Salt of the Earth — Engineering Salt-tolerant Plants

Secrets of the Sequence Video Series on the Life Sciences • Grades 9 – 12

Teaching materials developed by VCU Life Sciences.

Virginia Commonwealth University

Classroom Tested Lesson

Video Description

"Secrets of the Sequence," Show 145, Episode 3

"Salt of the Earth" – approximately 8 minutes viewing time

With the world population at 6 billion people and counting, a food supply is an ever-increasing concern. Meanwhile, twenty-five million acres of productive agricultural land are being lost each year as the soil becomes increasingly salty. We could face a substantial shortage. The question is: should we fix the soils or alter the genetics of plants? Eduardo Blumwald at the University of California has genetically engineered a plant to endure salty soils. His transgenic creation borrows a specific salt-tolerant gene from the lowly cabbage plant.

Ward Television
Producer: Kris Larsen
Associate Producer: Eric Wills
Featuring: Eduardo Blumwald, Pomology, University of California, Davis; Emanuel Epstein, Retired Plant Nutritionist, University of California, Davis; Andrew Kimbrell, Executive Director, Center for Food Safety
Lesson Author; Reviewers: Elizabeth Armstrong; Cathie Alder, Catherine Dahl, Dick Rezba
Trail Testing Teachers: Valerie May, Raananna Bayliss, Jason Lee

National and State Science Standards of Learning

National Science Education Standards Connection

Content Standard A: Life Science

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

- scientific inquiry;
- formulate and revise scientific explanations and models using logic and evidence.

Content Standard C: Life Science

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

- the cell.

Content Standard F: Science in Personal and Social Perspectives

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

- Population growth;
- Environmental quality;
- Natural and human-induced hazards;
- Science and technology on local, national, and global challenges

Selected State Science Standards Connection

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

Virginia

BIO.1 The student will plan and conduct investigations in which:

b) hypotheses are formed based on direct observations and information from scientific literature;
c) variables are defined and investigations are designed to test hypotheses;
d) graphing and arithmetic calculations are used as tools in data analysis;
e) conclusions are made based on recorded quantitative and qualitative data; and
h) chemicals and equipment are used in a safe manner.

BIO.3 The student will investigate and understand the chemical and biochemical principles essential for life, including:

a) water chemistry and its impact on life processes.

BIO.4 The student will investigate and understand relationships between cell structure and function, including:

d) the cell membrane model (diffusion, osmosis, and active transport).

BIO.6 The student will investigate and understand common mechanisms of inheritance and protein synthesis, including:

h) use, limitations, and misuses of genetic information; and
i) exploration of the impact of DNA technologies.

BIO.8 The student will investigate and understand how populations change through time, including:

b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations; and
d) emergence of new species.

BIO.9 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems, including:

d) the effects of natural events and human influences on ecosystems.

Oregon

Unifying Concepts & Processes: Content Standard – Structure and Function. CIM (Certificate of Initial Mastery – 10th grade)

- Student will compare and contrast interactions between structures and functions in physical and biological examples.
- Student will explain the relationship between structure and function at the cell level, e.g. structures in the cell membrane that control movement into and out of the cell, the nucleus that controls cell activities, and chloroplasts that make food in green plants.

Life Science: Content standard – Understand the characteristics, structure, and functions of organisms.

- Identify cell organelles and state how they help a particular cell carry out its life functions.
- Explain the roll of the cell membrane during cell transport. Distinguish between active and passive transport, including diffusion and osmosis, explaining the mechanics of each.

Overview

As the world's population increases and the amount of arable land decreases, scientists are looking for ways to produce crops that can thrive on the fringes of the environment. Among the problems faced in agriculture, accumulative soil salinity is an increasing concern. In areas where crops are irrigated, the water combines with the natural salts of the soil. Because salts do not evaporate, they are left behind near the surface of the soil when the water evaporates. Repeated irrigation hinders rather than helps this problem.

In order to counter this hostile growing environment, scientists have two options: remove the salt from the soil - which would be nearly impossible - or develop salt-tolerant plants. Botanists and plant geneticists at the University of California at Davis are trying the latter, and they seem to be on to something - but not everyone is happy about it.

This video episode teaches students about the problems faced when growing crops in salty soil, and the development of transgenic crops more suitable to land that is presently not in use due to increased soil salinity. It addresses the loss of arable land to salinity, the impact of this loss on world hunger, the stress that population increase will have on world hunger, and the debate over the role of genetically modified crops in feeding the world. Students will investigate the process of osmosis to understand the movement of salt water into and out of plant cells.

