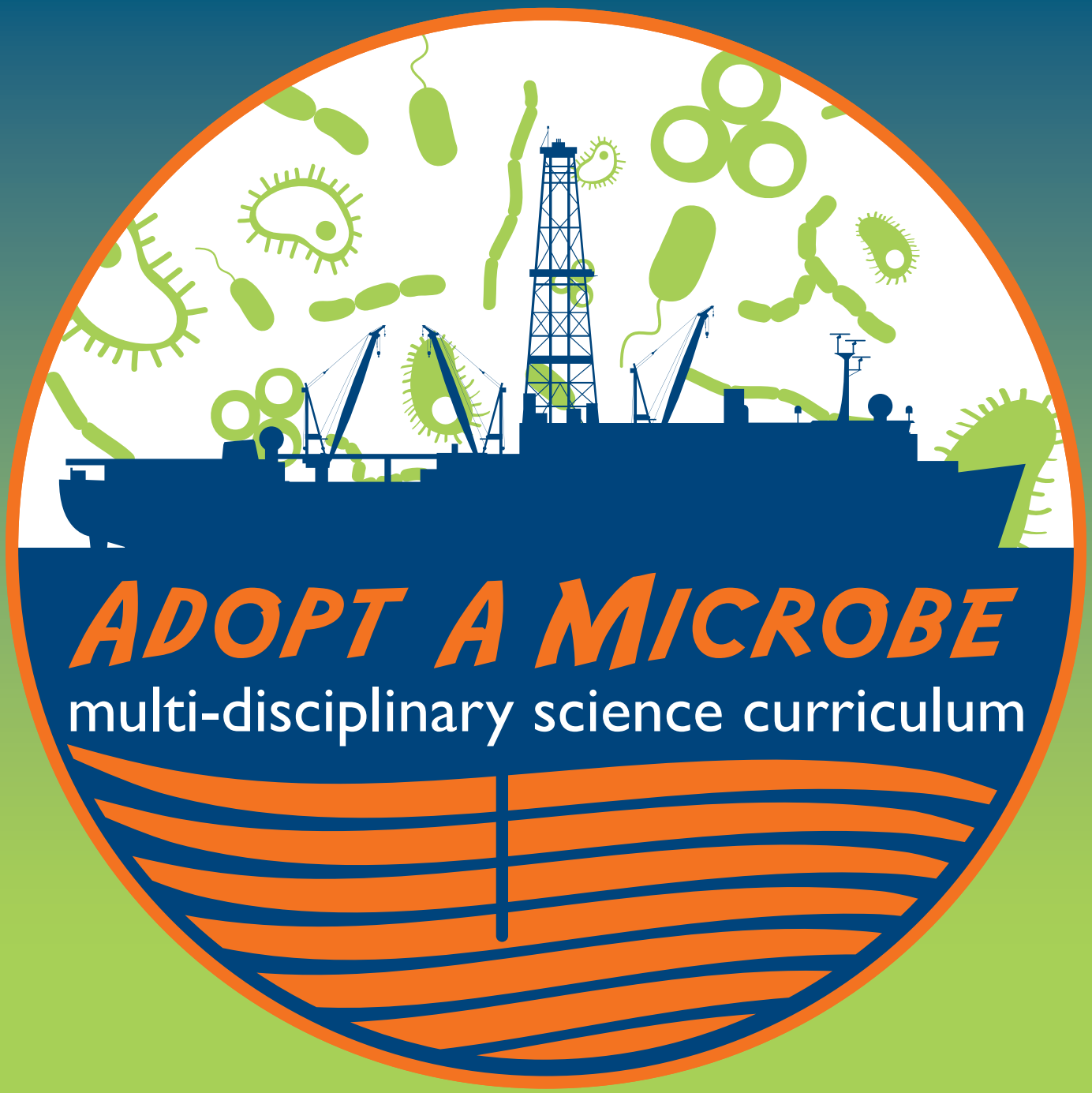


Adopt a Microbe

multi-disciplinary science curriculum

PREVIEW

EXPLORE • EDUCATE • ENGAGE

C-DEBI

Deep Earth Academy

CONSORTIUM FOR OCEAN LEADERSHIP

A multi-disciplinary science education project (aligned with National Standards) for middle school based on real scientists & experiments, the oceans, and exploration.

