Send in the Marines — Help From the Ocean

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 148, Episode 2

"Send in the Marine – Help from the Oceans" – approximately 9 minutes viewing time

We know that the mouse genome, so similar to a human's, is a component of multiple human-related biological studies. But can sea creatures be helpful research partners, too? In 1998, the Marine Biological lab sent three toadfish up on the Discovery with John Glenn to study the effects of weightlessness and space travel on humans. In our visit to the MBL, we learn that toadfish and people have virtually identical inner ears – one of many examples of a shared evolution found in the marine environment.

Ward Television
Producer: Paul Gasek
Associate Producer: Julie James
Featuring: Steve Highstein, Investigator, Marine Biological Lab, Roger Hanlon, Marine Resources Center, Marine Biological Lab, Eva Czerwiec, Investigator, Marine Biological Lab
Lesson Author; Reviewers: Catherine Dahl; Dick Rezba
Trial Testing Teacher: Brooke Williams

National and State Science Standards 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 understanding of

- Biological evolution
- Interdependence of organisms
- 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 heath
- Science and technology in local, national and global challenges

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.

Virginia

BIO.1 The student will plan and conduct investigations in which
a) observations of living organisms are recorded in the lab and in the field

BIO.2 The student will investigate and understand the history of biological concepts.
Key concepts include
b) scientific explanations of the development of organisms through time (biological evolution)

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 structure and functions vary between and within the kingdoms
c) analyses of their responses to the environment
e) human health issues, human anatomy, body systems, and life functions.

BIO.7 The student will investigate and understand bases for modern classification systems. Key concepts include
a) structural similarities among organisms
c) comparison of development stages in different organisms
d) examination of biochemical similarities and differences among organisms

Indiana

Development and Organismal Biology;

B.1.15 Understand and explain that in biological systems, structure and function must be considered together.

Evolution

B.1.30 Understand and explain that molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.

B.1.32 Explain how natural selection leads to organisms that are well suited for survival in particular environments, and discuss how natural selection provides scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.

B.1.34 Explain that evolution builds on what already exists, so the more variety there is, the more there can be in the future. Recognize, however that evolution does not necessitate long-term progress in some set direction.

B.1.35 Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely matches their classification based on anatomical similarities. Know that amino acid similarities also provide clues to this kinship.

Overview

Marine life can offer numerous insights into human physiology. Many sea creatures have features very similar to those of the human but on a scale or in a location that makes it easier for researchers to access and study. The double helix structure of DNA ties all living things together. The similarities of human DNA to the DNA of sea creatures provides evidence that life on land may have evolved from marine life. The video example of the toadfish with its virtually identical structure of a human inner ear shows an already highly evolved species. Specific traits of the toadfish, cone snail, skate, squid and zebra fish are also compared to similar traits in the human.

As certain species left the marine environment and were forced to adapt to more varied environments on land, their DNA became more complex in order to provide for the new functions they needed in their more evolved state. By studying the genetic "commonness" of all organisms on earth we can learn more about ourselves.

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

More than 1.5 million species of animals have been described, yet all of them have DNA that is made of the same building blocks. This is evidence that all animals have

1. A common ancestor *
2. Identical fossils
3. Similar appearances
4. The exact same DNA sequences

Source: Massachusetts Biology Test Session 2, Grade 10, 2004

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: "In what ways, if any, do you think humans are similar to marine creatures, such as the squid, toadfish, or a horseshoe crab?"
   These sea creatures are sensitive and responsive to their environment as are humans. Similarly, they share the basic life functions of respiration, digestion and reproduction, which are coded by DNA

2. While watching the video, have students make note of how specific marine creatures are similar to humans in very particular ways. Inform students they will be questioned on this later in the lesson and to take note that it is these similarities which are helpful to researchers in their quest to better understand the human body.

During Viewing

1. START the video

2. PAUSE the video (2.27 minutes into the video) after the narrator says, "…so we call that a highly evolved system."
   Ask: "What is meant by 'highly evolved systems'?" Determine if they understand the concept of evolutionary development and have a brief discussion on this topic.

