

Got Silk: Biotech Applications

Secrets of the Sequence Video Series on the Life Sciences • Grades 9 — 12
Teaching materials developed by VCU Life Sciences

V i r g i n i a C o m m o n w e a l t h U n i v e r s i t y

Classroom Tested Lesson

Video Description

“Secrets of the Sequence,” Show 133, Episode 1

“Got Silk? – Biotech Applications” – approximately 9 minutes viewing time

Imagine spinning goat milk into spider silk five times stronger than steel! Scientists have found a way to put a whole new spin on genetic research. It’s called biomimicry. Scientists are now able to mimic a spider’s web by breeding goats with spider genes in their mammary cells. The goat’s milk contains a protein that can be spun and stretched into a fine silk fit to cover Spiderman – the spidergoat is here.

Ward Television

Producer: Cecile Bourchardeau

Associate Producer: Trish Golden

Featuring: Randy Lewis, Molecular Biology, University of Wyoming, Costas Karatzas, Research and Development, Nexia Biotechnologies

Lesson Authors; Reviewers: Catherine Dahl, Dick Rezba; Kieron Torres

Trial Testing Teachers: Martin Shields

National and State Science Standards of Learning

National Science Education Standards Connection

Content Standard A: Science as Inquiry

As a result of activities in grades 9-12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

As a result of their activities in grades 9-12, all students should develop understanding of

- Interdependence of organisms
- Matter, energy, and organization in living systems
- Molecular basis of heredity

Content Standard E: Science and Technology

As a result of their activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Selected State Science Standards of Learning Connections

Use <http://www.eduhound.com> (click on "Standards by State") or a search engine to access additional state science standards.

Virginia

BIO.5 The student will investigate and understand life functions of archaebacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include

- a) how their structures and functions vary between and within the kingdoms;

BIO.6 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- c) cell specialization;
- e) genetic variation (mutation, recombination, deletions, additions to DNA);
- g) events involved in the construction of proteins;
- h) use, limitations, and misuse of genetic information; and
- i) exploration of the impact of DNA technologies.

BIO.7 The student will investigate and understand bases for modern classification systems.

Key concepts include

- a) structural similarities among organisms;
- d) examination of biochemical similarities and differences among organisms

California

Cell Biology

1. The fundamental life processes of plants and animals depend on a variety of chemical reactions that occur in specialized areas of the organism's cells. As a basis for understanding this concept:
 - h. *Students know* most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.

Genetics

4. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept:
 - c. *Students know* how mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein.
 - d. *Students know* specialization of cells in multicellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.
5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells. As a basis for understanding this concept:
 - c. *Students know* how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.

Overview

This video is about biomimicry- the study of genetically manipulating one species to have a specific trait of another species. In particular, researchers have isolated the gene in the spider that turns on the fiber-making process. This gene "instructs" a gland in the abdomen of the spider to produce a liquid that can be distilled, purified and spun into fibers that have proven in tests to be the strongest fibers in the world – approximately a 1 inch diameter thread would stop a jet in motion. Understanding the enormous potential for this type of fiber, researchers have recognized that it is not practical to harvest the amounts needed for commercial use from spider farms and so they have turned to goats to genetically engineer and insert the DNA of this specific gene that has been isolated in the spider. When these genetically altered goats lactate, their milk contains the same protein as that produced by the spider. It is then distilled, purified and spun just as with the spider except the amounts will hopefully enable researchers to put it to better commercial use in parachutes, bullet-proof vests, and fishing lines to name just a few. There have been numerous experiments with genetically altered animals that have been proven to be failures because side effects have often been

disastrous, but the process described in this video has had no extraneous effects on the goats and their behaviors are unchanged. Like new foods and drugs, "biosteel" will have to be approved by the FDA before it can be commercially available.

Testing: A sample related multiple choice item from State Standardized Exams

Bats use high frequency sound waves to locate their prey and to navigate in the dark. As sound waves reflect off an object and back to the bat's ear, the bat is able to determine the exact location of its prey. Which technical advance was aided by studying how bats locate objects using sound waves?

- A. 3-D computer modeling
- B. sonar navigation for submarines *
- C. x-rays for analyzing body structure
- D. night vision goggles for military operations

Source: Florida Comprehensive Assessment Test 2004: Grade 10

Video Preparation

Preview the video and make note of the locations you will need later to pause the video for discussion.

Before Viewing

1. Introduce students to the concept of transgenics.
Ask: What does the word transgenics mean? Show students that the word's structure – 'trans' and 'genics' gives a clue to its meaning. If time allows, have students do a Web search on the word.
Across - genes
2. In the video the scientist asserts that there have been no side effects or behavior changes in the genetically altered goats.
Ask: How do you feel about genetically altering a species from its normal state?

