Micro B3 Project: Ocean Sampling Day 2014

What a Day for Ocean Microbes!

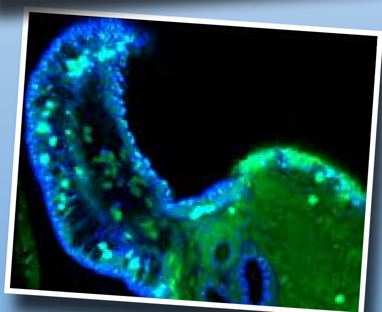

Image captions/credits on Page 2.

lesson plan

Focus
The Micro B3 Project and Ocean Sampling Day 2014

Grade Level
6-12

Focus Question
What is Ocean Sampling Day and why is it important?

Learning Objectives
- Students will explain what marine microbes are, and why they are important.
- Students will describe Ocean Sampling Day, and explain how it will contribute to building the largest dataset on microbial diversity and function.

Materials
- ❑ Computers with internet access, or printed resource materials copied from sources cited in Resources
- ❑ Copies of *Marine Microbes Inquiry Guide*; one copy for each student or student group

Audio-Visual Materials
- ❑ (Optional) Interactive white board

Teaching Time
Approximately one hour for each activity, plus time for student research and project work

Seating Arrangement
Varies depending upon activity

Maximum Number of Students
30

Key Words
Marine microbe
Ocean Sampling Day

The grayish black material is manganese oxide encrusted microbial mats and minerals. The yellow orange material is iron oxide encrusted microbial mats and minerals. Image courtesy of NOAA / NSF / WHOI.
http://oceanexplorer.noaa.gov/explorations/12fire/background/microbio/media/yellow_mats.html

Marine microbes are a source of natural products that can be detrimental or beneficial to the marine environment. For example, marine fungus (above) can produce diseases in fish and other marine living resources but they can also lead to the discovery of new marine natural products that are substances that could be helpful in treating human diseases. Image courtesy of deepseanews.com

Each spot on this agar plate is a bacterial colony recovered from a marine sponge sample. By the time a colony is visible to the human eye, it consists of at least one million cells. Less than one percent of bacteria can be grown under laboratory conditions, suggesting that there is a large reservoir of unknown microbial diversity. As a result, microbiologists use a combination of cultivation and molecular genetic characterizations to examine microbial communities. Image courtesy of the Twilight Zone Expedition Team 2007, NOAA-OE.
http://oceanexplorer.noaa.gov/explorations/07twilightzone/logs/hires/marine_microbes_hires.jpg

Images from Page 1 top to bottom:
Microbial mats coated in white sulfate material were observed and sampled at several vent sites at West Mata in 2009. These mats were dominated by Epsilonproteobacteria which is a class of bacteria often associated with sulfur oxidation in marine environments. Image courtesy of NOAA/NSF/WHOI.
http://oceanexplorer.noaa.gov/explorations/12fire/background/hires/mat_meadow_hires.jpg

Vibrio fischeri
The symbiotic association between the squid *Euprymna scolopes* and the luminous bacterium *Vibrio fischeri* provides a unique opportunity to study both immune and developmental signals associated with the establishment and maintenance of beneficial animal-bacterial interactions. Image courtesy: Margaret McFall-Ngal, University of Wisconsin-Madison
http://explore.noaa.gov/sites/OER/Documents/public-affairs/news-room/Marine-Microbes-Workshop-Report.pdf

An agar plate with microorganisms isolated from a deep-water sponge. Image courtesy NOAA Deep Sea Medicines 2003 Exploration.
http://oceanexplorer.noaa.gov/explorations/03bio/background/microbiology/media/figure_03.html

Sheryl Bolton cultures microbes in the lab aboard the research vessel (R/V) Melville. Image courtesy of Submarine Ring of Fire 2006 Exploration, NOAA Vents Program
http://oceanexplorer.noaa.gov/explorations/06fire/logs/may5/media/culturing_microbes.html

