ocean explorer
oceanexplorer.noaa.gov

2006 Exploring Ancient Coral Gardens

Cut-off Genes

(adapted from The Mountains in the Sea 2004 Expedition)

Focus
Gene sequence analysis

Grade Level
9-12 (Life Science)

Focus Question
How can gene sequence analysis be used to explore phylogenetic similarities of different organisms?

Learning Objectives
Students will be able to explain the concept of gene sequence analysis.

Given gene sequence data, students will be able to draw inferences about phylogenetic similarities of different organisms.

Materials
- ❒ Copies of "DNA Sequencing Student Worksheet," "DNA Fragments after Treatment with Restrictive Enzymes," and "The Genetic Code" (download from http://www.accessexcellence.org/AB/GG/genetic.html) one copy of each for each student group
- ❒ Poster board, meter stick, and markers for each student group

Audio/Visual Materials
- ❒ None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
30

Key Words
Seamount
Davidson Seamount
Gene
Gene sequence analysis
Polymerase chain reaction
Restrictive enzymes
Gel electrophoresis
DNA

Background Information
Seamounts are undersea mountains formed by volcanic processes, either as isolated peaks or as chains that may be thousands of miles long with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for many species of plant, animal, and microbial organisms. Recently, increasing attention is being directed toward deep water coral species found on seamounts. In contrast to shallow-water coral reefs, deep-sea coral communities are virtually unknown to the general public and have received much less scientific study. Yet, deep-water coral ecosystems may have a diversity of species comparable to that of corals reefs in shallow waters. Because many seamount species are endemic (that is, they are found nowhere else), these ecosystems may be a unique feature

of seamounts, and are likely to be important for several reasons. First, because of their high biological productivity, these communities are directly associated with important commercial fisheries. Moreover, deep-sea corals have been identified as promising sources for new drugs to treat cancer and other diseases, as well as natural pesticides and nutritional substances. Recent discoveries suggesting that some corals may be hundreds of years old means that these organisms can provide important records of past climactic conditions in the deep ocean. Apart from these potential benefits, deep-sea corals are part of our world heritage—the environment we hand down from one generation to the next.

Despite their importance, there is growing concern about the impact of human activities on these ecosystems. Commercial fisheries, particularly fisheries that use trawling gear, cause severe damage to seamount habitats. Scientists at the First International Symposium on Deep Sea Corals (August, 2000), warned that more than half of the world's deep-sea coral reefs have been destroyed. Ironically, some scientists believe that destruction of deep-sea corals by bottom trawlers is responsible for the decline of major fisheries such as cod.

In addition to impacts from fisheries, deep-sea coral communities can also be damaged by oil and mineral exploration, ocean dumping, and unregulated collecting. Other impacts may result from efforts to mitigate increasing levels of atmospheric carbon dioxide. One proposed mitigation is to sequester large quantities of the gas in the deep ocean, either by injecting liquid carbon dioxide into deep ocean areas where it would form a stable layer on the sea floor or by dropping torpedo-shaped blocks of solid carbon dioxide through the water column to eventually penetrate deep into benthic sediments. While the actual impacts are not known, some scientists speculate that since coral skeletons are made of calcium carbonate, their growth would probably decrease if more carbon dioxide were dissolved in the ocean.

The Davidson Seamount, located about 75 miles southwest of Monterey, CA, was the first geological feature to be described as a "seamount" in 1933. The now-extinct volcanoes that formed this and other nearby seamounts were different from typical ocean volcanoes. While the typical undersea volcano is steep-sided, with a flat top and a crater, seamounts in the Davidson vicinity are formed of parallel ridges topped by a series of knobs. These observations suggest that the ridges were formed by many small eruptions that occurred 3 to 5 million years apart. Typical undersea volcanoes are formed by more violent eruptions that gush out lava more frequently over several hundred thousand years.

Although it was the first recognized seamount and is relatively near the U.S. coast, the Davidson Seamount is still 99.98% unexplored. In 2002, a NOAA-funded expedition to the Seamount found a wide variety of organisms, including extensive deep-water coral communities. Among many intriguing discoveries were observations of animals that had never been seen live before, as well as indications that some coral species may be several hundred years old (visit http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html and http://montereybay.noaa.gov/reports/2002/eco/ocean.html for more information about the 2002 Expedition).

The 2006 Exploring Ancient Coral Gardens Expedition is focussed on learning more about deep-sea corals at Davidson Seamount, with four general goals:

- to understand why deep-sea corals live where they do on the seamount;
- to determine the age and growth patterns of the bamboo coral;
- to improve the species list and taxonomy of corals from the seamount; and
- to share the exciting experience with the public through television and the Internet.

Until very recently, the taxonomy of living organisms was largely based on visible physical char-

acteristics. Thanks to modern molecular biology techniques, it is now possible to measure the genetic similarity of individual organisms as a basis for recognizing different species as well as genetically distinct groups within species. This activity is intended to introduce students to some of the techniques used to investigate genetic similarity.

Learning Procedure

[NOTE: Portions of this activity are adapted from "DNA Sequencing" by Nancy Ridenour, available online as part of the Access Excellence Activities Exchange (http://www.accessexcellence.org/AE/newatg/Ridenour/)]

1. To prepare for this lesson, read the introductory essays for the 2006 Exploring Ancient Coral Gardens Expedition at http://oceanexplorer.noaa.gov/explorations/06davidson/welcome.html, and review the NOAA Learning Object on deep-sea corals at http://www.learningdemo.com/noaa/.

