ZOO IN YOU:
THE HUMAN MICROBIOME
EL MICROBIOMA HUMANO

Teacher's
Resource Guide

OMSI

Table of Contents

SEPA SCIENCE EDUCATION PARTNERSHIP AWARD
Supported by the National Institutes of Health

Introduction

Who would ever have thought that the human microbiome would be such a media star? From articles in the *New York Times* to the *Economist*, from TED Talk videos to skits on the Colbert Report, from detailed infographics in *Scientific American* to hilarious comic strips on xkcd, the trillions of microorganisms that call your body home have certainly captured public attention. Perhaps this has to do with the inherent "gross factor"—we are, of course, delving into the teeming microscopic hordes that thrive in our boogers, and the concept of a fecal microbial transplant (aka "poop transplant") never fails to make an indelible impression.

There's more than just the gross factor at work here, though. As it becomes increasingly clear that the majority of the players in the human microbiome can be beneficial to human health, we start to realize that our bodies are rich and vibrant ecosystems. Picture the skin between your toes as a flowering prairie, or the surface of your tongue as an intricate coral reef. This concept likely sends your sense of wonder and awe at the complexity of your body's systems through the roof, and it also starts to illuminate how delicately balanced and potentially fragile our healthy body systems really are.

We've designed the exhibit experiences and hands-on programs of *Zoo in You* to capture that sense of wonder and the thrill of the gross and yucky, as well as to spark people's imaginations so they want to keep learning more. It's an honor to introduce you to these trillions and trillions of little friends that might not have been on your radar before. Have fun getting to know them better!

Exhibit Overview

Did you know trillions of microbes make their homes inside your body? In fact, these non-human organisms outnumber our human cells 10 to 1, “colonize” us right from birth, and are so interwoven into our existence that without each other, none of us would survive! Thanks to new sophisticated technology and the cutting-edge research of the National Institutes of Health’s Human Microbiome Project, we are just starting to discover what these microbes are up to and how they affect us.

And now in *Zoo in You*, a 2,000 sq. ft. bilingual (English and Spanish) exhibit funded by a SEPA grant from NIH, we can explore this fascinating and complex world inside us that is our microbiome—a dynamic, adaptable, and delicately balanced ecosystem much like any other found in nature. In *Zoo in You*, you’ll meet the good microbes that aid digestion or crowd out less friendly freeloaders and also the bad ones that may trigger disease. You’ll learn who our constant microbial companions are, where they live, how diverse they are, and in what ways scientists are discovering just how important they are to our personal health. You can explore this vibrant world of our inner microorganisms through engaging, interactive exhibits and programs such as a bilingual website and science cafes for adult audiences.

A full description of the exhibition and its component exhibits can be found on the OMSI *Zoo in You* website: https://programs.omsi.edu/professionals/traveling-exhibits/zoo-you-human-microbiome.

Tips for Engaging Girls in STEM

Tip 1: Feature female role models

If the activity is facilitated, include a female facilitator whenever possible. Feature women in graphics and displays near the activity. Showcase real female scientists. It's important for not just for the girls to see female role models, but also for boys and parents to see female scientists.

Tip 2: Make it social

Encourage discussion of the activity with friends or family. Set up activities so that more than one person can participate at a time. Consider assigning roles so that every visitor has an active role to play.

Tip 3: Engage the senses

Promote a multisensory experience with a variety of colors, sounds, smells, and textures. Make sure the activity table remains neat and aesthetically pleasing.

Tip 4: Tell a story

Engage participants during the activity by telling a story they can relate to. This could be the story of the person who discovered the technology in the activity or a story of someone who might use this technology. It could even be a fictional story to grab their interest.

Tip 5: Highlight altruism

Feature ways the technology in the activity has been used to help people, or ways that it may one day be used to help others.

Tip 6: Make it Personal

Find common connections between the activity and the everyday lives of girls. Ask girls where they would see or experience a similar phenomenon. Encourage them to tell you a story of when they saw something similar, or where they would imagine using a related product in the future.

Tip 7: Use inclusive language

Watch the pronouns you use. When speaking about a scientist, do you say "he" or "his"? Make pronouns gender neutral whenever possible.

Tip 8: Encourage creativity

Find ways to allow for creative self-expression in the activity. Invite girls to draw, paint, make, or act!

Tip 9: Make sure there are many "right" answers

Encourage open-ended investigations by finding ways for girls to explore, discover, and try ideas without any one single answer.

Lesson Plan Overview

The four lesson plans contained in this guide offer a concise, hands-on way to convey topics from the exhibit and build on some of the main themes of microbiology and the human microbiome. These lesson plans can be conducted in a classroom as well as after-school settings. All of the lesson plans were designed to incorporate simple, easy-to-find supplies whenever possible.

- **Debating Biology** calls on students to analyze moral questions related to current news stories about biology and biological medicine.
- **Edible DNA** provides a fun, colorful, and edible way for students to learn that our genetic code is assembled in a certain way.
- **Grow Your Mold** challenges learners to become scientists and make detailed, repeated observations of how mold grows on bread slices.
- In **Sequence Bracelet**, students use beads to assemble DNA jewelry according to the genetic codes of different bacteria.

One of the lesson plans in particular is intended for students as young as second grade: **Edible DNA**. The remaining three lesson plans – **Debating Biology, Grow Your Mold, and Sequence Bracelet** – are most appropriate for students in at least grade 5; **Debating Biology** can easily be used with high school or even college students.

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Everyday Encounters with Science

The Human Microbiome
ZOO in YOU
El Microbioma Humano

Debating Biology

Program Type: Classroom Program	***Audience Type:*** Grades 5–12
Program Length: 60 minutes	***Class Size:*** 15–30 students

Description: Students debate about ethics and morality related to biology and medicine in the current news.

Topics: Biology, ethics, current news, debating

Process Skills Focus: Communicating, comparing, interpreting data

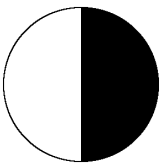
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- Students learn to debate complex questions about ethics, morality, and science in current news stories related to biology and medicine.

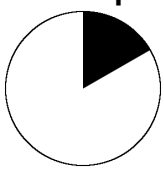
TIME REQUIRED

Advance Prep



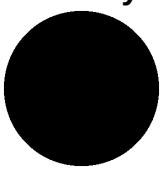
30 minutes

Set Up



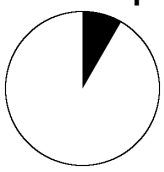
10 minutes

Activity



60 minutes

Clean Up



5 minutes

SITE REQUIREMENTS

- Internet and printer access (for Advance Preparation for the facilitator)
- Space for groups of students to stand at the front of the room
- Chairs for students to sit in and desks or work surfaces
- Access to a blackboard or whiteboard

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large Group Discussion	5 min
Individual Reading	Individual Activity	10 min
Debating Biology	Large Group Discussion	40 min
Wrap-Up	Large Group Discussion	5 min

SUPPLIES

Permanent Supplies	Amount
Stopwatch or other timekeeping device	1
Highlighters or colored markers	1 per student
Pens or pencils	1 per student

Major Consumables	Amount
Printouts of recent news articles relating to biology and medicine that highlight questions of ethics and morality	1–2 per student

ADVANCE PREPARATION

- Visit http://www.studentnewsdaily.com/ and click on "Tuesday's World Events" or visit http://www.microbeworld.org/news. Locate one recent news article relating to biology or medicine. For example:
  - Ivory Coast bans skin whitening creams, May 26, 2015
  - China shocks world by genetically engineering human embryos, May 5, 2015
- Print out the article, one copy for each student
- Read the article and brainstorm two ethics questions that begin with the word "should" (e.g., "Should the doctors have placed the sick patient in quarantine?")

