract. Explain the function of each.

Expanding Your Knowledge:

Interview a livestock producer. If you are unable to find one locally, check with a livestock breed association to obtain the necessary contact. Determine from your interview why a complete understanding of animal reproduction is important to the producer's success. Identify what combination of on-the-job experience and educational training contributed to the person's overall knowledge of the subject.

Web Links:

Reproduction in Farm Animals—Oklahoma State University

http://www.ansi.okstate.edu/course/3443/study/

Bird Reproductive System

http://www.birdsnways.com/wisdom/ww32eiv.htm

Sex Cell Production in Animals

REPRODUCTION is the process of producing new animals. In the animal industry, reproduction is one of the most important functions, regardless of the species. Without successful reproduction, the production of meat animals and other animals would cease.

Objective:

Describe the production of sex cells.

Key Terms:

diploid
gametes
haploid
meiosis
oogenesis
polar bodies
reproduction
sperm
spermatogenesis

Sex Cell Production

Reproduction begins with the production of **gametes**, or sex cells, in the male and the female. Testicles in the male and ovaries in the female are responsible for the formation of the cells that will form a new organism. **Meiosis** is the mechanism behind sexual reproduction. The significance of meiosis is that genetic material is recombined during the process. All offspring differ genetically from all others.

Chromosomes normally exist in pairs. When a cell contains the normal two sets of two chromosomes, it is said to have a **diploid** (2n) number of chromosomes. A **haploid** (n) cell

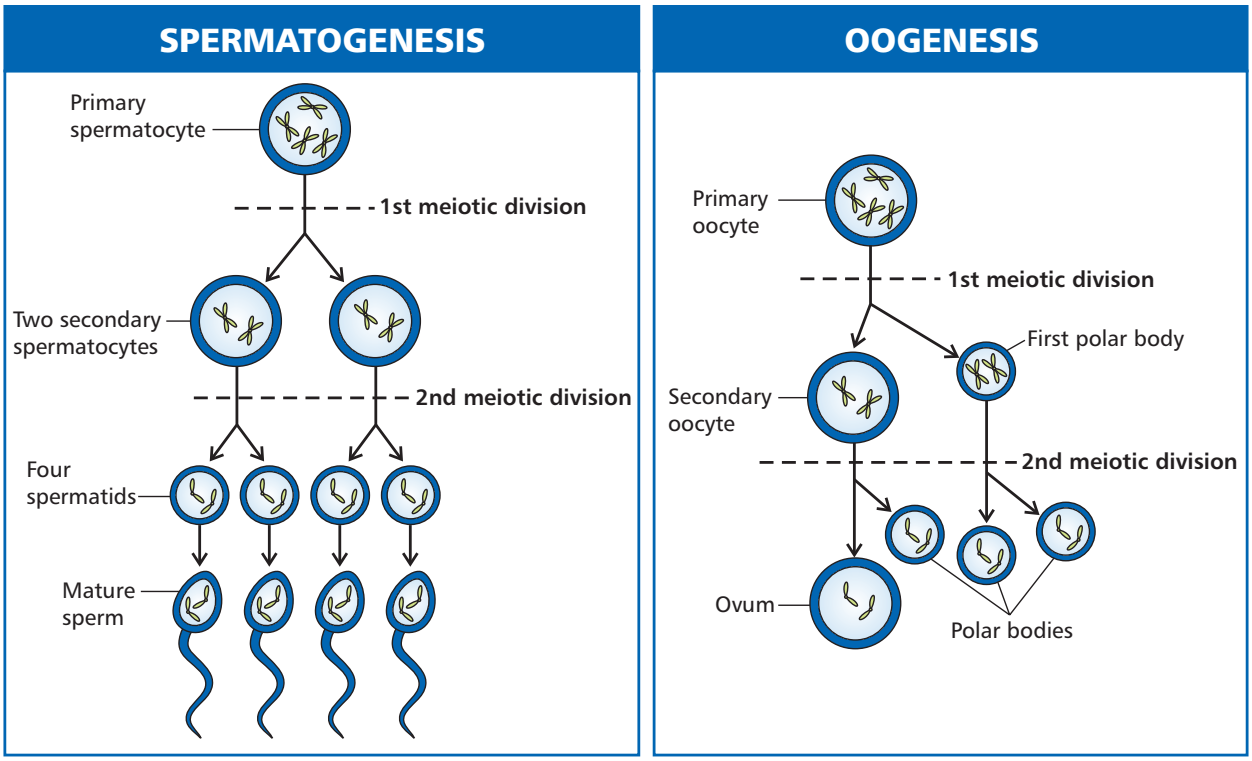


FIGURE 1. Meiosis results in the production of gametes.

has a single set of chromosomes. Gametes contain a haploid number of chromosomes. For example, a sheep has 54 chromosomes, so a sheep gamete would have only 27. Then, during mating, the male gamete and the female gamete unite, providing a full set of chromosomes for the offspring.

SPERMATOGENESIS

The male gamete is the **sperm** cell. It is produced in a testicle of a mature male. During the process of **spermatogenesis**, the testicle produces four sperm cells from the original germ cell. This occurs through a four-step process. During the first step, chromosomes replicate themselves, creating chromatids that are exact copies of the original chromosomes. During the second step, called synapsis, chromosomes pair together. During the third step, the cell divides, with the resulting cells receiving one chromosome from each pair. During the fourth step, the cells and chromosomes separate, resulting in sperm cells with a haploid number.

OOGENESIS

The female gamete is the egg cell, also known as the ovum. **Oogenesis** is the process that takes place in the ovary, resulting in the production of ova. It is a process similar to spermatogenesis with one primary difference. Instead of four gametes being produced from

one germ cell, only one egg cell is produced. The other three haploid cells are known as **polar bodies**, which provide food for the large, viable egg cell until fertilization.

Summary:

Reproduction is the process of producing new animals. Reproduction requires gametes, reproductive cells from each parent, to unite to form a zygote. Gametes are formed through meiosis. Meiosis is the cell division that results in sex cells containing one-half the chromosomes needed to form a new animal. The testes produce sperm cells. The ovaries produce ova.

Checking Your Knowledge:

1. What is the significance of meiosis?
2. Why do sex cells contain a haploid number of chromosomes?
3. Explain where male and female gametes are formed.
4. Describe the process of spermatogenesis.
5. Describe the process of oogenesis.