2. Lead a brief introductory discussion of the Davidson Seamount and the 2002 and 2006 Ocean Exploration expeditions to the area. You may want to show students some images from the 2002 Expedition Web site (http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html). Explain that while seamounts have not been extensively explored, expeditions to seamounts often report many species that are new to science and many that appear to be endemic to a particular group of seamounts. DNA analysis can be used to investigate the genetic relationships between organisms collected from different areas. You may want to review the following concepts:
   - DNA structure and function
   - How DNA base sequences encode information
   - Steps in DNA replication
   - Characteristics of the genetic code

   Be sure that students understand that genes consist of different numbers of nucleotides. Often, not all of these nucleotides are actually involved in coding for the gene's protein. Some species (including humans) have genes that contain long sequences of DNA whose function is unknown. These regions are called introns, and separate other regions of the gene called exons which contain the code that is actually used to produce the gene's protein. Similarly, a sequence of DNA is not necessarily a gene; it may contain several genes, or may only be a fragment of a single gene.

   The "Living by the Code" lesson plan from the 2003 Bioprospecting Expedition (http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/edu.html) has several activities that can be used as part of this review, as well as the Access Excellence Web site (see Resources).

   Tell students that this activity will introduce the concepts underlying three important techniques used to determine the sequence of genes in DNA samples: cutting fragments of DNA with restriction enzymes, making many copies of these fragments using the polymerase chain reaction (PCR) or gene amplification, and gel electrophoresis to determine the size of the fragments.

   The polymerase chain reaction (PCR) uses an enzyme (originally isolated from the hot spring bacterium *Thermus aquaticus*) that catalyzes synthesis of double stranded DNA from single DNA strands. To prepare many copies of a DNA sample, the two strands are separated by exposing the DNA to high temperature (about 95°C) which causes the strands to separate. Then the separated strands are incubated at a lower temperature with a solution containing the polymerase enzyme and four nucleotides (each consisting of a sugar called deoxyribose, a phosphate molecule, and a nitrogen base that may be adenine, guanine, cytosine, or thymine). This cycle of high-heat separation followed by lower-heat incubation is repeated

every few minutes until the desired amount of replicated DNA is obtained. Since the number of DNA strands increases exponentially with each cycle, after 30 cycles 230 (more than one billion) DNA strands have been produced from the original double strand. When the PCR cycles are completed, the replicated strands are mixed with a solution containing radioactive molecules that attach to one end of each strand.

Restriction enzymes are biological chemicals that catalyze the cleavage of phosphate bonds at specific locations within DNA strands. These enzymes are highly selective, and only cause cleavage at very specific sequences of bases. This selectivity allows scientists to "cut out" particular segments of DNA. Some restriction enzymes selectively cut at one of the nitrogen bases in a DNA strand (either adenine, guanine, cytosine, or thymine). The concentration of these enzymes is adjusted so that not all of the bonds at a particular base are cut on every copy of the DNA strand. The result is that treatment with each enzyme produces fragments of many different lengths.

Gel electrophoresis is a technique used to separate different molecules according to their weight and electrical charge. A drop of sample containing different molecules is placed on a thin piece of gelatin-like material, then an electric current is applied to the ends of the gel. This current causes many molecules to move through the gel, with smaller particles moving more rapidly than larger ones. When mixtures of DNA fragments resulting from treatment with restrictive enzymes are placed in a gel electrophoresis apparatus, the fragments are separated according to their size and charge, the smallest fragments moving the greatest distance through the gel. The location of the fragments can be seen by placing the gel on top of an unexposed piece of photographic film. The radioactive marker molecule causes the film to darken in areas where the fragments are concentrated.

3. Distribute copies of "DNA Sequencing Student Worksheet" and one version of "DNA Fragments after Treatment with Restrictive Enzymes," one copy of each for each student group. You may want to mask out the letter identification at the top of each "DNA Fragments" worksheet and write a unique number on each copy so that students will not easily know which groups have the same sheet.

4. Tell students that they will simulate a gel electrophoresis separation of fragments produced by treating replicated DNA strands with restrictive enzymes. Have students follow the steps described on the "Student Worksheets." Be sure students understand that each DNA strand produces at least two pieces when it is cut by restrictive enzymes, but only the fragment containing the radioactive marker will be visible on the photographic film. Since fragments without the marker molecule will not be seen on the gel, these fragments have been omitted from the "Fragments" sheets.

5. Have students compare their DNA sequences. Depending upon how you have distributed the "Fragments" sheets, some groups should be almost identical while others should be clearly different. Model DNA strands used to produce the "Fragments" sheets are described on the "Master Sequence" sheet.You may want to have each group prepare a written description of the mRNA sequence that would be transcribed from their DNA sequence, and list the amino acid sequence that corresponds to the mRNA sequence. Be sure students understand that scientists normally select specific segments of DNA for sequencing, and isolate these segments by using different restrictive enzymes.

The Bridge Connection

www.vims.edu/bridge/ –Click on "Ocean Science" in the navigation menu to the left, then click on "Habitats" then "Deep Sea" for resources on deep-sea communities. Click on

"Human Activities" then "Technology" then "Biotechnology" for resources on biotechnology. Click on "Lesson Plans" in the navigation menu, then "Secondary & Middle" and scroll down to "Project Grows" under "High School" for activities involving salmon DNA.