Deep Earth Academy
CONSORTIUM FOR OCEAN LEADERSHIP

Dear Educator,

Welcome to this preview of the "**Adopt A Microbe**" project! We have developed this set of educational materials to provide you with exciting and engaging stories, activities, and content for teaching scientific concepts to your middle-school-level students. This curriculum blends concepts from Earth sciences and biology, focusing on scientists conducting research in the oceans to understand the importance of microbial life there. Using real-life examples and hands-on activities tested through on-line classroom participation, this content was developed in alignment with National Standards as well as Earth Science and Ocean Literacy Principles. We hope that some or all of this content is useful for you in the classroom to engage your students in the process of science. Note: this packet is an overview and preview of the complete curriculum that will be available later this year. It is a subset of our much larger group of final activities.

This project was developed by Dr. Beth Orcutt, a scientist at the Bigelow Laboratory for Ocean Sciences in Maine, in collaboration with the Consortium for Ocean Leadership, the Center for Dark Energy Biosphere Investigations, and Amanda Haddad of the University of Southern California. You may have seen mention of the "Adopt A Microbe" project if you are a subscriber to Current: the *Journal of Marine Education* - we had a feature article in volume 27, number 3 in 2011.

The following outline provides an overview of the different themes covered in this material. We also provide a list of the associated activities you can use and online media resources that will enhance each theme. Please visit the Adopt a Microbe website *(http://aam.darkenergybiosphere.org/)* and *www.joidesresolution.org* to discover the complete curriculum module when it is ready, more materials that you can use in your classroom and to find opportunities to engage with real scientists over the course of the year.

THEME #1 - Get to know a marine scientist

OVERVIEW
Introduction to a marine scientist that started this project, with background about how she got interested in science, and an example of how she uses the process of science to learn new things about the world (in particular, about the microbial life at the bottom of the ocean)

ACTIVITIES
Discovering Life Below the Sea Floor

How Science Works

ONLINE MEDIA RESOURCES
YouTube: "What is it a like to be a marine scientist" *http://youtu.be/QS_d55k-m5I*

Online science presentation given by Orcutt: *http://youtu.be/xzR7XiHDp48*

NATIONAL STANDARDS
Strand 2, Concept 1 History of Science as a Human Endeavor

Grade 5

PO1 (diverse people/cultures making contributions past/present)

Grades 6 & 7

PO1, PO2, PO3, PO4 (major milestones in technology including ROVs, analyze impact of developments and describe/analyze use of technologies in careers)

Strand 2, Concept 2 Nature of Scientific Knowledge

Grade 5

PO1, PO2, PO3, PO4 (science as a process)

Grade 6 & 7

PO1, PO2, PO3 (applying science as a process)

OCEAN LITERACY PRINCIPLES
Principle 5 (the ocean supports a great diversity of life and ecosystems): 5b

Principle 7 (the ocean is largely unexplored) - 7b, 7d, 7f

EARTH SCIENCE LITERACY "BIG IDEAS"
Big Idea #1 (Earth scientists use repeatable observations…): 1.2, 1.3

Big Idea #5 (Earth is the water planet)

Big Idea #6 (life evolves on a dynamic Earth…): 6.3, 6.5, 6.9

THEME #2 - Microbiology 101 – Introduction to Microbes

OVERVIEW
What is a microbe? How are microbes different than other life that we know? How do scientists study microbes? How big are microbes? Why are microbes important?