3. RESUME the video.

4. PAUSE the video (7.00 minutes into the video) after the scientist says, "… you can not do that in a higher vertebrate like us because it's all inside…"

Ask students to list at least three reasons why they think it is useful for researchers to study marine animals in order to better understand the human body.

- *the marine creature often has a simpler version of what a human possesses that ultimately helps us understand our more complex DNA*
- *some marine creatures have organs that are easier to view than in humans*
- *cells are sometimes larger and easier to study*
- *there is an abundance of experimental subjects in the ocean*

5. RESUME the video and play to the end.

After Viewing

1. On the board create a chart listing the marine animals that are highlighted in the video. (See below)
   Ask: "What role does each species play in aiding researchers to better understand human anatomy and medical treatments?" Fill in the chart with student's responses.

Squid	*Possesses similar but much larger versions of nerve cells than humans*
Zebra Fish	*Embryo sac is visible on exterior of fish so the development of the spinal cord and other organs can be readily seen unlike similar developments in the human embryo that are hidden from view.*
Toadfish	*Has similar inner ear that can be studied for balance and equilibrium*
Skate	*Easier access to the eye to study the retina*
Horseshoe Crab	*Easier access to the eye to study the structure of the eye*
Cone snail	*Possesses a simpler version of an enzyme that humans also have, which makes it helpful in studying blood disorders.*

2. Discuss the relationship between environmental changes and changes in the gene pool. For example, the video mentions that when marine creatures moved to more varied land environments, their genetic sequences became more complex, and therefore longer, to accommodate all the additional responses and adaptations to new stimuli.
   Ask: "Can you give a reason why the sequence of the cone snail's enzymes is shorter than the corresponding sequence in humans?"

   Although the enzyme is similar in both species, the human enzyme is more highly evolved in that it has a more complex role to play than that of the cone snail, which merely produces venom. The enzyme in humans has to produce bone and also clot blood.

Teacher Notes for the Student Activity: Help from the Oceans

Introduction

There is an increasing demand for scientists to look to the oceans in their quest to better understand human life and to advance biomedical research. As concern for animal rights increases, scientists are looking for other living models that share similar characteristics with humans. From the sequencing of the human genome and our knowledge of genetics, it is clear that even the simplest of invertebrates share enormous DNA similarities with more highly evolved species. Although studies of the fruit fly and other insects have previously served as the basis for much of our knowledge of genetics, marine invertebrates are beginning to take center stage as research models. The reasons

are many. In addition to the growing public concern regarding the use of vertebrates, the expense of using vertebrates is high. But even more important, the ocean is full of organisms that allow researchers to study genetic functions at their most basic level – often with the advantage of translucent outer layers so that the inner workings of the organism are clearly revealed.

In this activity students will read a short paper on the use of invertebrates in research. Following their reading and having already watched the video, they will be asked to match the biomedical research areas listed in Column 3 on their handout with the actual marine organisms in Column 1 that are used in the research. Student groups will also discuss the relative importance of each of these research areas to human health.

Note: The vocabulary in the paper that students will read will be challenging for many students. If time allows, you might discuss the meaning of some words prior to students reading the paper. Or, you may want to just let students know that the paper is actually part of the class notes for a senior level course at a University and then challenge them to see how much they can understand from reading it, and perhaps from re-reading it. You could also do a follow-up activity where, as a class, students infer the meaning of some words by the context or root word analyses.

Materials

- Student Handout # 1: Help from the Oceans
- Student Handout # 2: Excerpt from *Use of Invertebrate Models in Biomedical Research* by Susan E. Wilson-Saunders, 2004, if Internet access is not available.

Procedure

1. Divide students into discussion groups of 3 or 4.
2. If the Internet is available, have students go to http://www.ahsc.arizona.edu/uac/notes/classes/invertebrate/Invert2004.htm and read the Introduction and the first section on Marine Invertebrates. If time is available, interested students might read the remainder of the paper for more information about the use of other invertebrates in biomedical research.

   If Internet access is not available, provide each student with a copy of the paper in Student Handout # 2.

