Six-Legged Spies – Bugs, Bombs and Bioaccumulation

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 104, Episode 2
"Six-Legged Spies" – approximately 6 minutes viewing time

Insects are everywhere, on everything, in everything – which makes them a terrific first line of detection for biological weapons attack. Bugs sample the environment thoroughly – if it's out there, it's on the insects. Spectrometry, PCR, and genetic analysis turn them into weapons against bioterrorism.

Ward Television
Producer: Paul Gasek
Featuring: Karen Kester, Department of Biology at Virginia Commonwealth University, Bonnie Brown, Director of Ecological Genetics Lab at Virginia Commonwealth University
Lesson Author; Reviewers: Elizabeth Armstrong; Susan Walton, Marilyn Elder, Catherine Dahl, Dick Rezba
Trial Testing Teachers: Cheryl Lowman, Nara Riplinger

National and State Science Standard of Learning

National Science Education Standards Connection

Content Standard C: Life Science

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

- Matter, energy, and organization in living systems.

Content Standard G: History and Nature of Science

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

- science as a human endeavor and
- nature of scientific knowledge.

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.

New York

Major Understandings: 1.1f Every population is linked, directly or indirectly, with many others in an ecosystem. Disruptions in the numbers and types of species and environmental changes can upset ecosystem stability

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

i) exploration of the impact of DNA technologies.

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

a) interactions within and among populations,
b) nutrient cycling with energy flow through ecosystems,
d) the effects of natural events and human influences, and
e) analysis of local ecosystems.

Overview

Food chains and food webs start with the energy from the sun. This energy is transferred into plant energy and carbohydrates through the process of photosynthesis. Plants are producers, or autotrophs; they make their own food. Plants produce the energy to be "consumed" by consumers, or heterotrophs. Primary consumers are herbivores; they consume plants. Secondary consumers and tertiary consumers are carnivores; they eat the herbivores and carnivores. The energy that came from the sun goes from producers to primary consumers to secondary consumers and finally tertiary consumers. A pyramid often represents this flow of energy through the ecosystem with plants on the bottom and tertiary consumers on the top.

Recent terrorist events have forced us to learn about bioterrorism that uses viruses and bacteria as weapons. Scientists are trying to find early detection methods of a bioterrorism threat. One method involves monitoring insects using probes and Polymerase Chain Reaction or PCR to identify foreign nucleic acids.

Scientists are monitoring bioaccumulation and biomagnification in insects. Bioaccumulation of a hazardous substance, such as those found in chemical or biological weapons, occurs because the substance doesn't break down to be eliminated by the organism that absorbs or ingests it. Instead, it *accumulates* in the organism, only to be eaten by the next consumer in the food chain or web. Biomagnification is the increasing concentration of a substance up a food chain, from one energy (trophic) level to the next.

Insects are ubiquitous in our environment. They live everywhere – in cities and in the country, in the air and on the ground, outside buildings and in our homes, in our kitchens and in our books. There is a species of insect to fill every environmental niche. They also fill every consumer energy level. They are herbivores and carnivores. If there is a change in an environment due to the presence of a hazardous substance, it will accumulate in an insect herbivore's body, which will be eaten in larger numbers by an insect carnivore, which will show in turn a much larger accumulation through biomagnification.

Scientists are using biotechnology to look for gene sequences unique to the viruses and bacteria that are used as weapons. This sequence is amplified or duplicated through a process called Polymerase Chain Reaction or PCR. Using this amplified gene sequence as a probe, scientists look for similar sequences in the insects. A large amount of an unknown substance in insects could indicate the presence of possible chemical or biological weapons.

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

Trophic Levels

At which trophic level would the greatest concentration of pesticides per gram of biomass be found?

A. level 1
B. level 2
C. level 3
D. level 4*

Source: Prairie State [Illinois] Achievement Examination, 2002

Before Viewing

1. Review the types of environments and unique jobs associated with a sampling of insects. Draw a chart on the board similar to the one given below and encourage the students to brainstorm as many different types of insects and their roles as they can. Some will have more than one answer. Alternatively you can list the insects in column 1and have students complete columns 2 and 3 as well as they can. Then ask students whether each of these types of insects is considered to be a benefactor or pest.

