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Deepwater Coral Expedition: Reefs, Rigs and Wrecks

Cut-off Genes

(adapted from the 2004 Mountains in the Sea 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 Inquiry 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
Gulf of Mexico
Deepwater coral
Gene
Gene sequence analysis
Polymerase chain reaction
Restrictive enzymes
Gel electrophoresis
DNA

Background Information
In recent years, rising costs of energy and a growing desire to reduce the United States' dependence upon foreign petroleum fuels have led to intensified efforts to find more crude oil and drill more wells in the Gulf of Mexico. This region produces more petroleum than any other area of the United States, even though its proven reserves are less than those in Alaska and Texas. Managing exploration and development of mineral resources on the nation's outer continental shelf is the responsibility of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks mission is to protect unique and sensitive environments where these resources are found.

To locate new sources of hydrocarbon fuels, MMS has conducted a series of seismic surveys to map areas between the edge of the continental shelf and the deepest portions of the Gulf of Mexico. These maps provide information about the depth of the water as well as the type of material that is found on the seafloor. Hard surfaces are often found where hydrocarbons are present. Carbonate rocks (such as limestone), in particular, are a part of nearly every site where fluids and gases containing hydrocarbons have been located. This is because when microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. This rock, in turn, provides a substrate where the larvae of many other deep sea bottom-dwelling organisms may attach, particularly corals. In addition to carbonate rocks associated with hydrocarbon seeps, deepwater corals in the Gulf of Mexico are also found on anthropogenic (human-made) structures, particularly ship wrecks and oil platforms.

Deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. Recent studies suggest that deepwater reef ecosystems may have a diversity of species comparable to that of coral reefs in shallow waters, and have found deepwater coral species on continental margins worldwide. One of the most conspicuous differences between shallow- and deepwater corals is that most shallow-water species have symbiotic algae (zooxanthellae) living inside the coral tissue, and these algae play an important part in reef-building and biological productivity. Deepwater corals do not contain symbiotic algae (so these corals are termed "azooxanthellate"). Yet, there are just as many species of deepwater corals (slightly more, in fact) as there are species of shallow-water corals. Deepwater reefs provide habitats for a variety of plant, animal, and microbial species, some of which have not been found anywhere else. Branching corals and other sessile (non-motile) benthic (bottom-dwelling) species with complex shapes provide essential habitat for other organisms including commercially-important fishes such as longfin hake, wreckfish, blackbelly rosefish, and grenadiers. In addition, recent research has shown that less obvious, obscure benthic species may contain powerful drugs that directly benefit humans.

The major structure-building corals in the deep sea belong to the genus *Lophelia*, but other organisms contribute to the framework as well, including antipatharians (black corals), gorgonians (sea fans and sea whips), alcyonaceans (soft corals), anemones, and sponges. While these organisms are capable of building substantial reefs, they are also quite fragile, and there is increasing concern that deepwater reefs and their associated resources may be in serious danger. Many investigations have reported large-scale damage due to commercial fishing trawlers, and there is also concern about impacts that might result from exploration and extraction of fossil fuels. These impacts are especially likely in the Gulf of Mexico, since the carbonate foundation for many deepwater reefs is strongly associated with the presence of hydrocarbons. Potential impacts include directly toxic effects of hydrocarbons on reef organisms, as well as effects from particulate materials produced by drilling operations. Since many deepwater reef organisms are filter feeders, increased particulates could clog their filter apparatus and possibly smother bottom-dwelling organisms.

A primary goal of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks is to develop the ability to recognize areas where deepwater corals are likely to occur in the Gulf of Mexico, and to obtain information about the biology and ecology of deepwater coral communities needed to develop effective strategies for protecting these communities. Because deepwater coral

communities in the Gulf of Mexico are relatively isolated from each other, they can vary greatly in their biodiversity (the number of different species present) and may also have a high degree of endemism (endemic species are species that are not found anywhere else). The isolated nature of these communities may also result in populations of some species that are genetically isolated from populations of the same species in other deepwater communities. One of the key activities of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks is to investigate genetic similarities and differences among deepwater coral reefs at various locations in the Gulf of Mexico. This activity is intended to introduce students to some of the techniques used in investigations of 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/ATG/data/released/0537-NancyRidenour/index.php)]

1. To prepare for this lesson, review introductory essays for the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html.

