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CITIZEN MICROBIOLOGY: A CASE STUDY IN SPACE

David Coil

At 3:25 PM on April 18, 2014, I stood on the viewing platform at Cape Canaveral, Florida, watching a massive rocket carry a nationwide citizen science microbiology project into space. This project would catalog hundreds of types of bacteria living on the space station, survey thousands more bacteria from participants around the country, and measure the growth of common bacteria in space. Mixed with the excitement and relief was a feeling of amazement that we live in a time where such things are possible. New and cheaper technology has completely changed our understanding of microbiology in the last decade or two. We can relatively cheaply ask questions that weren't even conceivable in the recent past. These changes, along with rapidly growing public interest in microbiology, have created the perfect conditions for an explosion of what we call "citizen microbiology." Our project involving microbes in space is but one example of this new and exciting field.

Over the last decade, microbiology has seen a renewed surge of interest in popular media, books, and films. While some of this relates to topics such as global pandemics and new diseases, increasing attention is being paid to subjects like the importance of beneficial human-associated microbes or the problem of antibiotic resistance. Given the current level of public interest in both microbiology and citizen science, it is perhaps no surprise to hear that citizen microbiology is taking off. In this chapter I'll discuss the idea of citizen microbiology, the opportunities and challenges therein, a few examples, and one detailed case study.

Before going into the details of citizen microbiology, a few definitions might be in order. A "microbe" is traditionally defined as a living organism too small to be seen with the naked eye. For our purposes this includes viruses, bacteria, fungi, and various other tiny creatures. “Microbiology” is the study of microbes and a “microbiome” is the collection of microbes found in a particular habitat (e.g., on a person or in a house).

A few microbiology citizen science projects that involved culture-based monitoring (i.e., growing microbes on plates in the lab) go back decades. For example, the State of the Oyster project in Washington State has helped volunteers monitor edible shellfish populations for harmful bacteria since 1987. However, the ease and low cost of DNA sequencing has been a major force for change. The majority of citizen microbiology projects today are less than ten years old, and rely in some way on cheap and easy DNA sequencing. This sequencing allows researchers to quickly and accurately identify most of the microbes in a given sample.

Microbes are hard to see, often viewed negatively, and have large impacts (good and bad) on human health. These features create both opportunities and challenges in conducting citizen microbiology.

Opportunities & Challenges of Citizen Microbiology

Every human being carries a complex and unique collection of microbes, making each person a valuable data point in understanding the human microbiome. Given our increasing understanding of the critical role played by microbes in human health, this understanding may transform numerous aspects of healthcare at an individual level. In addition to human-associated microbes, citizen microbiology efforts involving environmental and water monitoring can be extremely helpful in understanding microbial ecology.

Beyond the scientific benefits, there is a tremendous educational opportunity with microbiology. Many people react negatively to words like “microbes” and “bacteria.” It is far more common to find the term “germs” in the media, usually portrayed in a health-influencing and negative way. Engaging the public through actually doing microbiology provides an opening to discuss the fact that microbes are everywhere, and the vast majority of them are harmless or beneficial. Increased awareness of this fact has important implications for human health, both directly (e.g., through reduced use of unnecessary antibiotics) and indirectly (e.g., shifting away from “kill all the microbes” that is probably counterproductive for health).

Another opportunity with citizen microbiology is the accessibility of samples: to get started all you often need is a sterile swab. Citizen microbiology can also be adapted in a hands-on manner in the classroom in a way that might be difficult with, say, endangered birds. An excellent example is the Phage Hunters project run by Graham Hatfull at the University of Pittsburgh, where students actually discover and characterize novel bacteriophages (viruses that infect bacteria).

Citizen microbiology also presents a number of challenges, some of which are shared with other citizen science projects but many of which are unique to, or more problematic, when dealing with microbes. There is often, for instance, a very strong negative association with microbiology and microbes. This is really both a challenge and an opportunity, since educating the public about microbiology should be a primary goal of any citizen micro-biology project. Many people are both surprised and interested to learn how important microbes are to the world around us and our own health. In our experience, many times all that is needed is a couple examples of how "germs" aren't all bad to get people to be more open-minded about microbiology.