ACTIVITIES
Adopt A Microbe

Make A Microbe

ONLINE MEDIA RESOURCES
YouTube: Looking for Life Below the Seafloor: *http://youtu.be/yOgZy9TfSFo*

The secret, social lives of bacteria video: *http://youtu.be/TVfmUfr8VPA*

Introduction to Archaea: *http://www.youtube.com/watch?v=W25nI9kpxtU*

Classification of life: *http://youtu.be/tYL_8gv7RiE*

The three domains of life: *http://youtu.be/wGVgIcTpZkk*

NATIONAL STANDARDS
Strand 4 Concept 3: Populations of Organisms in an Ecosystem

Grade 7

PO2, PO3 (organisms, resources, carrying capacity, limiting factors)

Grade 3

PO2, PO3, PO5 (microscopic, macroscopic, producers, consumers, decomposers, environmental factors)

OCEAN LITERACY PRINCIPLES
Principle 4 (The ocean makes Earth habitable): 4a, 4b

Principle 5 (the ocean supports a great diversity of life and ecosystems): 5a, 5b, 5g

Principle 7 (the ocean is largely unexplored) - 7a, 7d

EARTH SCIENCE LITERACY "BIG IDEAS"
Big Idea #6 (life evolves on a dynamic Earth…): 6.5, 6.9

THEME #3 - Oceanography 101 – Introduction to the bottom of the ocean

OVERVIEW

How big is the ocean? What are the different parts of the ocean (surface ocean, deep water, sediments, crust, hydrothermal vents, mid-ocean ridge)? How does the bottom of the ocean change (plate tectonics, hydrothermal circulation)? Why is the bottom of the ocean important? What are some unique features about the bottom of the ocean (cold, dark, high pressure, etc.)?

ACTIVITIES

Microbe Math

Ocean Features

Under Pressure

ONLINE MEDIA RESOURCES

NOAA Education Resources: Ocean Floor Features Collection (website with videos)
http://www.education.noaa.gov/Ocean_and_Coasts/Ocean_Floor_Features.html

The Ocean Floor Revealed by the Daily Conversation
http://www.youtube.com/watch?v=K8bIL9Ki2mQ

Scientists "See" Ocean Floor via Sonar by National Geographic
http://www.youtube.com/watch?v=-fAAxEIFeLU

Exploring Landscapes Beneath the Oceans: Student Activity by National Geographic (web activity)
http://www.nationalgeographic.com/geobee/study-corner/activity-2/

THEME #4 - Environmental Microbiology 101 – Introduction to the secret lives of microbes on Earth

OVERVIEW

Why study microbes in the environment, why is it important? What about microbes in the human 'environment' – any connections? What do microbes do in the environment? How do they get energy to grow? How abundant are microbes in different environments? How do we study microbes in the environment?

THEME #5 – Ocean Technology 101 – Robots and sensors and submarines, oh my!

OVERVIEW

How do we study the bottom of the ocean? We'll explore ships, subs, ROVs, sensors, and long-term observatories.

THEME #6 – Sampling the Seafloor – Introduction to sediment and rock coring

OVERVIEW

What are different kinds of sediments? What are different kinds of rocks? How do fluids move through sediments and rocks, and how do they change? How do we collect sediment and rock cores and fluid samples?

THEME #7 – Buried Alive – The "Intraterrestrials" below the Seafloor

OVERVIEW

What is an extreme environment? What is the "Deep Biosphere"? How much life is in the deep biosphere? What do we know about life in the deep biosphere? Where on Earth is the deep biosphere being studied? How do scientists study the deep biosphere?

THEME #8 – Generation Genome – An Introduction to DNA-based science

OVERVIEW

What is genetic information? What is a genome? What is a metagenome? How do we process genetic information? How do we use genetic information? What can we learn from studying microbial genomes?

THEME #9 – You are in Charge – Design your own expedition

OVERVIEW

What question do you want to know the answer to? Why do you think finding answers to these questions are important? What are your hypotheses? What observations have you made that you are basing your hypotheses on? How will you evaluate your hypotheses? What ocean do you want to go to? What ports do you suggest an expedition should leave from? What kind of environment do you need to sample? What kind of samples do you need to collect? What kind of equipment will you need (ships, coring devices, observatories, sampling devices, ROVs or subs, etc.)? What kind of experts do you need to bring along? What kinds of data will you collect, and how will you analyze them? How long will it take you to do all of this? How will you present your findings to the public?

