

Barflies — Alcoholism

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 101, Episode 2

“Bar Flies: Alcoholism” – approximately 8 minutes viewing time

Never seen a drunken fruit fly? Then join us as we explore the genetic connection to alcoholism by studying fruit flies at the University of California, San Francisco. Ulrike Heberlein’s “barflies” tell us a lot about how well we hold liquor and why.

Ward Television

Producer: Elizabeth Pearson

Featuring: Ulrike Heberlein, Anatomy at the University of California – San Francisco, Dr. Kirk Wilhelmsen, Neurology at the University of California – San Francisco, Dr. Ivan Diamond, Director of the Ernest Gallo Clinic and Research Center

Lesson Author; Reviewers: Beth Richert; Catherine Dahl, Dick Rezba, and Kieron Torres
Trial Testing Teachers: Kate Henson, Tommy Sommerville

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

- Molecular basis of heredity
- Biological evolution
- Behavior of organisms

Content Standard F: Science in Personal and Social Perspectives.

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

- Personal and community health
- Science and technology in local, national and global challenges

Content Standard G: History and the Nature of Science.

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

- Science as a human endeavor
- Nature of scientific knowledge

Selected State Science Standards Connections

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

Louisiana

Understanding Scientific Inquiry

12. Cite evidence that scientific investigations are conducted for many different reasons (SI-H-B2)
14. Cite examples of scientific advances and emerging technologies and how they affect society (e.g., MRI, DNA in forensics) (SI-H-B3)

The Molecular Basis of Heredity

7. Identify the basic structure and function of nucleic acids (e.g., DNA, RNA) (LS-H-B1)
8. Describe the relationships among DNA, genes, chromosomes, and proteins (LS-H-B1)
10. Analyze pedigrees to identify patterns of inheritance for common genetic disorders (LS-H-B3)
11. Calculate the probability of genotypes and phenotypes of offspring given the parental genotypes (LS-H-B3)
12. Describe the processes used in modern biotechnology related to genetic engineering (LS-H-B4) (LS-H-B1)
13. Identify possible positive and negative effects of advances in biotechnology (LS-H-B4) (LS-H-B1)

Systems and the Behavior of Organisms

35. Explain how selected organisms respond to a variety of stimuli (LS-H-F3)

Personal and Community Health

42. Summarize the uses of selected technological developments related to the prevention, diagnosis, and treatment of diseases or disorders (LS-H-G5)

Oklahoma

Process Standard 3:

Experiment - Experimenting is a method of discovering information. It requires making observations and measurements to test ideas.

Evaluate the design of a biology laboratory investigation.

Identify the independent variables, dependent variables, and controls in an experiment.

Use mathematics to show relationships within a given set of observations

Identify a hypothesis for a given problem in biology investigations.

Recognize potential hazards and practice safety procedures in all biology activities.

Process Standard 4:

Interpret and Communicate - Interpreting is the process of recognizing patterns in collected data by making inferences, predictions, or conclusions. Communicating is the process of describing, recording, and reporting experimental procedures and results to others. Communication may be oral, written, or mathematical and includes organizing ideas, using appropriate vocabulary, graphs, other visual representations, and mathematical equations. Select appropriate predictions based on previously observed patterns of evidence.

* Report data in an appropriate manner.

Interpret data tables, line, bar, trend, and/or circle graphs.

1. Accept or reject hypotheses when given results of a biological investigation.
2. Evaluate experimental data to draw the most logical conclusion.
3. * Prepare a written report describing the sequence, results, and interpretation of a biological investigation or event.
4. * Communicate or defend scientific thinking that results in conclusions.
5. Identify and/or create an appropriate graph or chart from collected data, tables, or written description (e.g., population studies, plant growth, and heart rate).

Process Standard 6:

Inquiry - Inquiry can be defined as the skills necessary to carry out the process of scientific or systemic thinking. In order for inquiry to occur, students must have the opportunity to ask a question, formulate a procedure, and observe phenomena.

