IN SEARCH OF EXTREME MICROBIOMES AND MICROBIAL DARK MATTER

DNA tools reveal NEW SPECIES AND SURVIVAL STRATEGIES IN EXTREME ENVIRONMENTS from caves to outer space.

Remote and extreme environments, including ocean trenches, volcanic craters, deep caves, and polar regions host rich and diverse microbial life. But studying these microbiomes can be difficult, especially in areas with low biomass. Microbiologist Scott Tighe leads the Extreme Microbiome Project (XMP), an international research consortium founded in 2014 to explore these hidden biospheres. Their discoveries hold promise for healthcare and environmental science, and the tools being developed are proving valuable across multiple settings, from labs to spacecraft and subterranean systems.

What first inspired you to work in this field?

I fell in love with microbiology at high school in the 1980s. Yes, high school! I took a full semester class in the 11th grade where we had to isolate, grow, and identify environmental bacteria. I remember growing bacteria on a plate and being so intrigued by what these tiny organisms were doing — they have so many amazing functions. This early introduction to laboratory work has steered my life path, and I'm just as excited about microbiology now as I was then.

Tell us about the Extreme Microbiome Project

Extremophiles, which are microbes adapted to harsh conditions, represent a remarkable source of new biomolecules with incredible functions that we might not be able to engineer ourselves. For many reasons, including access issues, extreme conditions or even political climate, the environments where this 'microbial dark matter' lives are challenging to sample.

Since 2014, XMP teams have been profiling microorganisms everywhere, from the International Space Station (ISS) to acidic mine lakes, toxic hot springs and deep cave systems, to name a few. The XMP follows the Nagoya protocol, which allows researchers to collect microorganisms onsite, but all intellectual property stemming from discoveries must be shared with the country of origin. It is a fair-trade practice for sampling and discovery. We knew by working together that we would improve our chances of securing special permits, technologies, and funding.

Scott Tighe

▲ Collecting microbial biofilms in the Dry Valleys of Antarctica using aseptic 'DNA-free' collection techniques with XMP collaborators from Georgetown University.

How has collaboration shaped your research?

Nobody can do science alone; it's a team sport, and you need to surround yourself with as many talented people as you can who share your visions. This is also the philosophy of XMP co-founder, Chris Mason, a computational biophysicist at Weill Cornell University. Scientists usually use available resources, including pre-prepared chemicals and equipment to achieve results, but for the XMP that's not an option. Almost every expedition requires developing novel products and approaches because existing laboratory methods don't work effectively for extremophiles[1].

For example, accurately collecting samples from areas with limited microbes, such as a NASA cleanroom or strange and unusual sulfur caves, requires specialized tools. Working with Kasthuri Venkateswaran at NASA's Jet Propulsion Lab in Pasadena and Season Wong at AI Biosciences, we recently developed of two devices for spacecraft use; a zero-gravity DNA extraction device called uTitan[2] and a novel 'microbial squeegee' tool capable of gathering low-mass biomass samples[3]. The XMP has become a proving ground for testing and developing microbiome innovations. Two unique innovations that I created for use on XMP samples are the DNA extraction enzymes, Metapolyzyme and Exopolyzyme.

Scott Tighe

▲ Scott Tighe performs rapid DNA sequencing in Movile Cave off the coast of the Black Sea in Romania.

Have any moments in your lab led to an unexpected discovery?

We've had many unexpected moments. For example, we visited a European cave with speleologist Serban Sarbu, from California State University Chico, and discovered what appeared to be a rock-eating lichen. Under the microscope, it turned out not to be lichen. Instead, it appeared like an unknown bacteria-fungi symbiosis. We've metagenomically sequenced the DNA and had no nearest neighbour genetic hits, indicating it's previously undiscovered. We are still working on this today.

Describe a moment that led to a key breakthrough

We have recently profiled the microbiomes found in snow fields of Greenland and discovered several microbes capable of degrading microplastics[4]. Cold biodegradation of microplastics is unusual and valuable. Based on these findings, we tested a range of different microplastics as a 'food source' for these microbes in the lab in small bioreactors — it isolated several capable of 4°C biodegradation. This was a fantastic finding. I have also worked in Antarctica searching for long-term survival genes within ancient microbial biofilms with collaborator Sarah Johnson of Georgetown University. During this research, we were the first group to ever perform DNA sequencing in the field using Nanopore sequencing, and at McMurdo station using an Illumina MiniSeq[5].

The significance of being able to effectively obtain DNA from these microbial ecosystems and sequence the metagenomes can also provide insights into the lifeforms that could exist on other planets, and potentially help us understand planetary evolution. This is a focus of many XMP team members. So the better the equipment and methods, the better the data. ■

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