Spaceflight alters bacterial social networks

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STS-132 mission specialist Piers Sellers handles the group activation packs aboard space shuttle Atlantis. Credit: NASA

When astronauts launch into space, a microbial entourage follows. And the sheer number of these followers would give celebrities on Twitter a run for their money. The estimate is that normal, healthy adults have ten times as many microbial cells as human cells within their bodies; countless more populate the environment around us. Although invisible to the naked eye, microorganisms – some friend, some foe – are found practically everywhere.

Microorganisms like bacteria often are found attached to surfaces living in communities known as biofilms. Bacteria within biofilms are protected by a slimy matrix that they secrete. Skip brushing your teeth tomorrow morning and you may personally experience what a biofilm feels like.

One of NASA's goals is to minimize the health risks associated with extended spaceflight, so it is critical that methods for preventing and treating spaceflight-induced illnesses be developed before astronauts embark upon long-duration space missions. It is important for NASA to learn how bacterial communities that play roles in human health and disease are affected by spaceflight.

In two NASA-funded studies – Micro-2 and Micro-2A – biofilms made by the bacteria Pseudomonas aeruginosa were cultured on Earth and aboard space shuttle Atlantis in 2010 and 2011 to determine the impact of microgravity on their behavior. P. aeruginosa is an opportunistic human pathogen that is commonly used for biofilm studies. The research team compared the biofilms grown aboard the International Space Station bound space shuttle with those grown on the ground. The study results show for the first time that spaceflight changes the behavior of bacterial communities.

Although most bacterial biofilms are harmless, some threaten human health and safety. Biofilms can exhibit increased resistance to the immune system's defenses or treatment with antibiotics. They also can damage vital equipment aboard spacecraft by corroding surfaces or clogging air and water purification systems that provide life support for astronauts. Biofilms cause similar problems on Earth.

"Biofilms were rampant on the Mir space station and continue to be a challenge on the International Space Station, but we still don't really know what role gravity plays in their growth and development," said

Cynthia Collins, Ph.D., principal investigator for the study and assistant professor in the Department of Chemical and Biological Engineering at the Center for Biotechnology and Interdisciplinary Studies at the Rensselaer Polytechnic Institute in Troy, N.Y. "Before we start sending astronauts to Mars or embarking on other long-term spaceflight missions, we need to be as certain as possible that we have eliminated or significantly reduced the risk that biofilms pose to the human crew and their equipment."

The Micro-2 investigation launched aboard space shuttle Atlantis on May 14, 2010. Credit: NASA

In 2010 and 2011, during the STS-132 and STS-135 missions aboard space shuttle Atlantis, astronauts in space and scientists on Earth performed nearly simultaneous parallel experiments; both teams cultured samples of P. aeruginosa bacteria using conditions that encouraged biofilm formation.