Get to know a marine scientist

THEME 1

ADOPT A MICROBE
multi-disciplinary science curriculum

Meet Your Guide – Introduction to Beth Orcutt

First of all, what is the Adopt A Microbe project all about, anyway? Well, as a participant in this project, you will virtually "adopt" one of the awesome microbes featured in our Adoption Center. In case you are wondering, a microbe is a living organism that is so small that you can't see it with your naked eye - you need a microscope to see it. Other words for microbes that you might be familiar with are bacteria and microorganism. All of the microbes offered in the Adoption Center have an important role to play in the environment at the bottom of the ocean. Over the course of the next few weeks, you will learn all about the cool things your microbe can do while you conduct different science and art projects. You will learn how these microbes live their crazy lives at the bottom of the ocean, and hopefully you will also learn a little bit about what it is like to be a scientist, working on a big boat in the middle of the ocean for weeks at a time.

Maybe you are wondering why we are so interested in microbes living at the bottom of the ocean? What's the big deal?!? Well, did you know that there are more microbes living below the seafloor than there are anywhere else on Earth?!? There is so much (microbial) life down there, but we barely have any idea of who the microbes are and what they are doing! Unlike you and me, who need to breathe oxygen to get energy to live, microbes can "breathe" all sorts of weird things, like the iron found in rocks, or methane gas (also known as natural gas, or the stuff in cow farts), or rotten-egg smelling sulfide gas, to get energy to live. The activity of all of those microbes can have a big impact on the cycling of different elements, like carbon, in the ocean, so we need to study them to get a better understanding of what they are doing and how. By participating in this project, you will learn more about the ocean environment, about microbiology, and about cutting edge science at the bottom of the ocean – maybe you'll even be inspired to research some questions of your own! Along the way you will be flexing your learning muscles in pretty much every category of science - biology, chemistry, physics, engineering, and geology – while also getting a healthy dose of math and art.

LET'S GET STARTED!

When I say the word "SCIENTIST" – what are some of the first ideas, words, and thoughts that come to your mind? (Theme 1 Worksheet Question 1)

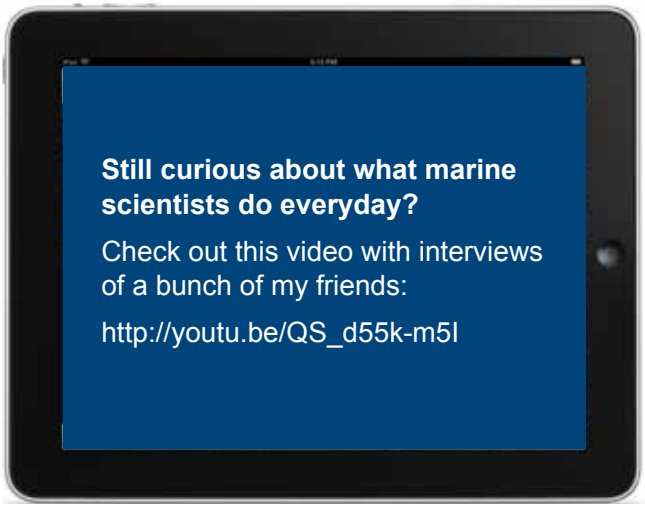
Maybe you thought of an Einstein look-alike – some strange person with disheveled white hair in a lab coat, pouring bubbling fluids from one flask into another. Or maybe you thought of someone more reserved and proper, with glasses and a pocket protector, carefully taking notes on a clipboard. Did you think of a person wielding a sledgehammer, ready to smash a big rock into small pieces while floating in the middle of the ocean on a giant ship? Or did you think of someone eagerly peaking out of a window in a submarine, looking at a colossal geyser on the seafloor, covered in eyeless shrimp and iridescent worms? Well, as a marine scientist, those are the kinds of things I get to do!