Web Links:

Spermatogenesis

http://distance.stcc.edu/AandP/AP/AP2pages/reprod/spermato.htm

Oogenesis

http://distance.stcc.edu/AandP/AP/AP2pages/reprod/oogenesi.htm

Name _____ Date _____

Biotechnology: Growing Flavors in the Laboratory

At one time there were two flavors of ice cream from which to choose: vanilla and chocolate. Today we must make hard choices between common flavors like strawberry and unusual flavors like bubblegum. We must make the choice between the subtle, well-rounded natural flavor and its more intense, artificial, synthetically produced cousin.

Now we face other choices as biotechnology firms learn how to grow flavors in living plant cells. One California firm is harvesting vanilla flavor from cells that have been surgically removed from vanilla plants and cultured in a glass bioreactor. One of the key techniques of this technology is plant tissue culture, the growth of plant cells in the laboratory. For example, in order to make vanilla, scientists first remove cells from the vanilla plant and culture them in a laboratory dish. Various hormones are added to the cell culture to prevent the cells from differentiating into root or leaf cells. The cell culture is then submerged in a bath of nutrients that help the cells multiply. To turn on the cells' flavor-making factories, additional hormones are added. The cells are finally placed in a protected material and packed into a glass column through which more nutrients flow. Flavor that leaks out of the cells is collected.

The production of pure, natural vanilla flavoring is perhaps less complicated, but more expensive and time-consuming. The vanilla orchid grows primarily in the Malagasy Republic and Indonesia. Each flower of the orchid opens for only one day of the year and must be hand pollinated in order to produce the fruit, or bean. The vanilla bean is cured in a labor-intensive process that takes three to six months. Two kilograms of uncured beans produce approximately one-half kilogram of cured beans. The pure, natural vanilla flavoring extracted from the beans sells for around $2000 per kilogram.

Artificial vanilla flavoring is much less expensive than pure, natural vanilla. Artificial vanilla sells for $10 per kilogram and is made primarily of vanillin. Vanillin is an inexpensive by-product of the paper industry, extracted from wood pulp.

There is no question as to what is natural vanilla and what is artificial vanilla, but how do we treat the vanilla produced by vanilla plant cell cultures? Is it natural or artificial? The biotechnology firms claim that it is natural because it is produced by vanilla plant cells. The vanilla industry insists that it is artificial. They maintain that since pure, natural vanilla contains 150 constituents and the biotechnology firms product contains only eight or ten of these constituents, one of which is vanillin, it cannot be considered natural vanilla flavor. By 1990, the California biotechnology firms expect to produce several hundred thousand kilograms of vanilla flavor a year. This is about the same amount of vanilla that is currently produced by the vanilla bean industry.

Vanilla is not the only flavor that can be produced by plant cell tissue cultures. Similar techniques can be used to produce strawberry, raspberry, grape, and nearly any other fruit flavor. In the future, when you say "I'll take vanilla," what kind of flavor will you get?

Questions:

1. How are flavors produced through plant cell culture similar to natural flavors? _____

2. Which type of vanilla flavoring would you prefer—natural, artificial, or that produced through biotechnology? Explain your reasoning. _____

3. If the laboratory-produced vanilla flavoring is accepted and approved for sale, what effect might this product have on the vanilla bean industry in the Malagasy Republic? (The cost of the laboratory-produced vanilla would be less expensive than pure, natural vanilla but slightly more than artificial vanilla.) _____

Name _____ Date _____

The Genetic Peril of the Cheetah

The cheetah is truly one of nature's marvels. A virtual running machine, its skull is small and lightweight, its limbs are long and slender, and its spinal column is unusually flexible. The cheetah's heart, lungs, and adrenal glands are all enlarged, enhancing the animal's ability to accelerate during a high-speed chase—a chase often clocked at up to 112 kilometers per hour. Unlike other cats, the cheetah's claws are always extended like cleats, enabling it to grip the ground. These adaptations have made the cheetah an effective hunter on the flat, open savannahs of central and southern Africa.

In spite of the cheetah's skill as a runner and hunter, the species seems to be headed for extinction. While the cheetah's body structure is superbly adapted to a running existence, the cheetah has traits that are considered maladaptive. It is extremely vulnerable to disease, and there is a high infant mortality rate. Although the cheetah is the world's fastest mammal, it can run rapidly for only a few hundred yards before it tires. After a typical chase, the cheetah collapses for half an hour in order to regain its strength. During this time, it is vulnerable to attack by other predators and can lose either its life or its catch. Cheetahs are rather timid creatures, with some 50 percent of their kills snatched away by more aggressive lions, leopards, and hyenas. The cheetah is now limited to a few, small areas in Africa. There are about 20 000 cheetahs left on Earth today.

Research over the last six years suggests that the cheetah has somehow lost most of its genetic variation. Scientific studies have revealed that, genetically, each cheetah is nearly identical to every other cheetah. In other words, the species exhibits genetic uniformity. Genetic uniformity hampers the ability of a species to adapt to environmental changes, such as temperature shifts, drought, glaciation, and even the emergence of new viruses or bacteria. Such uniformity is usually the result of intensive inbreeding.

Scientists have recently puzzled over the causes for the probable inbreeding and resultant genetic uniformity in the cheetah. The most plausible hypothesis to date is that at some point in the past the cheetah went through a severe population reduction. The population reduction was followed by inbreeding, which diminished genetic variability. How severe would the population reduction have to be in order to lead to genetic uniformity? Studies have shown that a population reduced to only seven individuals will retain about 95 percent of its original genetic variation. The population can retain that variation only if the survivors reproduce rapidly enough to expand the size of the population. Slow reproduction in a small population decreases the likelihood that different genetic types will survive. Scientists suspect that at least once in the past the cheetah's population dropped to only a few individuals. What caused the cheetah population to dwindle is not known. The possibilities include catastrophic climatic changes, viral or bacterial plagues, and even hunting by humans.

Several other animals have gone through severe population reductions and seem to be recovering. One example is the northern elephant seal. This population was reduced to about 20 animals. Yet after the passage of protective legislation, the seal population grew. Today the number of elephant seals reaches into the tens of thousands. Can the cheetah have the same good fortune?

Questions:

1. Provide a definition of genetic uniformity. _____

2. How does genetic uniformity occur?

3. How does genetic uniformity hamper the survival of the cheetah? _____

Name _____ Date _____

Purebred Dogs

You have probably heard that mutts, dogs that are not purebred, are healthier than purebred dogs. Whether that statement always holds true is a matter for debate. One has to wonder, however, how much a breeder can guarantee the health of a purebred dog when one sees the many genetic disorders that affect such animals.

