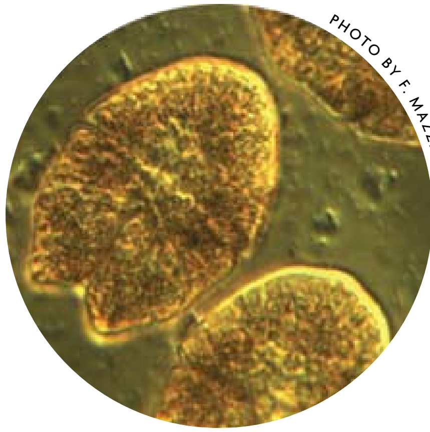
What Microbe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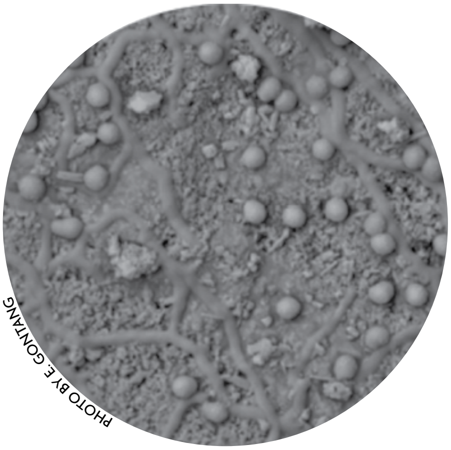
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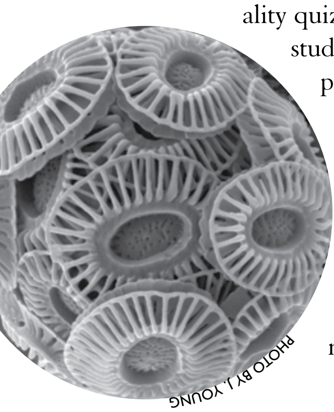
A personality quiz and modeling activity to build understanding of marine microbes

Kimberley Weersing, Jacqueline Padilla-Gamiño, and Barbara Bruno

Students—and just about everyone else—tend to have a wide range of misconceptions about microbes. In general, they think of microbes as germs, associated with disease and filth. They do not realize that life on Earth could not exist without microbes, nor do they appreciate how diverse and interesting microbes are.

This article is aimed at changing how students view microbes by engaging them in two hands-on activities that are fun and creative and align with both the National Science Education Standards (NRC 1996) and the Essential Principles of Ocean Literacy (NGS and NOAA 2006). By taking a microbe personality quiz and designing their own microbe models, students uncover the critical roles that microbes play in our environment.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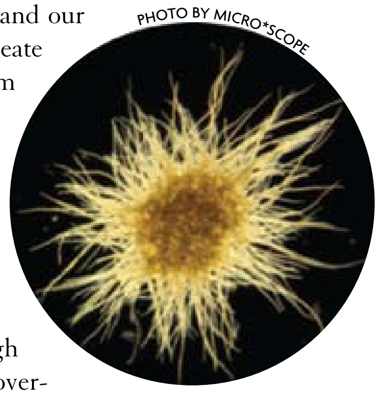
About microbes

Microbes are tiny organisms that are too small to be seen with the unaided eye. Also called *microorganisms,* microbes encompass a wide diversity of organisms—such as bacteria, fungi, archaea, protists, microscopic plants, and animals—that are generally unrelated except for their small size. Although they are tiny, they do big things for us and our environment. Microbes helped create the ozone layer that protects us from the Sun's ultraviolet rays; they also form the base of our food web. Virtually every other organism depends on microbes (either directly or indirectly) for food.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Microbes are found absolutely everywhere, in every land and ocean environment imaginable. Although some microbes can be harmful, the overwhelming majority are helpful. Life on Earth could not exist without them. This article focuses on marine microbes to increase awareness of their incredible diversity and their important roles in ocean ecosystems.

Marine microbes are Earth's biggest photosynthesizers: Like plants, they consume carbon dioxide and produce

FIGURE 1

Key concepts in microbial oceanography (C-MORE 2008).

1. Microbes significantly impact our global climate.
2. Marine microbes are very small and have been around for a long time.
3. Life on Earth could not exist without microbes.
4. Most marine microbes are beneficial.
5. Microbes are everywhere: They are extremely abundant and diverse.
6. There are new discoveries every day in the field of microbial oceanography.

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oxygen. In fact, marine microbes produce as much oxygen as all land plants combined (Field et al. 1998), and by consuming carbon dioxide (a greenhouse gas), they help regulate our global climate.

Interestingly, only a small percentage of marine microbes have been discovered (DeLong 2001), which means that a wealth of discoveries awaits scientists and endless opportunities exist to explore, inquire about, and study these fascinating and fundamental organisms.