So who am I? My name is Dr. Beth Orcutt, and I am a research scientist at the Bigelow Laboratory for Ocean Sciences in beautiful Maine. I have a borderline obsessive interest in the vast variety of life found way down deep at the bottom of the ocean, and even below the seafloor, and I started this project as a way to get other people excited about life down there too. Once you go deep, you never go back! Working with my good pals at the Center for Dark Energy Biosphere Investigations at the University of Southern California and the Consortium for Ocean Leadership's Deep Earth Academy, and a cast of others, we've turned what once was just an Internet project during a research cruise into this package you are working with today.

As a marine research scientist, I have a pretty interesting job (well, I think so, at least). I spend much of my time trying to figure out how the unseen world at the bottom of the ocean operates, and what impact events happening way down there have on us humans way up here at the surface of the Earth. Luckily, I also get to do more than just think – I get to go visit some of these places! Sometimes I get to visit them in a submarine – like the Alvin. Other times I get to virtually visit them, using the remotely operated robots like *Jason* or with fancy sampling equipment like the giant ocean drilling ship the *JOIDES Resolution*. For all of these visits, I get to ride along on one of the scientific ships used for research in our oceans, spending a few days to weeks at sea. If I'm lucky, I will get to collect some one-of-a-kind samples from the bottom of the ocean that I can then take back to my lab to detailed studies.

Before I head out on any expedition, I have to do a lot of planning. A big part of that planning includes developing hypotheses about the questions I am interested in, and then coming up with a plan to evaluate those hypotheses.

To learn more about the process I use to conduct science and to evaluation hypotheses, check out the "How Science Works Poster" and the "Discovering Life Below the Seafloor" Activity.



Theme 1 Activity: Adopt A Microbe

Recommended Grade Levels: 2-7

SUMMARY/OVERVIEW

Students will "adopt" a microbe and learn about characteristics of microbial life and cellular structure.

TIME NEEDED

30 minutes

LEARNING OBJECTIVES

Students will be able to:

- Describe a subseafloor microbe,
- Classify a microbe,
- Describe the habitat of a microbe,
- Create a model of a microbe

MATERIALS REQUIRED

Construction material for making model microbes: balloons, modeling clay, pipe-cleaners, googly-eyes, etc.

Access to Adoption Center: http://www.darkenergybiosphere.org/adoptamicrobe/category/adoption-center/

BACKGROUND

Scientists looking for microbial life beneath the seafloor often sail on the magnificent JOIDES Resolution – a gigantic research vessel that is 143 meters (469 feet) long (longer than a football field!) with a drilling derrick that rises 62 meters (205 feet) above the water. This vessel will be their cozy home-away-from-home for the next two months. Unlike big luxury cruises that ply the Atlantic Ocean with tourists, swimming pools, dance clubs and game rooms (oh my!), their voyage will be heading for one spot in the middle of the Atlantic and then sitting there for weeks, drilling down into the seabed in search of new forms of life.

