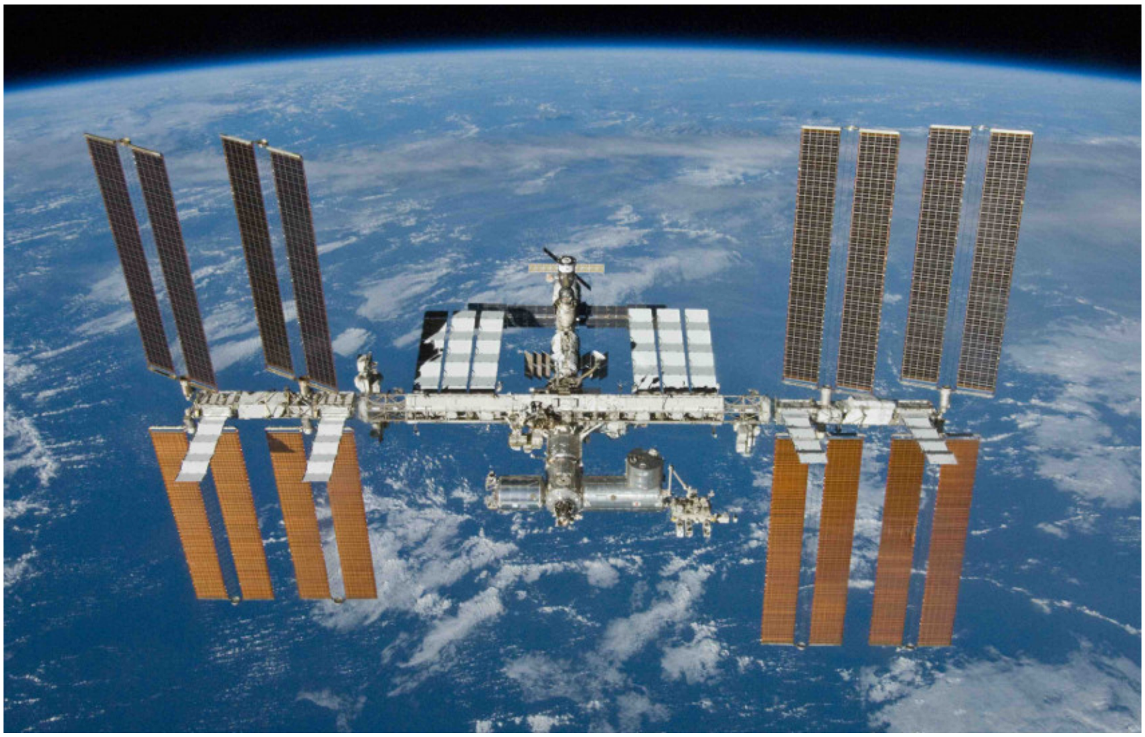
Project MERCCURI Educator Guide



http://www.spacemicrobes.org

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Credits:
This document was compiled and written by Debbie Biggs and Dr. David Coil.

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Project MERCCURI Overview

What are microbes?
"Microbes" are tiny organisms that usually cannot be seen without the aid of a microscope. While small in size, they are abundant everywhere imaginable on earth. Microbes have been found living in environments ranging from freezing cold to searing heat to the bottom of the ocean… even in radioactive waste! In addition to these extreme environments, microbes basically cover every surface around you, and are found on and inside your body.

While some microbes get a bad rap as "germs", the truth is that the overwhelming majority of microbes on the earth either have no effect on human health or are in fact beneficial. We could not exist without microbes. For example they help our bodies develop properly and they help digest much of our food.

There are millions of species of microbes on the planet and in fact they represent most of the biodiversity on earth. There are many ways to classify them, but microbes can be divided into four common types: Archaea, Bacteria, Microbial Eukaryotes, and Viruses**.**

- **Archaea** - These bacteria look-alikes were originally thought to be bacteria until modern DNA analysis showed them to be an entirely separate branch of life. While Archaea are found in mundane locales, they also thrive in extreme environments, such as hot thermal vents, under conditions with no oxygen, or in highly acid environments. No member of this group has ever been shown to cause human disease.

- **Bacteria** - Bacteria are what most people typically think of when they think of microbes. These include pathogens ranging from the well-known MRSA (methicillin-resistant *Staphylococcus aureus*) to the more exotic, such as *Mycobacterium leprae*, which causes leprosy. However, the vast majority of bacteria do not cause disease and many are quite beneficial. The include the bacteria required for making yogurt/cheese/beer, those required for composting, and even digesting food in the human body

- **Microbial Eukaryotes –** "Eukaryotes" are all those organisms (like plants and animals) that keep their DNA inside a special compartment called a nucleus in the cell. The most famous microbial eukaryotes are probably fungi. Fungi are critical for the health of most natural environments and are employed by humans for such irreplaceable functions as making bread, beer, and penicillin.

- **Viruses** - Viruses are made up of genetic material surrounded by some kind of protective covering. Viruses are not usually considered to be alive and they cannot replicate unless they are inside another living cell. While most famous for causing disease, viruses can also help control some bacteria and have played an important role in the evolution of more complex organisms.

Project MERCCURI Introduction

Project MERCCURI (Microbial Ecology Research Combining Citizen and University Researchers on ISS - the International Space Station) is a project designed to link studies on Earth of microbes found in and on buildings and other human constructions to studies of microbes on board the biggest building ever built in space - the ISS. The "links" we aim to make come from a combination of research and outreach goals. From a research point of view we are interested in two main topics - (1) how microbial diversity on the ISS compares to sites on Earth and (2) how different microbes are affected by growth in microgravity. Though in theory we could have made some progress in such experiments all by ourselves, we have linked this work to microbial education and outreach by engaging the public in helping to carry out both research projects. Thus this is what is known as a "Citizen Science" project. For this project we have recruited the public's help by having people collect "swabs" of microbe-containing surfaces to compare to each other and to the ISS. These swabs have also been used to grow the microbes that are being used for the microgravity experiments.