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

The movement of water molecules through a semi-permeable membrane, from an area of greater concentration of water to an area of lesser concentration is called

a. diffusion
b. meiosis
c. metabolism
d. osmosis*

Source: Oregon Example Item – Life Science

Video Preparation

Preview the video and make note of the locations at which you will later pause the video for discussion.

Before Viewing

1. Ask the students: "What would happen if you put a flower in a container of salt water?"
   It would wilt - the students should understand:
   - *That water is moving from an area of high concentration of water molecules inside the flower to an area of lower concentration of water molecules in the cup of salt water.*
   - *That his movement of water from an area of higher concentration to an area of lower concentration across a membrane is called <u>osmosis.</u>*

   This is a good time to introduce or review basics of salinity. If the plants are available, you may also wish to put salt water on a salt tolerant plant as well as a non-salt tolerant plant a few days before showing the video so students can observe the effects on both types of plants.
   Note: A trial testing teacher commented that lettuce leaves under extreme hypertonic solution overnight exhibit a good demonstration effect. Also this may be a good place to review hypo, hyper and isotonic solutions and plant cell and leaf anatomy.

2. Ask: "What might cause water to move out of the flower at a faster rate?"
   An increase in the concentration of salt in the water. The more similar the concentrations, the slower the rate of osmosis will be.

3. Ask: "What would happen if the water in a plant was naturally saltier (e.g., a plant from a tidal marsh). How would this affect the rate of osmosis?"
   The rate of osmosis would decrease, because the plant and the water in the cup are closer to equal - or closer to what is called 'equilibrium'.

4. Ask: "Why might it be beneficial to produce crop plants that are able to withstand higher levels of salt?"
   It would increase the amount of land available to grow crops. Explain that it is far easier to genetically alter plants than to remove salt from soil. Because salt does not evaporate, more salt is left behind every time water evaporates.

During Viewing

1. START the video.

2. PAUSE the video (4.29 minutes into the video) after the first computer explanation ends.

   Explain that a salt tolerant gene was inserted into the genome of the tomato plant. This gene allows the tomato plant to store salt in vacuoles and keep it away from more important structures, like the upper leaves and fruits so that the tomato itself would not be "salty". Explain that moving a gene from one organism to another is called transgenic shift/insertion – it creates a 'GM' or genetically modified plant. You may wish to have a diagram of the parts of a plant cell available.

3. RESUME the video.

4. PAUSE the video (6.50 minutes into the video) after Andrew Kimbrell says, "…it's that simple."

   Ask: "Andrew Kimbrell doesn't see technology (genetically engineered foods) as solving the world's hunger problems. What does he think are the solutions to the hunger problem?
   - *Land reform*
   - *More socially equitable societies*
   - *More equal distribution of wealth so people can actually afford food.*

5. RESUME the video and view to the end

After Viewing

1. Discuss one of the following two points raised in the video (or wait and have this discussion while students are waiting for results of the lab activity that follows.)
   - "What is meant by 'living pollution'? Do you think genetically modified plants are 'living pollution'?"
   - "What do you think will be the role of genetically modified foods in feeding future populations?"

2. Near the end of the video, Dr. Blumwald asks, " How many people have been harmed by consuming transgenic foods over the last 20 years?"
   Ask: "Is this a good argument? Why or why not? What else might influence the effect of consuming transgenic foods?"
   - *availability or lack of availability of transgenic foods*
   - *consumer knowledge of plants that have been genetically altered*.

3. If you have Internet capability including a "plug in" for downloading the site (you will have to check this ahead of time when visiting the site), there is an excellent demonstration of osmosis at http://www.mhhe.com/biosci/esp/2001_gbio/folder_structure/ce/m3/s3/cem3s3_3.htm

4. Conduct the Student Activity: Salt with those Fries?

Teacher Notes for the Student Activity: Salt with Those Fries?

Introduction

Explain to the students that they will conduct an experiment to measure the effects of salinity on osmosis. Distribute the Student Handout, Salt with Those Fries? READ through the directions as a class.