   You may also want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community in the Gulf of Mexico, and http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html for images of deep-sea corals and seamount communities.

2. Briefly introduce the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and describe deepwater coral communities. You may want to show images from http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html. Point out the variety of organisms found in these communities, and briefly discuss their importance.

   Explain that deepwater coral reefs are often highly productive, and while they have not been extensively explored, expeditions to study them often report many species that are new to science. Say that some of these species may be endemic to a particular group of deepwater reefs, and that DNA analysis can be used to investigate 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/media/Meds_LivingCode.pdf) 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 Inquiry Worksheet" and one version (A, B, C, or D) 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 Topics" 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" for resources on biotechnology. Click on "Lesson Plans" in the navigation menu, then "Secondary & Middle" and scroll down to "Project Grows" 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 5) provide opportunities for evaluation.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html to find out more about the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and to learn about opportunities for real-time interaction with scientists on the current expedition.
2. "The Electric Sieve" lesson plan from the 2003 Medicines from the Deep Sea Expedition (http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_ElecSieve.pdf) has directions for a simple electrophoresis apparatus suitable for classroom use.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

The Robot Archaeologist

(17 pages, 518k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/robot.pdf

Focus: Marine Archaeology/Marine Navigation (Earth Science/Mathematics)

In this activity, students will design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

My Wet Robot

(300kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles

In this activity, students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations, identify key

design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks, describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

Where Am I?

(PDF, 4 pages, 344k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwhereami.pdf

Focus: Marine navigation and position finding (Earth Science)

In this activity, students identify and explain at least seven different techniques used for marine navigation and position finding, explain the purpose of a marine sextant, and use an astrolabe to solve practical trigonometric problems.

Do You Have a Sinking Feeling?

(9 pages, 764k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandsinking.pdf

Focus: Marine archaeology (Earth Science/ Mathematics)

In this activity, students plot the position of a vessel given two bearings on appropriate landmarks, draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck, and explain how the debris field associated with a shipwreck gives clues about the circumstances of the sinking ship.

Where's My 'Bot?

(492kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wheresbot.pdf

Focus: Marine Navigation (Earth Science/ Mathematics)

In this activity, students will estimate geographic position based on speed and direction of travel, and integrate these calculations with GPS data to estimate the set and drift of currents.

The Big Burp: Where's the Proof?

(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/burp.pdf

Focus: Potential role of methane hydrates in global warming (Earth Science)

Students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global warming. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

What's the Big Deal?

(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/deal.pdf

Focus: Significance of methane hydrates (Life Science)

In this activity, students will be able to define methane hydrates and describe where these substances are typically found and how they are believed to be formed. Students will also describe at least three ways in which methane hydrates could have a direct impact on their own lives, and describe how additional knowledge of methane hydrates expected from the Blake Ridge expedition could provide human benefits.

Cool Corals

(7 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/corals.pdf

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

In this activity, 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.

This Old Tubeworm

(10 pages, 484k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus: Growth rate and age of species in cold-seep communities

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

What's Down There?

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/whatsdown.pdf

Focus: Mapping Coral Reef Habitats

In this activity, students will be able to access data on selected coral reefs and manipulate these data to characterize these reefs, and explain the need for baseline data in coral reef monitoring programs. Students also will be able to identify and explain five ways that coral reefs benefit human beings, and identify and explain three major threats to coral reefs.

The Benthic Drugstore

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/drugstore.pdf

Focus: Pharmacologically-active chemicals derived from marine invertebrates (Life Science/Chemistry)

In this activity, students will be able to identify at least three pharmacologically-active chemicals derived from marine invertebrates, describe the disease-fighting action of at least three pharmacologically-active chemicals derived from marine invertebrates, and infer why sessile marine invertebrates appear to be promising sources of new drugs.

Watch the Screen!

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/watchscreen.pdf

Focus: Screening natural products for biological activity (Life Science/Chemistry)

In this activity, students will be able to explain and carry out a simple process for screening natural products for biological activity, and will be able to infer why organisms such as sessile marine invertebrates appear to be promising sources of new drugs.

Now Take a Deep Breath

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/breath.pdf

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

In this activity, students will be able to define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

Biochemistry Detectives

(8 pages, 480k) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus: Biochemical clues to energy-obtaining strategies (Chemistry)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

Hot Food

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

Focus: Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)

In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

Submersible Designer

(4 pages, 452k) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9-12_l4.pdf

Focus: Deep Sea Submersibles

In this activity, students will understand that the physical features of water can be restrictive to movement, understand the importance of design in underwater vehicles by designing their own submersible, and understand how submersibles such as ALVIN and ABE, use energy, buoyancy, and gravity to enable them to move through the water.