The "Me" Connection

Have students describe three ways in which DNA sequencing is (or could be) important to their own lives.

Connections to Other Subjects

Language Arts, Chemistry

Assessment

Group reports on DNA sequence and written reports on mRNA and corresponding amino acid sequences (Step 4) provide opportunities for evaluation.

Extensions

1. Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Davidson Seamount Expedition discoveries, and to find out what researchers are learning about deep-water hard-bottom communities.

2. "The Electric Sieve" lesson plan from the 2003 Bioprospecting Expedition (http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/edu.html) has directions for simple electrophoresis apparatus suitable for classroom use.

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ – Click on the link to "Lesson 3 – Deep-Sea Corals" for an interactive multimedia presentation on deep-sea corals, as well as Learning Activities and additional information on global impacts and deep-sea coral communities.

Other Relevant Lesson Plans from the Ocean Exploration Program

Cool Corals (http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/cool.pdf; (7 pages, 476k)

Focus: Biology and ecology of *Lophelia* corals (Life Science)

Students will describe the basic morphology of *Lophelia* corals and explain the significance of these organisms, interpret preliminary observations on the behavior of *Lophelia* polyps, and infer possible explanations for these observations. Students will also discuss why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

What's the Difference? (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_difference.pdf; (15 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Identification of biological communities from survey data (Life Science)

Students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

Round and Round (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_round.pdf; (11 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Circulation cells in the vicinity of seamounts (Earth Science)

Students will be able to interpret data from a three-dimensional array of current monitors to infer an overall pattern of water circulation, hypothesize what effect an observed water circulation pattern might have on seamount fauna that reproduce by means of floating larvae, and describe the importance of measurements to verify theoretical predictions.

A Tough Neighborhood (http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_toughhood.pdf; (4 pages, 244k) (from The Charleston Bump 2003 Expedition)

Focus: Adaptations of benthic organisms to deep water, hard substrates, and strong currents (Life Science)

Students will be able to describe at least three attributes of the deep ocean physical environment that are radically different from ocean habitats near the sea surface and explain at least three morphological or physiological adaptations that allow organisms to survive in the physical environment of the deep ocean. Students will also be able to identify at least three organisms with adaptations to the deep ocean environment that are found (or may be found) on the Charleston Bump.

Keep It Complex! (http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_complex.pdf; (5 pages, 272k) (from The Charleston Bump 2003 Expedition)

Focus: Effects of habitat complexity on biological diversity (Life Science)

Students will be able to describe the significance of complexity in benthic habitats to organisms that live in these habitats and will describe at least three attributes of benthic habitats that can increase the physical complexity of these habitats. Students will also be able to give examples of organisms that increase the structural complexity of their communities and infer and explain relationships between species diversity and habitat complexity in benthic communities.

Eddies, Gyres, and Drowning Machines (http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_eddies.pdf; (5 pages, 256k) (from The Charleston Bump 2003 Expedition)

Focus: Effects of bottom topography on currents (Physical Science/Earth Science)

Students will be able to describe at least three types of effects that physical obstructions may have on water flowing past the obstructions, explain at least three ways in which current flow can be significant to benthic organisms, and explain how physical obstructions to current flow can create hazardous swimming conditions.

Top to Bottom (http://oceanexplorer.noaa.gov/explorations/05stepstones/background/education/ss_2005_topbottom.pdf; (7 pages, 348k) (from the North Atlantic Stepping Stones 2005 Expedition)

Focus (Earth Science/Life Science) - Impacts of climate change on biological communities of the deep ocean

Students will be able to describe thermohaline circulation, explain how climate change might affect thermohaline circulation, and identify the time scale over which such effects might take place. Students will also be able to explain how warmer temperatures might affect wind-driven surface currents and how these effects might impact biological communities of the deep ocean, and discuss at least three potential impacts on biological communities that might result from carbon dioxide sequestration in the deep ocean.

Designing Tools for Ocean Exploration (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_designingtools.pdf; (13 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Ocean Exploration

Students will understand the complexity of ocean exploration; students will understand the technological applications and capabilities required for ocean exploration; students will understand the importance of teamwork in scientific research projects; students will develop abilities necessary to do scientific inquiry.

Living in Extreme Environments (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_extremeenv.pdf; (12 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Biological Sampling Methods (Biological Science)

In this activity, students will understand the use of four methods commonly used by scientists to sample populations; students will understand how to gather, record, and analyze data from a scientific investigation; students will begin to think about what organisms need in order to survive; students will understand the concept of interdependence of organisms.

Mystery of the Alaskan Seamounts (http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/mystery9_12.pdf; (9 pages, 132k) (from the Exploring Alaska's Seamounts 2002 Expedition)

Focus: Earth Science - Formation of seamounts in the Axial-Cobb-Eikelberg-Patton chain, Gulf of Alaska

Students will be able to describe the processes that form seamounts, learn how isotope ratios can be used to determine the age of volcanic rock, and interpret basalt rock age data from seamounts in the Gulf of Alaska to investigate a hypothesis for the origin of these seamounts.