Classroom activities

The activities presented in this article can be successfully integrated into high school biology, environmental science, and marine science classes. The first activity, the "What Microbe Are You?" personality quiz, attempts to change the way students view microbes by matching them to their "microbial soul mate"; in the process, students learn about the tremendous diversity of these creatures. The second activity, "Make a Microbe," focuses on microbial adaptations to the ocean environment and teaches key concepts about density.

These two activities can be combined into one lesson on microbial diversity, or used independently. Either way, we recommend introducing Key Concepts in Microbial Oceanography (Figure 1)—identified by the Center for Microbial Oceanography: Research and Education (C-MORE)—before or during the activities.

Are You?

What Microbe Are You?

The What Microbe Are You? personality test is a free, quick, and easy online activity that introduces students to microbial diversity (C-MORE 2008; see "On the web"). Students

FIGURE 2

What Microbe Are You? quiz.

In the first set of statements below, the bedroom refers to the level of microbial cellular complexity. If the student is well-organized, he or she will be matched to a eukaryote (a cell that contains complex structures enclosed within membranes); if the student is messy, he or she will be matched to a prokaryote (which lacks internal cellular organization and organelles).

For the second pair of statements, the choice of bunkbed refers to the likelihood of living in the upper part of the ocean or near the seafloor.

(**Editor's note:** These images are taken from the print version of the What Microbe Are You? quiz, available as a flipbook. A PDF of this flipbook is available online [see "On the web"].)

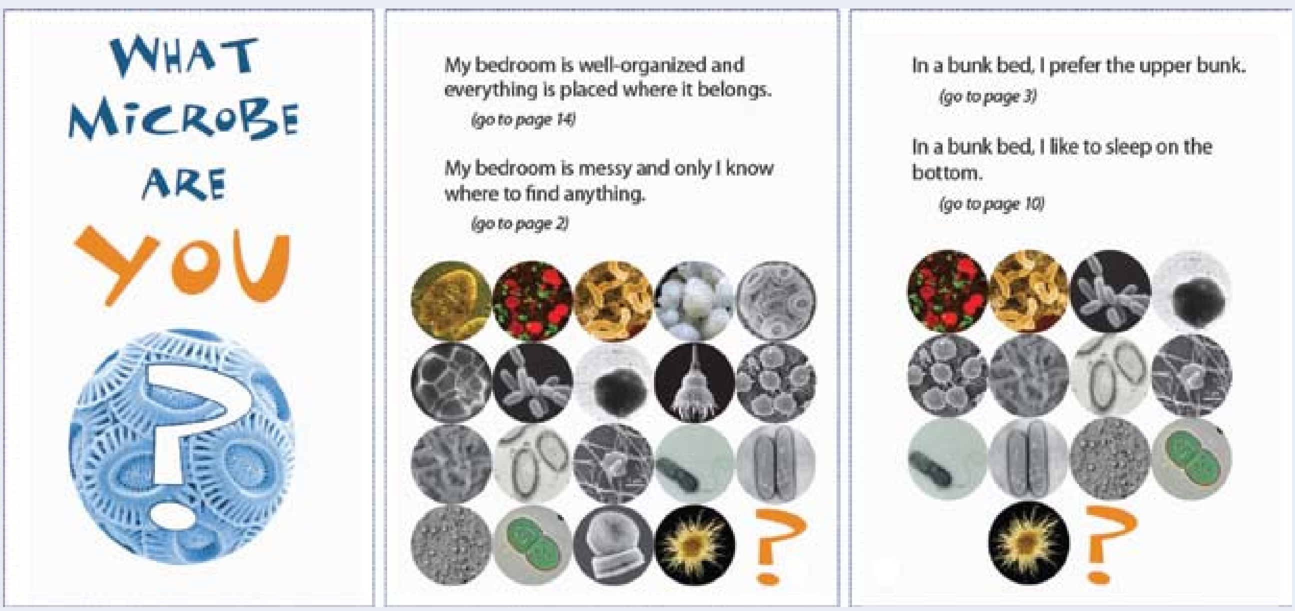
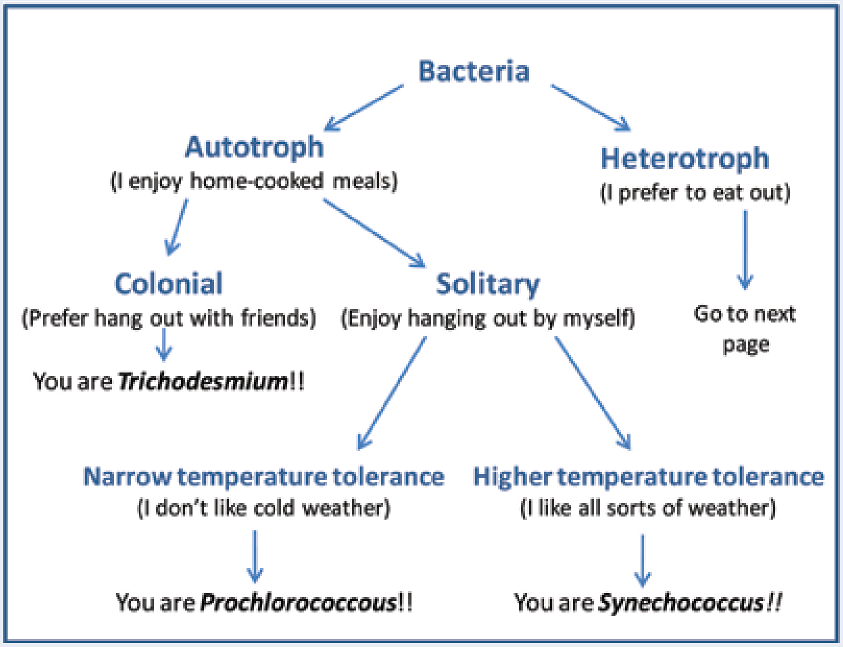