Perhaps the most common genetic disorder of purebred dogs is hip dysplasia. This disorder occurs mostly in larger dogs, such as German shepherds, Labrador retrievers, and Great Danes. Hip dysplasia occurs when the muscles do not develop and reach maturity at the same rate as the skeleton. This allows the hip, which depends upon muscle power for stability, to pull apart. A series of events is triggered that ultimately causes the hip socket and the head of the femur, or hip bone, to begin pulling apart from one another. Hip dysplasia often cripples a dog.

Hip dysplasia was recognized as a disease in the 1950s. At that time, most dog breeders believed it was caused by a dominant gene and it was assumed that hip dysplasia could be eliminated by destroying or by not breeding affected dogs. This soon proved to be a futile exercise as breeders found that they could mate two normal dogs, yet still end up with offspring that suffered from hip dysplasia. Additional research has revealed that the disease is caused by the cumulative effects of a number of genes. Hip dysplasia is said to be a polygenic disorder.

To date, the best way to eliminate hip dysplasia is to breed dogs who have pedigree depth for normal hips. Pedigree depth for normal hips means that the bloodline has been free of hip dysplasia for at least three generations. While this method does not guarantee that all offspring will be free of the disease, it does substantially reduce the number of offspring that will suffer from it.

Hip dysplasia is not the only genetic disorder that affects purebred dogs. Disorders of the eyes, ears, and nose can cause more than discomfort for the dog and can needlessly handicap the animal. Deafness is inherited by dalmatians, bulldogs, bullterriers, and many white-coated breeds. Breathing difficulties often plague pugs, bulldogs, boxers, and other breeds with very short noses. They often suffer fits of sneezing and snorting.

Disorders of the eyes include cataracts, entropion, and glaucoma. Cataracts are opaque areas that develop within the lens of the eye. Cataracts interfere with vision and can lead to blindness. Accidents, injuries, and old age can cause cataracts, and they can also be inherited. Irish setters, Afghan hounds, German shepherds, poodles, schnauzers, cocker spaniels, and several types of retrievers are breeds that suffer from inherited cataracts. A dog with entropion has an upper or lower eyelid that is turned, a condition that causes the cornea of the eye to become irritated. Permanent corneal damage can result. Nearly all cases of entropion are inherited and particularly afflict chow chows, Irish setters, Kerry blue terriers, Saint Bernards, and several breeds of retrievers. Glaucoma occurs when drainage of the fluid in the eyes is impaired. The fluid builds up in the eyes and can result in blindness if not corrected. Glaucoma can be caused by an injury or infection, and it is inherited as well. The following breeds of dogs are known to carry genes for glaucoma: cocker spaniels, beagle, poodle, Alaskan malamute, basset hound, and many kinds of terriers.

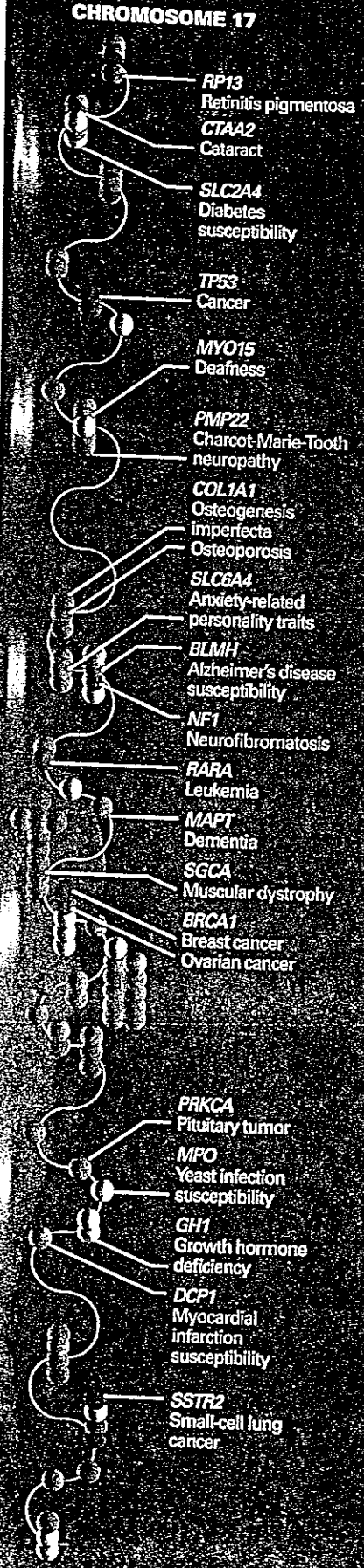
Questions:

1. You plan to buy a German shepherd puppy. You soon discover that the mother is a two year old with a mild case of hip dysplasia. The hip condition of the father is unknown but he is five years old and has some eye problems. Would you buy a puppy from this litter? Why? Why not?
2. You have purchased a Saint Bernard puppy from a well-known breeder. The breeder assures you that the puppy's parents have pedigree depth for normal hips. You hope to breed this dog when it is three years old. However, at the age of two your dog begins to show signs of hip dysplasia. Will you still breed your dog? Why? Why not?
3. You plan to buy a white, toy poodle. What questions might you ask the breeder before you purchase a puppy? What would you do if the breeder did not have enough information about the puppy's pedigree to answer your questions?
4. Should a dog breeder assume any responsibilities when selling his or her animals? What responsibilities?

The stories in our genes

Cancers · Cardiovascular disorders · Other · Metabolic/endocrine disorders · Neurologic/psychiatric disorders

Someday DNA tests may provide instant snapshots of future ailments and life expectancy, but not yet. Genes for more than 1,200 disorders have been identified (selected examples below and left), but most people probably can learn more from their parents' health history than they can from a DNA printout (background). Most of us carry a few defective genes with no signs of disease, and many genes only contribute to susceptibility. Lifestyle choices such as diet and smoking and environmental factors can raise or lower disease risk.