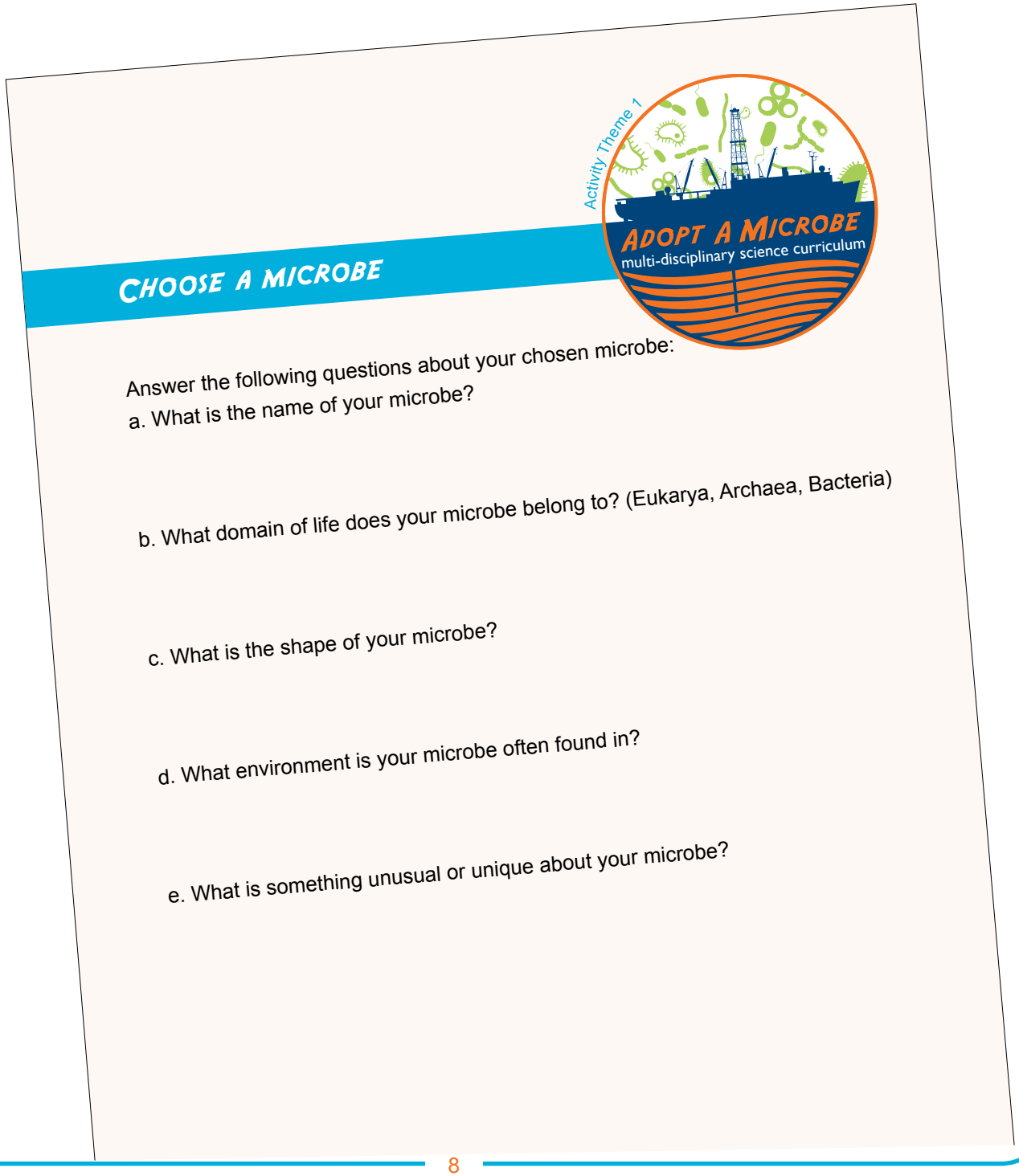
Using a giant drilling vessel is a rather crude way to investigate the seafloor, but it is currently one of the only tools available for collecting deeply buried samples. Sometimes, ocean scientists can also use high-tech cameras mounted on awesome submarines to explore the seafloor. Recently, many teams of scientists were exploring the seafloor of the Pacific Ocean, in search of new habitats and life around a recently erupted underwater volcano. There, new seafloor in the form of basaltic lavas had just been formed. Those scientists were very nice and posted some really amazing high-definition videos (http://ooicruises.ocean.washington.edu/visions11/video) on their website from their submersible dives. In them, you can see the bumpy new seafloor rocks, rusty crusts, hot water, weird animals, and so much more. For scientists, one of the coolest things of all is to imagine all of the microbes colonizing the rocks. There are probably bunches of cool iron eating bacteria – like Mariprofundus ferrooxydans in the Adoption Center - living in those rusty crusts! These microbes 'breathe' oxygen and iron to gain energy, and they produce very intricate twisted stalks of rust as they grow. Some scientists recently made some cool movies of these microbes – check them out on the web (http://onlinelibrary.wiley.com/doi/10.1111/j.1462-2920.2011.02567.x/suppinfo) to see really close up details of how the stalks are formed.

In this activity, students will select a Deep Biosphere microbe to "adopt," answer some questions about their microbes, and then make models of these microbes.