FIGURE 3

Dichotomous key.

This portion of the dichotomous key focuses on the bacteria section. The complete dichotomous key is available online (see "On the web").



Glossary of terms

Bacteria—one-celled organism that lacks cell organization

Autotroph—organism that produces its own food, often by photosynthesis
Heterotroph—organism that feeds on organic carbon

Colonial—organism that lives in groups
Solitary—organism that lives alone

Narrow temperature tolerance—organism that performs well under a limited range of temperatures; not as widely distributed
High temperature tolerance—organism that can cope with wider temperature ranges; generally has wider distribution

are presented with a series of either/or statements to help determine which microbe they most resemble (Figure 2, p. 41). These statements are linked to a dichotomous key that relates students' personality traits to those of a given microbe, such as cell organization, habitat, geographical distribution, physiological characteristics, and food-acquisition mechanisms.

In each pair of statements, students select the one that best describes them and are then routed to a new pair of statements, depending on their answer. In this fashion, students are guided through the dichotomous key, which matches them with their "microbial soul mate" and provides information about how they are similar to the marine microbe identified.

For example, a student who chooses "my bedroom is messy and only I know where to find anything"; "in a bunk-bed, I prefer the upper bunk"; "I enjoy home-cooked meals"; and "during my free time, I prefer to hang out with friends" will reach the following page:

> Yippee! You are *Trichodesmium erythraeum,* a.k.a. "Tricho"! Both you and this microbe tend to be somewhat messy (its cell contents aren't well-organized), and you both enjoy spending time with friends; Tricho forms colonies with other individual cells. Just as you like eating home-cooked meals, Tricho uses photosynthesis to make its own food. Under just the right conditions, cells can grow so rapidly that a bloom is formed that can be seen from space!

Teachers can share the dichotomous key (Figure 3) with students to discover how C-MORE scientists and educators characterize different marine microbes and incorporated them into this quiz (see "On the web"). Once students have identified their microbial match, these resources can stimulate discussion about how organisms are classified, the broad range of attributes that enable organisms to occupy various niches, and why particular adaptations improve an organism's chance for survival.

This is also a good opportunity to emphasize the fact that the ocean remains largely unexplored and that current microbial discoveries are helping us understand novel ways of how life in the ocean works. This truly is an exciting time to be a microbial oceanographer!

Make a Microbe

The Make a Microbe activity is designed to enhance students' creativity while teaching fundamental concepts about microbial diversity and density. This activity is based on "Sinking Races," a lesson developed by the Sea Education Association (SEA 1998).

We suggest that the teacher begin by explaining what phytoplankton (plant-like drifters) are and why they need to stay relatively close to the ocean's surface (see "What are

FIGURE 4

Sample pre- and posttest.

For each pair of sentences, circle the correct statement:

1. You can change a submerged object's ability to float only by changing its shape.
   You can change a submerged object's ability to float only by changing its weight.
2. Life on Earth could not exist without microbes.
   Life on Earth could exist without microbes.
3. We have discovered most of the microbes living on the planet.
   There are still many microbes that we do not know about.
4. Some microbes need sunlight.
   Sunlight is not necessary for any microbe.

PHOTOS BY RYAN KAGAMI AND MICHELLE HSIA

Microbe models with varying flotation.

phytoplankton?" p. 44). Then, discuss with students the potential dangers of living at the surface (e.g., greater exposure to predators and the Sun's ultraviolet rays) and the possible consequences these dangers pose for phytoplankton.

Next, explain that each student will receive arts-and-crafts materials to design and construct a microbe (e.g., one weight [nut or washer], one Styrofoam or Wiffle ball, paper clips, buttons, and beads). The goal is to make a microbe that has the ability to protect itself against predators *and* sinks slowly though the water column—this is because an organism tends to maintain its position at a specific depth (see photos).