Are You Related? (http://oceanexplorer.noaa.gov/explorations/05deepcorals/background/edu/media/05deepcorals_related.pdf; (11 pages, 465k) (from the Florida Coast Deep Corals 2005 Expedition)

Focus: Molecular genetics of deepwater corals (Life Science)

Students will define "microsatellite markers" and explain how they may be used to identify different populations and species, explain two definitions of "species," and describe processes that result in speciation. Students will also use microsatellite data to make inferences about populations of deep sea corals.

How Does Your (Coral) Garden Grow? (http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_growth.pdf; (6 pages, 456k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Growth rate estimates based on isotope ratios (Life Science/Chemistry)

Students will identify and briefly explain two methods for estimating the age of hard corals, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

Gellin (http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_gellin.pdf; (4 pages, 372k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: DNA analysis

Students will explain and carry out a simple process for separating DNA from tissue samples, explain and carry out a simple process for separating complex mixtures, and explain the process of restriction enzyme analysis.

Breaking Away (Or Not . . .) (http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/breaking9_12.pdf; (5 pages, 96k) (from the Exploring Alaska's Seamounts 2002 Expedition)

Focus: Life Science - Reproductive/ developmental strategies of some benthic seamount species

Students will be able to compare and contrast common reproductive strategies used by benthic invertebrates, describe the most common reproductive strategies among benthic invertebrates on a seamount and explain why these strategies are appropriate to seamount conditions. They will also describe how certain reproductive strategies favor survival of species on seamounts and what changes on seamounts might favor other strategies, and discuss the implications of reproductive strategy to the conservation and protection of seamount communities.

Other Links and Resources

http://www.ncbi.nlm.nih.gov/Entrez/ and http://workbench.sdsc.edu – Web sites that provide access to gene sequences for many different organisms

http://www.accessexcellence.org/AB/GG/#Anchor-From-14210 – The Access Excellence Graphics Gallery which offers a series of labeled diagrams with explanations representing the important processes of biotechnology. Each diagram is followed by a summary of information, providing a context for the process illustrated.

http://www.embo.org/projects/scisoc/download/teachers/tw02pcr.pdf — Article describing a classroom experiment with PCR

http://www.woodrow.org/teachers/bi/1993/ — Activities related to biotechnology from the 1993 Woodrow Wilson Biology Institute.

http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html – Daily logs, photos, video clips, and backgrounds essays on the 2002 Davidson Seamount Expedition

http://montereybay.noaa.gov/reports/2002/eco/ocean.html – Web page from the Monterey Bay National Marine Sanctuary describing the 2002 exploration of the Davidson Seamount

http://www.mbari.org/ghgases/ – Web page from the Monterey Bay Aquarium Research Institute describing MBARI's work on the Ocean Chemistry of Greenhouse Gases, including work on the potential effects of ocean sequestration of carbon dioxide

http://seamounts.edsc.edu/main.html — Web site sponsored by the National Science Foundation

Pickrell, J. 2004. Trawlers Destroying Deep-Sea Reefs, Scientists Say. National Geographic News. http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html

http://www.mcbi.org/Current_Magazine/Current_Magazine.htm – A special issue of Current: the Journal of Marine Education on deep-sea corals.

Morgan, L. E. 2005. What are deep-sea corals? Current 21(4):2-4; available online at http://www.mcbi.org/Current_Magazine/What_are_DSC.pdf

Reed, J. K. and S. W. Ross. 2005. Deep-water reefs off the southeastern U.S.: Recent discoveries and research. Current 21(4): 33-37; available online at http://www.mcbi.org/Current_Magazine/Southeastern_US.pdf

Frame, C. and H. Gillelan. 2005. Threats to deep-sea corals and their conservation in U.S. waters. Current 21(4):46-47; available online at http://www.mcbi.org/Current_Magazine/Threats_Conservation.pdf

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/uploads/oceana_coral_report.pdf — Background on deep-water coral reefs

http://www.oceanicresearch.org/ – The Oceanic Research Group Web site; lots of photos, but note that they are very explicit about their copyrights; check out "Cnidarians: Simple but Deadly Animals!" by Jonathan Bird, which provides an easy introduction designed for classroom use

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

http://oceanica.cofc.edu/activities.htm – Project Oceanica Web site, with a variety of resources on ocean exploration topics

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard B: Physical Science

- Chemical reactions

Content Standard C: Life Science

- Molecular basis of heredity

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

- *Fundamental Concept b.* An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates.
- *Fundamental Concept h.* Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

- *Fundamental Concept c.* Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
- *Fundamental Concept d.* Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
- *Fundamental Concept e.* The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
- *Fundamental Concept f.* Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

- *Fundamental Concept b.* From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides

jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

- *Fundamental Concept c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *Fundamental Concept e.* Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
- *Fundamental Concept g.* Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

- *Fundamental Concept a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept c.* Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Office of Ocean Exploration
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

Student Handout

DNA Sequencing Student Worksheet

	G	A	T	C
1		--		
2	--			
3	--			
4				--
5			--	
6			--	

1. This diagram illustrates a piece of photographic film that has been exposed to a gel used to separate fragments from a DNA strand using electrophoresis. The letters at the top stand for the four bases found in nucleotides of a DNA molecule, and correspond to the places where the strand was cut by restrictive enzymes (fragments under "C' were cut by a restrictive enzyme that cuts the strand after cytosine; fragments under "G" were cut by a restrictive enzyme that cuts the strand after guanine; etc.). The marks under each of these letters correspond to fragments of DNA that migrated through the gel (the radioactive markers attached to the fragments expose portions of the photographic film and cause these portions to appear dark when the film is developed). The numbers represent the relative distance traveled by the fragments; "1" is the shortest distance traveled and "6" is the farthest distance traveled. The smallest fragments travel most easily through the gel, and as a result move the farthest distance. When you read a gel, begin with the fragment that traveled farthest (the smallest fragment). So the sequence of nucleotides on the DNA strand that contained these fragments was TTCGGA.