1. Formulate a testable hypothesis and design an appropriate experiment relating to the living world.
2. *Design and conduct biological investigations in which variables are identified and controlled.
3. *Use a variety of technologies, such as hand tools, microscopes, measuring instruments, and computers to collect, analyze, and display data.
4. *Inquiries should lead to the formulation of explanations or models (physical, conceptual, and mathematical). In answering questions, students should engage in discussions (based on scientific knowledge, the use of logic, and evidence from the investigation) and arguments that encourage the revision of their explanations, leading to further inquiry.

Biology 1 Content Standards

Standard 2: The Molecular Basis of Heredity - DNA determines the characteristics of organisms. :

Cells function according to the information contained in the master code of DNA. A sorting and recombination of genes in reproduction results in a great variety of possible gene combinations from the offspring of any two parents

Standard 6: The Behavior of Organisms - Organisms have behavioral responses to internal changes and to external stimuli

Overview

In this lesson students learn that 60% of the human genome is the same as a fruit fly's genome. Because of this similarity researchers are studying fruit flies to better understand the genetic links to alcoholism, and ultimately its treatment in humans. Scientists are mutating one gene at a time in the fruit fly genome to see how the fly behaves in response to an intake of alcohol. They hope to find one or more genes that affect the fly's behavior while under the influence of alcohol. If they can identify those same genes in a human, we will be a long way towards understanding the hereditary aspect of alcoholism.

Various characteristics of an alcoholic are examined to illustrate the probability that no one gene causes this disease. It is more likely that multiple genes may contribute to alcoholism. The video also highlights the role of persistence in scientific inquiry when Dr. Heberlein says, "...so at the end of all of this if even one of our genes ends up being relevant to human alcoholism, I will feel that all of these *years* have been worth it."

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

Scientists are studying the mating behavior of hanging flies. Female hanging flies typically require their male mates to bring them gifts such as a moth to eat. Scientists raised male and female hanging fly larvae in isolation from adult hanging flies. When the females' larvae became adults they also required a gift from their male mates.

Which of these is the best explanation for this behavior?

- A. The behavior is acquired randomly
- B. The behavior is acquired through genes *
- C. The behavior is learned through experience
- D. The behavior is inherited through imprinting

(Source: 2003-2004 Parent and Student Guide Oklahoma Core Curriculum Test Practice Questions)

Video Preparation

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

Before Viewing

1. Ask: "What do you think are the characteristics or behaviors of someone who is an alcoholic? List them on the board.

Cravings, withdrawal symptoms, risk-seeking behavior, anti-social behaviors

Have students compare their list to those mentioned in the upcoming video.

2. Ask: "What do you think causes alcoholism?" "Does it run in families?" "Does one's environment influence whether you become an alcoholic or not?" "Are there ways persons could adjust their behavior if they knew that there was an increased risk for alcoholism in their family?"

Note: Field test teachers noted that many students were quite open about whether their parents or brothers or sisters had these problems.

3. Ask: "When people use the expression, "The apple does not fall far from the tree", what do you think that means?"

During Viewing

1. **START** the video.

2. **PAUSE** the video (3.20 minutes into the video) when the narrator quotes Dr. Heberlein as saying that "We are just big flies without wings".

Ask: Since we do not look anything like a fly, what does Dr. Heberlein mean when she says we are just big flies without wings?

(Our genomes are very similar (about 60%). Thus, many of our molecular pathways are so similar that if a genetic mutation in a fly's genome causes a change in behavior due to alcohol, then it is likely that a similar marker may exist on the human genome. Through this technique scientists may be able to better understand the causes of alcoholism, and ultimately its treatment.)

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

After Viewing

1. Have students compare their list of characteristics of alcoholics on the board with those mentioned in the video.
2. In this video you saw a team of researchers working in a laboratory. Genetic research involves large amounts of data, experimentation over long periods of time, the collaborative work of many individuals, and the researchers' devotion and perseverance.

Recall that Dr. Heberlein begins this video by telling us that she mutates one gene at a time in a completely random fashion and looks to see how that mutation affects the fruit fly's sensitivity to alcohol. Clearly, the experiment must be repeated thousands of times to examine the fly's genome, and therefore studies can last for many years.