3. Distribute Student Handout # 1 to each student. Explain that they are to match areas of biomedical research using marine organisms listed in Column 3 with the corresponding marine organism in Column 1 that is used for that research study. Some answers can be found in the article they will read, others are mentioned in the video, and some can be determined by using a search engine and the Internet. If Internet access is not available, they may be able to 'infer' some of the remaining ones by the process of elimination.
4. Naturally there are some areas of biomedical research in which the study of more than one marine organism has proven to be beneficial. For example toxicology studies use several marine organisms. For this activity, however, students should pick the one marine organism specifically mentioned in the article if it is referenced.
5. Once they have completed the exercise, encourage the students to discuss in their groups the relative importance of each of these areas of research to human health. Encourage students to use the given bullet points to help focus their discussion.

Answer Key

Matching Activity on the Student Handout # 1: Help from the Oceans

COLUMN 1 COLUMN 2 COLUMN 3

Marine Organisms	Research Area (Use Letter)	Area of Biomedical Research Using Marine Organisms
1. Coral	*k) immunity responses, rejection, antibiotics*	a) immunity responses, antibiotics
2. Horseshoe crab	*f)light reception in the retina of the eye*	b) metabolism of vitamins
3. Blue mussel	i) *Liquid adhesive- Could enable surgeons to operate without sutures.*	c) psychology, behavior patterns
4. Jellyfish	*a) immunity responses, antibiotics*	d) crystallins in the eye responsible for optical properties of the lens
5. Sea slug	*g) circulatory system*	e) neurology –structure of nerve fibers
6.Cold water fish	*j) Organ antifreeze-New ways to freeze human transplant organs without injury.*	f) light reception in the retina of the eye
7. Octopus	*c) psychology, behavior patterns*	g) circulatory system
8. Daphnids, crustaceans	*l) toxicology*	h) blood clotting
9. Conus textile	*b) metabolism of vitamins*	i) Liquid adhesive- Could enable surgeons to operate without sutures.
10. Anemones	*o) immunity responses, antibiotics, fungicides*	j) Organ antifreeze-New ways to freeze human transplant organs without injury.
11. Scallop	*d) crystallins in the eye responsible for optical properties of the lens*	k) immunity responses, rejection, antibiotics
12. Cone snail	*h) blood clotting*	l) toxicology
13. Sea sponge	*n) anti-inflammation ointments*	m) anti-cancer drugs
14. Shark	*m) anti-cancer drugs*	n) anti-inflammation ointments

15.Squid	*e) neurology-structure of nerve fibers*	o) immunity responses, antibiotics, fungicides

Student Handout # 1: Help from the Ocean

Introduction

There is an increasing demand for scientists to look to the oceans in their quest to better understand human life and to advance biomedical research. As concern for animal rights increases, scientists are looking for other living models that share similar characteristics with humans. From the sequencing of the human genome and our knowledge of genetics, it is clear that even the simplest of invertebrates share enormous DNA similarities with more highly evolved species. Although studies of the fruit fly and other insects have previously served as the basis for much of our knowledge of genetics, marine invertebrates are beginning to take center stage as research models. The reasons are many. In addition to the growing public concern regarding the use of vertebrates, the expense of using vertebrates is high. But even more important, the ocean is full of organisms that allow researchers to study genetic functions at their most basic level – often with the advantage of translucent outer layers so that the inner workings of the organism are clearly revealed.

In this activity you will read a paper on the use of marine organisms in research and then match as many of the biomedical research areas listed in Column 3 on your handout with the actual marine organisms in Column 1 that are used in the research. Your group will also discuss the relative importance of each of these research areas to human health.