PROCEDURE

1. Give students a little time to select a microbe to adopt from the Adoption Center: http://www.darkenergybiosphere.org/adoptamicrobe/category/adoption-center/
2. Ask students to fill out the Microbe Adoption Student Page about their adopted microbe.
3. Based on the pictures of their microbes, have students make 3D models of their microbes, using balloons, modeling clay, or whatever materials you would like and

have available. Ask/tell students: Don't forget to accessorize your microbe! Does your microbe have flagella to help it swim? What could you add to your microbe to indicate flagella? Does your microbe make nanowire structures? What could you add to make nanowires? What about texture? If you would like your microbe to have eyes and a mouth, that's OK. If you want to get really fancy, you could also make a habitat for your microbe, by, for example, using foil or paper to make a hydrothermal vent. Be creative! If you need inspiration, here are some examples (https://sites.google.com/site/adoptamicrobe/project-updates/balloonmicrobes) that were made during past Adopt A Microbe projects.



Theme 1: Microbiology 101
Introduction to Microbes

Recommended Grade Levels: 2-7

Teacher Background

A microorganism, or microbe, is a microscopic organism (also known as something that you need a microscope to see) that comprises either a single cell (unicellular), cell clusters, or small multicellular organisms (see Figure #). The study of microorganisms is called microbiology, a subject that began with Anton van Leeuwenhoek's discovery of microorganisms in 1675, using a microscope of his own design.

Microbes can be found everywhere on Earth, even though we can't "see" them. In fact, there are approximately ten times more microbial cells in the human body than there are "human" cells, with most of those microbes on your skin or in your gut. We are more microbe than human (see "The secret, social lives of Bacteria" Youtube video)! Most microbes in your body are harmless, and some are even beneficial to your health and well-being. Some microbes in the body are pathogenic, however, meaning they cause infection and disease. Likewise, there are many microbes in the environment, where they are essential for recycling nutrients, consuming toxins and contaminants during "bioremediation" (sort of like biology fixing a chemical problem in the environment), and performing other essential "services" for mankind, which we will learn about more in another theme.

Although most people think of microbes as "Bacteria" only, microbes are actually found all across the "tree of life". The "tree of life" is divided into three domains - Bacteria, Archaea, and Eukarya. Bacteria and Archaea are almost always microscopic, but there are also microscopic eukaryotes including some protists, fungi, plants and even animals! Bacteria and Archaea are classified as Prokaryotes, defined as organisms that lack a cell nucleus and the other membrane-bound organelles found in eukaryotic cells. Almost all prokaryotes are invisible to the naked eye, with a few extremely rare exceptions, such as Thiomargarita namibiensis from the Adoption Center.

Although mostly unicellular, microbes exist in several different shapes and sizes, including spherical (coccus in Latin), rod-shaped (bacillus), comma-shaped (vibrio), or spirally (spirillum). Microbial cells are typically only a few micrometers in length and width, although some cells can be almost a millimeter in length (for comparison, a 5-foot tall human is 1,524,000 micrometers in length!).

Associated Activities

1) Pick a microbe to adopt

2) Answer questions about the microbes

3) Make a microbe model

Theme 2 Activity: Microbe Math

Recommended Grade Levels: 5-9

SUMMARY/OVERVIEW

Students will use data to make calculations and learn about the process of science and environmental microbiology.

TIME NEEDED

30 minutes

LEARNING OBJECTIVES

Students will be able to:

- explain how scientists conduct research at sea
- make several calculations related to microbes found in the ocean
- develop an appreciation of the huge numbers involved with studying microbes

MATERIALS REQUIRED

- Microbe Math Student Page
- Pencils, calculators

PROCEDURE

1. Explain to students that they will be using some microbe data to make calculations about microbes on the seafloor.
2. Distribute the Microbe Math student pages and give students time to work, either alone or in pairs, on the questions provided.
3. Bring the class back together to discuss what they discovered.

Microbe Math

Activity

Adopt a Microbe
multi-disciplinary science curriculum

Dr. Orcutt recently went on an oceanographic expedition to try to figure out which microbes are living in the hard rocky crust of the seafloor, and to understand what they are eating to survive and thrive. Although the oceanic crust is a huge undersea aquifer where microbes live, we know very little about them. By comparison, some clever scientists calculated that roughly 10 to the power of 30 (10^30, or 1 with 30 zeroes behind it) microbes are 'buried alive' in the deep oceanic sediments that blanket the rocky crust at the seafloor. That's a lot!