Living in Extreme Environments

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

Focus: Biological Sampling Methods (Biological Science)

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

in order to survive; and understand the concept of interdependence of organisms.

What Was for Dinner?

(5 pages, 400k) (from the 2003 Life on the Edge Expedition)
http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/dinner.pdf

Focus: Use of isotopes to help define trophic relationships (Life Science)

In this activity, students will describe at least three energy-obtaining strategies used by organisms in deep-reef communities and interpret analyses of $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ isotope values.

Chemosynthesis for the Classroom

(9 pages, 276k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Chemo.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Chemistry/Biology)

In this activity, students will observe the development of chemosynthetic bacterial communities and will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive. Students will also be able to explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

How Diverse is That?

(12 pages, 296k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Diverse.pdf

Focus: Quantifying biological diversity (Life Science)

In this activity, students will be able to discuss the meaning of biological diversity and will be able to compare and contrast the concepts of variety and relative abundance as they relate to biological diversity. Given abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

C.S.I. on the Deep Reef

(Chemotrophic Species Investigations, That Is) (11 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20CSI.pdf

Focus: Chemotrophic organisms (Life Science/Chemistry)

In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

This Life Stinks

(9 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Stinks.pdf

Focus: Methane-based chemosynthetic processes (Physical Science)

In this activity, students will be able to define the process of chemosynthesis, and contrast this process with photosynthesis. Students will also explain the process of methane-based chemosynthesis and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean

Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focussing on the exploration, understanding, and protection of Earth as a whole system

http://www.ncbi.nlm.nih.gov/Entrez/ and http://workbench.sdsc.edu – Two 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/scisoc/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://www.gomr.mms.gov/index_common.html – Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf – "Chemosynthetic Communities in the Gulf of Mexico" teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students.

http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html – Kids Page on the Minerals Management Service Web site, with posters, teaching guides and other resources on various marine science topics

http://www.coast-nopp.org/ – Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ – Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico (COSEE-CGOM)

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings 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 g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to

estuaries and to the ocean.

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 b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

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.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

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 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.

Send Us Your Feedback

We value your feedback on this lesson. Please send your comments to: oceanexeducation@noaa.gov

For More Information

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Acknowledgements

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Student Handout

DNA Sequencing Inquiry 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 an equal distance between each of the numbers on the left side of the poster board.

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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).

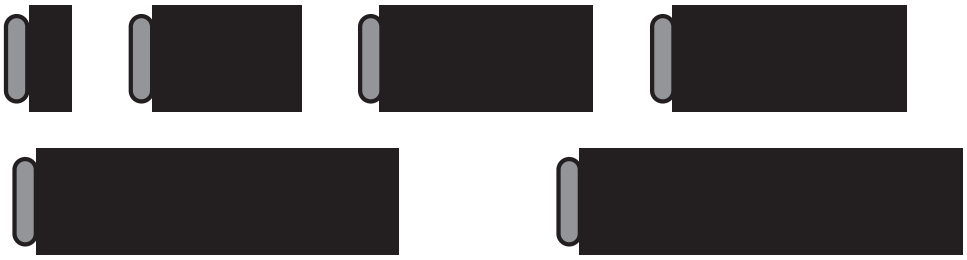
6. What mRNA sequence would be transcribed from this strand of DNA?