Ask: Does a career in life sciences research interest you? Have students share their thoughts about careers in science. Encourage interested students to visit the career site for the life sciences at

<http://www.lscareers.vcu.edu>

3. If time allows for this unit, one field test teacher suggested that a good homework assignment or extension exercise would be to have the students research which genes fruit flies share with humans, and if these genes also parallel those of other species.

Teacher Notes for the Student Activity A: Alcohol Tolerance in *Drosophila* and You

(Source of this lesson: <http://www.bjbarton.com/lessons/alcohol.pdf>)

Background information

At a molecular level, this activity attempts to reinforce a student's understanding of how a gene controls the production of an enzyme. From an ethical standpoint, the activity addresses the issue of genetic testing and whether an individual should be penalized for their genetic make-up.

Caution: This lesson requires the use of 'red wine' as the source of alcohol for the fruit flies. Before proceeding, check your school or school district policy regarding alcohol on school premises. You may have to request special permission. If permitted, take extra precautions to secure the alcohol from pranksters or others. If you use Alka seltzer to generate CO₂, remember that this and other over-the-counter drugs are considered drugs in some schools' 'zero tolerance' policies. Keep tight control of these effervescent tablets to prevent loss and inappropriate student behavior.

Required of students

The laboratory part of this activity requires that the students have a basic understanding of alcohol and its effects on the body, protein synthesis, and Mendelian genetics. Moreover, the students will need to watch their flies over a 24-hour period; you may wish to require them to take the flies home for a night. Or at least, ask them to stop by the classroom before and after school.

Class time needed

The activity can take up to three class periods, depending on how much time the instructor allows for student exploration. The actual laboratory activity takes 20 minutes. A period of 20 minutes the following day gives ample time to discuss class data. The ethics exploration will take up to 30 minutes for small group discussion.

Abstract of Activity

If you open any magazine or newspaper these days, you can typically find an article on the most recent genetic breakthrough. While most of these discoveries are on a genetic disease, more and more studies are implicating DNA's involvement in such areas as mental disorders, sexual orientations, and addictions. At a molecular level, genes have been found to influence alcohol tolerance in *Drosophila melanogaster*. In 1990, Rutgers State University offered a summer program in conjunction with the National Association of Biology Teachers that included a unit on *Drosophila*. Several activities in this unit studied the ADH gene, which controls the production of alcohol dehydrogenase (ADH) enzyme. Flies possessing the dominant ADH gene have the ability to oxidize ethanol:



ADH- flies cannot break down the ethanol they consume, leading to visible inebriation in their behavior and flying, ultimately leading to alcohol poisoning.

In this activity, students develop and run a laboratory comparing alcohol tolerance in flies with and without the ADH enzyme. Following the experiment, they participate in a fictional court case involving denying humans possessing a malfunctioning ADH gene the right to purchase alcohol.

Note: A field test teacher suggested that before starting the activity it might be useful to review the basics of molecular mechanisms and enzyme function using the following questions.

1. Why are enzymes so important to make these mechanisms go forward?
2. What happens to the mechanism if there is little or no enzyme present?
3. What other kinds of diseases (other than alcoholism) are the results of there being little or none of a particular enzyme present?"

Lesson/activity

Materials

- **Fruit flies:**
Flies can be obtained from biological supply houses. For example, two cultures of ADH- and ADH+ fruit flies are available (in 2005) at Carolina Biological, #17-1970, \$9.95. They *may* also be available free of charge from the Mid-American Drosophila Stock Center. Call Ms. Phyllis Oster, Curator of Stocks (419-372-2631) for wild type and ADH negative flies (strain 1383F1 ADH -fn23 cn bwd). As only one vial of each type of flies is sent, place your order two months prior to the activity date. It takes about one week for the flies to hatch upon arrival, and two weeks for each subculture to increase the fly population to reach the size necessary for classroom use.
- **Fly vials:**
Enough for subculturing the fly strains and at least one vial and sponge for every lab pair.
- **Other:**
Instant fly media, cotton balls, stirring rods, pipettes/sm. graduated cylinders, cheap wine (note previous caution about alcohol in schools), paint brushes, refrigerator or Flynap, student handout on courtroom scenario.