Procedure

1. If the Internet is available, go to http://www.ahsc.arizona.edu/uac/notes/classes/invertebrate/Invert2004.htm and read the Introduction and the section on Marine Invertebrates. If you have time, you may also wish to read the remainder of the paper for more information about the use of other invertebrates in biomedical research. If Internet access is not available, your teacher will give you a copy of the paper to read. *Note*: Some of the vocabulary is challenging. Do not be discouraged. You are reading notes for a University level course so your teacher may choose to discuss the meaning of some of the words.
2. Looking at the table on the next page, match the biomedical research areas from Column 3 with the corresponding marine organism used in that research in Column 1 and put your answers in Column 2. *Note*: Some of the answers can be found in the paper, others were mentioned in the video, and some can be determined by using a search engine and the Internet. If Internet access is not available, you may be able to 'infer' some of the remaining ones by the process of elimination. See how many you can match!
3. Note that there are some areas of biomedical research in which the study of more than one kind of marine organism has proven to be beneficial. For example, toxicology studies use a number of different marine organisms. For the purposes of this activity, select the marine organism specifically mentioned in the paper.
4. In your group, discuss the relative importance of each of these areas of biomedical research to human health.
    - Are you familiar with anyone who would benefit from advances in any of the areas listed in column 3?
    - Can you list the symptoms that those persons exhibit?
    - Are there any experiments/procedures that you could imagine being performed on other humans in each of these areas that could contribute to our understanding?
    - In what ways do you believe using marine creatures to study these areas is beneficial?
    - Which research area do you find most fascinating and why?
    - Which research area do you think is most important and why?

- Animal rights groups are making experimentation on animals more and more difficult. Do you believe that there will be increasing pressure to prevent experimentation on marine creatures? If so, how do you think scientists will continue their research in these areas of biomedical research?

MATCHING ACTIVITY:HELP FROM THE OCEANS - Match Column 3 with Column 1

COLUMN 1 COLUMN 2 COLUMN 3

Marine Organism	Research Area (Use Letter)	Area of Biomedical Research Using Marine Organisms
1. Coral		a) immunity responses, antibiotics
2. Horseshoe crab		b) metabolism of vitamins
3. Blue mussel		c) psychology, behavior patterns
4. Jellyfish		d) crystallins in the eye responsible for optical properties of the lens
5. Sea slug		e) neurology –structure of nerves
6.Cold water fish		f) light reception in the retina of the eye
7. Octopus		g) circulatory system
8. Daphnids, crustaceans		h) blood clotting
9. Conus textile		i) Liquid adhesive- Could enable surgeons to operate without sutures.
10. Anemones		j) Organ antifreeze-New ways to freeze human transplant organs without injury.
11. Scallop		k) immunity responses, rejection, antibiotics
12. Cone snail		l) toxicology
13. Sea sponge		m) anti-cancer drugs
14. Shark		n) anti-inflammation ointments

15.Squid		o) immunity responses, antibiotics, fungicides

Student Handout #2: Excerpt from *Use of Invertebrate Models in Biomedical Research* by Susan E. Wilson-Sanders, D.V.M., M.S.:

Use of Invertebrate Models in Biomedical Research

Many members of the invertebrate branch of the animal kingdom are looked upon with disgust and disdain. A huge roach is considered a household pest that deserves an immediate stomping, ticks infest our dogs (and spread Lyme disease and rocky mountain spotted fever) and crawl on and bite us, mosquitoes are the brunt of Minnesota jokes, and night crawlers are fishermen's (and the poor fish's) favorite bait. Other invertebrates are creatures that engender fear and trepidation---these are mostly sea creatures from the vicious Man of War jelly fish to the "monster of the deep", the giant squid. Seldom do we consider that invertebrates are really our distant relatives and that we can gain much from understanding their biology, pathophysiology, genetics, and the psychology of their habits. In actuality, invertebrates are often the first "animal model" many young people come into contact with. For example, children often study bees as science fair projects or receive a glass ant kingdom as a present. Often, the lowly earthworm is the first classroom dissection model for kids to become squeamish over when they squish them instead of dissect them.

Much scientific knowledge has been gained from the study of invertebrates. Karl van Frisch spent his entire scientific career studying the language of bees. The study of the fruit fly has served as a basis for much of our knowledge of genetics. With growing public concern regarding the use of vertebrates in biomedical research, the expense of using animals, and the need to find new models, the use of invertebrates in research has increased dramatically over the past decade. Here at the University of Arizona we have experienced an exponential increase in the use of invertebrates, primarily insects, during this time period. In the mid-1980's virtually no research was performed on invertebrates other than entomologic studies to understand specific insects and to find control measures for eliminating these pests. In contrast, during the current fiscal year, over $5 million in extramural funding was provided to the University of Arizona for basic research involving insect models.