COLUMN 1	COLUMN 2	COLUMN 3
INSECT TYPE	JOB DESCRIPTION	ENVIRONMENT
Bees	Pollinators	Air
Wasps	Pollinators	Attics
Mantids	Predators	Air, garden plants
Lady bugs	Predators	Air
Cockroaches	Scavengers	Kitchens
Houseflies	Scavengers	Air
Termites	Decomposers	Trees
Beetles	Decomposers	Grain or seeds, dung
Grasshoppers	Grass and grain consumers	Grass
Ants	Grass and grain consumers	Grass, kitchens
Moths	Silk Producers	Attics, storage areas
Honeybees	Food producers	Flowering plants
Fly larvae	Water pollution monitors	Water

Mosquito larvae	Water pollution monitors	Water
Mites	Decomposers	Beds
Silverfish	Decomposers	Attic kitchens
Caterpillar	Grass consumers	Garden plants
Flies	Scavengers	Air

2. Lead a brief discussion on bioaccumulation – both in insects and in humans.
   a) Insects: in addition to eating many plants that may have hazardous substances on or in them, an insect's body is perfect for accumulating substances from the environment.
   - Show a scanning electron micrograph picture of a honeybee leg. http://micro.magnet.fsu.edu/primer/techniques/fluorescence/gallery/honeybeeleg.html Explain how pollen or any extraneous material may attach to the leg of the honeybee.
   - If time allows show other images of insects in their habitats and give some statistics about insect populations and the number of insect species there are - (e.g. 300,000 species of beetles!). This will give the students some understanding of the massive roles insects play in the environment and the extensive diversity of them. Researchers are finding ways to use bioaccumulation to monitor the environment.

   b) Humans: humans also pick up many things from their surroundings. Ask students to think of things they pick up every day without necessarily noticing.
   burrs and other seeds they find on their socks and pants after walking through a field, or getting gum stuck to the bottom of a shoe

3. Ask students if they are familiar with types of pesticides as well as chemical and biological weapons. They should understand that a bio-weapon contains living organisms and, hence, nucleic acids.
   - *Pesticides- DDT, pyrethins, diazinon*
   - *Chemical - ricin, sarin, nerve gas*
   - *Biological - Botulism toxin, Anthrax, Smallpox, Plague*

   Then give one student a dictionary to look up the word "sentinel".
   "One who watches or guards; specifically (Mil.), a soldier set to guard an army, camp, or other place, from surprise, to observe the approach of danger, and give notice of it; a sentry." Merriam-Webster Medical Dictionary, 2002.

   - Have the student read the definition for sentinel to the class. Discuss the definition.
   - Discuss what types of materials/chemicals insects might pick up. How might this happen?
   - How could this information be used to help us?

During Viewing

1. START the video.

2. PAUSE the video (about 2.10 minutes into the video) after the narrator says, "…analyze light to see what they have."
   Ask the following questions:
   - "How can we tell what DNA an organism has?"

- "What are DNA fingerprints?"
- "What significance does this have?"

3. RESUME the video and play to the end.

After Viewing

1. Ask: "What are some benefits of understanding insect behavior, what they eat, and where they live?
   If we know what insects do, what they eat, and where they live, we will understand the extent to which they have been able to accumulate potentially hazardous substances, such as used in bio-warfare.

2. Discuss the role of insects in a food chain or food web. Review the meaning of producer, consumer, levels of consumers (primary, secondary, tertiary), food web, herbicide, and insecticide before proceeding.

3. Conduct the Student Activity: Pyramid Scheme.

Teaching Notes for the Student Activity: Pyramid Scheme

Materials

- Copies of Student Handout: Pyramid Scheme
- A 4-function calculator for each pair of students

Procedure

1. Distribute calculators and copies of the handout.

2. Read through the background information and introduction as a class.

3. Students construct their pyramid, calculate the amount of bioaccumulation, and answer the questions in the analysis section.

   Note*:* Some students may have difficulty working with so many decimal places so you will need to remind them to use extra care. They may also find it challenging to estimate the amount of food a specific organism will consume in a day. Tell them it is more important that they make reasonable comparative estimates between the organisms. (e.g., the higher up the food chain, the larger the organisms become, and the fewer the number of organisms consumed on a daily basis.)

4. Compare class pyramids because each student may have used a different set of organisms to create their pyramid. If time allows, lead a discussion on the differing speeds at which certain toxins can affect the higher levels of the food chain. Discuss the fact that by targeting certain organisms that consume more on a daily basis than others, the effects of a pesticide, herbicide or a bioterrorism agent may be dramatically increased.

5. Extension activity: Have students use a search engine to do further research on the effects of DDT and discuss biomagnification in the osprey and eagles. As a homework assignment have students read Rachel Carson's classic The Silent Spring.

Student Handout: Pyramid Scheme

Background: In the 1960's, environmentalists noticed a frightening die-off of bald eagles and osprey. It was believed and later proven to be caused by the insecticide DDT (dichlorodiethyltrichlorylethane). DDT was banned in 1973 in the United States and the numbers of bald eagles and osprey have since increased. Linking the use of DDT to the death of bald eagles and ospreys obviously entailed researching not only the general environments in which they are naturally found but also the specific organisms in the food chain that these predators fed upon. Following this food chain backwards led to a common substance, DDT, which was found to have permeated each level in the chain. Understanding why smaller organisms lower in the food chain might have survived this toxin while their predators were becoming extinct is explained more easily by studying a Pyramid scheme and measuring the amounts of a specific toxin that has accumulated at each level. This activity seeks to highlight just this type of occurrence.