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

For most of us, the term “marine organism” brings to mind images of fishes, coral reefs, marine mammals, or other animals that are easy to see with the naked eye. Yet, 98% of the biomass in Earth’s ocean, and most of its biological activity, is provided by marine microbes; organisms that are exceedingly small, less than a few thousandths of a millimeter. Marine microbes produce about half of the oxygen in Earth’s atmosphere; are involved in most biological, geological, and chemical interactions; and are found in habitats ranging from the ocean surface to deep within rocks beneath the ocean floor. A least ten million bacterial species are estimated to exist in Earth’s ocean, and up

Biodiversity. Bioinformatics. Biotechnology.

Micro B3 Logo
http://www.microb3.eu/media-material/picture-gallery

Rhodopirellula baltica (c) Micro B3
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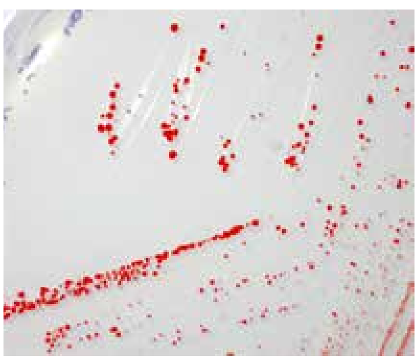

Rhodopirellula baltica growing on plate (c) Micro B3
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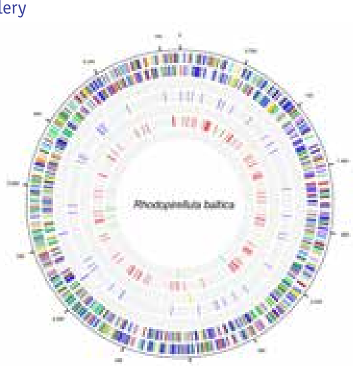


The genome of *Rhodopirellula baltica* (c) Micro B3
http://www.microb3.eu/media-material/picture-gallery

to a million marine microbes can live in just one milliliter of seawater. The term "marine microbe" includes Bacteria, Archaea, Eukaryota, and viruses. Most exist in highly organized and complex biological communities.

Marine microbial communities and organisms are difficult to analyze because 99% of marine microbial species cannot be cultured under laboratory conditions, and cannot easily be observed in their natural environment. Scientists have studied marine microbes for many years using basic microscopy. However, much of this microbial life remains unknown. Technology has rapidly evolved in recent years, due to what is often referred to as the "-omic revolution", with collective information from genomics, proteonomics, transcriptomics, metabolomics and metagenomics. As a result, our ability to study marine microbes and their communities has improved dramatically due to these advances in technologies for genetic analysis.

As we learn more about the diversity of microorganisms and their associated biogeochemical processes, our view of the world's ocean ecosystems is being transformed, and the relevance of microbes to ocean resiliency and marine resource management is becoming undeniable. Yet, the sheer number of microorganisms as well as their vast diversity and different functions has led to the realization that we only poorly understand the biogeochemical processes that exist on our planet. We need to advance the understanding of how emerging diseases are responding to global changes (warming, acidification, coastal urbanization, pollution, etc.), and how microbial processes should be integrated into our biogeochemical and ecosystem health forecasts.

Marine microorganisms are also essential players in the health of marine ecosystems. They can have a positive influence on ecosystems' health. For example, in coral reefs, microscopic coral-specific algae live in symbiosis with the coral polyps and provide them with photosynthetic energy used by the colony for its biological functions. Over the past decades, increases in microbial abundance, as well as changes in community structure and function, have occurred in response to increased environmental stress mostly related to climate change and eutrophication.

Marine biotechnology developments have led to the discovery of valuable natural products extracted from marine microbes that can benefit human health. Although, a large number of bioactive substances have been identified, the first drugs from the ocean were only recently approved. For example, the harmful algae *Karenia brevis* produces Brevetoxin, a very potent toxin that could aid in stroke recovery. Other potentially useful chemicals extracted from the same microalgae include Brevenal, for treating cystic fibrosis, as well as COPD. Escortin has the potential to transform cancer treatment by escorting anti-cancer drugs directly into cancerous cells.