Procedure

- A. Have the flies presorted into vials of 20 or so before lab. These flies can be anesthetized when class starts. Chilling flies requires 5-10 minutes before they are manageable. Keeping them on ice afterwards also slows their revival. Other means of anesthetizing the flies are using Fly nap, or CO₂ exposure (Alka seltzer tablets or dry ice). Use accepted safety guidelines when dealing with any controlled substance, including alcohol. Directions are available at <http://biology.arizona.edu/sciconn/lessons2/Geiger/intro2.htm>.
- B. Tell students to read the discussion questions on Handout A. Then lead a discussion on alcoholism and its effects on the body and on society at large. As the discussion of the causes of alcoholism ensues, introduce the students to flies lacking the ADH gene and to some of the background on the condition.
- C. Ask: "How would you test for alcohol tolerance in fruit flies?" Guide the students to design a procedure to answer the question. Compare their solutions with the following protocol that has been very effective. Then have students work through the steps of this protocol.
 1. Each person should obtain an empty vial, 3-4 small cotton balls, and a stirring rod.
 2. Each person should wedge the cotton balls in the bottom of their vial.
 3. Working in teams of four, choose which set up you will perform.
Person A: ADH- flies in water Person C: ADH- flies in wine
Person B: ADH+ flies in water Person D: ADH+ flies in wine
 4. Persons A and B should add 5 ml of water to their vial.
 5. Persons C and D should add 5 ml of wine to their vial. Each cotton ball should be soaked but not submerged. Using the stirring rod, tap down the cotton balls to wedge them in place and to drain off excess fluid. Test the cotton ball's security by inverting the vial.
Note: Make sure the cotton ball is well-drained, so as not to drown the flies. The cotton ball should be very damp, but not leak wine when pressed.

6. Dry the inside walls of the vials. (Flies can drown in drops of fluid)
7. Use a piece of tape and a marker to label the vial with your name, type of flies and whether water or wine is included.
8. Obtain the vial of chilled flies assigned to your lab team. The flies in the vial should not be moving. If the flies wings or legs appear to trembling they should be chilled further. As soon as the flies warm up, they wake up and fly away.
9. Open the chilled vial and pour the flies onto a piece of paper. Using the paintbrush, gently sweep 5 flies of the strain you require into your vial. Stopper the vial, but leave the vial on its side so the "sleeping" flies will not drown in the wet cotton.
10. When the flies revive, turn the vial upright. If less than 3 flies recover, obtain more.
11. Observe the flies over the next 24-hours at the times listed below. Students make a data table of their observations. Note all behaviors observed.
 - 15 minutes
 - 30 minutes
 - 60 minutes
 - 4 hours
 - 8 hours
 - Whenever you wake up
12. After the students have studied their flies for the 24 hour period, a discussion of class data comparing results should occur. Students need to be sure to differentiate fly death due to alcohol poisoning versus other factors.
13. You might also ask students what other kinds of diseases are the result of there being little or none of a particular enzyme present
14. Tell students they will be required to turn in a formal laboratory report on the fly activity including an introductory statement, procedure, data tables and conclusion. (see <http://www.howe.k.12.ok.us/~jimaskew/evalab.htm> for a printable Lab Report Rubric)

Teacher Notes for the Student Activity B: Future Mandatory Alcohol Abstinence Law

1. Distribute Student Handout B – Future Mandatory Alcohol Abstinence Law to each student group. This handout includes some background information on alcoholism, the proposed law, and discussion questions.
2. You may want to have the students read the first paragraph of this handout and then review the many functions of the liver. Then tell them to read to the rest of the handout.
3. You might want them to read through their handout in their small groups to discuss the law and its implications, taking any notes on their ideas.
4. Tell students their homework that night is to individually draw a conclusion as to whether they would support this law based on their discussion and turn it in with a paragraph supporting their rationale.
5. The following day the instructor should mediate a class debate on the proposed law.