There are a host of invertebrate animal models which we could discuss, but we will limit our discussion to some of the most recent advances using invertebrate models, some of the most common models, and those which are used here on our Campus.

Marine Invertebrates

Immune responsiveness: The corals, jellyfish, and sea anemones, while lacking the blood-vascular system, organs, and lymphoid cells associated with vertebrate-type immune responses, still show evidence of an immune system. These organisms have what is known as a primordial cell-mediated immunity which leads to death of nonisogenic cells which come into contact with each species. Unrelated colonies of corals will not grow together, while clones derived from one colony will readily be accepted by that colony. When incompatible corals are placed next to each other, each will become hyperplastic in the localized area of contact between the two corals. This hyperplastic overgrowth is the coral's parallel to histo-incompatibility and the ability to reject what is not recognized as "self". Mollusks have the ability to effectively defend themselves against pathogens and foreign substances. Snails are able to phagocytose bacteria, foreign cells, and other particles. These creatures produce their own cytotoxins to kill bacteria and have their own natural agglutinins. All of these invertebrates are used in the study of the phylogenetic development of the immune system.

ACTH (adrenocorticotropic hormone) is found in cells from many different invertebrates and function of this compound in immune mechanisms can be studied in invertebrates.

Comparative psychology: Octopuses are used in the study of animal behavior with extrapolations to human psychology.

Environmental Toxicology: Aquatic invertebrates are commonly used in acute and chronic toxicity studies of organic chemicals which could potentially pollute oceans and harm all phyla of aquatic life, and other animals, such as birds and humans. Daphnids, tiny water crustaceans, are being used in toxicity studies of heavy metals.

Molecular pharmacology of the eye: Horseshoe crabs (*Limulus,* an arachnid) are used to study retinal photoreception and the electrical events which occur in the eye in different intensities of light and darkness. Scallops and squid have been used to study the crystallins present in the eye which are responsible for the optical properties of the lens. Octopuses have been used to study rhodopsin, a pigment which is present in the eye.

Neuronal research: In the 1930's, the structure of nerve fibers in cephalopods and crustaceans was first described and found to be comparable to that in vertebrates, including man. Squid have giant axons and synapses which can be harvested and used for examination of many biological problems. In-vitro preparations of squid axons/synapses have been utilized in the study of axonal conduction and synaptic transmission. Similar work has also been conducted using neuromuscular junctions from the lobster and crab. Neuronal integration has been studied in crabs, mollusks, and the *Aplysia*. Because preparations can be made which have small numbers of neurons which are large and accessible, these marine animals have also been used in cellular neuropharmacology and neurochemistry studies.

The *Aplysia* abdominal ganglion is remarkable in size, with individual neurons ranging up to 1 mm in diameter. This creature, commonly known as the sea slug or sea hare, resembles a giant naked snail (they weigh up to a pound or more). Its circulatory system resembles vertebrates in some important aspects, such as vascular neural control of the heart pacemaker. Because of this similarity to mammalian systems, the *Aplysia* has been used extensively to understand the neuronal control of circulation. Squid and *Aplysia* are also used in developmental neurobiology. For many years our University of Arizona medical physiology classes used *Aplysia* to demonstrate neurosynaptic functions. These classes are no longer offered because of public discontent about the use of animals in medical physiology teaching.

Neural toxicity can be studied in many invertebrate species including mollusks and snails. The nervous system of these animals can be used to clarify toxic mechanisms which affect the nervous system. With increasing pressure from animal rights activists regarding use of vertebrate animals, the use of invertebrate species for this type of research may be the wave of the future. *Neuropeptides* can also be studied in molluscs and worms.

Vitamin K metabolism can be studied in *Conus textile*, a marine invertebrate

To read the complete paper including the role of other invertebrates - Arthropods, go to http://www.ahsc.arizona.edu/uac/notes/classes/invertebrate/Invert2004.htm

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://www.mbl.edu/marine_org/marine_why.html

http://www.at-sea.org/missions/floridafrontiers/preview.html

http://www.hboi.edu/news/features/biomed.html

http://www.musc.edu/catalyst/archive/2002/co1-18marine.html

http://www.findarticles.com/p/articles/mi_1511/is_3_20/ai_54359909

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