Microbes are pervasive and can evolve rapidly in response to environmental shifts and could be used as indicators of ocean change. In fact, marine microbes are "the canary in the coal mine" for the marine environment. In addition, they can also be drivers of change in the ocean. Consequently, it is very important to acquire baseline information against which future changes could be identified. Detecting environmental shifts, however, depends upon knowing enough about marine microbes at one point in time to be able to recognize when changes have occurred at a later time. In other words, we need to have baseline information that can be compared with future conditions. And that is where Ocean Sampling Day comes in. A consortium of 32 industrial and academic partners from all over Europe organized Ocean Sampling Day (OSD) with the goal of providing the largest dataset on marine microbial diversity and function ever taken on a single day. These data will provide a baseline for recognizing and studying environmental changes in Earth's ocean.

The core concept of OSD is that simultaneous samples are collected from many locations in Earth's ocean using the same methods for collecting, storing, shipping, analyzing, and archiving the collected samples. Methods and procedures for OSD were pilot-tested during the 2012 summer and winter solstices (June 20 and December 21, respectively), and again in June 2013. In 2014, OSD will take place during the summer solstice on June 21, and will include sites from Europe, Western Asia, North Africa, North and Central America, Australia, South Pacific and Antarctica. Ocean Sampling Day is supported by the Micro B3 (Biodiversity, Bioinformatics, Biotechnology) project (www.microb3.eu) of the Seventh Framework Programme through which the European Union supports research and development activities covering almost all scientific disciplines.

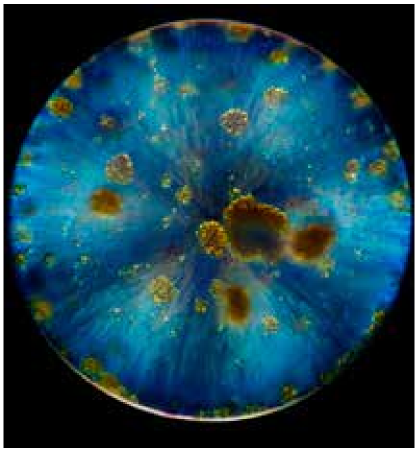
Additional information about some of the scientists involved with OSD is available at www.oceansamplingday.org. Please see http://www.my-osd.org/ for more information about OSD, including a video about the project and opportunities for participation.

Activities

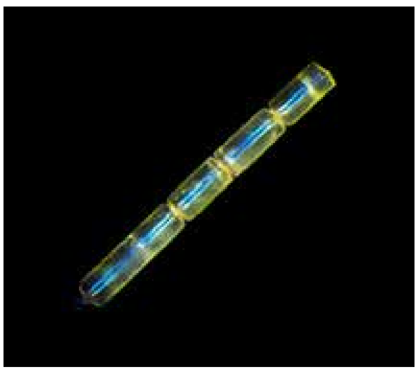
Two activities are provided that are related to OSD:

1. A survey of marine microbes, and introduction to OSD;
2. A simulation to introduce random sampling of marine microbes; and

The first activity may be used alone, or in combination with Activity 2 if time is available.



Diatom Bacillariophyta (c)Luis Gutierrez Heredia
http://www.microb3.eu/media-material/picture-gallery



Diatom (c)Jennifer Gillette Tara Oceans
http://www.microb3.eu/media-material/picture-gallery

Activity 1 – Introducing Marine Microbes

This activity is adapted from the lesson, "Microfriends," included in the NOAA Ship *Okeanos Explore*r Education Materials Collection, Volume 1: Why Do We Explore? (http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_microfriends.pdf). In addition to the survey activity, the lesson also includes information about aseptic procedures and directions for obtaining and culturing a bacterial sample on a nutrient medium.