SET UP

- Arrange student desks into groups of 3–4

INTRODUCTION

5 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

Today we'll be discussing how science can involve complex moral decisions. For instance, if a scientist discovers an amazing microbe in your nose that can cure diseases, should the scientist be able to sell that microbe to any pharmaceutical company and make lots of money? Should the scientist have to ask your permission first? Should the scientist have to share the profits with you?

Engage students in a short discussion about the morality of what the scientist should do.

This kind of debate raises questions about ethics and morals. "Ethics" refers to determining the rightness or wrongness of a particular situation. "Morals" refers to rules that govern our actions.

INDIVIDUAL ACTIVITY

Individual Reading

10 minutes

We've seen that science can involve some tough questions of what is ethically right. Now, we're going to examine a real science story that happened recently. All of you will have a chance to participate in a debate about this story.

This story is about _____ [summarize the study in a few sentences].

I'm now going to hand out a copy of this story to each of you. I'd like you to read this story and write down three questions about it related to ethics or morality. A good way to think of questions is to write down sentences starting with the word "should."

Write down two examples on the blackboard or whiteboard about ethics questions specific to this study (use the questions that you thought of earlier):

Should _____?
Should _____?

You can't use these questions – think of your own! You can write down your questions directly on the news article. You can also use a highlighter to indicate important parts of the article.

Hand out a copy of one of the news articles to each student, along with a pen or pencil and a highlighter or colored marker.

LARGE GROUP DISCUSSION

Debating Biology

40 minutes

In your groups, decide on one question that you think would make the most interesting debate topic. Choose this question from the pool of questions that you all wrote down individually.

After you've chosen one question discuss with your group possible answers to this question – both "yes" and "no." Try

to develop good arguments based on facts and the information provided in the article. Is there other information that you'd like to know to make a better argument? For example, if you're discussing allowing terminally ill patients to kill themselves perhaps you'd want to know what new drugs will be available in the future that might cure these diseases.

We're going to work together as a class to debate the questions that you chose. Each group will get a chance to stand up in front of the classroom and debate with another group. I'll be checking that everyone has a chance to speak, so don't be shy.

When you're debating it's important to be respectful and not interrupt anyone. Let's practice a debate with a silly topic: should I wear red or blue tomorrow? Who has a good reason why I should wear red? Who has a good reason why I should wear blue?

Engage the class in a debate for a few minutes.

We're now going to debate the questions that you chose. Each group will get a chance to stand up in front of the classroom and debate with another group. I'll be checking that everyone has a chance to speak so don't be shy. Remember to be respectful, too.

Ask two groups to come up to the front of the room. The groups should stand separated from one another and students should bring their copy of the news article with them. Ask another group, still sitting down, to read their question.

The students at the front of the room will now debate this question. One group (point to one group) will argue "yes" to the question and the other group (point to the other group) will argue no. Each group will have two minutes to present their debate.

Set your stopwatch for two minutes. After two minutes, allow the other group to speak. Permit each group an additional one minute to make rebuttal arguments about what the other group said.

Continue this process by calling up two new groups each time and selecting a third group to read its question.

WRAP-UP

5 minutes

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

Can anyone think of one of the debate questions that most of the class would probably agree on? Why? What are good ways for people to share their different opinions?

CLEAN UP

5 minutes

- Recycle the news stories and put away the pens and highlighters.

RESOURCES

News website[1] for students with background information and questions and website[2] devoted to news about microbes.

GLOSSARY

Vocabulary	**Definition**
Ethics	The principles that govern how someone should act
Morals	Beliefs about what actions are acceptable

Vocabulario	**Definición**
Ética	Principios que rigen la forma en que alguien debe actuar
Moral	Creencias acerca de las acciones que son aceptables

[1] http://www.studentnewsdaily.com/
[2] http://www.microbeworld.org/news

NEXT GENERATION SCIENCE STANDARDS

Practices

- Asking questions and defining problems
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Patterns
- Cause and effect

	Disciplinary Core Idea	K	1	2	3	4	5	MS	HS
Physical Science									
PS1	Matter and Its Interaction	n/a	n/a		n/a	n/a			
PS2	Motion and Stability: Forces and Interactions		n/a	n/a		n/a			
PS3	Energy		n/a	n/a	n/a				
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	n/a		n/a		
Life Science									
LS1	From molecules to organisms: Structures and processes			n/a					
LS2	Ecosystems: Interactions, Energy, and Dynamics	n/a	n/a			n/a			
LS3	Heredity: Inheritance and Variation of Traits	n/a		n/a		n/a	n/a		
LS4	Biological Evolution: Unity and Diversity	n/a	n/a			n/a	n/a		
Earth & Space Science									
ESS1	Earth's Place in the Universe	n/a			n/a				
ESS2	Earth's Systems		n/a						
ESS3	Earth and Human Activity		n/a	n/a					
Engineering, Technology, and Applications of Science									
ETS1	Engineering Design								

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Edible DNA

Program Type: Classroom activity	***Audience Type:*** Grades 2–5
Program Length: 60 minutes	***Class Size:*** 15–30 students

Description: Students assemble an edible model of DNA based on DNA sections from various microbes.

Topics: DNA, microbe, biology, helix, structure

Process Skills Focus: Classifying, communicating, formulating models

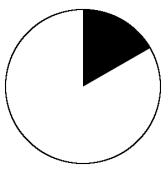
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- DNA is a molecule that contains the genetic code for living things.
- The structure of DNA is a double helix and its constituent parts pair in specific ways.

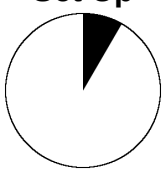
TIME REQUIRED

Advance Prep



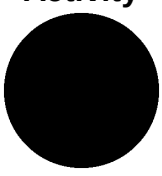
10 minutes

Set Up



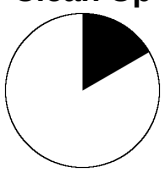
5 minutes

Activity



60 minutes

Clean Up



10 minutes

SITE REQUIREMENTS

- Desks or work surface tables
- Access to a sink with hand soap and paper towels
- Access to a blackboard or whiteboard

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large Group Discussion	20 min
Edible DNA	Group Activity	35 min
Wrap-Up	Large Group Discussion	5 min

SUPPLIES

Permanent Supplies	Amount
Deck of playing cards	1
Scissors	1
Black Sharpie® pen	1
Microbe DNA sheet (pages 24 or 25)	2 per 3–4 students

Major Consumables	Amount
Wax paper	1 25-ft roll (enough for 25 students to each have 1 foot)
Masking tape	1 roll
Red licorice ropes, approximately 20 cm (8”) long (e.g., Red Vines®)	2 per student
Gumdrops: red, green, blue*, and yellow **Substitute purple if necessary.*	Approx. 5 of each color per student
Toothpicks	10 per student

ADVANCE PREPARATION

- Cut a piece of wax paper (approximately 30 cm × 30 cm or 12” × 12”) for each student
- Print the microbe DNA sheets (pages 24 or 25), 2 per group of 3–4 students

SET UP

- Arrange student desks into groups of 3–4 desks

INTRODUCTION

20 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor’s benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

Welcome! Today we’ll be learning about biology and a special molecule that controls the genetic code of all living things. **Does anyone know what DNA is?**

DNA is what makes me me and you you. Every living thing has a unique code of DNA (except for identical twins, which have the same DNA). Your DNA causes you to have the looks that you do, such as your hair color, the size of your hands, and the length of your legs. DNA is located in every cell of your body.