For the researchers, the logistics of organizing sample collections with citizen scientists can be quite complex. For example, samples collected for DNA analysis need to be protected from contamination and often kept frozen or otherwise preserved. This can be particularly difficult in the absence of electricity, which would require sub-optimal chemical preservation methods or lugging around crates of dry ice. Human-associated microbes run into issues related to privacy, informed consent, and human-subject research. Solutions to this problem range from pretending it doesn't exist, to anonymizing all data, to (for example) collecting microbes from a cell phone instead of a person directly. Actually growing microbes as part of citizen microbiology (or in an educational setting) can present biosafety concerns. When microbes are given rich growth conditions (lots of food, warmth, liquid, etc.) it can be hard to predict what will appear. In particular, growth of human-associated microbes typically requires specialized equipment and training to ensure a minimal risk of either contamination or spread. Government regulations, and transportation/collection permits are other potential snags. In one frustrating example from our own lab, we recently discovered that while we could have mailed animal feces (rich with microbes) internationally without permits, once we had extracted DNA from the same samples it was considered highly regulated "biological material from a protected species."

Beyond the considerations in the field, one of the challenges with citizen microbiology—particularly that associated with humans is in not over-interpreting the data. Conversations about the human microbiome tend to range between "kill all the germs" and "I take three kinds of probiotics and am considering a fecal transplant to get a more healthy microbiome." Scientists involved in citizen microbiology need to be very careful about how they present information about the human microbiome. Along these lines, there is a lot of concern about "selfexperimentation" with projects that measure the microbiomes of participants. There's nothing to prevent people from radically changing their diet or lifestyle just to see what that does to their microbiome. The problem is mainly with interpretation: surely, for instance, if you eat nothing but beets for two weeks you'll observe changes in your gut microbiome, but no one can really say (yet) what those changes mean.

Another challenge is that of communicating the data back to the public. Traditional outputs of bacterial surveys include statistics and graphs (with dozens of

Latin species names) that are hard to make sense of. Finding ways to display this complex data in a way that is meaningful to the public is, to my mind, one of the great remaining challenges in citizen microbiology.

Citizen Microbiology in Action

Most current citizen microbiology projects are focused on low-cost DNA sequencing to ask questions about what microbes are living where, and they collect data in collaboration with the public. For example, the Wildlife of Our Homes project examines what microbes (and other organisms) are present in the homes of volunteers. The Home Microbiome Project went even further and found people who were about to changes houses, sampling both houses before and after—as well as the participants themselves—in order to understand the relationship of the human microbiome and the home microbiome. People are often very excited to participate in this kind of project, as they not only have the opportunity to learn more about microbiology in general, but also to learn what lives in their own home. Who isn't curious about that?

However, the closer a project gets to the participant (e.g. a local beach, versus your home, versus you) the more potential legal, ethical, privacy, and biosafety complications arise. Entering this realm are projects where members of the public can collect personal samples from themselves (skin, saliva, feces, etc.) and have the microbiomes of those samples analyzed. Two example projects in this area are the publicly funded American Gut Project and the privately funded uBiome Project. These projects, along with conventional microbiology research (e.g. the Human Microbiome Project) are already sparking a paradigm shift in our understanding of human health and disease and our interdependence with our microbes. This is a case where public participation can generate critical scientific data, as well as be directly relevant to the participant. As discussed above, this presents a number of opportunities as well as challenges.

I have experienced many of these opportunities and challenges though my involvement in helping to organize a nationwide citizen microbiology project called Project MERCCURI. MERCCURI is a tortured acronym for Microbial Ecology Research Combining Citizen and University Researchers on ISS (International Space Station). This project had several interrelated goals:

- To conduct a large nationwide survey of microbes found on shoes and cell phones.
- To collect microbial samples from the International Space Station.
- To observe the growth of a number of "nonpathogenic" (non disease-causing) microbes in microgravity on the ISS and compare this to growth on earth.
- To use these three scientific goals to engage the public in thinking about microbiology, and to a lesser extent, doing science in space.

This project was conceived by and co-organized with Science Cheerleader, a nationwide organization of professional cheerleaders pursuing science careers. Through this project, we organized a number of events at various venues, usually sporting events or museums. At these events, members of the public volunteered to swab their cell phones and shoes for microbes. These swabs were later analyzed to determine which bacteria were present there and for comparison to similar swabs on the ISS. Also at these events, different swabs were taken from surfaces like doors, handrails, etc. Bacteria from these surface swabs were cultured, and a candidate species was chosen from each event to fly to the International Space Station for the growth experiment.