1. Provide each student group with a copy of *Marine Microbes Inquiry Guide*, and provide directions to appropriate sources for student research. This may be an in-class assignment or homework.

2. Review students' answers to questions on the worksheet. The following points should be included:

   (1) Bacteria have existed on Earth longer than any other known organism.

   (2) Bacterial cells are structurally simpler than those of other organisms and do not have a nucleus.

   (3) Bacteria are extremely hardy; some can live well below freezing, others survive in boiling water, and others live in solid rock.

   (4) Bacteria are everywhere, and in large numbers; a teaspoon of garden soil contains about ten billion bacteria, and there are more bacteria in the human mouth than the total number of people who have ever lived.

   (5) Virtually all plants and animals live in association with bacteria and other microorganisms; these associations may benefit both organisms (mutualism), benefit one organism without affecting the other (commensalism); or benefit one organism and harm the other (parasitism).

   (6) Most bacteria are not parasitic.

   (7) Some benefits provided by bacteria include:
   - Bacteria in human intestines aid in the digestion of certain foods;
   - Production of cheese, yogurt, and other foods;
   - Decomposition and recycling of dead organisms;
   - Fixation of nitrogen from the atmosphere into useable nitrogen in soils;

- Production of antibiotics;
- Photosynthetic bacteria produce oxygen; cyanobacteria produced the Earth's oxygen atmosphere 2,000 million years ago;
- Bacteria are responsible for the production of fossil fuels;
- Bacteria are used to clean up polluted areas, including oil spills;
- Bacteria produce a variety of chemicals used in many industries, including acetone, butanol, and citric acid;
- Bacteria are used to treat sewage;
- Bacteria are what makes composting work; and
- Bacteria can be used to generate methane gas from sewage waste.

(8) Ocean Sampling Day (OSD) is a day (June 21, 2014) on which simultaneous samples will be collected from many locations in Earth's ocean to investigate the distribution of marine microbes on a global scale.

OSD is important because marine microbes are the base of marine food webs, control much of the flow of marine energy and nutrients, are involved with impacts of climate change and ocean acidification, and are essential to life on Earth; yet, very little is known about these organisms nor about the communities of which they are an important part. At present, the study of marine microbes is hampered by a shortage of samples from many parts of Earth's ocean due to the cost and difficulty of getting to sea. OSD will be a significant step toward filling this gap.

(9) Some ways that students and school groups may become involved with OSD include:

- Participate in the OSD crowdfunding campaign
- Plan to use the OSD Mobile App to generate important data on OSD
- Raise awareness about marine microbes and OSD using information materials from http://www.my-osd.org/?page_id=503

3. Have students develop a plan to raise public awareness about marine microbes and OSD, and create materials to support the plan. These may include posters, short videos, dramatic or musical performances, slide presentations, or other media. Regardless of the medium, the core message of these materials should specifically include one or more of the Ocean Literacy Essential Principles and Fundamental Concepts listed below. You may want to suggest that students investigate the Ocean

Sampling Day Web page (http://www.microb3.eu/) and the Center for Microbial Ecology: Research and Education's Education and Outreach Web page (http://cmore.soest.hawaii.edu/education/kidskorner/index.htm) for resources that may suggest some ideas for this project.

Activity 2 – Simulating Random Sampling of Marine Microbes (http://www.asm.org/images/Education/K-12/2010%20marine%20microbes.pdf)

This is an American Society of Microbiology Microbial Discovery Activity written by Barbara Bruno, Kimberly Tice, Kate Achilles, and Joan Matsuzaki. Background information is provided on the abundance and diversity of marine microbes, followed by an explanation of how scientists quantify the abundance of these organisms based on students randomly sampling simulated "marine microbes" (colored beads in a bag). Students learn about the inherent variability of random sampling by comparing the composition of their individual samples, their group's pooled sample data, and composition of the entire population. The file includes teacher background, detailed instructions, materials list, student worksheets, and student reading.