Hold up one finger. Your DNA is in your finger.

Try to touch your tongue to your nose. Your DNA is both in your tongue and in your nose.

Now point to something in this room that isn’t alive, like a light bulb or your pen.

Do these things contain DNA? *No, DNA is only in things that are alive.*

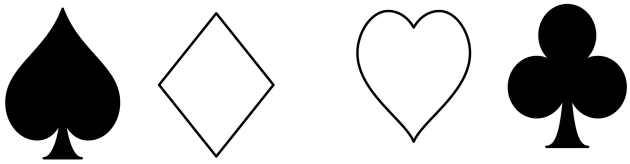
But now look at your pencil. It's made of wood that contains DNA!

We're now going to look at DNA in more detail. This molecule has four components, sort of like the four different types of cards in a deck of cards.

Hold up a few cards.

These cards are four different types: spades, diamonds, hearts, and clubs.

Draw these shapes on a blackboard or whiteboard and label them:



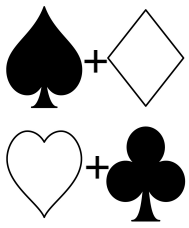
spades diamonds hearts clubs

You can think of the four components of DNA like these different cards. We're going to play a quick game to get you thinking about the four components of DNA.

Hand out one playing card to each student and keep one spade card for yourself.

The four components on DNA can bond together, but only in certain ways. Let's pretend that we're making DNA from our playing cards. Here are the rules:

Write these rules on the blackboard or whiteboard:



So, spades can only pair with diamonds, and hearts can only pair with clubs. These are the rules.

We'll start with my card, which is a spade.

Place the card on the ledge used for holding chalk or whiteboard markers.

Ask students in the order that they are sitting who has a diamond card. The first student who possesses a diamond card should come to the front of the classroom and place his/her card next to the first spade card.

We've now made the first pairing – spades and diamonds.

The next student should then place his or her card on the ledge, but separated from the first pair. Then, the next student who possesses a card that pairs with that card should come forward. Continue this process until the ledge is filled with pairs of cards.

If students are unable to play their cards, continue handing out cards.

GROUP ACTIVITY

Edible DNA

35 minutes

Now that we've finished seeing how playing cards can be matched together, we're going to explore how the different parts of a DNA molecule also match together. We'll be making an edible model of DNA, so you'll get to eat to what you make!

Since we'll be working with food today, everyone needs to wash his or her hands with soap and water.

Wait for students to wash their hands.

Hand out a piece of wax paper for each student.

This piece of wax paper is your work surface, so keep it clean. I'm now going to hand out pieces of paper that show the DNA of four different organisms. These organisms are called microbes and some of them are good for humans and some are not.

Microbes live in and on our noses, our intestines, our mouths, and on our skin. They're everywhere in us! Microbes have only one cell, so they're very tiny and we can't see them with our eyes. Some microbes help us stay healthy and some can make us sick. Some are even a mystery – scientists don't know what they do. When scientists are trying to learn what microbes live in our bodies, they look at the DNA of each microbe to figure out its identity. Just like other living things, microbes have unique patterns of DNA that let us identify them. By learning which microbes are in which parts of our bodies, scientists hope to find clues that let us understand how diseases like allergies, diabetes, and cancer could be detected early on or even prevented.

Hand out the microbe DNA sheets, 2 per group of students.

I'm handing out a page that shows pictures of four different microbes. Remember that these microbes are very tiny – you can't see them with your eyes! Everyone should choose which microbe they want to use for their edible model of DNA.

Look at your microbe's DNA. Do you see letters A, T, G, and C? These different letters represent different building blocks of DNA, like the different types of playing cards. These building blocks of DNA only pair together in certain ways.

Write these rules on the blackboard or whiteboard:

A + T
G + C

These pairing rules represent how DNA is assembled. You can think of these rules just like the rules for matching the playing cards.

Now, we'll be making models of these DNA sections using licorice and gumdrops. The licorice ropes [hold them up for the students to see] will represent the backone of the DNA molecule and the gumdrops [hold them up for the students to see] will represent the different building blocks of the DNA, the A, T, G, and C.

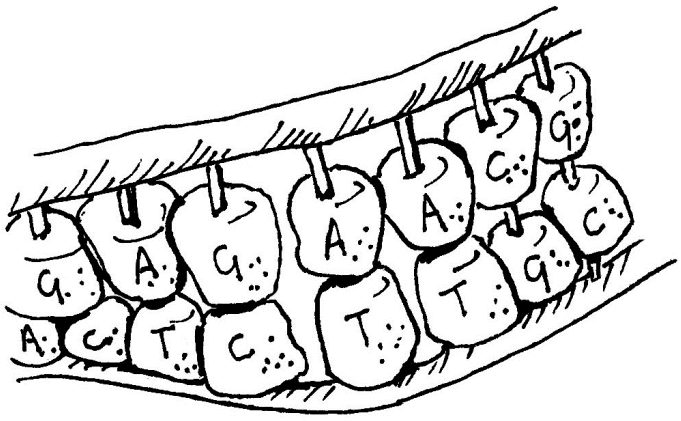
We'll assemble our DNA model using toothpicks. First, you need a key to tell you which gumdrop color represents A, which represents T, which represents G, and which represents C.

Write down the information on this blackboard or whiteboard:

A = green gumdrop
T = red gumdrop
G = yellow gumdrop
C = blue gumdrop

I'll show you how to start assembling your DNA section, and then each of you can model your own microbe's DNA.

Demonstrate pushing a toothpick through one of the licorice ropes, then through two gumdrops (of the correctly paired colors), and then through the other licorice rope.



Using your microbe DNA sheets for information create your own section of DNA using your licorice, gumdrops, and toothpicks.

Hand out two pieces of licorice to each student and a large handful of gumdrops and toothpicks to each group of students.

As the students are working, circulate the room to distribute additional gumdrops and toothpicks as needed and check on the progress of the students. At the same time, use the Sharpie® pen to write the name of each student on his or her piece of wax paper.

WRAP-UP

5 minutes

When you're finished making your model of DNA, twist your model like a spiral staircase. This structure is called a helix, and it's the same shape that real DNA has.

You can now eat one pair of gumdrops from your model. You'll take the rest of the model home to show your families.

Help the students wrap up their model in their sheet of waxed paper; seal the package with masking tape.

Instruct the students to wash their hands again, if necessary.

CLEAN UP

10 minutes

- Collect the playing cards.
- Dispose of leftover gumdrops and toothpicks.
- Collect microbe DNA sheets.

OPTIONAL EXTENSIONS

- Challenge students to think about how life can be so diverse on Earth (humans, dogs, worms, fleas, etc.) but still be composed of the same components of DNA. The students can look at their gumdrop models to realize that there are many, many ways in which the pairs of gumdrops can be arranged – this diversity in DNA patterns translates into the diversity of life we see!

BACKGROUND INFORMATION

Microbes are tiny organisms that live in and on our bodies. They help us digest food and maintain our healthy skin. Microbes have DNA, like all living creatures. Humans have DNA sequences as well, and over 99% of all human DNA is identical. The remaining 1% of our DNA is what makes us different: different skin colors, different heights, different hair colors, etc.

RESOURCES

What is DNA?[1] and information from Learn.Genetics at the University of Utah[2].