Project MERCCURI Goals

Goal One: *Determine the effects of microgravity on the growth rate of Earth-collected microbe samples.*

SciStarter.com and the Science Cheerleader organization engaged citizen scientists across the country to collect surface samples at sporting events, national historic sites, and schools. A large variety of microbes were grown from these samples and then identified at the Eisen Lab located at the University of California (UC) - Davis. Results from previous experiments done by others that have flown in space have shown that some microbes grow differently than they do on Earth. Therefore, 48 of these selected microbes will fly on the ISS where their growth rates will be compared with an exact duplicate of the experiment on the ground. The goal is to better understand microbial growth mechanics and the effects of microgravity on different microbes. Information gained from experiments like this help scientists understand microbe growth in closed-loop environments. This is potentially important for maintaining crew health in environments such as the ISS and for long-duration human spaceflights to Mars.[1]

Image Credit: Science Cheerleaders

[1] http://microbe.net/microbiomes-of-the-built-environment-network-microbenet/project-iss-microbiome-collaboration-with-science-cheerleaders/microbial-playoffs-in-spaaaace/, retrieved November, 2013.

Goal Two: *Collect and examine microbial populations found on high-touch surfaces within the ISS.*
Astronauts onboard the ISS will collect microbial samples of surfaces similar to those that were used on Earth. These samples will be returned to Earth for analysis using identical methods from the ground-based collection. Researchers will be able to compare the results from the ground-based samples to the ISS samples and identify any similarities and differences.

Goal Three: *Collect 4000 microbial community samples around the country to help understand the biogeography ("who is where?") of microbes and to compare to the results in Goal Two.*
SciStarter.com and the Science Cheerleader organization engaged citizen scientists across the country to use the venues of professional and youth sporting events, as well as homes and school classrooms, for the collection of samples of microbial populations. Citizen scientists in attendance at youth or professional football or basketball games were provided swab sample kits and asked to sample the microbes on their cell phones and the bottoms of their shoes.

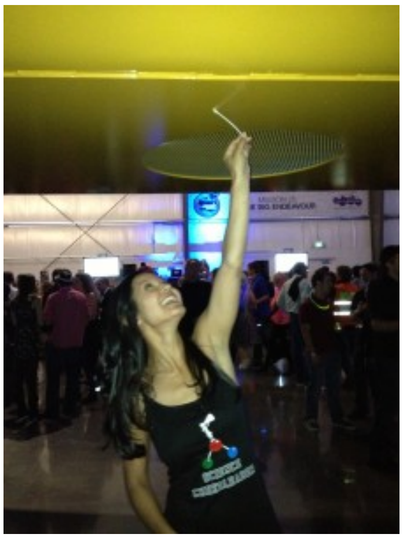
Image Credit: Science Cheerleaders

The cell phone and shoe samples were sent to Argonne National Laboratory where they were sequenced and added to the public Earth Microbiome Project (http://www.earthmicrobiome.org/). The Earth Microbiome Project is a systematic attempt to characterize the global microbial taxonomic and functional diversity for the benefit of the planet and humankind.

Goal Four: *Engage citizen and student scientists in this study.*
The public participation in this experiment was important in collecting a wide-range of samples to be analyzed. From the beginning, the research team was committed to raising the microbial education awareness of the general public. To maintain the integrity of the experiment, the research team developed and implemented a consistent methodology for collecting the public venue samples and encompassed the full experimental protocol.


Image Credit: Science Cheerleaders

Participants will get feedback on how well their samples are doing onboard the ISS. For example, there will be a "playoff" competition between samples from different venues. Awards will be given in three different categories:

- **"Best Sprinter** - For the microbial competitor who can grow the fastest during the sprinting portion of growth (technically known as the "exponential growth phase").
- **Best Huddle** - For the microbial competitor who can grow to the highest density… really packing those cells into the space allowed.
- **Best Tip Off** - For the microbial competitor who takes off growing like crazy from the start."[2]

Project MERCCURI Results
"Project MERCCURI is an extension of ongoing research conducted at UC Davis on the microbial ecology of the built environment. This research examines the type of microbes that surround humans all of the time, in buildings where we work and live in and on the surfaces we touch. Much is understood about the "bad microbes" or pathogens that can make us ill, but little has been done to characterize the rest of the microbial environment at the DNA level.

The purpose of this activity is to compare the general microbial make-up (population distribution) of microbes collected from large, public venues (including various NBA and NFL stadiums as well as college and high school sports venues) with the microbial population on the International Space Station (a very controlled, closed environment). The research team hopes to build towards a global microbe population map to help uncover patterns.

Samples will be sequenced and the results posted online in a user-friendly, easy to understand manner (colored dots on a map). Please note that a select group of the most common set of microbes from all samples will be posted. This isn't a project to look for "good" or "bad" microbes. Microbes exist EVERYWHERE and we're looking, in very general terms, at the differences in the population distribution on a global scale and how the Earth-bound findings compare to what is found on the ISS."[3]

Be sure to check the Project MERCCURI website at http://www.spacemicrobes.org regularly for updates and results.

The Project MERCCURI Team
Project MERCCURI was one of eight proposals announced on November 29, 2012 as winners of the International Space Station Research Competition sponsored by Space Florida and NanoRacks Inc.