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

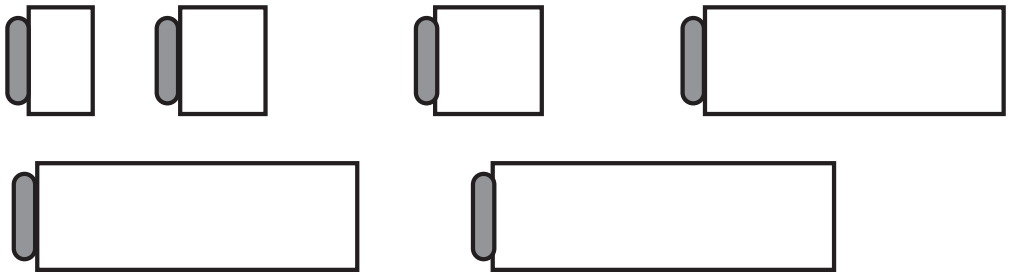
Student Handout

DNA Fragments after Treatment with Restrictive Enzymes Strand A

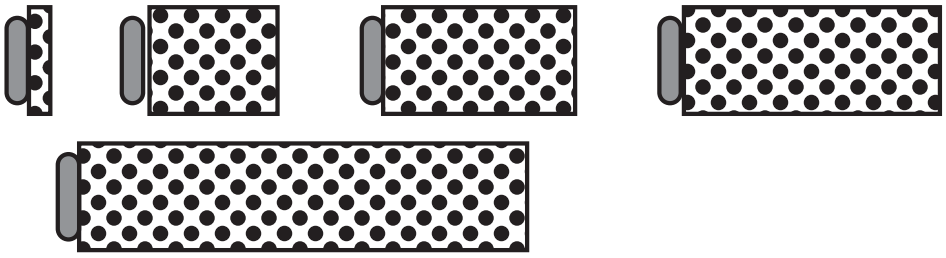
Fragments cut with Restrictive Enzyme after Cytosine



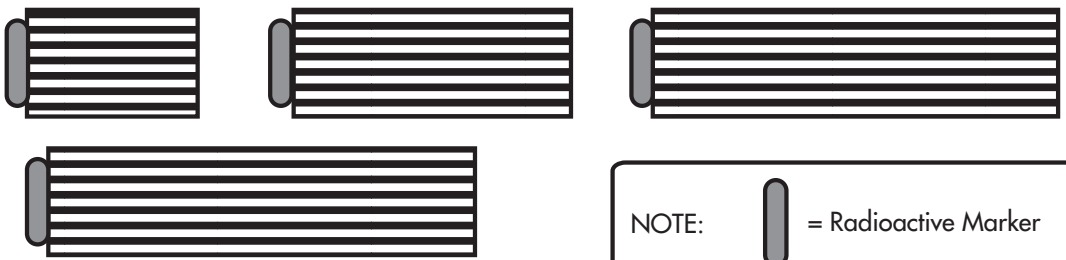
Fragments cut with Restrictive Enzyme after Guanine



Fragments cut with Restrictive Enzyme after Adenine



Fragments cut with Restrictive Enzyme after Thymine



NOTE: = Radioactive Marker

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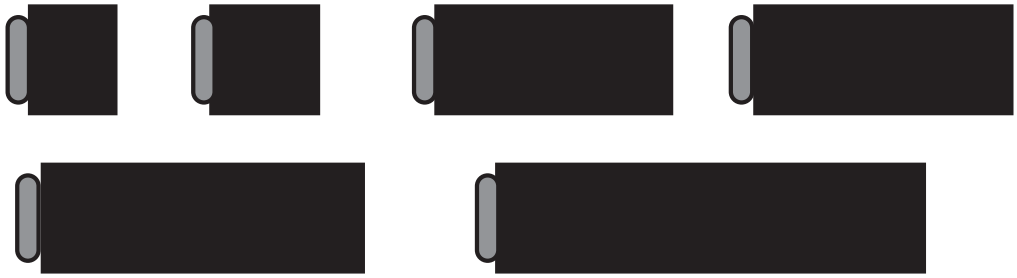
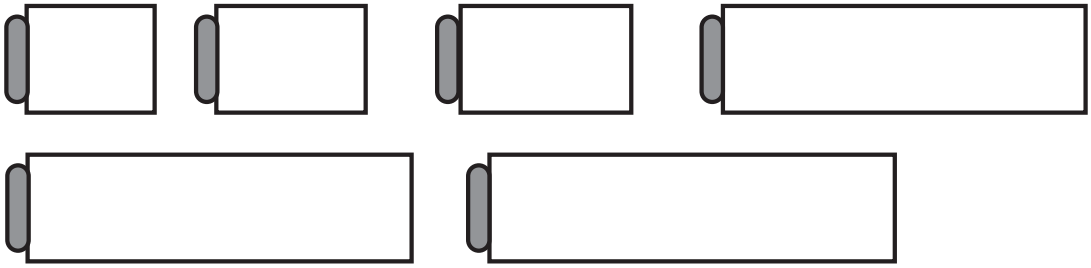
DNA Fragments after Treatment with Restrictive Enzymes Strand B