2. Obtain a "DNA Fragments After Treatment with Restrictive Enzymes" worksheet and a piece of poster board from your teacher. Cut out the 21 rectangles on your worksheet. These rectangles represent fragments of a replicated DNA strand that have been cut by four restrictive enzymes. The rectangles are shaded to help keep track of which restrictive enzyme was used to cut the DNA strands to produce the fragments. A radioactive marker is attached to each of these fragments. Of course, the solutions containing these fragments would also contain the other part of each strand as well, but these parts would not be visible on the photographic film since the radioactive marker is only attached to one end of each strand.

3. On your poster board, construct an electrophoresis gel template with G, A, T, and C at the top of the "gel." Number down the left side from 1 to 21 (because the strands we are working with contain 21 nitrogen bases). "1" will represent the distance traveled by the largest fragment (which would contain 21 nitrogen bases), while "21" will represent the distance traveled by the smallest fragment (which would contain 1 nitrogen base). There should be a equal distance between each of the numbers on the left side of the poster board.

4. Arrange all of the fragments from largest to smallest. Now place these fragments on the poster board next to the number corresponding to the distance that each fragment would travel through the gel (remember that "1" is the smallest distance, and would correspond to the largest fragment). Be sure each fragment is in the column that corresponds to the action site of the restrictive enzyme that was used to produce the fragment. So all of the solid rectangles should be in the column beneath "C," since these fragments were produced by a restrictive enzyme that splits DNA strands after a nucleotide containing cytosine (beginning with the end attached to the radioactive marker). All of the dotted rectangles should be in the column beneath "A," since these fragments were produced by a restrictive enzyme that splits DNA strands after a nucleotide containing adenine, and so forth.

5. Record the DNA sequence of the strands that produced these fragments, beginning with the smallest fragment (the one that moved the farthest).

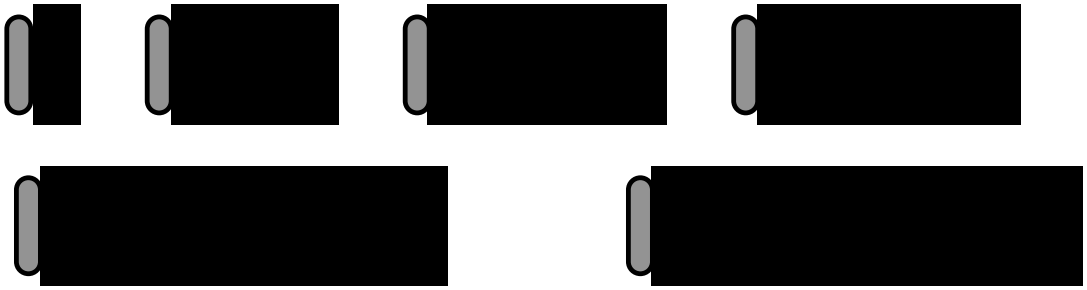
6. What mRNA sequence would be transcribed from this strand of DNA?

7. Using a chart of the genetic code, give the amino acid sequence that is coded by the mRNA sequence.

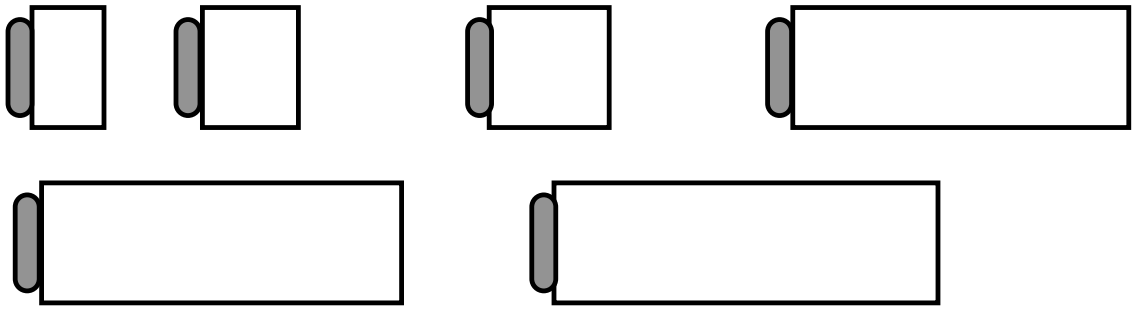
Student Handout

DNA Fragments after Treatment with Restrictive Enzymes Strand A

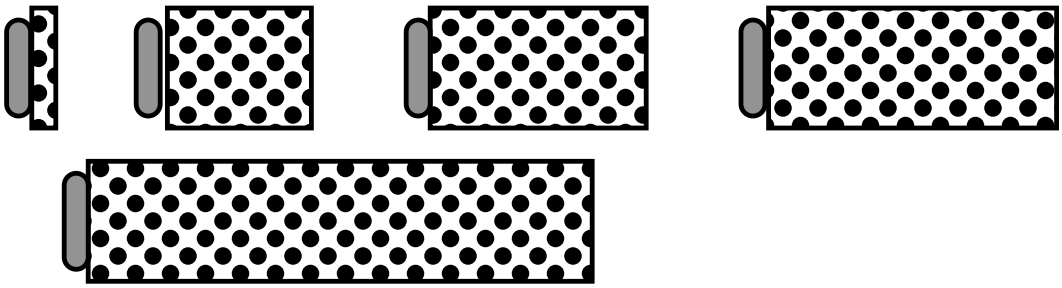
Fragments cut with Restrictive Enzyme after Cytosine