Over the course of the project we experienced many of the challenges and opportunities common to large citizen science projects. A number of additional challenges and opportunities arose because of the microbial component. We present here a brief summary of our experiences in the hope that it is helpful to anyone participating in, organizing, or simply interested in citizen microbiology.

For Project MERCCURI, we dealt with the biosafety consideration by only having members of the public collect swabs, but not be involved in growing the organisms (all of which took place in a microbiology laboratory at the University of California Davis). Swabbing a doorknob probably presents less risk than touching it normally! We dealt with some regulatory issues by limiting the project to the United States. Most importantly, this meant that samples couldn't get stuck in customs for days, killing the microbes or confounding the results.

To address privacy concerns, all participants signed a detailed consent form. We also had a separate photography consent form, particularly if minors were involved. Privacy was addressed through barcoding the samples and keeping participant information separate from the samples themselves. We also agreed to pool the data from each event, and not track individual participants for this reason. Because of the pooling, and the fact that we didn't collect samples from people directly, we were able to get approval for a waiver from an Institutional Review Board (IRB). If, for example, we had given each participant data about their own microbes (as with uBiome and American Gut), this could have become much more complicated. IRB approval is normally required for any human subject research at any publicly funded institution.

Sample preservation was addressed through the use of dry swabs (freezing not required) and giving event coordinators a FedEx account number so that all samples could be shipped overnight to the lab at UC Davis. This neatly avoided the biosafety issue of growing microbes on site, but did require that participants were on the ball. In one unfortunate case a group of volunteers lost the sterile swabs we mailed and bought cotton swabs at a local drugstore, which turned out to be heavily contaminated with fungal spores. In several cases, swabs were left in hot car trunks for a couple of days and didn't produce any living microbes by the time they got to California.

Logistical and organizational constraints aside, our biggest challenges related to communication about the project. First, even explaining the project to people was challenging, given the many moving parts and the non-obvious relationship of cheerleaders, microbes, and space. Second was the major hurdle of the reaction of many participants along the lines of “germs are gross” or “I’ll bet you’ll find a lot of nasty stuff on my cell phone.” Part of how we dealt with these two challenges was through providing access to relevant information, including a website with information about the project and information fliers distributed to everyone we talked to about the project. Once the candidate species were selected for flight into space we created “baseball cards” of each microbe that emphasized the beneficial (or at least not harmful) nature of all the bacteria we chose.

But anecdotally, our biggest success with regard to public education was simply through talking to hundreds and hundreds of people at these events. The very nature of the project drew people to our tables and attracted volunteers who might not otherwise have given microbiology a second thought. People were excited to participate in a nationwide survey of microbes and many were thrilled at the chance to be involved with something associated with space. Through these “hooks” we were able to convey our core messages about the ubiquity and benefits of microbes.

Conclusion

As discussed in previous chapters, citizen science is an incredibly powerful tool from both the perspectives of scientists and the public. Scientists gain the benefits of additional data and samples, as well as the opportunity to educate people about their work. Participants gain a chance to contribute to the process of science and to learn and become excited about a particular area of science. Citizen microbiology shares much with other kinds of citizen science projects, but brings some unique challenges and opportunities. Challenges include negative associations with microbes, logistical issues, privacy concerns, and problems with both interpretation of data and communication of the results. The opportunities include the ease of many experiments, the potential value of the data, and getting people excited about the microbes that affect the world around us and our own health. Because of the existing preconceptions about microbes (both good and bad), and the possible human health implications, citizen microbiology has incredible potential on both the scientific and educational sides of the coin.

Further Reading

Project MERCCURI: http://spacemicrobes.org

State of the Oyster: https://wsg.washington.edu/state-of-the-oyster-study-testing-shellfish-for-health-and-safety

Phage Hunters: http://phagesdb.org/phagehunters

Wildlife of Our Homes: http://homes.yourwildlife.org

Home Microbiome Project: http://homemicrobiome.com

American Gut: http://humanfoodproject.com/americangut

uBiome: http://ubiome.com

David Coil

David Coil is a Project Scientist in the lab of Jonathan Eisen at the University of California Davis. His background is in microbiology and his current research interests focus on bacterial genomics and microbial ecology. He loves teaching, mentoring, citizen science, and other forms of science communication, including designing an educational board game called Gut Check: The Microbiome Game.