GLOSSARY

Vocabulary	Definition
Base pair	The building blocks of DNA; there are four different kinds: A=adenine, T=thymine, G=guanine, C=cytosine
DNA	Deoxyribonucleic acid; the molecule that controls the genetic code of all living things.
Helix	A three-dimensional spiral structure; DNA is arranged as two intertwined helixes.
Microbe	Single-celled organisms that live inside and on our bodies.

Vocabulario	Definición
Par de bases	Los componentes básicos del ADN; hay cuatro tipos diferentes: A = adenina, T = timina, G = guanina, C = citosina
ADN	Ácido desoxirribonucleico; la molécula que controla el código genético de todos los seres vivos.
Hélice	Una estructura tridimensional en espiral; el ADN está organizado en forma de dos hélices entrelazadas.
Microbio	Organismos unicelulares que viven en nuestros cuerpos.

NEXT GENERATION SCIENCE STANDARDS

Practices

- Asking questions and defining problems
- Developing and using models
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Patterns
- Systems and system models

[1] http://ghr.nlm.nih.gov/handbook/basics/dna
[2] http://learn.genetics.utah.edu/

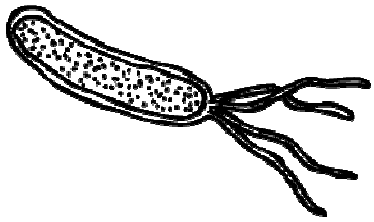
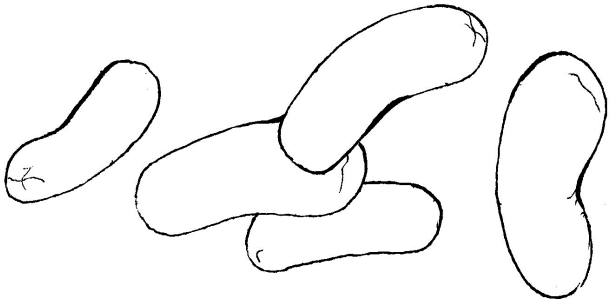
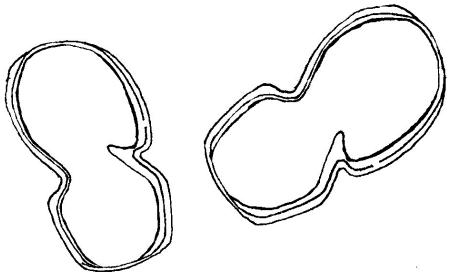
	Disciplinary Core Idea	K	1	2	3	4	5	MS	HS
Physical Science									
PS1	Matter and Its Interaction	n/a	n/a	✓	n/a	n/a			
PS2	Motion and Stability: Forces and Interactions		n/a	n/a		n/a			
PS3	Energy		n/a	n/a	n/a				
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	n/a		n/a		
Life Science									
LS1	From molecules to organisms: Structures and processes			n/a					
LS2	Ecosystems: Interactions, Energy, and Dynamics	n/a	n/a			n/a			
LS3	Heredity: Inheritance and Variation of Traits	n/a		n/a		n/a	n/a		
LS4	Biological Evolution: Unity and Diversity	n/a	n/a			n/a	n/a		
Earth & Space Science									
ESS1	Earth's Place in the Universe	n/a			n/a				
ESS2	Earth's Systems		n/a						
ESS3	Earth and Human Activity		n/a	n/a					
Engineering, Technology, and Applications of Science									
ETS1	Engineering Design								

DCI Grade Band Endpoints

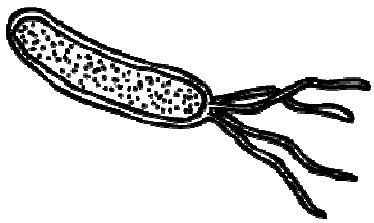
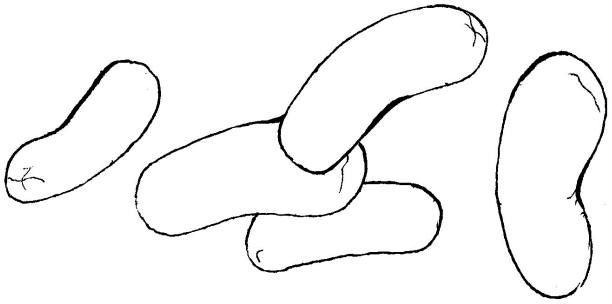
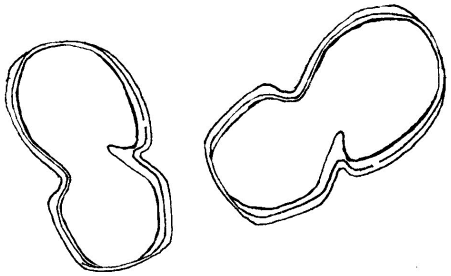
PS1.A *A great variety of objects can be built up from a small set of pieces (e.g., blocks, construction sets).* (By the end of grade 2.)

Performance Expectations

2-PS1-3 *Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.*

Heliobacter pylori *Might cause certain types of stomach cancers.* ATGCAAGAGT*	
Mycobacterium vaccae *Can affect your brain, reducing stress and depression.* GGGCTCGGCC	
Nitrosomonas eutropha *These bacteria break down your sweat, keeping you cleaner*. GAGTTTGATC	
Yersinia pestis *Causes deadly bubonic plague.* GTGAAAAACC	

*Just a small section of the DNA sequence, which contains over 2 million base pairs!

Heliobacter pylori *Puede causar algunos tipos de cáncer de estómago.* ATGCAAGAGT*	
Mycobacterium vaccae *Estas bacterias del suelo pueden afectar tu cerebro, reduciendo el estrés y la depresión.* GGGCTCGGCC	
Nitrosomonas eutropha *Estas bacterias descomponen tu sudor, manteniéndote más limpio.* GAGTTTGATC	
Yersinia pestis *Causa la mortal peste bubónica.* GTGAAAAACC	

*Sólo una pequeña sección de la secuencia de ADN, ¡contiene más de 2 millones de pares de bases!

Grow Your Mold

Program Type: Classroom Program	***Audience Type:*** Grades 5–8
Program Length: 60 minutes	***Class Size:*** 15–30 students

Description: Microbes grow all over your body. Investigate how quickly mold grows – not on you, but on slices of bread. Record your findings over two weeks using an observation journal.

Topics: Mold, variables, scientific method

Process Skills Focus: Observing, measuring, communicating, predicting

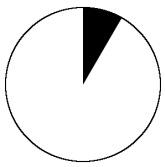
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- Tiny spores in the air develop into mold, a type of fungus.
- Molds grow at different rates depending on environmental conditions.

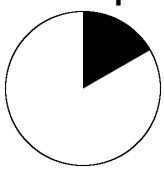
TIME REQUIRED

Advance Prep



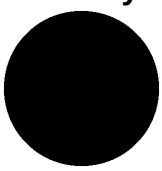
5 minutes

Set Up



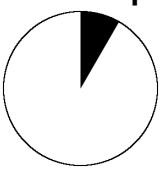
10 minutes

Activity



60 minutes (over 2 weeks)

Clean Up



5 minutes

SITE REQUIREMENTS

- Access to a water source
- Access to a whiteboard or blackboard
- An additional facilitator is helpful but not required

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large Group Discussion	3 min
Grow Your Mold	Individual Activity	55 min (over 2 weeks)
Wrap-Up	Large Group Discussion	2 min

SUPPLIES

Permanent Supplies	Amount
Pens	1 per student
Sprayer (for holding water)	1 (or 2 if 2 facilitators are present)

Major Consumables	Amount
Sliced white sandwich bread	3 slices per student
Ziplock®-like plastic bags, large enough to hold a slice of bread	3 per student
Masking tape	1 roll
"A Mold Journal" (pages 36 or 37)	1 per student

SAFETY PRECAUTION:
• Avoid breads with seeds or nuts given allergy considerations.