SciStarter.com is teaming up with their sister site, Science Cheerleader (an organization of more than 250 current and former NFL and NBA cheerleaders who are also scientists and

[2] http://microbe.net/microbiomes-of-the-built-environment-network-microbenet/project-iss-microbiome-collaboration-with-science-cheerleaders/microbial-playoffs-in-spaaaace/, retrieved November, 2013.
[3] Quoted text from http://www.scistarter.com/ISS/, retrieved November, 2013.

engineers) and scientists at the University of California - Davis to conduct the research with funding from the Alfred P. Sloan Foundation.

The research team includes:

- Jonathan A. Eisen, Ph.D., a Full Professor at UC Davis and is the Principal Investigator for Project MERCCURI. His lab is in the UC Davis Genome Center and he holds appointments in the Department of Medical Microbiology and Immunology in the School of Medicine and the Department of Evolution and Ecology in the College of Biological Sciences.
- Science Cheerleader Wendy Brown, a PhD student in the Biomedical Engineering Graduate Group at UC Davis and cheerleader for the Oakland Raiders.
- Dr. Jenna Lang, a researcher working in the Eisen Lab.
- Dr. David Coil, a researcher working in the Eisen Lab.
- Russell Neches, a PhD student in the Microbiology Graduate Group at UC Davis.
- Darlene Cavalier, founder of Science Cheerleader and SciStarter.com.
- Science Cheerleader Summer Williams, an aerospace engineer at the NASA-Johnson Space Center (JSC) in Houston, Texas.
- Mark Severance, a career NASA engineer.

Key participants include:

- Dr. Jack Gilbert and the Earth Microbiome Project
- Science Cheerleaders Dr. Talmesha Richards, Ashley Keegan, Lindsey Yoder, Mari Campuzano, Dionn Schaffner, Heather Crockett Washington, Tracy Nicewanner, Alexa Schmidt, Thera Albers, Taylor Hooks, and event manager Bart Leahy.

Special thanks to the Sacramento Kings, San Antonio Spurs, Orlando Magic, Philadelphia 76ers, Philadelphia Phillies, Washington Redskins, New England Patriots, Arizona Cardinals, Oakland Raiders, San Francisco 49ers, the Georgia Tech Gold Rush Dance Team, Pop Warner Little Scholars, Inc., and Yuri's Night.

Funding for this project came from Space Florida, NanoRacks Inc., and the Alfred P. Sloan Foundation.

(Much of the text in this document was taken from the project grant application to Space Florida: "Comparison of the Growth Rate & DNA/RNA Quantitation of Microgravity Exposed Microbial Community Samples Collected by the Astronauts Onboard the International Space Station And by Citizen Scientists & Student Scientists at Public Venues", Eisen, et al. October, 2012.)

What is the International Space Station?

The International Space Station (ISS) is a human-made object orbiting the Earth at an average altitude of 400 kilometers.[4] With an inclination of 51.6°,[5] the ISS flies over 75% of the Earth's surface.[6] Traveling at a speed of 28,000 kilometers per hour,[7] the ISS orbits the Earth every 90 minutes. Six crewmembers live and work onboard the ISS conducting microgravity research in wide range of disciplines.

Image Credit: NASA

The first ISS module was launched in 1998 and construction was completed in 2011. The ISS consists of pressurized modules, trusses, solar arrays, radiators and many other components. The ISS has the volume of a 5-bedroom house and is larger than a football field including the end zones.[8]

The first crew, commanded by U.S. Astronaut Bill Shepherd, arrived in November of 2000.[9] Since then, the ISS has been continuously occupied by crewmembers from over a dozen nations. Several different spacecraft have visited the ISS, including the Soyuz spacecraft, Progress spacecraft, the Automated Transfer Vehicle, the H-II Transfer Vehicle, the Dragon spacecraft and the Cygnus spacecraft service the station. [10]

The ISS is a joint project among the United States, Russia, Europe, Japan, and Canada.[11] "The ISS has been the most politically complex space exploration program ever undertaken.

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[4] http://www.nasa.gov/mission_pages/station/expeditions/expedition26/iss_altitude.html, retrieved November, 2013.
[5] http://spaceflight.nasa.gov/shuttle/reference/faq/index.html#29, retrieved November, 2013.
[6] http://spaceflight.nasa.gov/feedback/expert/answer/mcc/sts-112/09_04_12_54_17.html, retrieved November, 2013.
[7] http://www.nasa.gov/mission_pages/station/expeditions/expedition26/iss_altitude.html, retrieved November, 2013.
[8] http://www.nasa.gov/audience/forstudents/5-8/features/what-is-the-iss-58.html#.UojpTI0SpAM, retrieved November, 2013.
[9] http://www.nasa.gov/mission_pages/station/expeditions/expedition01/index.html#.UojyJI0SpAM, retrieved November, 2013.
[10] http://www.nasa.gov/mission_pages/station/main/onthestation/facts_and_figures.html#.UojnFI0SpAN, retrieved November, 2013.
[11] http://www.nasa.gov/mission_pages/station/cooperation/index.html#.Uoj0P40SpAM, retrieved November 2013.

The International Space Station Program brings together international flight crews, multiple launch vehicles, globally distributed launch, operations, training, engineering, and development facilities; communications networks, and the international scientific research community."[12] The ISS is an engineering achievement as well as an example of international cooperation.

Image Credit: NASA

Microgravity

Gravity is the attraction between two objects and is found throughout the solar system. Gravity is what keeps the planets in orbit around the sun, the Moon in orbit around Earth, and the ISS in low Earth orbit.