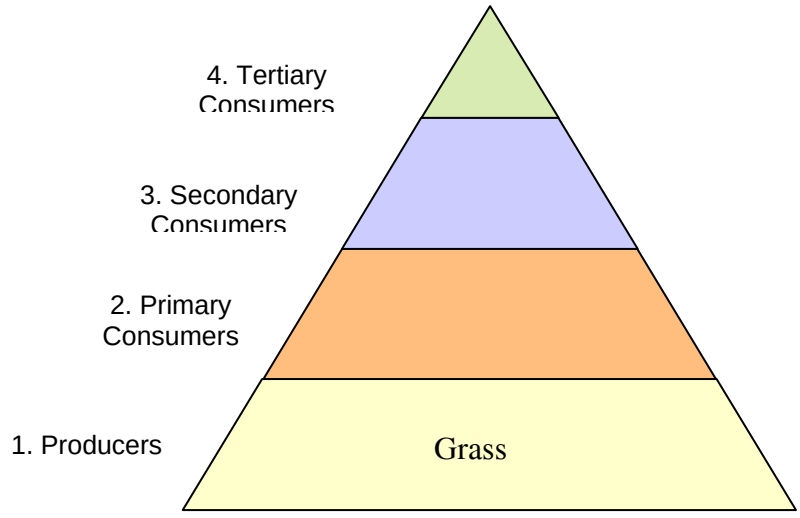
Introduction:

- Bioaccumulation is the accumulation of a substance in a biological tissue. Organisms at any trophic level may be capable of bioaccumulation.
- Biomagnification is the increasing concentration of a substance up a food chain from one trophic level to the next.

Whenever any kind of substance is released into the air, it eventually settles on plants. The plants will be consumed by insect herbivores, the primary consumer. When a primary consumer is eaten by a secondary consumer, the secondary consumer is eating the accumulated poison of its prey. The increasing concentration of a substance up a food chain from one trophic level to the next is called biomagnification. Whenever herbicides or insecticides are sprayed on grass, for example, those poisons are ingested by the animals eating the grass. Because the poisons are fat soluble, they stay stored in the animal's fatty tissue.

Procedure:

1. Create an energy (trophic level) pyramid. The bottom of the pyramid (producers) begins with grass. Your second level (a primary consumer) must eat grass. Your topmost level should be your top predator (tertiary consumer). You can end either on the third or fourth level.



2. Select from the following to complete your pyramid.

Hawk	Robin	Rabbit	Grasshopper
Frog	Snake	Caterpillar	Preying Mantis

Analysis

1. Suppose the grass that is eaten has been recently sprayed with a pesticide, herbicide or bioterrorism substance. How will that substance get concentrated in an energy pyramid?

_____
_____
_____
_____

2. Calculate the bioaccumulation of the substance in your energy pyramid. Your results will be based on what is eaten in just <u>one day</u>. Each blade of grass contains .00003 ppm (parts per million) of a toxic substance. You will need to estimate how much grass your primary consumer eats in one day.
Note: Part of the fun of this activity is to think about how much these organisms actually eat in a day. If you want to verify your estimates, you might try using a search engine and the Internet… good luck.

_____ eats ____ blades of grass per day x .00003 ppm = _____ ppm.
(Primary consumer) (Enter an estimate)

_____ eats _____per day x _____ppm = _____ ppm.
(Secondary consumer) (Enter # of primary consumers) (Enter previous ppm)

_____eats _____ per day x _____ppm = _____ppm.
(Tertiary consumer) (Enter # of secondary consumers) (Enter previous ppm)

3. Answer the following questions:
    a. What was the amount of the substance in your top predator?

    _____

    b. Compare this amount at the top of the pyramid with that at the bottom. Calculate the number of times the substance was magnified.

    _____

    _____

    c. Fill in the following sentences for each of the organisms in your pyramid.

    The _____ has _____ times more toxic substance than the grass.

    The _____ has _____ times more toxic substance than the grass.

    The _____ has _____ times more toxic substance than the grass.

4. Use your energy (trophic level) pyramid to explain the concept of biomagnification.

_____
_____

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.

http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/F/FoodChains.html
An advanced primer on food chains and trophic levels.

http://www.marietta.edu/~mcshaffd/lead/trophic.pdf
A PDF lesson on trophic levels, bioaccumulation, and DDT.

http://apps.rgp.ufl.edu/research/bioterrorism.cfm?sparam=1
A University of Florida Web site on how insects could be used in bioterrorism.

http://aginfo.psu.edu/psa/f2003/sentinel.html
A Penn State Web site on how plants can be used to monitor bioterrorism attacks.

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