ADVANCE PREPARATION

- Print copies of "A Mold Journal," one for each student (English version on page 36; Spanish version on page 37).
- Plan to do the activity so students will be able to conduct observations every 5 days, if possible (days 5, 10, and 15).
- Fill the sprayer with water.

SET UP

- Place three plastic Ziplock®-like bags and three pieces of masking tape (about 8 cm (3 in) long) on each student's desk.

INTRODUCTION

3 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

We're going to be scientists studying mold. **What is mold?**

Mold is a type of fungus. There are many types of fungus in the world, including big, juicy mushrooms and tiny yeasts that help us bake bread. Mold is a fungus that sends tiny seeds into the air. That's right, there's fungus in the air, floating right here! These tiny seeds, which scientists call spores, can develop into the mold that we see with our eyes and smell with our noses.

Who has seen mold before? Where did you see it? What does mold look like?

Invite a few students to the blackboard or whiteboard to sketch a few molds that they have seen.

Mold can form on foods that are left too long in the refrigerator. Molds can be dangerous to eat, so be sure to throw out any food that you find with mold on it.

INDIVIDUAL ACTIVITY

Grow Your Mold

55 minutes, spread over 2 weeks
25 minutes today
10 minutes on day #5
10 minutes on day #10
10 minutes on day #15

Today we're going to start investigating how mold forms. Everyone will get to grow samples of mold, and then we'll investigate these samples using observations, just like scientists do.

We're going to conduct an experiment about mold to determine what conditions help mold grow.

Did you know that fungus even grows on your own body? That's right – mold spores can be found on your skin, in your noise, and in your mouth. And many types of yeasts, a tiny one-celled fungus, live in our mouths and guts. In fact, athlete's foot is caused by fungus growing between your toes! But today we'll be focusing on bread mold.

We'll be growing mold on these slices of bread (hold up a slice of bread). Each of you will receive three pieces of bread, and you'll have to decide how to conduct your mold experiment. You can choose to test one of two conditions: location or wetness. For example, you could place your bread slices in different locations like a windowsill that gets sunlight or under your desk. Or, you can add different amounts of water to your bread slices and see which slice develops the most mold. Your goal, as scientists, is to understand how mold grows in different conditions.

You can think of these different conditions as being similar to the different places on your body, like your wet mouth and your dry hand. Different kinds of microbes – fungus, bacteria, and viruses – like different temperatures, moisture levels, and light levels. **What parts of your body get the most sun? What parts of your body don't get much light?**

Stick one piece of tape on each of your plastic bags. We'll be writing down information on these pieces of tape about the conditions of each slice of bread. If I'm investigating how mold grows in different locations in the classroom, my pieces of tape might say:

Top of the bookshelf in the back of the classroom
Under the box where we keep crayons
On the blackboard tray

Write these phrases on the blackboard or whiteboard.

Or, if I'm testing how mold grows in different water conditions, my pieces of tape might say:

Bread totally dry
Bread sprinkled with water
Bread really wet

Write these phrases on the blackboard or whiteboard.

If I was testing different water conditions, I'd want to place all three of my bread slices in the same location, since I'm testing only differences in wetness.

We have a few rules here – you can only place your bread in locations in the classroom that won't disrupt our ordinary activities. So, putting the bread on the middle of your desk won't be allowed.

Hand out a pen to each student.

Write down what you'll be testing on each piece of tape. We'll put the bread inside of these bags and then conduct our experiment! Don't forget to write your name on each piece of tape as well!

Hand out three slices of bread to each student.

If you're going to explore how mold grows in wet and dry conditions, I'll bring you a water sprayer so I can make your bread wet. Raise your hand so I know to come by your desk. If you're going to place your bread in different locations you can place one of your

bread slices in each bag and then seal the bag.

Circulate the room to distribute water from the sprayer. *An extra facilitator is helpful during this step.*

We're now going to write down some information in our lab notebook, just like scientists do.

Hand out a copy of "A Mold Journal" to each student.

Write your name on the first line of this page and then write down whether you are testing different locations or different wetnesses.

Help the students to distribute their bags around the classroom, according to the locations that they wrote on the tape labels. Or, if students chose different wetnesses, help the students to place their pieces of bread in one location in the classroom. *An extra facilitator is helpful during this step.*

We're going to observe our pieces of bread on three different days, to see how the mold is growing. These three days will be _____, _____, and _____. Write these dates in your copy of "A Mold Journal."

We'll return to this investigation in about five days! For now, you can put your copy of "A Mold Journal" in a safe place.

<u>Observation 1 (+5 days in the future):</u>

It's now time to check on our bread slices! Find your copy of "A Mold Journal" and collect your three slices of bread. Do not open the bags – only observe the bread in the bag! Record what mold you see growing on the bread and make a sketch of each slice of bread. Also record a few notes of what you observe. **Is there mold? What does it look like? Which bread slice has the most mold on it?** When you're finished, return the bread slices to the same places they were before. Do not add water again if you added water the first time.

Observation 2 (+10 days in the future):

It's now time to check on our bread slices! Find your copy of "A Mold Journal" and collect your three slices of bread. Do not open the bags – only observe the bread in the bag! Record what mold you see growing on the bread and make a sketch of each slice of bread. Also record a few notes of what you observe. **Is there mold? What does it look like? Which bread slice has the most mold on it?** When you're finished, return the bread slices to the same places they were before. Do not add water again if you added water the first time.

Observation 3 (+15 days in the future):

It's now time to check on our bread slices! Find your copy of "A Mold Journal" and collect your three slices of bread. Do not open the bags – only observe the bread in the bag! Record what mold you see growing on the bread and make a sketch of each slice of bread. Also record a few notes of what you observe. **Is there mold? What does it look like? Which bread slice has the most mold on it?** When you're finished, return the bread slices to the same places they were before. Do not add water again if you added water the first time.

Our experiment about mold is now finished. **What did you learn about how mold grows?**

WRAP-UP

2 minutes

Which bread slices showed the most mold growth? Which showed the least? What other experiments would you like to run about how mold grows?

CLEAN UP

5 minutes

- Dispose of all the sealed bags containing the bread slices.

SAFETY PRECAUTION:
• Make that the students do not open the bags containing the moldy bread samples. All samples should be disposed of in the garbage at the completion of the experiment.

OPTIONAL EXTENSIONS

- Repeat the activity, this time allowing students to rub the bread on various surfaces before placing each slice in a bag. These surfaces could include a handrail, a bathroom door knob, the bottom of a kitchen sink, or even a student's hand!

BACKGROUND INFORMATION

Most foods will grow mold if left exposed to the air. Breads, fruits, and vegetables are all examples of substances that can grow impressive mold colonies, even if kept in the refrigerator.

This YouTube video[1] shows time-lapse photography of a molding watermelon.

RESOURCES

Information about mold[2] and a website[3] about different types of body fungus.

GLOSSARY

Vocabulary	Definition
Microbe	Single-celled organisms that live in and on our bodies.
Microbiome	The system of microbes that live in and on our bodies.
Mold	A type of fungus that grows from airborne spores.
Spore	Single-celled organisms.