Microgravity is frequently described as a state that exists when an object is in free fall. If an object is in an elevator and the cable is cut, both the object and elevator fall back to Earth at the same rate. However, the object is floating within the elevator since it is in free fall. It no longer exhibits the effects of gravity and appears to be weightless.

The ISS is put into orbit at a speed that enables it to free-fall around the Earth. In this state, objects and people in the ISS float in what is referred to as a weightless environment. The microgravity environment allows researchers the unique opportunity to conduct long-term experiments where the effects of gravity-induced phenomena are greatly reduced.

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[12] http://www.nasa.gov/mission_pages/station/cooperation/index.html#.Uoj0P40SpAM, retrieved November, 2013.

Scientific research
From the moment the first crew arrived in 2000, the ISS has been used as a scientific laboratory. The primary fields of research include biology and biotechnology, Earth and space science, educational activities, human research, physical sciences and technology.[13] Experiments from around the world have flown aboard the ISS resulting in further understanding of life on Earth and the effects of long-duration spaceflight on the human body. In addition, the ISS has become an orbiting classroom where educators and students can fly experiments and interact with crewmembers to discuss living and working on the ISS.

Advances in human health research have resulted in greater understanding of aging, trauma, disease and the environment. "Advances in telemedicine, disease models, psychological stress response systems, nutrition, cell behavior and environmental health are just a few examples of benefits that have been gained from the unique space station microgravity environment."[14]

Looking back at Earth is one of the activities Astronauts enjoy doing most in their free time. Earth science experiments have been conducted onboard the ISS since construction began. These experiments contribute to a greater understanding of Earth, its systems and the environmental challenges humans face today. Having humans in orbit provides the opportunity to capture real-time events on Earth such as hurricanes and volcanic eruptions. In addition, data collection instruments can be mounted in windows or to external locations. "The station contributes to humanity by collecting data on the global climate, environmental change and natural hazards using its unique complement of crew-operated and automated Earth-observation payloads."[15]

Researchers continue to study the effects of the harsh environment of space on various materials and electronic systems. Results from this research lead to the development of materials that will withstand the rigors of a long duration spaceflight, such as sending humans to Mars.

Image Credit: NASA

Plant growth experiments study the effects of the weightless environment on gravitropism, phototropism and plant growth processes. Scientists are interested in understanding how to grow food to help feed crews that will be away from Earth for a long period of time. These studies contribute to identifying more efficient

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[13] http://www.nasa.gov/mission_pages/station/research/experiments_category/index.html#.UokKqo0SpAM , retrieved November 2013.
[14] http://www.nasa.gov/mission_pages/station/research/benefits/human_health.html, retrieved November, 2013.
[15] http://www.nasa.gov/mission_pages/station/research/benefits/observation.html, retrieved November, 2013.

growing methods on Earth. Conducting protein crystal growth experiments in space enable the growth of crystals that do not exhibit the effects of gravity such as sedimentation. These experiments aid in the generation of computer models of carbohydrates, nucleic acids and proteins, and further advance the progress of biotechnology. "Understanding these results will lead to advances in manufacturing and biological processes, both in medicine and agriculture."[16]


Image Credit: NASA

Of particular interest to Project MERCCURI are experiments being conducting in microbiology. Recently, researchers at the Durham Veterans Affairs Medical Center and Arizona State University have conducted research in the quest to identify vaccines against Salmonella bacteria. "Salmonella infection is one of the most common forms of food poisoning in the United States. Worldwide, Salmonella diarrhea remains one of the top three causes of infant mortality, so a vaccine has the potential to make dramatic improvements in health for developing countries. The space environment has been shown to induce key changes in microbial cells that are directly relevant to infectious disease, including alterations of microbial growth rates, antibiotic resistance, microbial invasion of host tissue, organism virulence (the relative ability of a microbe to cause disease) and genetic changes within the microbe. Collectively, this body of work has shown that the virulence of this organism increases in microgravity. The targets identified from each of these microgravity-induced alterations represent an opportunity to develop new and improved therapeutics, including vaccines, as well as biological and pharmaceutical agents aimed specifically at eradicating the pathogen."[17]


Image Credit: NASA

Another area of research revolves around understanding the behavior of fluids in a microgravity environment. How fluids behave is at the core of understanding many phenomena. "Surface tension-driven flows, for example, affect some techniques of semiconductor crystal growth, welding, and the spread of flames on liquids. Results from microgravity Fluid physics research will lead to better understanding of the effects of

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[16] http://www.nasa.gov/mission_pages/station/research/experiments/252.html, retrieved November, 2013.
[17] http://www.nasa.gov/mission_pages/station/research/benefits/vaccine_development.html, retrieved November, 2013.

miniaturization of electronic materials. Advances in the field will lead to even smaller and more efficient electronic devices with reduced costs for the consumer."[18]

Combustion research continues to be another area of high interest to scientists. Flames burn very differently in microgravity and do not look like flames burned on Earth. These findings may improve current knowledge about how to prevent the spread of fire and to identify ways to better extinguish flames. Understanding these phenomena will be particularly important when sending humans on long duration spaceflights.[19]

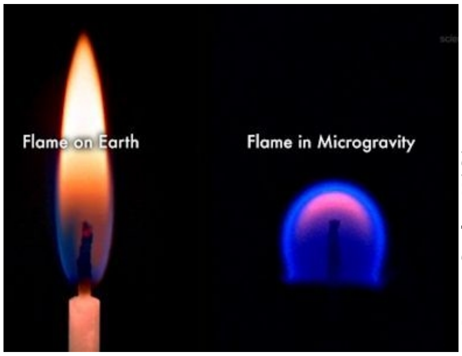

Image Credit: NASA

With a six-person crew onboard the ISS, more time can be devoted to conducting research and advancing our understanding of complex scientific principles. The ISS continues to be a valuable platform in which conduct these types of experiments.