CALCULATION SET 1

If we consider that each microbe is, on average, 1 micrometer in diameter, and that there are 10^30 microbes in deep sediments, how long would a string of sediment microbes be if you placed them end to end? Remember that 1 micrometer is 10^-6 meters, or 0.000001 meters. Would this invisible string of microbes reach from the Earth to the Sun? Remember that the distance from the Earth to the Sun = 1 astronomical unit = ~1.5 x 10^8 kilometers or 1.5 x 10^11 meters.

In a way, the scientists on Dr. Orcutt's expedition were interested in knowing how long a string of microbes from the rocky oceanic crust would be in comparison to the string of sediment microbes. Are there more or fewer microbes living in the rocks at the bottom of the ocean? Are they the same types of microbes, or are they different? What are they doing? How does their little microbe life in the depths of the ocean affect our human lives way up on land? We want to know!

One way the scientists on that expedition tried to answer those questions was by installing tricked out experiments below the seafloor to carefully spy on the microbes in their environment. First, we installed what is basically a well into the seafloor, using the drilling ship *JOIDES Resolution*. We call these wells "CORKs", because it is kind of like placing a cork into a hole in the seafloor to keep the ocean water from above from mixing with the water from down below. Here is a link to a video that explains what a CORK is: http://www.youtube.com/watch?v=stqhtI-N7eg&list=FLvvTCRXplNk-Vtnfs6inqxg&index=3

On the inside of the CORK, scientists will place a long string of instruments to collect water samples from the fluids circulating through the oceanic crust. These instruments are called 'OsmoSamplers' because they are powered by osmotic membrane pumps. Here is a link to a video to show you what an OsmoSampler instrument string looks like: http://www.youtube.com/watch?v=-SNINUg6rz0

During our expedition, scientists installed a whole bunch of these OsmoSamplers below the seafloor. Prior to the cruise, the scientists had to spend a lot of time figuring out how many parts and materials would be needed for the experiments, so that everything could be ordered ahead of time and brought out to sea. Once they were out there in the middle of the Atlantic, they couldn't really head on over to the hardware store if they forgot something! Let's try some calculations to figure out how much stuff the scientists had to get.

CALCULATION SET 2

Each subseafloor experiment will require 10 different osmo pumps, 24 coils of Teflon tubing, and 3 coils of copper tubing. Considering that they installed nine different subseafloor experiments during their cruise, how many total pumps, Teflon coils and copper coils did they need? Next, if you consider that each coil contains 300 meters of spooled tubing, what is the total length in meters of Teflon and copper tubing that they needed? Finally, if each pump and coil requires two tubing fittings to connect to the other devices on the instrument string, how many total fittings did they need to bring?

The pictures on the left may help you to visualize what these different parts look like, and the videos linked above will also help.

CALCULATION SET 3

On average, one teaspoon full of deep, dark ocean water contains fifty thousand (50,000) microbes. Crazy, huh?! Ok, so the global volume of deep, dark ocean has roughly 200 sextillion teaspoons of seawater – that's 200,000,000,000,000,000,000,000 teaspoons, or 2 x 1023. So, roughly how many microbes are there in all of the deep, dark ocean?

CALCULATION SET 4

On the RV *JOIDES Resolution*, the cores that are used to collect samples of muddy sediment and hard rocks are roughly 9.5 meters long. How long is that in feet? How many cores could you fit end to end on an American football field? If a scientist can work on 10 cm of sample every 10 minutes, how long would it take a scientist to process a full football field length of core?

CALCULATION SET 5

On average, there are 120 people sailing on the RV *JOIDES Resolution* for each expedition. Each expedition usually lasts 60 days. Assuming that each person uses about 50 sheets of toilet paper a day, and that an average roll of toilet paper has 500 sheets, how many rolls of toilet paper does the ship have to carry to meet everyone's needs for the expedition?