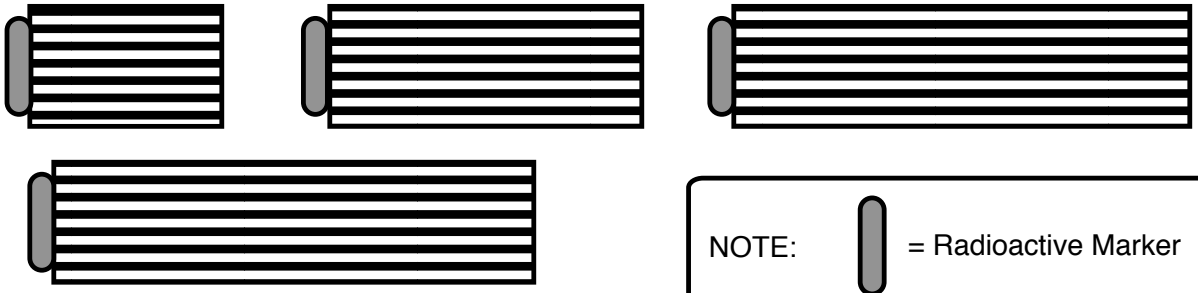
Fragments cut with Restrictive Enzyme after Guanine



Fragments cut with Restrictive Enzyme after Adenine



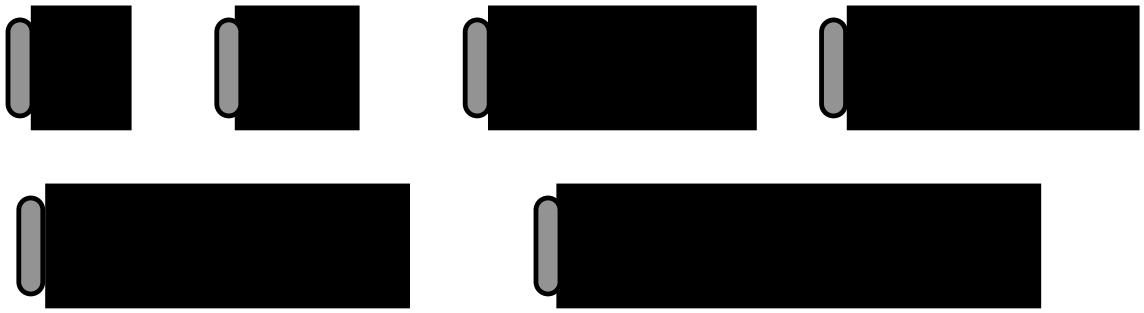
Fragments cut with Restrictive Enzyme after Thymine



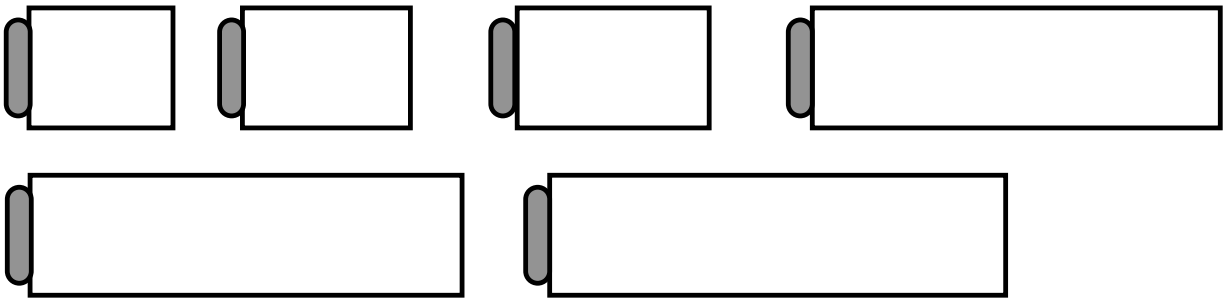
Student Handout

DNA Fragments after Treatment with Restrictive Enzymes Strand B

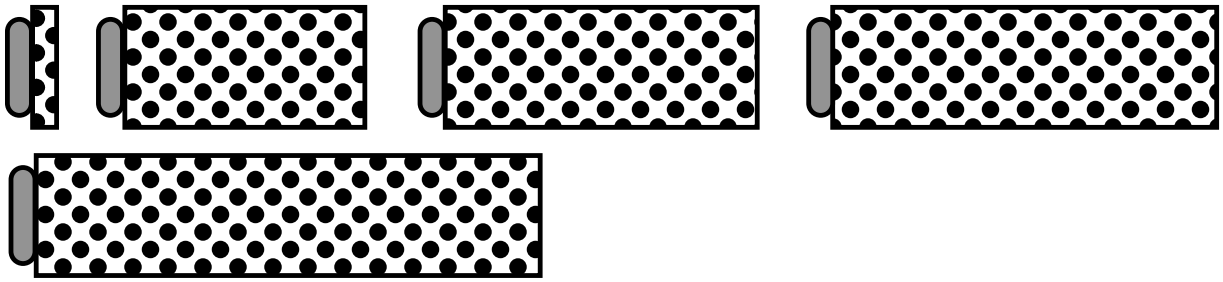
Fragments cut with Restrictive Enzyme after Cytosine