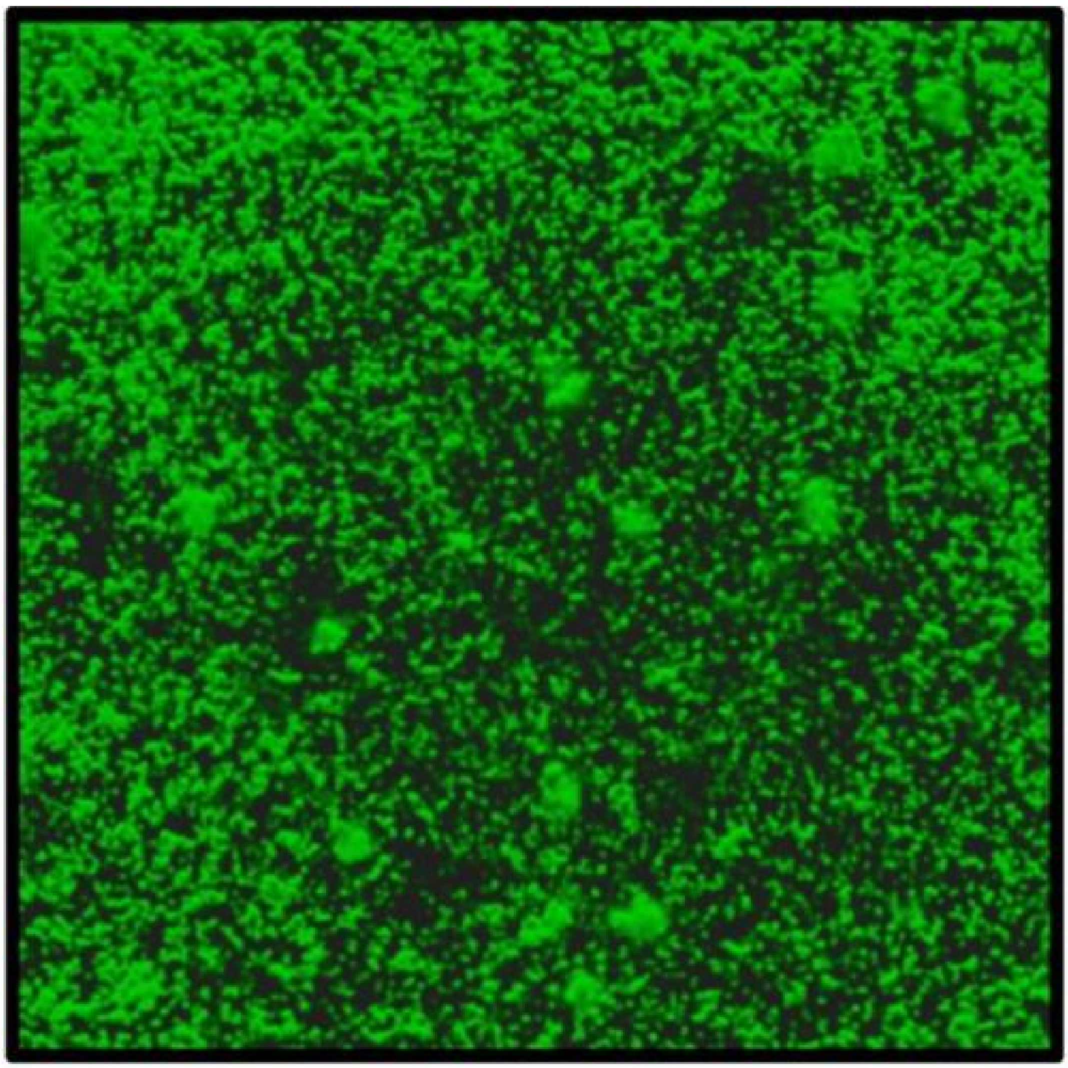
Identical hardware designed for growing cells during spaceflight were used for both the flight and ground studies. According to Collins, "artificial urine was chosen as a growth medium because it is a physiologically relevant environment for the study of biofilms formed both inside and outside the human body."

Biofilms were cultured inside specialized fluid processing apparatus composed of glass tubes divided into chambers. The researchers loaded each tube with a membrane that provided a surface on which the bacteria could grow; the artificial urine was used for the bacteria's nourishment. Samples of P. aeruginosa were loaded into separate chambers within each tube.

The prepared tubes were placed in groups of eight inside another specialized device called a group activation pack (GAP) – designed to activate all of the bacterial cultures at once. The research team prepared identical sets of GAPs for the concurrent spaceflight and ground experiments.

Astronauts aboard the shuttle initiated the flight experiments by operating the GAPs and introducing the bacteria to the artificial urine medium. Scientists on Earth performed the same operations with the control group of GAPs at NASA's Kennedy Space Center in Florida. After activation, the GAPs were housed in incubators on Earth and aboard the shuttle to maintain temperatures appropriate for bacterial growth.

After the microgravity samples returned to Earth, the researchers determined the thickness of the biofilms, the number of living cells and the volume of biofilm per area on the membranes. Additionally, they used a microscopy technique that allowed them to capture high-resolution images at different depths within the biofilms, revealing details of their three-dimensional structures.



P. aeruginosa biofilm cultured during spaceflight. Credit: Rensselaer Polytechnic Institute

What the scientists found was that the P. aeruginosa biofilms grown in space contained more cells, more mass and were thicker than the control biofilms grown on Earth. When they viewed the microscopy images of the space-grown biofilms, the researchers saw a unique, previously unobserved structure consisting of a dense mat-like "canopy" structure supported above the membrane by "columns." The Earth grown biofilms were uniformly dense, flat structures. These results provide the first evidence that spaceflight affects community-level behavior of bacteria.

Microbes experience "low shear" conditions in microgravity that resemble conditions inside the human body, but are difficult to study. According to Collins, "Beyond its importance for astronauts and future space explorers, this research also could lead to novel methods for preventing and treating human disease on Earth. Examining the effects of spaceflight on biofilm formation can provide new insights into how different factors, such as gravity, fluid dynamics and nutrient availability affect biofilm formation on Earth. Additionally, the research findings one day could help inform new, innovative approaches for curbing the spread of infections in hospitals."

NASA's Space Biology Program funded the Micro-2 and Micro-2A investigations. Related space biology research continues aboard the space station, including recently selected studies that are planned for future launch to the orbiting laboratory.

Wherever we go, microbial communities will faithfully follow, making this evidence of the effects of spaceflight on bacterial physiology relevant to human health. That bacterial biofilms exhibit different behavior in space versus on Earth is critical information as NASA strives to keep astronauts healthy and safe during future long-duration space missions.

Provided by NASA