Before distributing materials to the class, have students assess the density of the materials by placing them in a tub of water and observing whether they float, sink quickly, or sink slowly. Next, have the class brainstorm how materials can be combined or shaped to vary the density of their microbes. Students then work individually to design their own microbes.

For microbes that do not sink slowly, students can make appropriate adjustments and try again. This is a fun and valuable opportunity for students to be creative, develop ideas, and build and test their designs. (**Note:** See "On the web" for step-by-step instructions for this activity).

Activities assessment

We recommend using pre- and posttests as evaluation instruments to assess any changes in content knowledge or attitudes (Figure 4). These tests evaluate student understanding of microbes' importance for life on Earth and how microbes interact with the environment. These assessments serve as valuable tools for identifying and addressing misconceptions or gaps in understanding.

Creativity in action

The What Microbe Are You? and Make a Microbe activities have been successfully carried out in classrooms and during OceanFEST (Families Exploring Science Together), a free program for families in Hawaii (see "On the web"). Both of these popular activities spark imagination by enabling students and families to explore the mysterious world of marine microbes and learn about the important relationships between microbes and the environment—in a fun and innovative way. Creativity is an important skill to cultivate in our students, and these activities provide resources that encourage creative expression and provide students with the freedom to explore their ideas. ■

Addressing the Standards.

The activities presented in this article address both the National Science Education Standards (NRC 1996) and the Essential Principles of Ocean Literacy (NGS and NOAA 2006).

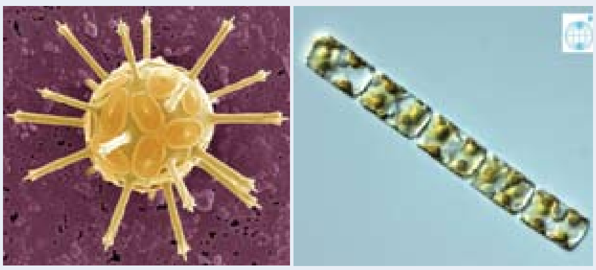
The Standards	Ocean literacy principles
Standard C: Life Science ◆ Biological evolution (p. 185) Standard D: Earth and Space Science ◆ Origin and evolution of the Earth system (p. 189) Standard E: Science and Technology ◆ Propose designs and choose between alternative solutions (p. 192)	Principle 4: The ocean makes Earth habitable (a, b) Principle 5: The ocean supports a great diversity of life and ecosystems (b) Principle 7: The ocean is largely unexplored (a, b)

What are phytoplankton?

In the ocean, plant-like organisms called *phytoplankton* form the base of the marine food web. These microbes serve as food for zooplankton and small fish, which in turn are eaten by larger fish, birds, and mammals. Thus, without phytoplankton, the entire marine food web would collapse (C-MORE 2008).

The word "phytoplankton" can be loosely translated as "floating plant." Like plants, phytoplankton harness the Sun's energy to convert water and carbon dioxide into carbohydrates and oxygen. This process, called *photosynthesis,* requires phytoplankton to stay relatively near the ocean surface: The deeper they go, the less sunlight is available. However, staying too close to the surface may expose these tiny plant-like organisms to predators and harmful damage from the Sun's ultraviolet rays.

Although some phytoplankton are capable of weak locomotion, they are not great swimmers and tend to simply float with the current. They are relatively immobile—so how do they remain in the right depth zone to maximize photosynthesis but prevent harmful damage? Let's take a closer look at some types of phytoplankton.



PHOTOS COURTESY OF MICRO*SCOPE

Coccolithophores (left) have hard shells and spines to protect them against predators. These spines also help with buoyancy. Diatoms (right) form chains, which help with buoyancy. Each cell is encased in silica (a major component of glass), which provides protection from predators.

Phytoplankton have a tremendous diversity of physical characteristics that aid in flotation or protection from predators. Some types of phytoplankton, such as coccolithophores (left), have long spines or bristles. Others, such as diatoms (right), form long chains, spirals, or circles. These adaptations influence their vertical position in the water column, allowing them to stay near their energy source—the Sun—and be protected from harmful predators.

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On the web

What Microbe Are You? personality quiz (online version in English and Spanish): *http://cmore.soest.hawaii.edu/education/kidskorner/ur_q1.htm*

What Microbe Are You? personality quiz (flipbook version), dichotomous key for teachers, and Make a Microbe Teacher's Guide with step-by-step instructions: *www.nsta.org/highschool/connections.aspx*

OceanFEST: *http://oceanfest.soest.hawaii.edu*

"Sinking Races" lesson plan: *www.sea.edu/academics/k12.aspx?plan=sinkingraces*

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