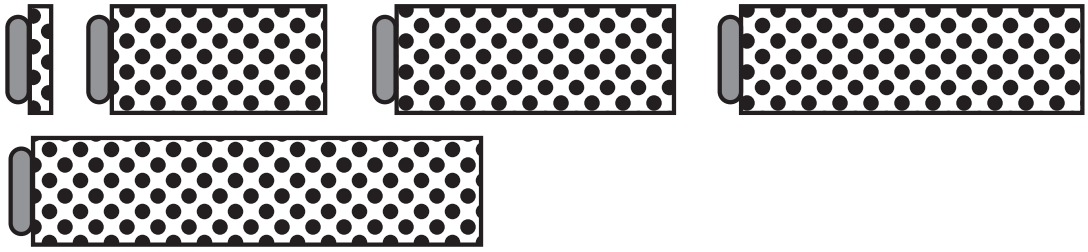
Fragments cut with Restrictive Enzyme after Cytosine



Fragments cut with Restrictive Enzyme after Guanine



Fragments cut with Restrictive Enzyme after Adenine



Fragments cut with Restrictive Enzyme after Thymine

NOTE: = Radioactive Marker

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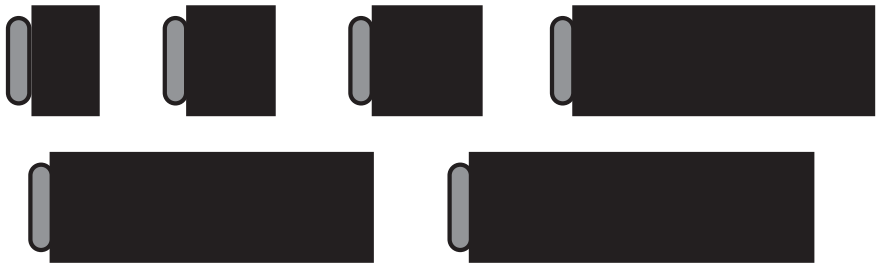
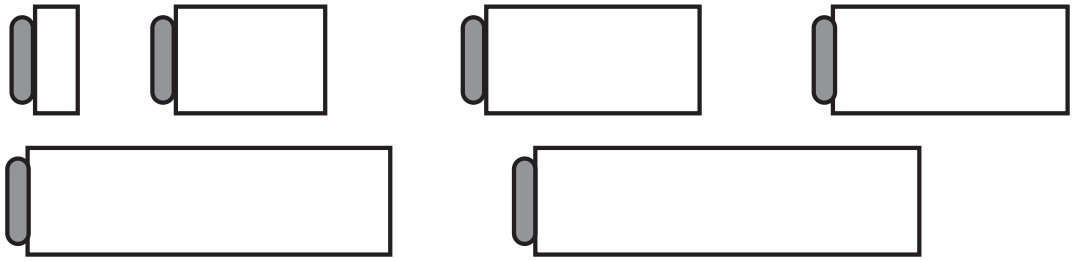
DNA Fragments after Treatment with Restrictive Enzymes Strand C

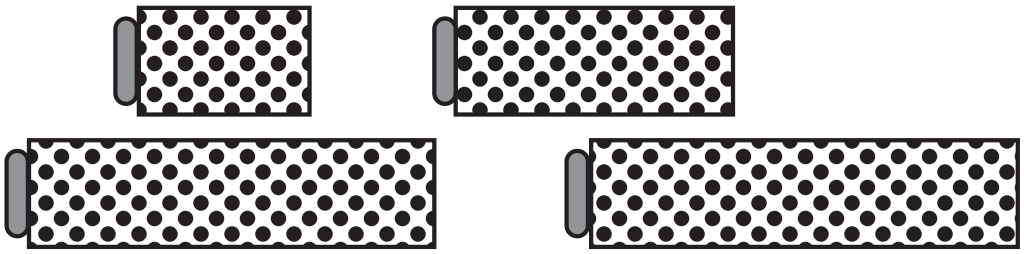
Fragments cut with Restrictive Enzyme after Cytosine