Extension

The Mysterious Microbial Mats
(from the Submarine Ring of Fire 2012: NE Lau Basin Expedition)
http://oceanexplorer.noaa.gov/explorations/12fire/background/edu/media/microbmats_56.pdf

Focus: Ecological role of microbial mats in hydrothermal vent ecosystems (Life Science)

Students plan an investigation using a model ecosystem to explain some of the components of an anaerobic ecosystem, and construct explanations for the potential role of microbial mats in hydrothermal vent ecosystems.

Resources

Bruno, B., K. Tice, K. Achilles, and J. Matsuzaki. 2010. Quantifying Marine Microbes: A Simulation to Introduce Random Sampling. American Society for Microbiology Classroom and Outreach Activities (online), April 2010, 1-19. Online at http://www.asm.org/images/Education/K-12/2010%20marine%20microbes.pdf.

Center for Microbial Ecology: Research and Education. 2008. Key Concepts in Microbial Oceanography. http://cmore.soest.hawaii.edu/downloads/MO_key_concepts_hi-res.pdf. Accessed February 24, 2014.

Centers for Ocean Sciences Education Excellence. Marine microbes resources webpage. http://www.cosee.net/resources/themes/marinemicrobes/index.cfm?FuseAction=ShowResourceDetails&ResourceID=543. Accessed February 24, 2014.

http://www.microb3.eu/
Visit the Media and Materials Links in the bottom banner of this Web page for press release, photographic images, logos, smart device wallpapers, slides, and coloring pages.

http://www.microbeworld.org/types-of-microbes
Website that describes the six main types of microbes

http://cmore.soest.hawaii.edu/education/kidskorner/index.htm – Center for Microbial Ecology: Research and Education's Education and Outreach Web page, with information and games about marine microbes.

NOAA. 2011. NOAA Marine Microbes Workshop Report. Held in Charleston, South Carolina on November 29-30, 2011. Online at explore.noaa.gov/sites/OER/Documents/Marine-Microbes-Workshop-Report.pdf.

NOAA Office of Ocean Exploration and Research. www.oceanexplorer.noaa.gov. Enter "Microbes" into the search engine for a number of background essays and additional information on microbes in the deep-sea.

Stewart, R. 2004. Our ocean planet: Oceanography in the 21st century. http://oceanworld.tamu.edu/resources/oceanography-book/microbialweb.htm Accessed February 23, 2014.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept h. Although the ocean is large, it is finite, and resources are limited.

Essential Principle 2.
The ocean and life in the ocean shape the features of Earth.
Fundamental Concept a. Many earth materials and biogeochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

Fundamental Concept d. The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.

Essential Principle 3.
The ocean is a major influence on weather and climate.
Fundamental Concept e. The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.
Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
Fundamental Concept g. Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.

Essential Principle 4.
The ocean made Earth habitable.
Fundamental Concept a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. This accumulation of oxygen in Earth's atmosphere was necessary for life to develop and be sustained on land.
Fundamental Concept b. The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.
Fundamental Concept c. The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept a. Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.
Fundamental Concept b. Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles, and produce a huge amount of the carbon and oxygen on Earth.
Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.
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 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.The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.
Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.
Fundamental Concept c. Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.
Fundamental Concept d. New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.
Fundamental Concept e. Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.
Fundamental Concept f. Ocean exploration is truly interdisciplinary.

It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

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Marine Microbes Inquiry Guide

1. How long have bacteria existed on Earth compared to other organisms?
2. How are bacterial cells different from the cells of other organisms?
3. Are bacteria, in general, delicate or hardy?
4. Where are bacteria found? In general, are bacteria rare or abundant?
5. Are bacteria generally absent from healthy plants and animals?
6. Are most bacteria harmful to humans?
7. What are at least three benefits that we may receive from bacteria?
8. What is Ocean Sampling Day, and why is it important?
9. How can students and school groups become involved with Ocean Sampling Day?