CHROMOSOME 1
- Malignant melanoma
- Prostate cancer
- Deafness

CHROMOSOME 2
- Congenital hypothyroidism
- Colorectal cancer

CHROMOSOME 3
- Susceptibility to HIV infection
- Small-cell lung cancer
- Dementia

CHROMOSOME 4
- Huntington's disease
- Polycystic kidney disease

CHROMOSOME 5
- Spinal muscular atrophy
- Endometrial carcinoma

CHROMOSOME 6
- Hemochromatosis
- Dyslexia
- Schizophrenia
- Myoclonus epilepsy
- Estrogen resistance

CHROMOSOME 7
- Growth hormone deficient dwarfism
- Pregnancy-induced hypertension
- Cystic fibrosis
- Severe obesity

CHROMOSOME 8
- Hemolytic anemia
- Burkitt's lymphoma

CHROMOSOME 9
- Dilated cardiomyopathy
- Fructose intolerance

CHROMOSOME 10
- Congenital cataracts
- Late onset cockayne syndrome

CHROMOSOME 11
- Sickle-cell anemia
- Albinism

CHROMOSOME 12
- Inflammatory bowel disease
- Rickets

CHROMOSOME 13
- Breast cancer, early onset
- Retinoblastoma
- Pancreatic cancer

CHROMOSOME 14
- Leukemia / T-cell lymphoma
- Goiter

CHROMOSOME 15
- Marfan's syndrome
- Juvenile epilepsy

CHROMOSOME 16
- Polycystic kidney disease
- Familial gastric cancer
- Tuberous sclerosis-2

CHROMOSOME 17 (shown at left)

CHROMOSOME 18
- Diabetes mellitus
- Familial carpal tunnel syndrome

CHROMOSOME 19
- Myotonic dystrophy
- Malignant hyperthermia

CHROMOSOME 20
- Isolated growth hormone deficiency
- Fatal familial insomnia
- Creutzfeldt-Jakob's disease

CHROMOSOME 21
- Autoimmune polyglandular disease
- Amyotrophic lateral sclerosis

CHROMOSOME 22
- Ewing's sarcoma
- Giant-cell fibroblastoma

X CHROMOSOME
- Colorblindness
- Mental retardation
- Gout
- Hemophilia
- Male pseudohermaphroditism

Y CHROMOSOME
- Gonadal dysgenesis

MITOCHONDRIAL DNA
- Leber's hereditary optic neuropathy
- Diabetes and deafness
- Myopathy and cardiomyopathy
- Dystonia

SOURCE: VICTOR A. McKUSICK, JOANNA AMBERGER, AND ADA HAMOSH, ONLINE MENDELIAN INHERITANCE IN MAN (WWW.NCBI.NLM.NIH.GOV/OMIM/) AND GREG SCHULER, NATIONAL CENTER FOR BIOTECHNOLOGY INFORMATION; ART BY CHRISTOPHER SLOAN, NGS STAFF, AND DOUG STERN; PHOTOGRAPH BY O. LOUIS MAZZATENTA

When did Biotechnology Get Started?

The development of biotechnology continues at a fast pace, and it is hard to believe that most of today's biotechnology products did not begin coming to the marketplace until the mid-1990's. The scientific work that led up to today's capabilities, however, spans more than a century.

1860's - Austrian botanist Gregor Mendel recognizes that hereditary information is stored in discrete units now called genes

1870's - Using crude microscopes, scientists discover chromosomes. They learn that the sperm and egg contribute an equal number of chromosomes to an embryo.

1953 - James Watson and Francis Crick describe the structure of DNA and how it is passed from generation to generation.

1966 - Scientists decipher the genetic code along the DNA chain.

1970 - Enzymes are discovered that "cut" the DNA chain at specific spots, making it possible to isolate and transfer individual genes

1972 - Paul Berg of Stanford University combines the genetic material of two different viruses for the first recombinant DNA.

1973 - New DNA fragments are inserted into plasmid DNA and then reinserted into the bacterium *E. coli*.

1978 - Recombinant DNA is used to produce human insulin in bacterial cells.

1980's - Genetically-engineered human insulin is commercialized; First recombinant petunia plant cell that carries and expresses a bacterial gene; Field tests of agricultural plants modified to resist viral disease, insects and herbicides begin

Early 1990's - A bovine protein, BST, is commercialized to increase milk production; an enzyme used in cheese making is produced; a tomato is developed that softens more slowly, allowing it to remain on the vine longer; potato plants are developed with built-in resistance to the Colorado beetle.

Late 1990's - An explosion of products comes to market: Corn, potatoes, and cotton that naturally resist the certain insect larvae; Soybeans, cotton, and corn that can grow in the presence of specific herbicides. Livestock animals cloned from cells of adult animals; Human plasminogen activator, used in treating burns, produced in the milk of farm animals; microbes used to clean water and soil. Many new companies form and many existing ones merge. Research into new food and pharmaceutical products continues at an accelerated pace. Researchers work on genetic maps of many plants and animals

Adapted and updated from *Circle of Life: Using Biotechnology to Improve Agriculture Worldwide,* National FFA Organization, 1995.

GENETIC MODIFICATION ISN'T AN UNNATURAL PROCESS, BORLAUG SAYS

Norman Borlaug, 84, who won the Nobel Peace Prize in 1970 for his achievements in breeding high-yielding wheat and now teaches crop history at Texas A&M University when he isn't in Africa working with former President Jimmy Carter to help farmers extract higher yields from their crops under a project called Sasakawa-Global 2000, was cited as saying that ordinary leavened bread is made from wheat that carries the genes of three plant species. And the genetic engineering didn't happen in the past decade or even the past millennium. Nature spliced the genes before the rise of the Roman Empire.

Borlaug was quoted as saying, "Genetically modified organisms are the result of a natural process that was going on long before humans became involved," and insisted that there has been "too much emotion and too little science" in the reaction to crops that are genetically modified in laboratories. Species barriers, he says, are significant in nature, but not inviolate. For example, when primitive farmers selected the wild grass that came to be known as wheat, they sowed a plant that had seven chromosomes in its pollen stage. Somehow that wheat crossed with another plant to create a new species with 14 chromosomes. Borlaug calls it "spaghetti wheat." It was the leading commercial grain until Roman times, and we use its descendants today for pasta and unleavened bread. Then yet another species emerged with 21 chromosomes.

We know it today as "bread wheat," Borlaug said. "It had crossed again, by itself, to another wild grass."

Over the centuries, farmers and plant breeders have tried to mimic nature's creativity, he said. As a result, almost all crops under cultivation today are the result of shuffled genes.

Borlaug was quoted as saying, "When we said we were transferring a gene for stem-rust resistance, there were a considerable number of others that were on the same parts of the chromosome that were trailing along with it."

Many of those tag-along genes gave the plants traits that farmers didn't want. To get rid of them, breeders developed a system of "backcrossing." In Mexico, for example, Borlaug would cross a local variety with a Minnesota wheat, grow the plants to maturity, plant their seeds, determine which of the offspring resisted stem rust and cross those plants back to the Mexican varieties. The technique of the day called for repeating the process again and again until the plants were similar to the Mexican varieties but also resisted stem rust.