Vocabulario	Definición
Microbio	Organismos unicelulares que viven en nuestros cuerpos.
Microbioma	El sistema de microbios que vive en nuestros cuerpos, fuera y sobre él.
Moho	Un tipo de hongo que crece a partir de las esporas en el aire.
Espora	Organismos unicelulares

[1] https://www.youtube.com/watch?v=S12zZhdOckc
[2] http://whatscookingamerica.net/Q-A/Mold.htm
[3] http://www.healthline.com/health/skin/candida-fungus#Overview1

NEXT GENERATION SCIENCE STANDARDS

Practices

- Asking questions and defining problems
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Stability and change

	Disciplinary Core Idea	K	1	2	3	4	5	MS	HS
Physical Science									
PS1	Matter and Its Interaction	n/a	n/a		n/a	n/a			
PS2	Motion and Stability: Forces and Interactions		n/a	n/a		n/a			
PS3	Energy		n/a	n/a	n/a				
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	n/a		n/a		
Life Science									
LS1	From molecules to organisms: Structures and processes			n/a					
LS2	Ecosystems: Interactions, Energy, and Dynamics	n/a	n/a			n/a			
LS3	Heredity: Inheritance and Variation of Traits	n/a		n/a		n/a	n/a		
LS4	Biological Evolution: Unity and Diversity	n/a	n/a			n/a	n/a		
Earth & Space Science									
ESS1	Earth's Place in the Universe	n/a			n/a				
ESS2	Earth's Systems		n/a						
ESS3	Earth and Human Activity		n/a	n/a					
Engineering, Technology, and Applications of Science									
ETS1	Engineering Design				✓	✓	✓		

DCI Grade Band Endpoints

ETS1.A	*Asking questions, making observations, and gathering information are helpful in thinking about problems.* (By the end of grade 2.)

Performance Expectations

3-5-ETS1-3	*Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.*

A Mold Journal

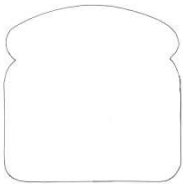
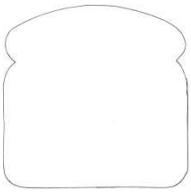
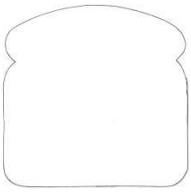
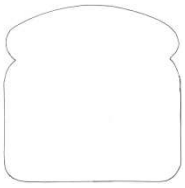
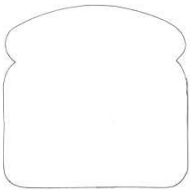
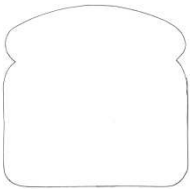
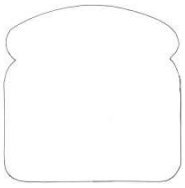
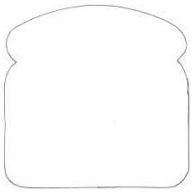
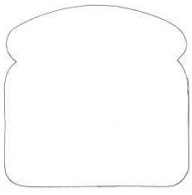
by _____

I investigated breads with different_____.

Slice #1 was _____.

Slice #2 was _____.

Slice #3 was _____.

Date: _____	Date: _____	Date: _____
Notes:	Notes:	Notes:
Sketches: #1  #2  #3 	Sketches: #1  #2  #3 	Sketches: #1  #2  #3 

Diario de Moho

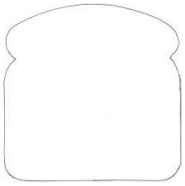
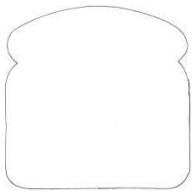
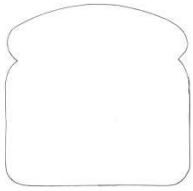
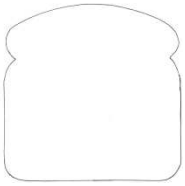
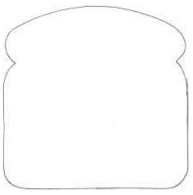
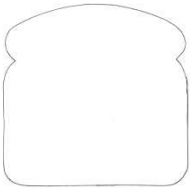
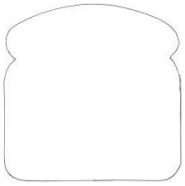
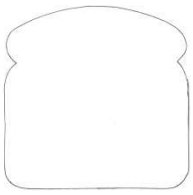
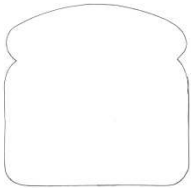
Autor: _____

Investigué panes con diferentes _____.

La rebanada #1 era _____.

La rebanada #2 era _____.

La rebanada #3 era _____.

Fecha: _____	Fecha: _____	Fecha: _____
Notas:	Notas:	Notas:
Bocetos:  #2  #3 	Bocetos:  #2  #3 	Bocetos:  #2  #3 

OMSI
Everyday Encounters with Science

The Human Microbiome
ZOO in YOU
El Microbioma Humano

Sequence Bracelet

Program Type: Classroom Program	***Audience Type:*** Grades 5–12
Program Length: 60 minutes	***Class Size:*** 15–30 students

Description: Assemble a beaded bracelet representing microbe DNA. Learn how the base pairs of DNA partner in specific ways.

Topics: DNA, microbes, base pairs, sequence

Process Skills Focus: Observing, communicating, classifying

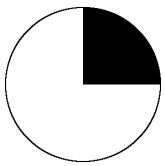
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- All living things contain DNA.
- The base pairs of DNA partner in specific ways.

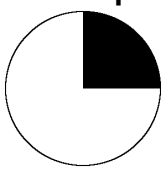
TIME REQUIRED

Advance Prep



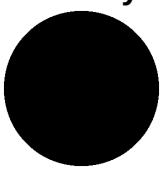
15+ minutes

Set Up



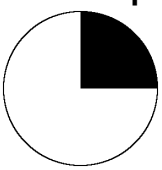
15 minutes

Activity



60 minutes

Clean Up



15 minutes

SITE REQUIREMENTS

- Standard size classroom with desks or other work surfaces
- Access to a blackboard or whiteboard (with ledge for holding markers)
- Access to water

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large Group Discussion	5 min
DNA Extraction	Instructor-led Demonstration	10 min
Sequence Bracelet	Group Activity	40 min
Wrap-Up	Large Group Discussion	5 min

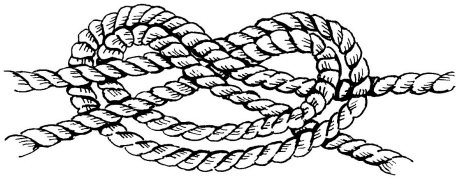
SUPPLIES

Permanent Supplies	Amount
Scissors	1
Printouts of microbe DNA sequences in either English or Spanish (pages 50 or 51)	2 per group of 3–4 students
Chalk or whiteboard markers	1
Tall, clear, narrow plastic cup	1
Plastic spoon	1
Pencil	1
Deck of playing cards	1
Disposable drinking cups	4

Major Consumables	Amount
Strawberry	1
Sealing plastic bag (e.g., Ziplock®)	1
Liquid dish soap	½ teaspoon
Pineapple juice	1 teaspoon
Bucket of ice, about 1 gallon	1
99% isopropyl alcohol	¼ cup
Bracelet cord (e.g., waxed linen, waxed cotton)	60 cm (24”) per student
Pony beads (assortment of green, red, blue, and yellow)	At least 25 per student
Disposable drinking cups	1 per student group
If using pasta instead of beads:	
Dried pasta (short, small tubes)	1 lb
Isopropyl alcohol	16 oz
Food coloring	4 bottles: green, red, blue, and yellow
Paper towels	1 roll
Disposable drinking cups	8

ADVANCE PREPARATION

- Print out the microbe DNA sequences (pages 50 or 51), two copies per 3–4 students
- Cut the bracelet cord into 30-cm (12-inch) lengths, two for each student.
- Tie an overhand knot around both strands, about 2 inches from one end:



- Place the ¼ cup of 99% isopropyl alcohol in the bucket of ice for at least 15 minutes
- Dilute the liquid soap with 1 teaspoon of water
- Place 75–100 pony beads of assorted colors into the disposable drinking cups, one for each student group (or follow directions below if using pasta)

If using pasta instead of beads, dye the pasta pieces different colors:

- Place the dried pasta in the 8 disposable drinking cups (fill the cups about 75%).
- Add rubbing alcohol to cover the pasta
- Add several drops of the green food coloring to the first disposable drinking cup and then the red, blue, and yellow food coloring to the remaining drinking cups. You'll end up with four different colors of pasta (2 cups of each color). Stir the pasta well.