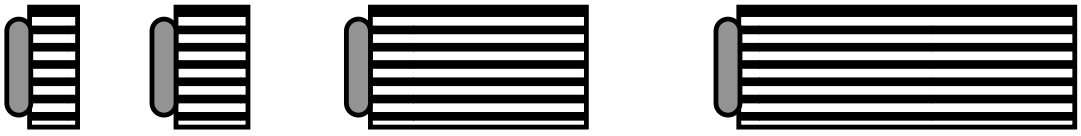
Fragments cut with Restrictive Enzyme after Guanine



Fragments cut with Restrictive Enzyme after Adenine



Fragments cut with Restrictive Enzyme after Thymine

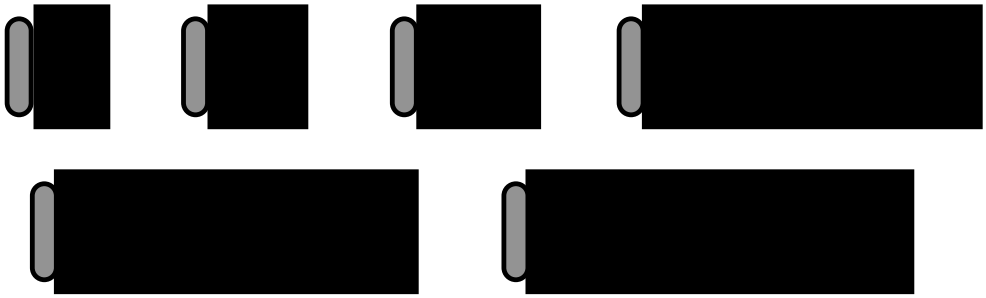


NOTE: = Radioactive Marker

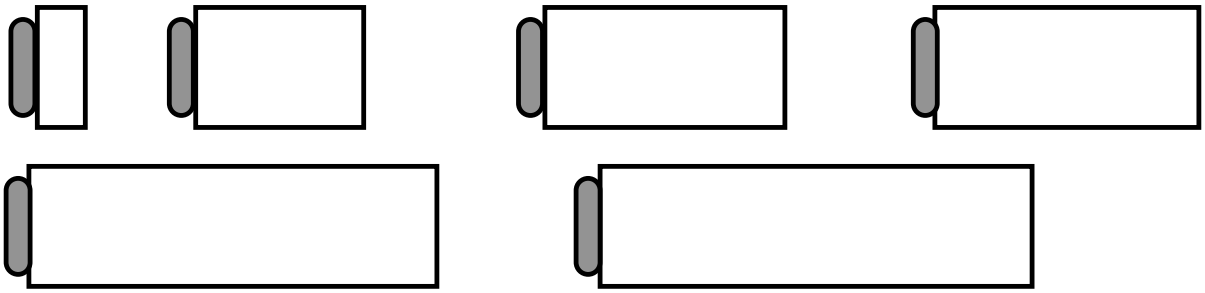
Student Handout

DNA Fragments after Treatment with Restrictive Enzymes Strand C

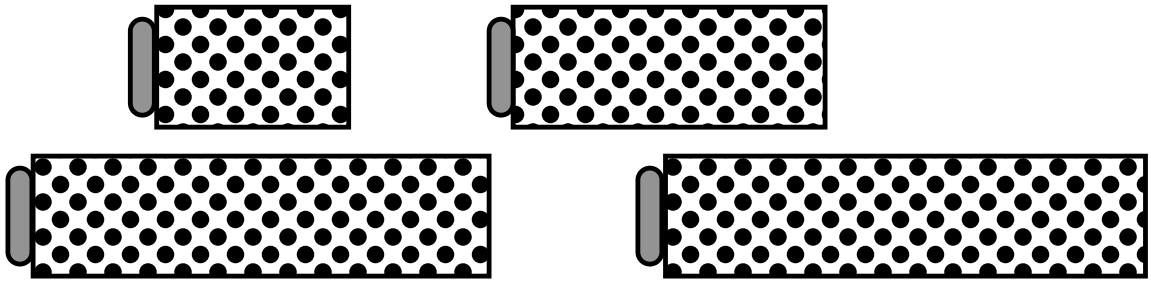
Fragments cut with Restrictive Enzyme after Cytosine



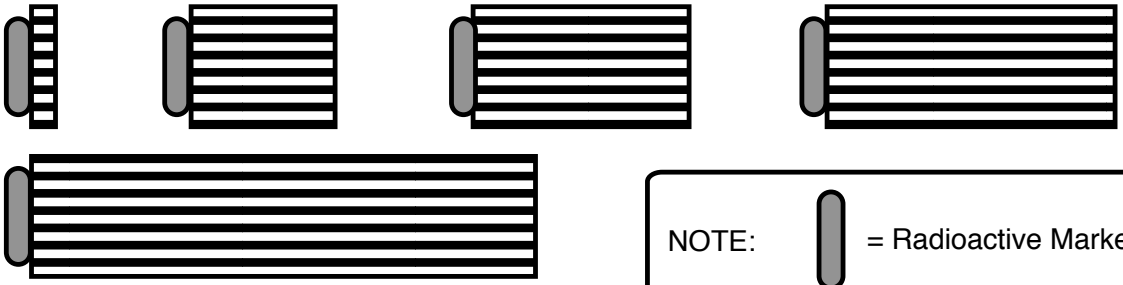
Fragments cut with Restrictive Enzyme after Guanine