It generally took 10 generations or more that is, 10 growing seasons to get only the genes of interest with nothing else tagged along, Borlaug said. In Mexico, he shortened the time by shuttling between the north and the south to sneak in two growing seasons a year. The key difference today is that plant breeders can isolate precisely the genes they want and insert them directly into plants. Thus, they "aren't carrying along a lot of other garbage that we knew was there but we had no way of controlling," he said.

Those calling for caution in using the products of modern genetic engineering on farms argue that there is another huge difference: Scientists are combining genes from species that would have almost no chance of crossing in the wild.

The Union of Concerned Scientists put it this way in a primer on the technology: Formerly, someone who wanted a purple cow could breed one only if purple genes were available in a cow or a near relative to cows. But a modern-day genetic engineer has no such restrictions. "If purple genes are available anywhere in nature in a sea urchin or an iris those genes could be used in attempts to produce a purple cow."

Borlaug acknowledged that there has been a significant leap from his example of crossing wild grasses. The appropriate response, he argued, is not to reject the crops but to make sure they are thoroughly tested under government regulation. The varieties available, he noted, have been adequately tested by their makers under standards carefully set by three federal government agencies in consultation with many scientists.

"Reprinted with permission of the Star Tribune, Minneapolis-St. Paul"
February 2, 2000, Minneapolis Star Tribune, Editorial, Sharon Schmickle

Name _____ Date _____

Purebred Dogs

You have probably heard that mutts, dogs that are not purebred, are healthier than purebred dogs. Whether that statement always holds true is a matter for debate. One has to wonder, however, how much a breeder can guarantee the health of a purebred dog when one sees the many genetic disorders that affect such animals.

Perhaps the most common genetic disorder of purebred dogs is hip dysplasia. This disorder occurs mostly in larger dogs, such as German shepherds, Labrador retrievers, and Great Danes. Hip dysplasia occurs when the muscles do not develop and reach maturity at the same rate as the skeleton. This allows the hip, which depends upon muscle power for stability, to pull apart. A series of events is triggered that ultimately causes the hip socket and the head of the femur, or hip bone, to begin pulling apart from one another. Hip dysplasia often cripples a dog.

Hip dysplasia was recognized as a disease in the 1950s. At that time, most dog breeders believed it was caused by a dominant gene and it was assumed that hip dysplasia could be eliminated by destroying or by not breeding affected dogs. This soon proved to be a futile exercise as breeders found that they could mate two normal dogs, yet still end up with offspring that suffered from hip dysplasia. Additional research has revealed that the disease is caused by the cumulative effects of a number of genes. Hip dysplasia is said to be a polygenic disorder.

To date, the best way to eliminate hip dysplasia is to breed dogs who have pedigree depth for normal hips. Pedigree depth for normal hips means that the bloodline has been free of hip dysplasia for at least three generations. While this method does not guarantee that all offspring will be free of the disease, it does substantially reduce the number of offspring that will suffer from it.

Hip dysplasia is not the only genetic disorder that affects purebred dogs. Disorders of the eyes, ears, and nose can cause more than discomfort for the dog and can needlessly handicap the animal. Deafness is inherited by dalmatians, bulldogs, bullterriers, and many white-coated breeds. Breathing difficulties often plague pugs, bulldogs, boxers, and other breeds with very short noses. They often suffer fits of sneezing and snorting.

Disorders of the eyes include cataracts, entropion, and glaucoma. Cataracts are opaque areas that develop within the lens of the eye. Cataracts interfere with vision and can lead to blindness. Accidents, injuries, and old age can cause cataracts, and they can also be inherited. Irish setters, Afghan hounds, German shepherds, poodles, schnauzers, cocker spaniels, and several types of retrievers are breeds that suffer from inherited cataracts. A dog with entropion has an upper or lower eyelid that is turned, a condition that causes the cornea of the eye to become irritated. Permanent corneal damage can result. Nearly all cases of entropion are inherited and particularly afflict chow chows, Irish setters, Kerry blue terriers, Saint Bernards, and several breeds of retrievers. Glaucoma occurs when drainage of the fluid in the eyes is impaired. The fluid builds up in the eyes and can result in blindness if not corrected. Glaucoma can be caused by an injury or infection, and it is inherited as well. The following breeds of dogs are known to carry genes for glaucoma: cocker spaniels, beagle, poodle, Alaskan malamute, basset hound, and many kinds of terriers.

Questions:

1. You plan to buy a German shepherd puppy. You soon discover that the mother is a two year old with a mild case of hip dysplasia. The hip condition of the father is unknown but he is five years old and has some eye problems. Would you buy a puppy from this litter? Why? Why not?
2. You have purchased a Saint Bernard puppy from a well-known breeder. The breeder assures you that the puppy's parents have pedigree depth for normal hips. You hope to breed this dog when it is three years old. However, at the age of two your dog begins to show signs of hip dysplasia. Will you still breed your dog? Why? Why not?
3. You plan to buy a white, toy poodle. What questions might you ask the breeder before you purchase a puppy? What would you do if the breeder did not have enough information about the puppy's pedigree to answer your questions?
4. Should a dog breeder assume any responsibilities when selling his or her animals? What responsibilities?

BIOTECHNOLOGY IN HUMAN HEALTH CARE

Biotechnology Public Education Program
Iowa State University

Biotechnology Defined

- Broad Definition:
  - Using living organisms or their products for commercial purposes.
- Narrow Definition:
  - The commercial application of living organisms or their products, which involves the deliberate manipulation of their DNA molecules

Impacts of Biotechnology

- Human Health
- Agriculture
- Food

Impacts on Human Health

- Pharmaceuticals
- Diagnosis
  - Infectious Diseases
  - Genetic Diseases
- Gene Therapy
  - Genetic Diseases
  - Cancer
  - AIDS

Pharmaceutical Products

- Human Insulin - Diabetes
- Growth Hormone - Dwarfism
- Factor VIII - Hemophilia A
- Tissue Plasminogen Activator - Heart disease and stroke
- Hepatitis B Vaccine

Production of pharmaceuticals

- Proteins
- Microorganisms
- Cultured Cells
- "Pharm" Animals

Biotechnology Principles

- All organisms are composed of cells that contain the hereditary material DNA in chromosomes.
- The characteristics of any living thing are determined by the information in its DNA molecules.
- DNA is made of 4 kinds of building blocks called nucleotides.

Biotechnology Principles

- The building blocks comprise a 4 letter alphabet (A, G, C, & T)
- The order of the letters in the DNA alphabet supplies information in a manner similar to the letters in a word.
- DNA "words" are called genes and usually contain 1,000 to 100,000 letters.