- Let the cups sit undisturbed for 8 hours
- Drain the liquid and place the wet pasta on sheets of paper towels to dry for at least 2 hours
- Place 75–100 pasta pieces of assorted colors into the four remaining disposable drinking cups, one cup for each student group

SET UP

- Place the knotted pieces of bracelet cord on each student's desk.
- Arrange student desks in groups of 3–4

INTRODUCTION

5 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

Today we're going to be making art and learning about science at the same time. **Does anyone know what DNA is?**

Write "deoxyribonucleic acid" on a blackboard or whiteboard.

DNA is what makes me me and you you. It's a molecule that controls our genetics. Every living thing has a unique code of DNA (except for identical twins, which have the same DNA). Your DNA causes you to have the looks that you do, such as your hair color, the size of your hands, and the length of your legs. DNA is located in all of the cells of your body.

Hold up one finger. Your DNA is in your finger.

Try to touch your tongue to your nose. Your DNA is both in your tongue and in your nose.

Now point to something in this room that isn't alive, like a light bulb or your pen.

Do these things contain DNA? *No, DNA is only in things that are alive.* But now look at your pencil. It's made of wood that contains DNA!

DNA Extraction

10 minutes

INSTRUCTOR-LED DEMONSTRATION

We're now going to look at some real DNA from a strawberry. DNA molecules are tiny, and they are found within each cell of the strawberry plant.
We're first going to smash one strawberry so that we break apart its cells.

Place the strawberry in the sealing plastic bag and smash it gently to create a red-colored pulp.

Now we're going to add some dish soap, which helps to break open the cells to release the DNA.

Add one spoonful of the soap and water mixture to the bag and mix well.

We'll also add some pineapple juice, which helps to untangle the long strands of DNA.

Add one spoonful of the pineapple juice to the bag and mix well.

So, now we've broken open the cells with the soap and untangled the DNA with the pineapple juice. However, we still need to separate the DNA from the rest of the cells, which are mostly made of water. We'll use rubbing alcohol, which lifts the DNA out of the water.

Open the bag and pour all of the contents into the tall, clear, narrow plastic cup.

Retrieve the isopropyl alcohol from the ice bucket. Slowly pour the chilled alcohol carefully down the side of the narrow plastic cup, so that the alcohol gently comes to rest on top of the strawberry mixture. Keep pouring until approximately 3 cm (1 inch) of alcohol covers the strawberry mixture.

Set the cup aside for approximately 30 seconds.

Dip the pencil into the cup to retrieve the whitish clumps of DNA. Walk around the room to show the DNA to all of the students.

These whitish clumps that you see are strawberry DNA. DNA can also be extracted in a similar manner from other fruits, vegetables, and meats.

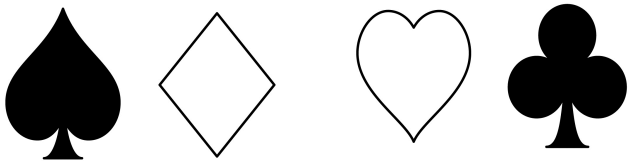
GROUP ACTIVITY

Sequence Bracelet

40 minutes

We're now going to look at DNA in more detail. This molecule has four components, sort of like the four suits in a deck of cards. Can anyone name one of the suits in a deck of cards? *Spades, diamonds, hearts, and clubs.*

Draw these shapes on a blackboard or whiteboard:



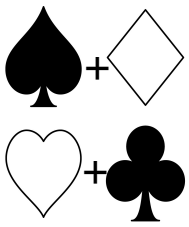
spades diamonds hearts clubs

You can think of the four components of DNA like these suits. We're going to play a quick game to get you thinking about the four components of DNA.

Hand out one playing card to each student and keep one spade card for yourself.

The four components on DNA can bond together, but only in certain ways. Let's pretend that we're making DNA from our playing cards. Here are the rules:

Write these rules on the blackboard or whiteboard:



So, spades can only pair with diamonds, and hearts can only pair with clubs. These are the rules.

We'll start with my card, which is a spade.

Place the card on the ledge used for holding chalk or whiteboard markers.

Ask students in the order that they are sitting who has a diamond card. The first student who possesses a diamond card should come to the front of the classroom and place his/her card next to the first spade card.

We've now made the first pairing – spades and diamonds.

The next student should then place his or her card on the ledge, but separated from the first pair. Then, the next student who possesses a card that pairs with that card should come forward. Continue this process until the ledge is filled with pairs of cards.

If students are unable to play their cards, continue handing out cards.

Now let's use this same idea of pairing and look at real DNA.

I'm handing out some diagrams showing DNA sequences from tiny organisms called microbes that live in and on our

bodies. Microbes live in our noses, our intestines, our mouths, and on our skin. They're everywhere in and on us! Microbes have only one cell, so they're very tiny and we can't see them with our eyes. Some microbes help us stay healthy and some can make us sick. Some are even a mystery – scientists don't know what they do. When scientists are trying to learn what microbes live in our bodies, they look at the DNA of each microbe to figure out its identity. Just like other living things, microbes have unique patterns of DNA that let us identify them. By learning which microbes are in which parts of our bodies, scientists hope to find clues that let us understand how diseases like allergies, diabetes, and cancer could be detected early on or even prevented.

Hand out a diagram and a handful of beads to each student group.

We're going to use our knowledge from the playing card activity to assemble bracelets that represent the DNA codes of these microbes.

First, decide which microbe you'd like to focus on.

Look at your microbe's DNA. Do you see letters A, T, G, and C? These different letters represent different building blocks of DNA, like the different types of playing cards. These parts of DNA only pair together in certain ways.

Write these rules on the blackboard or whiteboard:

A + T
G + C

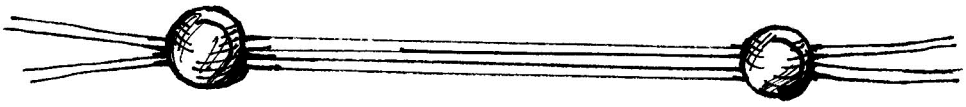
We'll be assembling beaded bracelets that represent a microbe's DNA sequence. Each bracelet will contain two strands of beads, just like the building blocks of DNA are paired. Here is our color matching key.

Write down this information on the blackboard or whiteboard:

A = green bead
T = red bead
G = yellow bead
C = blue bead

Pick up the two pieces of cord that are on your desk. You'll be stringing the beads on these strands. On the page that lists the microbe's DNA, you'll see a list of T, A, G, and C letters. This pattern will form one strand of the bracelet. Then, you'll make another strand of the bracelet using the matching letters. So, for example, stringing T on the first strand means that you should string A on the second strand.