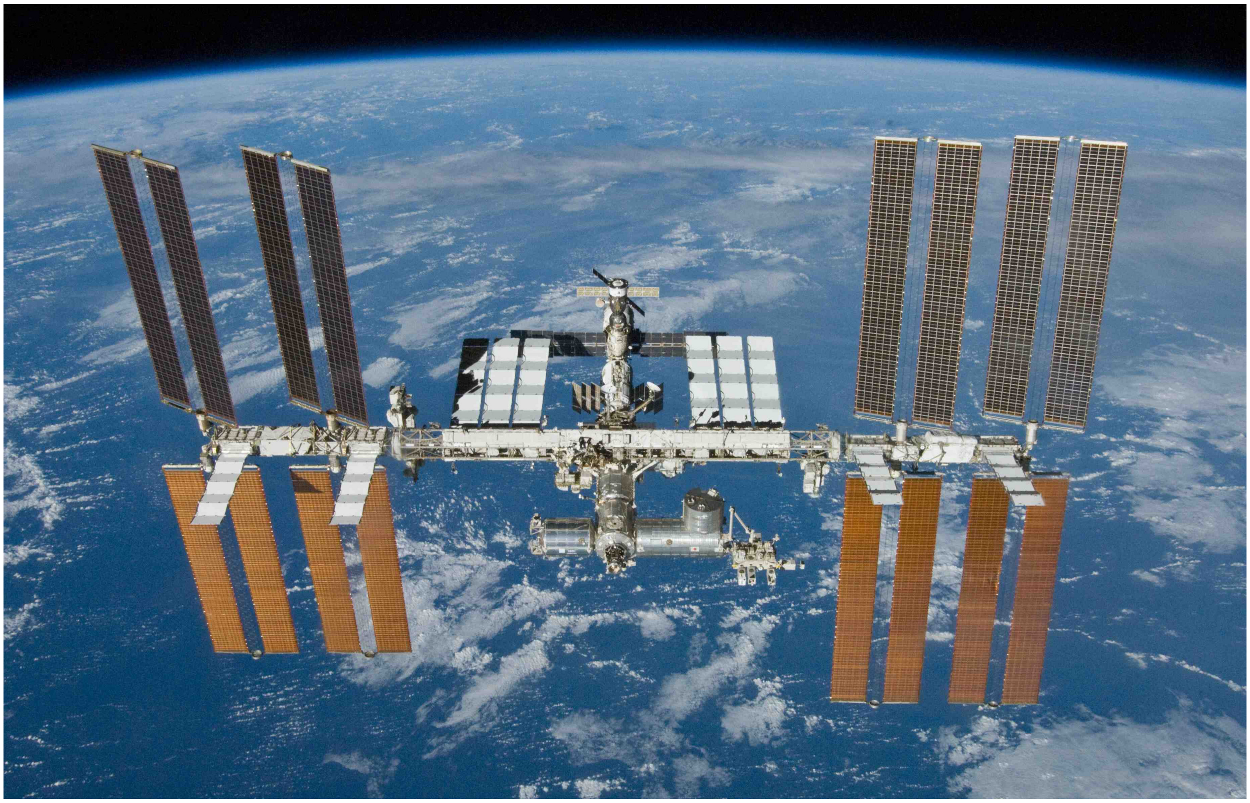

Image Credit: NASA

ISS Assembly Complete

[18] http://www.nasa.gov/centers/marshall/news/background/facts/microgravity.html, retrieved November, 2013.
[19] http://science1.nasa.gov/science-news/science-at-nasa/2000/ast12may_1/, retrieved November, 2013.

Project MERCCURI Activity
Researching Microorganisms

Subject: Biology

Learning Objectives:
Students will:

- Research connections between microbes and humans
- Explain the relationship between microbes and humans
- Develop a presentation about a specific microbe and its connection to the human world
- Communicate their results to their peers

National Science Education Standards:

- Science Practices: Asking Questions, Analyzing and Interpreting Data, Constructing Explanations

Background:
This activity provides an opportunity for students to conduct research on specific microbes that were selected to fly to the International Space Station (ISS) as part of the Project MERCCURI research experiment (http://www.spacemicrobes.org/). Refer to the background information on Project MERCCURI and the International Space Station found at the beginning of the Project MERCCURI Educator guide.

Materials:
Computer
Access to the Internet

Procedures:

1. Discuss with students what microbes are and where they can be found. Questions to aid in the discussion could include:
    a. What is the definition of microbe?
    b. What are the different types of microbes?
    c. Where can you find microbes?
2. Provide information to students on Project MERCCURI from the overview section of the Project MERCCURI Educator guide and http://www.spacemicrobes.org.
3. Explain to students they will be researching the various microorganisms selected to fly to the International Space Station as part of the Project MERCCURI research experiment.
4. Have students select at least three microorganisms from the list below to research. Students should develop a one-page PowerPoint document on each microorganism. Research should include:
    a. The scientific name of the microbe
    b. Any common names
    c. A color picture, with citation

d. Information on why the microbe is important
e. How does the microbe interact with the human environment (if any)
f. The date of its discovery
g. Any interesting facts

List of microbes:

- Paenibacillus elgii
- Curtobacterium pusillum
- Bacillus horikoshii
- Bacillus aryabhatti
- Kocuria rosea
- Streptomyces kanamyceticus
- Unclassified Spingomonadaceae
- Leucobacter chironomi
- Bacillus amyloliquefaciens
- Bacillus flexus
- Micrococcus luteus
- Bacillus tequilensis
- Exiguobacterium indicum
- Exiguobacterium sibiricum
- Exiguobacterium acetylicum
- Macrococcus brunensis
- Microbacterium oleivorans
- Macrococcus equipercicus
- Arthrobacter nitroguajacolicus
- Paenibacillus mucilaginosus
- Pantoea eucrina
- Bacillus licheniformis
- Bacillus megaterium
- Bacillus atrophaeus
- Bacillus subtilis
- Kocuria marina
- Bacillus methylotrophicus
- Kocuria rhizophila
- Kocuria kristinae
- Bacillus pumilus
- Bacillus safensis
- Microbacterium arborescens
- Bacillus marisflavi
- Bacillus stratosphericus
- Bacillus altitudinis
- Micrococcus yunnanensis

5. Have students present their findings to the rest of the class.

Extensions:

1. Have students research ways other microorganisms are beneficial to humans. Students can create a short presentation and share it with the class.
2. Have students research ways other microorganisms are harmful to humans. Students can create a short presentation and share it with the class.
3. Discuss ways humans manage beneficial and harmful microorganisms.

Project MERCCURI Activity
Mini-Ponds

Subject: Biology

Learning Objectives:
Students will:
- Identify microorganisms.
- Determine the differences in the growth of microorganisms in varying environments.
- Set up several experiments using a variety of variables.

Next Generation Science Standards:
Standard MS.Matter and Energy in Organisms and Ecosystems
- Performance Expectation: MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- Science Practices: Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Constructing Explanations
- Disciplinary Core Idea: LS2.A Interdependent Relationships in Ecosystems
- Crosscutting Concept: Cause and Effect

Background:
This activity introduces students to the environment of microorganisms. Students, in groups of 2-3, will build mini-ponds using a variety of materials and water. Each group will use a different combination of components to create their mini-pond. This will allow students to compare and contrast results from different mini-ponds.

Materials:
A container for each group: Quart size jars (or large beakers)
Soil samples from different places (school yard, potting soil, home, etc.)
Rain water
Tap water
Distilled water
Well water
Pond Water
Plastic Wrap
Rubber Bands
Student Journal Worksheet
Gloves
Safety Goggles
Note: Students can be tasked to bring in the various soil and water samples required to complete this experiment.

Safety Note: Follow all lab safety procedures outlined by your school when disposing of experiment samples. If there are no established guidelines, you can decontaminate your experimental samples and materials by using disinfectants. The best disinfectant is household bleach at 10% strength. You can make a 10% bleach solution by mixing one part of regular laundry bleach with 9 parts of water. At the conclusion of the experiment, place the samples and equipment used into the bleach solution and let soak for 1-2 hours before disposal. In addition, it is a good laboratory practice to have students wash hands before and after any laboratory activity. Sterilize all lab surfaces with the bleach solution following each lab session.

Procedure:

1. Discuss with students what microbes are and where they can be found. Potential questions to aid in the discussion could include:
2. What is the definition of microbe?
3. What are the different types of microbes?
4. Where can you find microbes?
5. Discuss with students the types of microorganisms that can generally be found in ponds. Websites with good background info: http://microbewiki.kenyon.edu/index.php/Pond_water and
6. http://www.buzzle.com/articles/microorganisms-in-pond-water.html
7. Divide students into groups of 2-3 students.
8. Discuss with students the different types of soil and water that will be used in this experiment. As a class, develop a hypothesis to determine if there will be differences among the experiments, what those differences might be and why they exist.
9. Have each student group choose one soil and one water sample to use in setting up their experiment. Be sure to have students label their jars to indicate what type of soil and water make up their mini-pond.
10. Place 1-2 inches of soil into each container.
11. Add water to within 1-2 inches of the top of the container.
12. Stretch plastic wrap across the top of the container and secure with a rubber band. Have students punch a few holes in the plastic wrap to allow air to circulate.
13. Store the containers in an area of the classroom that does not receive direct sunlight.
14. Have students record daily observations of their mini ponds on the student journal worksheet. Students should determine what is significant to record. However, examples can include:
15. Water level in the container.
16. Color of water and soil.
17. Cloudiness of water
18. Is there any movement?
19. After one week, have students remove a sample of water and a sample of soil. Have students observe the samples through a magnifying glass. Students should also prepare a sample on a slide for viewing under a microscope. Have students record their observations on the student journal worksheet.
20. Repeat step 10 after two weeks.

Discussion:

1. Which mini-ponds grew the most microorganisms? Why?
2. Which mini-ponds grew the least microorganisms? Why?
3. Have students organize their mini-ponds in a row from the fewest to the most microorganisms.
4. Revisit the original hypothesis and discuss how the results of the experiment compare with the hypothesis. Can a new hypothesis be developed and tested?

Extension:

1. Create a graph that depicts the results from the entire class.
2. Create a map that shows where the samples came from. Discuss external variables (or nearby influences) that may have contributed to the results achieved in the mini-ponds.
3. Repeat the experiment using the same materials for each mini-pond. Place the mini-ponds in locations that have varying temperatures or light exposure. Observe and record results. Determine the impact temperature and/or light has on the growth of microorganisms.
4. Check out the Citizen Scientist website (http://www.scistarter.com) for additional experiments on studying ponds and ways to participate in ongoing research.
5. Check out the Project MERCCURI website (http://www.spacemicrobes.org/) to learn about the microorganisms grown and selected to fly as part of an International Space Station Experiment.

Project MERCCURI
Mini-Pond Student Journal Worksheet

Describe the condition of the water in your mini-pond.

Day 1	
Day 2	
Day 3	
Day 4	
Day 5	
Day 6	
Day 7	

Describe the condition of the soil in your mini-pond.