Biotechnology Principles

- DNA from any organism is the same except for the sequence and number of letters in the genes.
- DNA from one organism can be transferred into other organisms and it will still continue to function!

BIOTECHNOLOGY IN HUMAN HEALTH CARE

Biotechnology Public Education Program
Iowa State University

Biotechnology Defined

- Broad Definition:
  - Using living organisms or their products for commercial purposes.
- Narrow Definition:
  - The commercial application of living organisms or their products, which involves the deliberate manipulation of their DNA molecules

Impacts of Biotechnology

- Human Health
- Agriculture
- Food

Impacts on Human Health

- Pharmaceuticals
- Diagnosis
  - Infectious Diseases
  - Genetic Diseases
- Gene Therapy
  - Genetic Diseases
  - Cancer
  - AIDS

Pharmaceutical Products

- Human Insulin - Diabetes
- Growth Hormone - Dwarfism
- Factor VIII - Hemophilia A
- Tissue Plasminogen Activator - Heart disease and stroke
- Hepatitis B Vaccine

Production of pharmaceuticals

- Proteins
- Microorganisms
- Cultured Cells
- "Pharm" Animals

Biotechnology Principles

- All organisms are composed of cells that contain the hereditary material DNA in chromosomes.
- The characteristics of any living thing are determined by the information in its DNA molecules.
- DNA is made of 4 kinds of building blocks called nucleotides.

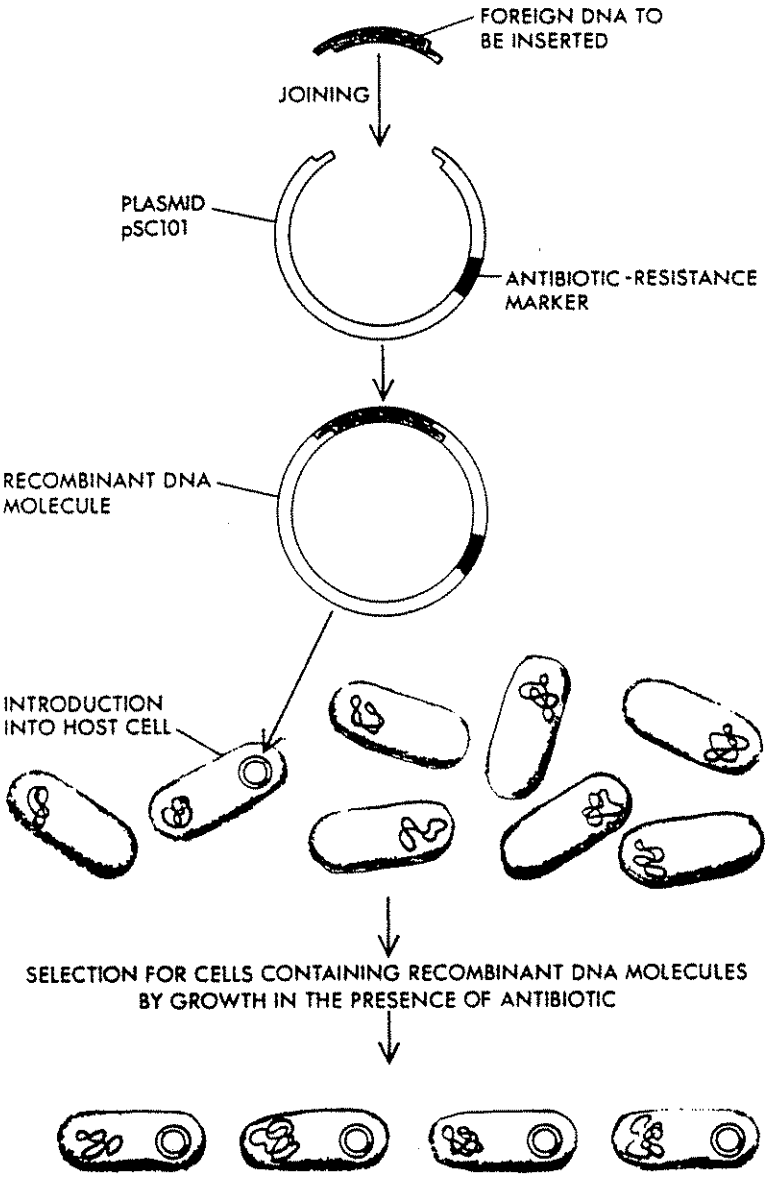
Biotechnology Principles

- The building blocks comprise a 4 letter alphabet (A, G, C, & T)
- The order of the letters in the DNA alphabet supplies information in a manner similar to the letters in a word.
- DNA "words" are called genes and usually contain 1,000 to 100,000 letters.

Biotechnology Principles

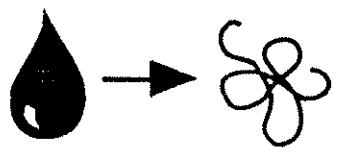
- DNA from any organism is the same except for the sequence and number of letters in the genes.
- DNA from one organism can be transferred into other organisms and it will still continue to function!

CLONING OF DNA IN A PLASMID

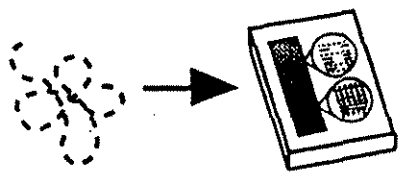


THE PROCESS OF DNA FINGERPRINTING

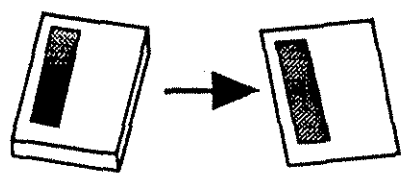
1. The process begins with a blood or cell sample from which the DNA is extracted.



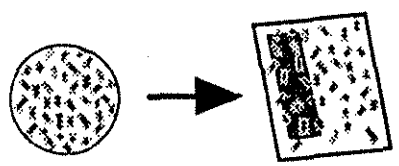
2. The DNA is cut into fragments using a restriction enzyme. The fragments are then separated into bands by electrophoresis through an agarose gel.