Student Handout A: Alcohol Tolerance in *Drosophila* and You

Name _____

Introduction

If you open any magazine or newspaper these days, you can typically find an article on the most recent genetic breakthrough. While most of these discoveries are on a genetic disease, more and more studies are implicating DNA's involvement in such areas as mental disorders, sexual orientations, and addictions. At a molecular level, genes have been found to influence alcohol tolerance in *Drosophila melanogaster* (fruit flies). In 1990, Rutgers State University offered a summer program in conjunction with the National Teachers of Biology that included a unit on *Drosophila*. Several activities in this unit studied the ADH gene, which controls the production of alcohol dehydrogenase (ADH) enzyme. Flies possessing the dominant ADH gene have the ability to oxidize ethanol:

$\text{NAD}^+ + \text{ADH} + \text{alcohol} \rightarrow \text{NADH} + \text{aldehyde (or ketone)} + \text{H}^+$

ADH- flies cannot break down the ethanol they consume, leading to visible inebriation in their behavior and flying, ultimately leading to alcohol poisoning and eventual death.

In this activity, you will develop and run an investigation comparing alcohol tolerance in flies with and without the ADH enzyme. Following the experiment, you will participate in a fictional court case involving denying humans possessing a malfunctioning ADH gene the right to purchase alcohol.

Procedure

- A. Your teacher will have the flies presorted into vials of 20 or so before lab. The Flies will be anesthetized when class starts. You teacher will chill the flies in an ice water bath for 5-10 minutes so that they do not fly away during your investigation. You will need to return them to the ice water bath after you have transferred them to your own vial to slow their revival. Other means of anesthetizing the flies are using Fly nap, or CO₂ exposure (Alka seltzer tablets or dry ice). Use accepted safety guidelines when dealing with any controlled substance, including alcohol. If your teacher prefers one of these methods, please listen closely to his/her instructions on how to proceed.
- B. Before beginning the activity, your teacher will review some basics in molecular mechanisms and enzyme functions.
- C. Read through the questions below in preparation for a class discussion on alcoholism and its effects on the body and on society at large.
 1. What causes alcoholism?
 2. What are the symptoms of alcoholism?
 3. What personal and family problems do alcoholics encounter?
 4. What societal problems do alcoholics cause?
 5. According to the introductory information, what gene is responsible for the ability to break down alcohol in the body?
 6. How might the lack of the ADH gene lead to alcoholism?
 7. Is this based on sound science?
 8. Should a person be denied certain rights due to their genetic make-up?
- D. Conduct activity using the following protocol.
 1. Each person should obtain an empty vial, 3-4 cotton balls, and a stirring rod
 2. Each person should wedge the cotton balls in the bottom of their vial.
 3. Working in teams of four, choose which set up you will perform.
Person A: ADH- flies in water Person C: ADH- flies in wine
Person B: ADH+ flies in water Person D: ADH+ flies in wine
 4. Persons A and B should add 5 ml of water to their vial.

5. Persons C and D should add 5 ml of wine to their vial. (Note: For both steps 4 and 5, make sure the cotton ball is well drained so as not to drown the flies. The cotton balls should be very damp but not drip wine when pressed with a stirring rod.)
6. Dry the inside walls of the vials. (Flies can drown in drops of fluid)
7. Use a piece of tape and a marker to label the vial with your name, type of flies and whether water or wine is included.
8. Obtain the vial of chilled flies assigned to your lab team. Read vial label carefully. The flies in the vial should not be moving. If the flies wings or legs appear to trembling they should be chilled further. As soon as the flies warm up, they wake up and fly away.
9. Open the chilled vial and pour the flies onto a piece of paper. Using the paintbrush, gently sweep 5 flies of the strain you require into your vial. Stopper the vial, but leave the vial on its side so the "sleeping" flies will not drown in the wet cotton.
10. When the flies revive, turn the vial upright. If less than 3 flies recover, obtain more.
11. Observe the flies over the next 24-hours at the times listed below. Make a data table of your observations. Note all behaviors observed.
 - 15 minutes
 - 30 minutes
 - 60 minutes
 - 4 hours
 - 8 hours
 - whenever you wake up
12. Be prepared to discuss your data in class. Be sure to differentiate fly death due to alcohol poisoning versus other factors.