Day 1	
Day 2	
Day 3	
Day 4	
Day 5	
Day 6	
Day 7	

After Day 7, remove a sample of water and a sample of soil from your mini-pond. Observe the samples through a magnifying glass and a microscope. Draw and describe your observations.

Magnifying Glass - Water:

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Microscope - Water:

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Magnifying Glass - Soil:

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Microscope - Soil:

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Describe the condition of the water in your mini-pond.

Day 8	
Day 9	
Day 10	
Day 11	
Day 12	
Day 13	
Day 14	

Describe the condition of the soil in your mini-pond.

Day 8	
Day 9	
Day 10	
Day 11	
Day 12	
Day 13	
Day 14	

After Day 14, remove a sample of water and a sample of soil from your mini-pond. Observe the samples through a magnifying glass and a microscope. Draw and describe your observations.

Magnifying Glass - Water:

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Microscope - Water:

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Magnifying Glass - Soil:

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Microscope - Soil:

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Conclusions:

1. Identify the type of microorganisms found in your mini-pond.

2. After the entire class has had an opportunity to compare the results of all of the mini-ponds, which soil and water samples had the most microorganisms?

3. Which soil and water samples had the least microorganisms?

4. Why?

Project MERCCURI Activity
Observing Microbes

Subject: Biology

Learning Objectives:
Students will:

- Research spaceflight microbiology experiments.
- Identify the effects of microgravity on microbiology experiments.
- Document and record the growth of microbe samples.

Next Generation Science Standards:

- Science Practices: Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Constructing Explanations

Background:
This activity complements the Project MERCCURI (http://www.spacemicrobes.org/) experiment, an International Space Station (ISS) research experiment. Refer to the background information on Project MERCCURI and the International Space Station found at the beginning of the Project MERCCURI Educator guide. Additional information can be found on the Project MERCCURI Frequently Asked Questions page located at http://spacemicrobes.ucdavis.edu/faq/.

For this activity, students will observe bacteria found in yogurt samples. They will record their observations with descriptions and drawings.

Materials:
For each student pair:

- Microscope
- Microscope slides and cover slips
- Samples of plain yogurt with active cultures
- Sterile wooden applicators
- Distilled water
- Small pipettes
- Student lab journals

Procedure:

1. Ask students to describe the International Space Station (ISS). Create a list of descriptors for the ISS (size, distance from Earth, speed of travel, countries involved, etc.). Provide additional information, as needed, from the "What is the International Space Station" section of the Project MERCCURI Educator guide.
2. Show all or part of Suni Williams' tour of the ISS - http://www.youtube.com/watch?v=doN4t5NKW-k. (You can also access live video from the ISS at http://www.ustream.tv/channel/live-iss-stream.)

3. Discuss with students what microbes are and where they can be found. Questions to aid in the discussion could include:
    a. What is the definition of microbe?
    b. What are the different types of microbes?
    c. Where can you find microbes?
4. Provide information to students on Project MERCCURI from the overview section of the Project MERCCURI Educator guide and http://www.spacemicrobes.org. Have students research previous spaceflight microbiology experiments. Good resources to begin with include:
    a. http://www.nasa.gov/mission_pages/station/research/experiments/experiments_hardware.html#Biology-and-Biotechnology
    b. http://www.biomedcentral.com/1471-2180/13/241
    c. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2832349/
    d. http://www.nasa.gov/mission_pages/station/research/experiments/87.html
    e. http://issresearchproject.nasa.gov/Ames/Biology/
5. Discuss with students findings from previous spaceflight microbiology experiments. Questions to aid in the discussion could include:
    a. What are common findings from the various research experiments?
    b. How did microgravity affect the experiments?
    c. What questions do you think still need to be explored?
6. Explain to students they will be observing bacteria found in yogurt over the course of 24 hours under changing conditions.
7. Have each group work together to develop and write a hypothesis for the experiment.
8. Review lab safety procedures with students.
9. Using the sterile wooden applicators, have each group obtain a very small sample from the plain yogurt and place it on the center of a clean microscope slide.
10. Students should add one drop of distilled water to the yogurt and cover the sample with a cover slip.
11. Have students place the sample on the microscope. Using low power, students should observe the yogurt through a thin section of the sample.
12. Have students switch the microscope to high power and observe the bacteria.
13. Students should record their observations with descriptions and drawings.
14. Set the yogurt container in a warm dark place for 24 hours.
15. Repeat steps 9 – 13.
16. Students should develop and record their conclusions in their lab journals.
17. Students should revisit their hypothesis to determine if they need to make changes or refinements.

Discussion:

Possible discussion questions could include:

1. Discuss how the two samples look different and how the growth of bacteria varied over time.
2. How did temperature and light levels affect the growth of the bacteria?
3. What variables do you think microgravity changes when growing microbes?
4. How will microbe growth in space (microgravity) compare to microbe growth on Earth?

Extension:

1. Check out the Citizen Scientist website (http://www.scistarter.com) for additional experiments on microorganisms and ways to participate in ongoing research.
2. Check out the Project MERCCURI website (http://www.spacemicrobes.org/) to learn about the microorganisms grown and selected to fly as part of an International Space Station Experiment.

Project MERCCURI
Observing Microbes Student Journal Worksheet

Observe the yogurt sample using the microscope on both low and high power. Draw and describe your observations.

Microscope Low Power:

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Microscope High Power:

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24 hours later - observe the yogurt sample using the microscope on both low and high power. Draw and describe your observations.

Microscope Low Power:

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Microscope High Power:

Conclusions:

1. Discuss how the two samples look different and how the growth of bacteria varied over time.

2. How did temperature and light levels affect the growth of the bacteria?

Project MERCCURI Education Resources

Note: All quoted text is taken directly from the URL following the text.