3. The DNA band pattern is transfered to a nylon membrane.

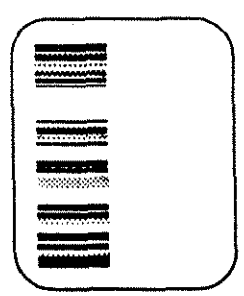


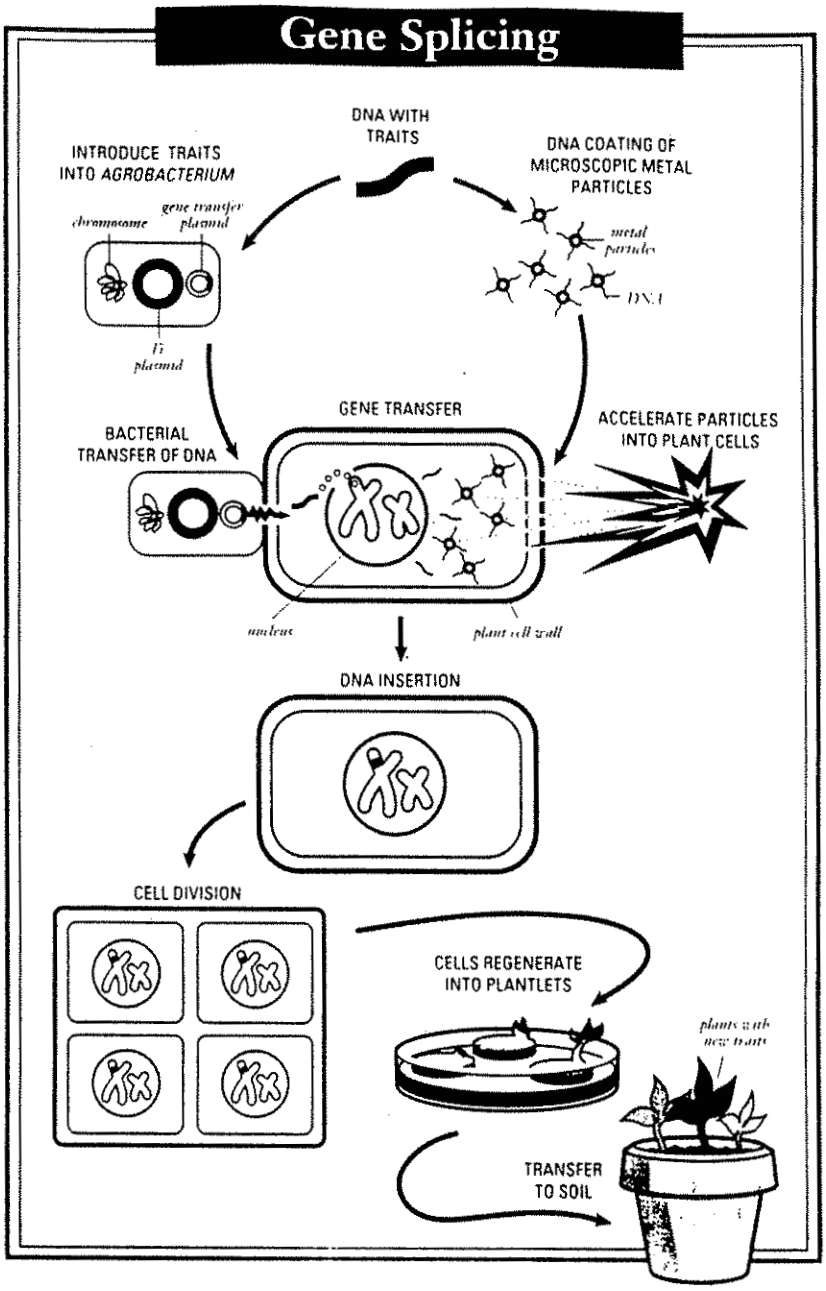
4. A radioactive DNA probe is introduced. The DNA probe binds to specific DNA sequences on the nylon membrane.



5. The excess probe material is washed away leaving the unique DNA band pattern.

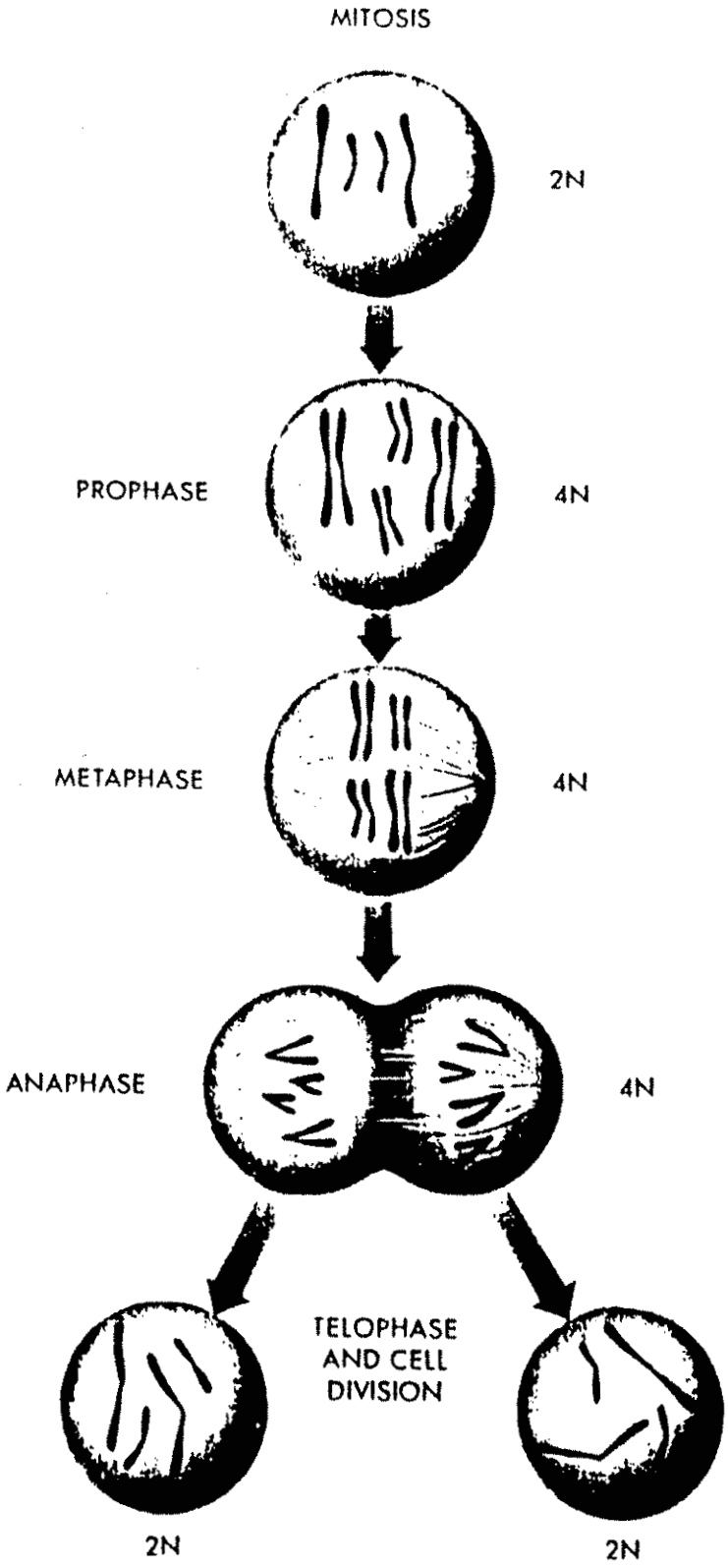
6. The radioactive DNA pattern is transfered to X-ray film by direct exposure. When developed the resultant visible pattern is the DNA FINGERPRINT