Student Handout B

Future Mandatory Alcohol Abstinence Law

Background

Alcoholism is a serious problem in the United States. Long-term use of alcohol leads to many known problems. Alcohol is known to damage neurons when taken in large amounts, leading to permanent peripheral nerve damage. Cirrhotic livers result from scar tissue formation after liver cell death. Liver failure is 9th leading cause of death in the United States. Habitual alcohol use has been implicated in reproductive, hormonal, and immune problems. Constant use also leads to ulcers in the stomach, esophagus, and intestines. Hypertension and enlarged hearts are often found in alcoholics. It is estimated that between 10-15 percent of Americans are alcoholics, thus subject to such damaging effects.

It should be noted that alcohol abuse does not affect the drinker alone. Families, friends, employers, and even strangers are all affected by an individual's drinking. It is estimated that 3 out of every 100 deaths in this country can be tied to alcohol use. For instance in 1990, 19,990 people died in alcohol related car accidents, which is about one half of all automobile deaths. Many examples of physical abuse, acts of violence, and suicide can be linked to alcohol abuse. Estimates of \$25 billion worth of damage occur each year at work sites due to employees under the influence. Moreover, there are more than 50,000 babies born with fetal alcohol syndrome each year, resulting in children with specific facial defects and often mental retardation.

As with other addictions, alcoholism's causes and cures are not clear. Being raised in an alcoholic household suggests the influence of environmental factors such as social, cultural and peer influences. However, in light of evidence from twin and adoption studies, a genetic component has also been implicated. While not as simple as the ADH gene in fruit flies, a complex polygenic predisposition to alcoholism may exist in humans.

Proposed Law

Suppose in the future all applicants for a driver's license, (including teenagers) must undergo a genetic test for alcoholism susceptibility. Those individuals who possess multiple (3-4) alleles for a malfunctioning ADH gene will be issued a special license. The alcoholism susceptibility license will possess hologram stating "ineligible to purchase alcoholic beverages" making it against the law for any such individual to buy alcohol. Any such person caught purchasing alcohol will have their license suspended for two years and serve a two-month jail term. In addition, any individual who sells alcohol to a susceptible individual will be fined \$5,000. Any individual who purchases or gives alcohol to said person would face a 1-month jail term.

What do you think about this?

Discussion Questions

1. How might the lack of the ADH gene product lead to alcoholism? Is this based on sound science?
2. Is this law constitutional? Will it stand up in a civil rights court? Consider the recent smoking laws.
3. Does this law discriminate against one's genotype?
4. Does this law solve all causes of drunk driving?
5. Is the law enforceable?

Written assignment:

Write at least one paragraph supporting your judgment of this fictional law.

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.

Fruit Fly Supplies

Click on "Search" and type in "fruit flies" for a list of materials including kits, vials, media, etc.

<http://www.carolina.com/>

<http://sciencekit.com/>

<http://www.freyscientific.com/>

<http://www.fishersci.com/>

Culturing and Anesthetizing Fruit Flies

<http://biology.arizona.edu/sciconn/lessons2/Geiger/intro2.htm>

Cause of Alcoholism

What is the cause of alcoholism? Easy to understand information.

<http://Flash-Med.com>

Alcoholism & Genetics

New findings on the genetics of alcoholism.

<http://www.familystudies.org/alcoholism&genetics.htm>

Investigating a 'protective gene' against alcoholism

The ADH2*3 allele is a variant form of the gene that codes for the ADH enzyme - may be associated with a lowered risk for the development of alcoholism.

http://www.eurekalert.org/pub_releases/2001-12/ace-ia121101.php

Research Links

Glossary of Genetic Terms - National Human Genome Research Institute

Control of DNA Replication - Salk Institute for Biological Studies

Molecular Biology Desk Reference - National Institutes of Health

Biochemistry Page - Indiana State University

Molecular Biology Protocols - US Dept Commerce, Microbial Pathogens Lab

The Human Genome - Oak Ridge National Laboratory

GenLink - Washington University, St. Louis, MO

GeneCards - Weizmann Institute of Science, Israel

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

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

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