NASA: Teach Station
"Teach Station is the platform for space station focused education resources, science and research information for students and teachers, crew updates, and up-to-the-minute education news."
Grade Level: K-12
Website: http://www.nasa.gov/education/teachstation/

NASA: A Day in the Life Aboard the International Space Station
"Follow astronauts on the International Space Station in a series of videos as they explain their daily routines. Learn where they sleep, and how they eat, exercise, work and spend free time. Compare life in space with life on Earth. Educators can use this series of videos and resources to enhance K-12 science, technology, engineering and mathematics curricula."
Grade Level: K-12
Website:
http://www.nasa.gov/audience/foreducators/teachingfromspace/dayinthelife/index.html

NASA: ISS Live!
"Monitor the crew activities and systems onboard the International Space Station by viewing real-time data on displays adopted from those used in Mission Control Center-Houston. Follow what the crew is doing by looking at their timelines and watching streaming video. Incorporate the data and activities you are monitoring into the classroom by using the ISS Live! educator guides and gain an understanding of how the world's largest space station actually functions."
Grade Level: K-12
Website: http://spacestationlive.nasa.gov/index.html

Citizen Science – Posted with Permission
"SciStarter is a free resource that makes it easy for people to learn about and get involved in hundreds of current, easily searchable citizen science projects in need of their help. Researchers post their projects on SciStarter to enlist the help of teachers, students and the general public to classify galaxies, track migration patterns, build inexpensive spectrometers, monitor weather and environmental quality and, yes, even collect and compare microbes!"
Grade Level: Students through Adults
Website: http://www.scistarter.com

NASA: Spot the ISS
"See the International Space Station! As the third brightest object in the sky the space station is easy to see if you know when to look up. NASA's Spot The Station service gives

you a list of upcoming sighting opportunities for thousands of locations worldwide, and will let you sign up to receive notices of opportunities in your email inbox or cell phone."
Website: http://spotthestation.nasa.gov/

NASA: Careers
"Use this page as a starting point to learn about careers at NASA. Meet scientists, technical experts, engineers, mathematicians, physicists, accountants, attorneys, astronauts, educators, pilots, astronomers and experts in many other fields. Career information on this page includes the following:

- Opportunities for students to intern at NASA
- Programs for visiting faculty
- Profiles of NASA employees
- Descriptions of jobs at NASA
- Posters and resources with career information
- Descriptions of NASA education programs
- Career pages with content sorted by grade levels."

Grade Level: 5 – University
Website: http://www.nasa.gov/audience/forstudents/careers-index.html

Careers - Science Cheerleader – Posted with Permission
"Science Cheerleader is an organization of more than 250 current and former NFL and NBA cheerleaders who are also scientists and engineers. They aim to challenge stereotypes, inspire kids to consider STEM careers, and engage people from all walks of life in science. Learn how and why the Science Cheerleaders choose their STEM careers at http://www.sciencecheerleader.com."
Grade Level: Students through Adults

NASA: Microgravity Educator Guide
"This educator guide contains excellent background information accompanied by classroom activities that enable students to experiment with the forces and processes that scientists who study microgravity are investigating today."
Grade Level: 5-12
Website:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Microgravity_Teachers_Guide.html

NASA: ISS L.A.B.S. Educator Resource Guide
"The International Space Station Learning, Achieving, Believing and Succeeding, or ISS L.A.B.S., Educator Resource Guide consists of eight guided educational learning activities. The guide highlights the international collaboration involved in building and operating the space station, and provides an overview of space station construction and assembly. The eight activities in the guide cover topics relating to science, technology, engineering and mathematics. All lessons are aligned with national education standards.

The guide includes student sheets, lesson plan instructions, background information, answer keys and a certificate of completion to award to students after completing the activities."
Grade Level: 5-8
Website:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/ISS_LABS_Guide.html

NASA: What is Microgravity?
"This NASA video segment defines microgravity. Viewers learn that microgravity is, in essence, a product of free fall and that experiments aboard the space shuttle experience continuous free fall. The segment also discusses ways to briefly recreate microgravity on Earth."
Grade Level: 5-12
Website:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/What_Is_Microgravity.html

American Society for Microbiology (ASM) – Posted with Permission
"A collection of activities designed to illustrate the incorporation of the microbial world in the K-12 community either through science courses or through community-based events and programs. The activities come from classroom teachers and microbiologists. All activities have been reviewed by the ASM Committee on K-12 Outreach for scientific and educational content, active learning and engagement, alignment with the National Science Education Standards, and clarity of accompanying instructions."
Grade Level: K-12
Website: http://www.asm.org/index.php/educators/k-12-classroom-activities

BioBuilder® - Posted with Permission
"BioBuilder® is an open-access website offering informative animations and activities for anyone who wants to teach or learn about synthetic biology. BioBuilder® is populated with short, animated narratives that support a more formal curriculum aimed at the advanced high school/early college level. BioBuilder® provides an opportunity for students to learn new aspects of the field, and for teachers to find start-to-finish class activities to integrate into their biology curriculum."
Grade Level: Upper high school and college
Website: http://www.biobuilder.org/

Introduction to Bacteria – Posted with Permission
This article provides a brief introduction to bacteria and discusses the following key subjects:

- Morphology and classification
- Growth
- Factors that affect growth

http://www.umsl.edu/~microbes/pdf/introductiontobacteria.pdf

Other education resources developed by the University of Missouri – St. Louis can be found at http://www.umsl.edu/~microbes/index.html.
Grade Level: K-12