During Viewing

1. **START** the video.
2. **PAUSE** the video (6:40 minutes into the video) after the narrator says, "...that's a lot of silk from one goat"

Ask: What are the steps involved in creating spider silk using goats? Then list these steps on the board.

- i. Identify gene associated with "silk" production in spider*
- ii. Genetically engineer the DNA for this gene.*
- iii. Implant this DNA into the embryo of a goat*
- iv. Lactation*
- v. Distillation*
- vi. Purification*
- vii. Spinning*
- viii. Stretch the fiber.*

4. **RESUME** the video and play to the end.

After Viewing

1. Ask: What are the various uses for goat silk that were described in the video? Explain how the silk would be effective for each use. Can you think of any other uses for this silk?
 - *medical surgical suture*
 - *fishing line*
 - *bullet proof vest*
 - *jeans*
 - *other*
2. Ask: Why is it *not* practical to use spider farms to harvest the silk fibers?

Spiders are both territorial and cannibalistic so very large spaces are needed to ensure the spiders continue to weave their webs of silk fibers. Therefore it is far more productive to raise goats and distill the fiber-making protein from their milk.

3. Ask: Has anyone changed their opinion on how they feel about genetically altering a species? (Refer the students back to the question in # 2 of the Before Viewing section.)
4. Ask: Is silk production in goats an acceptable use of biotechnology?

Teacher Notes for the Student Activity: Biomimicry in Action

Procedure

1. Divide students into discussion groups of 3 or 4.
2. Explain how nature often inspires inventors and scientists to develop new products.
3. Remind them of how the strength of spider silk in the video inspired scientists to develop a process to make the protein that can be used for strong sutures, fishing line, and other products.
4. Distribute copies of the student handout to each group member.
5. Explain how they are to match as many of the human accomplishments and products in Column III on their handout as they can with the Natural Objects or Systems in Column I that inspired them. Give them the classic example of how the barbs on weed seeds (1) inspired the development of Velcro (k).
6. Encourage them to discuss each natural object or system and its possible corresponding human accomplishment or product in their groups and then record their group's decision in Column II on their handout.

Note:

- Some matches will be made easily by students but others are very difficult. When students become stuck, give them an opportunity to search for more information on the Internet if available. They may, for example, want to do a search for abalone nacre to learn about it. This information will better enable them to make the matches in the table. A trial test teacher reported that challenging students to find information to make the matches made the activity like a scavenger hunt, which they enjoyed.
- After students have filled in their tables as well as they can, lead a discussion having each group share their match choices and explain/justify them.
- After confirming correct matches, share the "Additional information for the teacher" with the students.

Answer Key for Student Handout

Column I Natural Object or System	Column II Human accomplishments and products that were or might be inspired by a natural object or system	Column III Additional information for the teacher
1. Barbs on weed seeds	k) <i>Velcro</i>	
2. Abalone nacre (mother of pearl coating)	f) <i>Windshields and bodies of solar cars, airplanes, or anything that needs to be lightweight but fracture-resistant.</i>	A crystalline coating self-assembles in perfect precision atop protein templates. In the abalone, it's a 3-D masterpiece, tougher than anything we can manufacture!
3. Blue mussel adhesive	p) <i>Liquid adhesive - Could enable surgeons to operate without sutures.</i>	Unlike available glues, it sets underwater and doesn't need a primer, an initiator, or a catalyst to work.
4. Mussel byssus threads	a) <i>Alternative to plastics - A time-release coating for disposable cups, silverware, plates, etc</i>	It protects for a certain period of time (a few months, perhaps), and then degrades, allowing the degradable material underneath to be composted.
5. Dolphin and shark skin	g) <i>Submarine - Hull material that deforms slightly to shrug off water pressure.</i>	Same with airplanes and air pressure.
6. Cold water fish	j) <i>Organ antifreeze - New ways to freeze human transplant organs without injury.</i>	
7. Orb-weaver spider silk	c) <i>New fiber manufacturing technique - Used in parachute wires, suspension bridge cables, sutures, protective clothing, etc.</i>	A way to manufacture fiber without using high heat, high pressure, or toxic chemicals. It is stronger and more resilient than anything we now have.
8. Porcupine quills	l) <i>Stronger wheat and barley crop</i>	Design could help agronomists breed better wind resistance in wheat and barley.
9. Rhinoceros horn	b) <i>Self-healing material that is both compressively and laterally strong - a new fender?</i>	
10. Anemones, and other marine creatures	o) <i>New antibiotics, fungicides</i>	Marine creatures, which live surrounded by pathogens in the sea, are full of novel defenses.