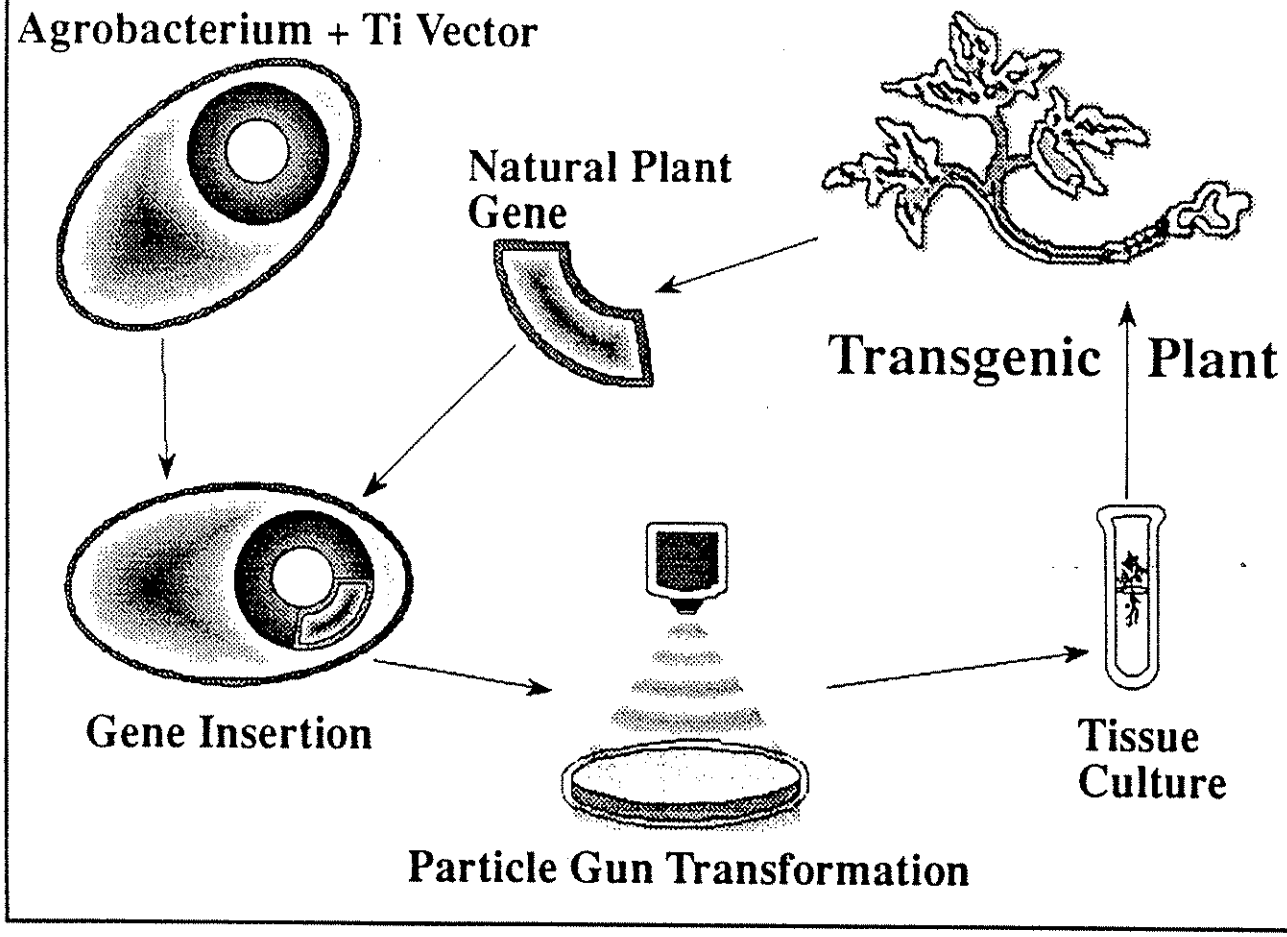


AGROBACTERIUM OR A PARTICLE GUN CAN BE USED TO TRANSFER DNA FROM ONE ORGANISM TO ANOTHER

CELL MULTIPLICATION



Production of Transgenic Plants



Some Restriction Enzymes and Their Cleavage Sequences

Microorganism	*Abbreviation*	*Sequence* 5′ → 3′ 3′ → 5′
Bacillus amyloliquefaciens H	*Bam*HI	G↓G A T C C C C T A G↑G
Brevibacterium albidum	*Bal*I	T G G↓C C A A C C↑G G T
Escherichia coli RY13	*Eco*RI	G↓A A T T C C T T A A↑G
Haemophilus aegyptius	*Hae*II	Pu G C G C↓Py Py↑C G C G Pu
Haemophilus aegyptius	*Hae*III	G G↓C C C C↑G G

THE GENETIC CODE

First Position (5' end)	Second Position U	Second Position C	Second Position A	Second Position G	Third Position (3' end)
U	PHE	SER	TYR	CYS	U
	PHE	SER	TYR	CYS	C
	LEU	SER	Stop	Stop	A
	LEU	SER	Stop	TRP	G
C	LEU	PRO	HIS	ARG	U
	LEU	PRO	HIS	ARG	C
	LEU	PRO	GLN	ARG	A
	LEU	PRO	GLN	ARG	G
A	ILE	THR	ASN	SER	U
	ILE	THR	ASN	SER	C
	ILE	TIIR	LYS	ARG	A
	MET	TIIR	LYS	ARG	G
G	VAL	ALA	ASP	GLY	U
	VAL	ALA	ASP	GLY	C
	VAL	ALA	GLU	GLY	A
	VAL	ALA	GLU	GLY	G