Fragments cut with Restrictive Enzyme after Adenine



Fragments cut with Restrictive Enzyme after Thymine

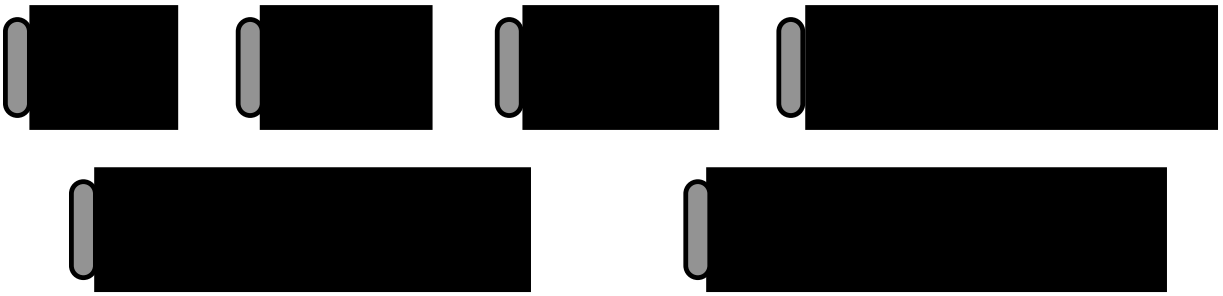


NOTE: = Radioactive Marker

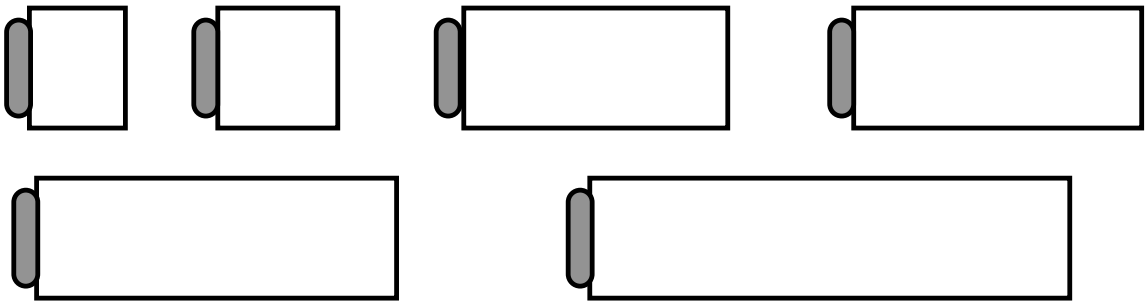
Student Handout

DNA Fragments after Treatment with Restrictive Enzymes Strand D

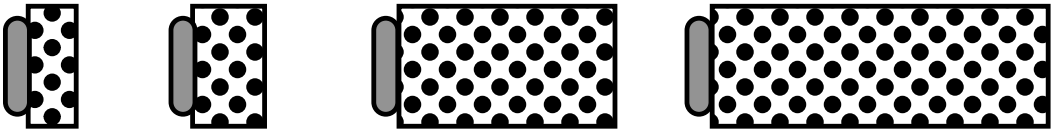
Fragments cut with Restrictive Enzyme after Cytosine



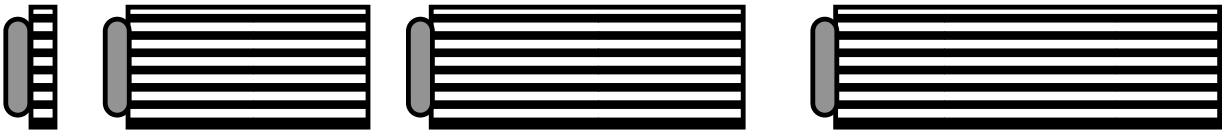
Fragments cut with Restrictive Enzyme after Guanine

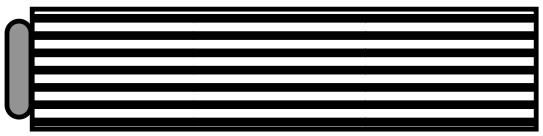


Fragments cut with Restrictive Enzyme after Adenine



Fragments cut with Restrictive Enzyme after Thymine





NOTE:  = Radioactive Marker

Student Handout

DNA Sequencing Master Sheet

Sequence of Strand "A"

A	C	G	G	G	A	C	T	A	C	C	A	T	G	G	G	C	C	T	T	A

Sequence of Strand "B"

A	T	T	C	C	G	G	G	T	A	C	C	A	T	C	A	G	G	G	C	A

Sequence of Strand "C"

T	G	C	C	C	T	G	A	T	G	G	T	A	C	C	C	G	G	A	A	T

Sequence of Strand "D"

T	A	A	G	G	C	C	C	A	T	G	G	T	A	G	T	C	C	C	G	T