Materials

For each group of 4 students:

- 4 beakers – 100ml
- 4 potato cubes without skin - ½" cubes (about the size of dice)
- China marker or tape for marking beakers
- 4 solutions
    - 25ml distilled water with no salt
    - 25ml with 1% salt solution
    - 25ml with 10% salt solution
    - 25ml with 20% salt solution
- Paper towels
- Access to an electronic or other balance (for the class, more than one is better)

Potato cubes can be prepared ahead of time and kept in a solution of .8% to 1% salt solution (or covered with cold water and kept refrigerated). Pat dry before use. It is best if the cubes can be prepared just before use. A reasonable compromise would be to cut the potatoes into ½" discs at the pre-lab and then cut them into cubes just before doing the activity.

Solutions are made by adding 10 grams of salt to 1 liter of distilled water (1%), 100g for 10%, and 200g for 20% (you may need to warm the 20% solution to dissolve all the salt). Keep these in flasks; they should be CLEARLY labeled. You will need one set of solutions for each class, so you may want to mix several at the beginning of the day. Keep the flask openings covered with aluminum foil to prevent evaporation.

Student Handout: Salt with Those Fries?

In this laboratory activity, you will determine the effects of salinity on the rate of osmosis in potato cells. Read through the directions carefully before starting the activity.

Materials

For each group of 4 students:

- 100 ml beakers (4)
- 4 potato cubes without skin - ½" cubes (about the size of dice)
- China marker or tape for marking beakers
- 4 solutions
    - 25ml distilled water with no salt
    - 25ml with 1% salt solution
    - 25ml with 10% salt solution
    - 25ml with 20% salt solution
- Paper towels
- Access to an electronic or other balance (for the class, more than one is better)

Procedure

1. Place each of your 4 potato cubes on a separate paper towel. Label the paper towels 0, 1, 10, and 20%.

2. Have two members of your group find the mass of each of these 4 cubes. Write the mass on the paper towels.

3. While your lab partners are massing the cubes, mark each of your beakers 0, 1, 10, and 20%.

4. Once the cubes are weighed, place them in their appropriate beakers. Record the *starting masses* of your cubes in the chart below.

   Final mass – starting mass = change in mass

Group	Final mass	*Starting mass*	Change in mass	% Change in mass
0% (Distilled)				
1%				
10%				
20%				

5. Cover the cubes with the corresponding % solution. BE CAREFUL! Be sure that the label on the solution matches the label on your beaker. Add enough solution to <u>just cover</u> the cubes.

6. While you wait, develop a hypothesis for each of the 4 solutions: Will the potato cubes gain mass or lose mass? Explain your reasoning.

0% (Distilled): Hypothesis: _____

Reason: _____

1%: Hypothesis: _____

Reason: _____

10%: Hypothesis: _____

Reason: _____

20%: Hypothesis: _____

Reason: _____

7. What process is at work in this lab? Diffusion or osmosis? _____ Explain your answer:

_____

_____

_____

8. After 30 minutes, remove the cubes from their solutions. Blot them dry (don't squeeze them) and place them on new paper towels (make a note of the beaker percentage!). Mass the cubes and record the new masses in the table above in the column labeled 'Final Mass'.

9. Determine the difference in mass by subtracting the final mass from the starting mass. Record this in the third column of your table above.

10. Determine the percentage of change *for each group*:

Percentage of change = (Difference in Mass / Starting mass) x 100 = _____%

Enter your results in the table above.

Analysis

1. Does the data support or not support your hypotheses?

0% (Distilled): _____

1% _____

10% _____

20% _____

2. What do you think the actual salinity of a potato is? _____ Why? _____

_____

3. If we left the skin on the potato, what effect do you think the skin of the potato would have had on this experiment?

_____

4. Think back to the video. When the salinity level of the soil increases, what happens to the plant on a

cellular level? Be as specific as you can. _____

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 locate new Web sites

Field of Genes, Transgenic Crops
http://whyfiles.org/062ag_gene_eng/index.html
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TransgenicPlants.html
http://www.nap.edu/html/transgenic/

Effects of Salinity on the growth of Plants
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/S/Soil.html#Deserts
http://www.ash.udel.edu/ash/teacher/collab/Env_salinity.html

Genetically Modified Food
http://scope.educ.washington.edu/gmfood/
http://www.howstuffworks.com/question148.htm
http://scope.educ.washington.edu/gmfood/index.php
http://www.sciencecases.org/gmfoods/gmfoods.asp

Genomic Revolution
http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtmL
This Web site of the government-funded Human Genome Project has 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/sosq