11. Bat and Dolphin sonar system	d) <i>Navigation</i>	We're still not even close to a bat's sophistication in sonar.
12. Cell membranes	q) <i>Super filters - Desalination and chemical separation devices.</i>	
13. Chlorophyll and enzymes	s) <i>Photozymes - Can break down pollutants such as PCBs into harmless compounds.</i>	Photozymes are like enzymes in that they trap molecules in a "sweet spot", using the absorbed sun energy to do chemistry.
14. Hibernating bears	m) <i>Clues to fighting diabetes.</i>	Bears sleep 6 months without urinating, and yet don't poison themselves.
15. Human ear drum	e) <i>Telephone</i>	Bell's original design was biomimetic
16. Mantled howler monkeys	h) <i>New birth control drugs</i>	Howlers regulate their own reproduction, and even the gender of their offspring, by eating certain plants. Can lead us to plants that have an effect on fertility.
17. Sea shell	r) <i>Sydney Opera House</i>	An example of biomimetic architecture.
18. Neurons and other kinds of cells	t) <i>Jigsaw computing that is exponentially faster than digital or silicon models</i>	A new computer processor based on the lock-and-key match-ups between organic molecules.
19. Vulture wings	i) <i>Airplanes – The Wright brothers were birdwatchers.</i>	
20. Firefly Fluorescence	n) <i>Cancer treatments using "markers" to make abnormal cells identifiable</i>	

Adapted from http://www.biomimicry.net/case_studies_materials.html

Student Handout: Biomimicry in Action

Group Members: _____

Natural objects often inspire inventors and scientists to develop new products and processes. In this activity you will match as many of the human accomplishments and products in Column III as you can with the Natural Objects or Systems in Column I that inspired them. For example, the barbs on weed seeds (1) inspired the development of Velcro (k). In your group discuss each natural object or system and its possible corresponding human accomplishment or product. Record your group's decision in Column II. If you need some additional information, ask your teacher.

Column I	Column II	Column III
Natural Object or System	<i>Match Column III with Column I</i>	Human accomplishments and products that were or might be inspired by a natural object or system
1. Barbs on weed seeds	<i>k</i>	<i>a) Alternative to plastics-A time-release coating for disposable cups, silverware, plates, etc</i>
2. Abalone nacre (mother of pearl coating)		<i>b) Self-healing material-that is both compressively and laterally strong- -a new fender?</i>
3. Blue mussel adhesive		<i>c) New fiber manufacturing technique- used in parachute wires, suspension bridge cables, sutures, protective clothing, etc.</i>
4. Mussel byssus threads		<i>d) Navigation</i>
5. Dolphin and shark skin		<i>e) Telephone</i>
6. Cold water fish		<i>f) Windshields and bodies of solar cars, airplanes, or anything that needs to be lightweight but fracture-resistant.</i>
7. Orb-weaver spider silk		<i>g) Submarine-Hull material that deforms slightly to shrug off water pressure.</i>
8. Porcupine quills		<i>h) New birth control drugs</i>
9. Rhinoceros horn		<i>i) Airplanes</i>
10. Anemones, and other marine creatures		<i>j) Organ antifreeze-New ways to freeze human transplant organs without injury.</i>
11. Bat and Dolphin sonar system		<i>k) Velcro</i>
12. Cell membranes		<i>l) Stronger wheat and barley crop</i>
13. Chlorophyll and enzymes		<i>m) Clues to fighting diabetes</i>
14. Hibernating bears		<i>n) Cancer treatments using "markers "to make abnormal cells identifiable</i>
15. Human ear drum		<i>o) New antibiotics, fungicides</i>
16. Mantled howler monkeys		<i>p) Liquid adhesive- Could enable surgeons to operate without sutures.</i>
17. Sea shell		<i>q) Super filters-Desalination and chemical separation devices.</i>
18. Neurons and other kinds of cells		<i>r) Sydney Opera House</i>
19. Vulture wings		<i>s) Photozymes- can break down pollutants such as PCBs into harmless compounds</i>
20. Firefly fluorescence		<i>t) Jigsaw computing which is exponentially faster than digital or silicon models.</i>

Additional Resources

Because Web sites frequently change, some of these resources may no longer be available. Use a search engine and related key words to generate new Web sites.

Information on Biomimicry

http://www.biomimicry.net/case_studies_materials.html

<http://www.biomimicry.org/>

<http://www.bfi.org/Trimtab/spring01/biomimicry.htm>

KNAU : Biomimicry: <http://www.knauradio.org/News/News.cfm?ID=640&c=19>

Genomic Revolution

http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtml

The Web site to the government-funded Human Genome Project with links about genomics, the history of the project, and more.

Secrets of the Sequence Videos and Lessons

This video and 49 others with their accompanying lessons are available *at no charge* from www.vcu.edu/lifesci/sosg