Circulate around the room to help the students string their two strands of beads. Some students will string both stands simultaneously and other students will finish one strand before starting the other; both techniques work well. When the students have finished stringing the two strands, tie another overhand knot when the beads end:



WRAP-UP

5 minutes

Challenge students to think about how life can be so diverse on Earth (humans, dogs, worms, fleas, etc.) but still be composed of the same components of DNA. The students can look at their beaded bracelets to realize that there are many, many ways in which the beads can be arranged – this diversity in DNA patterns translates into the diversity of life we see!

CLEAN UP

5 minutes

- Gather up beads (or pasta) and collect the printouts of microbe DNA sections. Return the playing cards to their box.

OPTIONAL EXTENSIONS

- Students can make another bracelet based on the DNA of a different microbe.

References

BACKGROUND INFORMATION

Microbes are tiny organisms that live in and on our bodies. They help us digest food and maintain our healthy skin. Microbes have DNA, like all living creatures. Humans have DNA sequences as well, and over 99% of all human DNA is identical. The remaining 1% of our DNA is what makes us different: different skin colors, different heights, different hair colors, etc.

RESOURCES

Introduction to DNA[1]

GLOSSARY

Vocabulary	Definition
Base pair	The building blocks of DNA; there are four different kinds: A=adenine, T=thymine, G=guanine, C=cytosine
DNA	Deoxyribonucleic acid; the molecule that makes up the genetic code of all living things.
Microbe	Single-celled organisms that live inside and on our bodies.

Vocabulario	Definición
Par de bases	Los componentes básicos del ADN; hay cuatro tipos diferentes: A = adenina, T = timina, G = guanina, C = citosina
ADN	Ácido desoxirribonucleico; la molécula que controla el código genético de todos los seres vivos.
Microbio	Organismos unicelulares que viven en nuestros cuerpos.

[1] http://www.genome.gov/25520880

NEXT GENERATION SCIENCE STANDARDS

Practices

- Asking questions and defining problems
- Developing and using models
- Analyzing and interpreting data
- Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Patterns
- Scale, proportion, and quantity

	Disciplinary Core Idea	K	1	2	3	4	5	MS	HS
Physical Science									
PS1	Matter and Its Interaction	n/a	n/a		n/a	n/a			
PS2	Motion and Stability: Forces and Interactions		n/a	n/a		n/a			
PS3	Energy		n/a	n/a	n/a				
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	n/a		n/a		
Life Science									
LS1	From molecules to organisms: Structures and processes			n/a					
LS2	Ecosystems: Interactions, Energy, and Dynamics	n/a	n/a			n/a			
LS3	Heredity: Inheritance and Variation of Traits	n/a		n/a		n/a	n/a		✓
LS4	Biological Evolution: Unity and Diversity	n/a	n/a			n/a	n/a		
Earth & Space Science									
ESS1	Earth's Place in the Universe	n/a			n/a				
ESS2	Earth's Systems		n/a						
ESS3	Earth and Human Activity		n/a	n/a					
Engineering, Technology, and Applications of Science									
ETS1	Engineering Design								

DCI Grade Band Endpoints

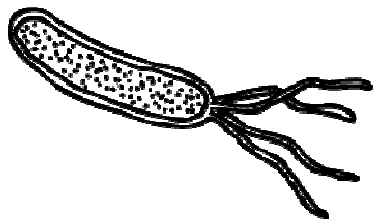
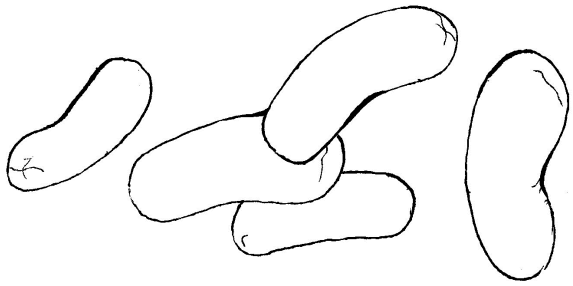
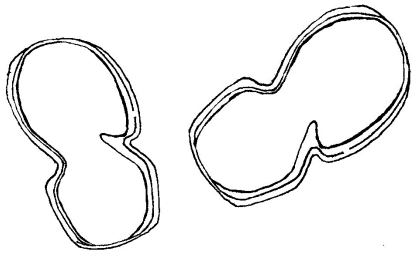
LS3.B *The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes.* (By the end of grade 12.)

LS4.A *DNA sequences vary among species.* (By the end of grade 12.)

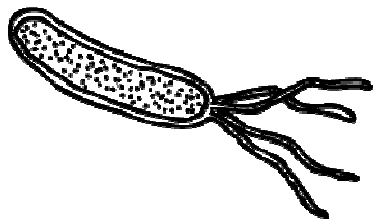
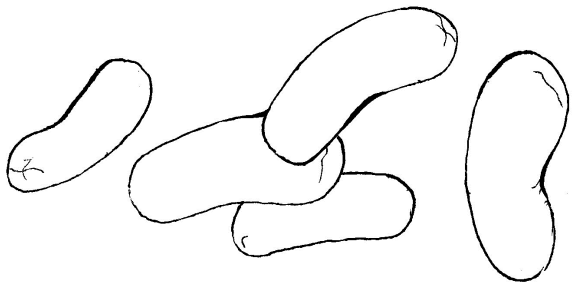
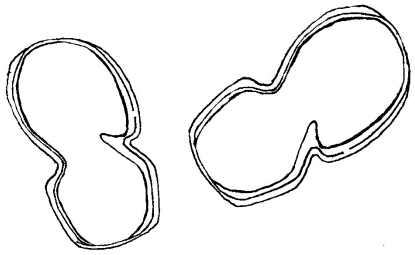
Performance Expectations

HS-LS3-1 *Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.*

HS-LS4-1 *Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.*

Heliobacter pylori *Might cause certain types of stomach cancers.* ATGCAAGAGTTTTTAGGTTTTGGTGTGGTGGGGAAT*	
Mycobacterium vaccae *Can affect your brain, reducing stress and depression.* GGGCTCGGCCGACTCGTCCGGGTCGGCGCCGCCG	
Nitrosomonas eutropha *These bacteria break down your sweat, keeping you cleaner*. GAGTTTGATCCTGGCTCAGATTGAACGCTGGCGGCA	
Yersinia pestis *Causes deadly bubonic plague.* GTGAAAACCTTCCCGATGCCTATTCGGTATTCCCT	

*Just a small section of the DNA sequence, which contains over 2 million base pairs!

Heliobacter pylori *Puede causar algunos tipos de cáncer de estómago.* ATGCAAGAGTTTTTAGGTTTTGGTGTGGTGGGGAAT*	
Mycobacterium vaccae *Estas bacterias del suelo pueden afectar tu cerebro, reduciendo el estrés y la depresión.* GGGCTCGGCCGACTCGTCCGGGTCGGCGCCGCCG	
Nitrosomonas eutropha *Estas bacterias descomponen tu sudor, manteniéndote más limpio.* GAGTTTGATCCTGGCTCAGATTGAACGCTGGCGGCA	
Yersinia pestis *Causa la mortal peste bubónica.* GTGAAAACCTTCCCGATGCCTATTCGGTATTCCCT	

*Sólo una pequeña sección de la secuencia de ADN, ¡contiene más de 2 millones de pares de bases!