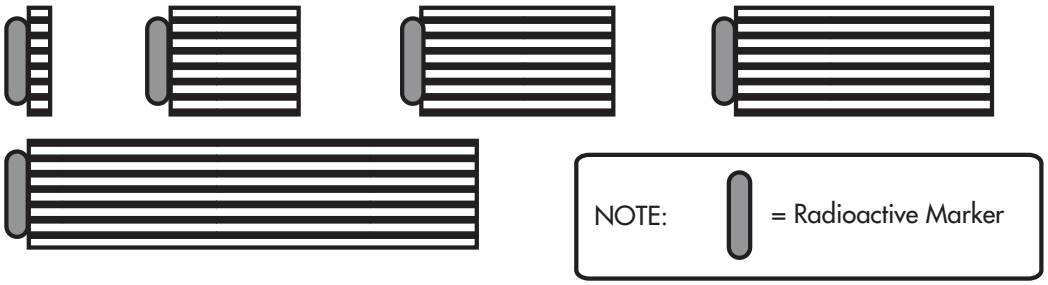
Fragments cut with Restrictive Enzyme after Guanine



Fragments cut with Restrictive Enzyme after Adenine



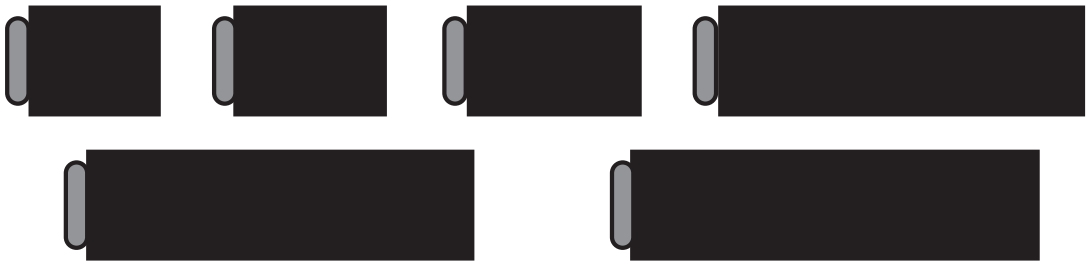
Fragments cut with Restrictive Enzyme after Thymine



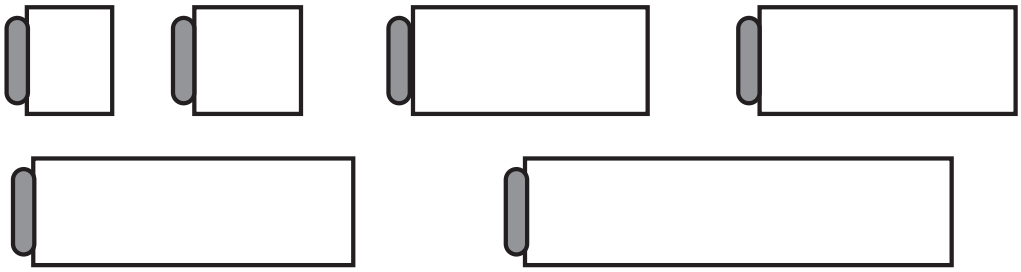
Student Handout

DNA Fragments after Treatment with Restrictive Enzymes Strand D

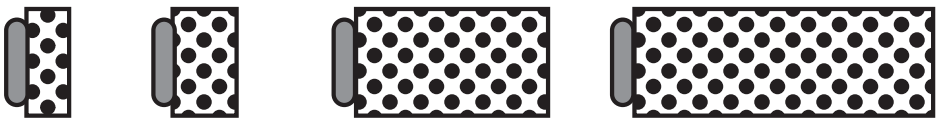
Fragments cut with Restrictive Enzyme after Cytosine



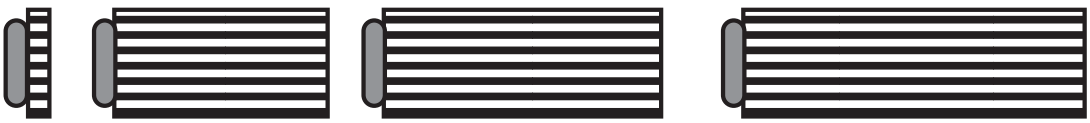
Fragments cut with Restrictive Enzyme after Guanine

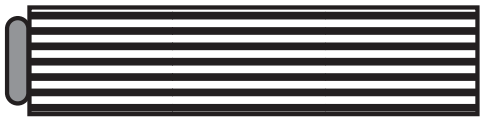


Fragments cut with Restrictive Enzyme after Adenine



Fragments cut with Restrictive Enzyme after Thymine





NOTE: = Radioactive Marker

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