Plastic pollution: Understanding threats to human health & bioremediation strategies

Duke UNIVERSITY | BASS CONNECTIONS

Laney Chang[1], Rita Glazer[1], Ella Gunady[2], Sage Hirschfeld[2], Alexander Hong[1], Jas Santos[3], Sophie Vincoff[2], Jenny Yoon[1]

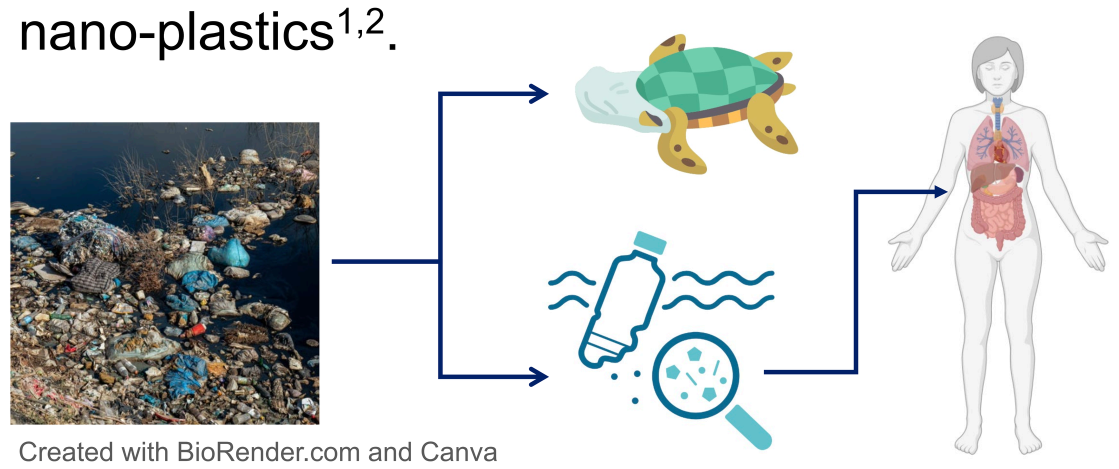
[1]Trinity College of Arts & Sciences, [2]Pratt School of Engineering, [3]Duke Kunshan University

Authors are listed in alphabetical order.

Bass Connections in Energy & Environment

Introduction

Millions of tons of plastic pollution enter the natural environment each year, harming wildlife and potentially harming human health through widespread exposure to micro- and nano-plastics[1,2].



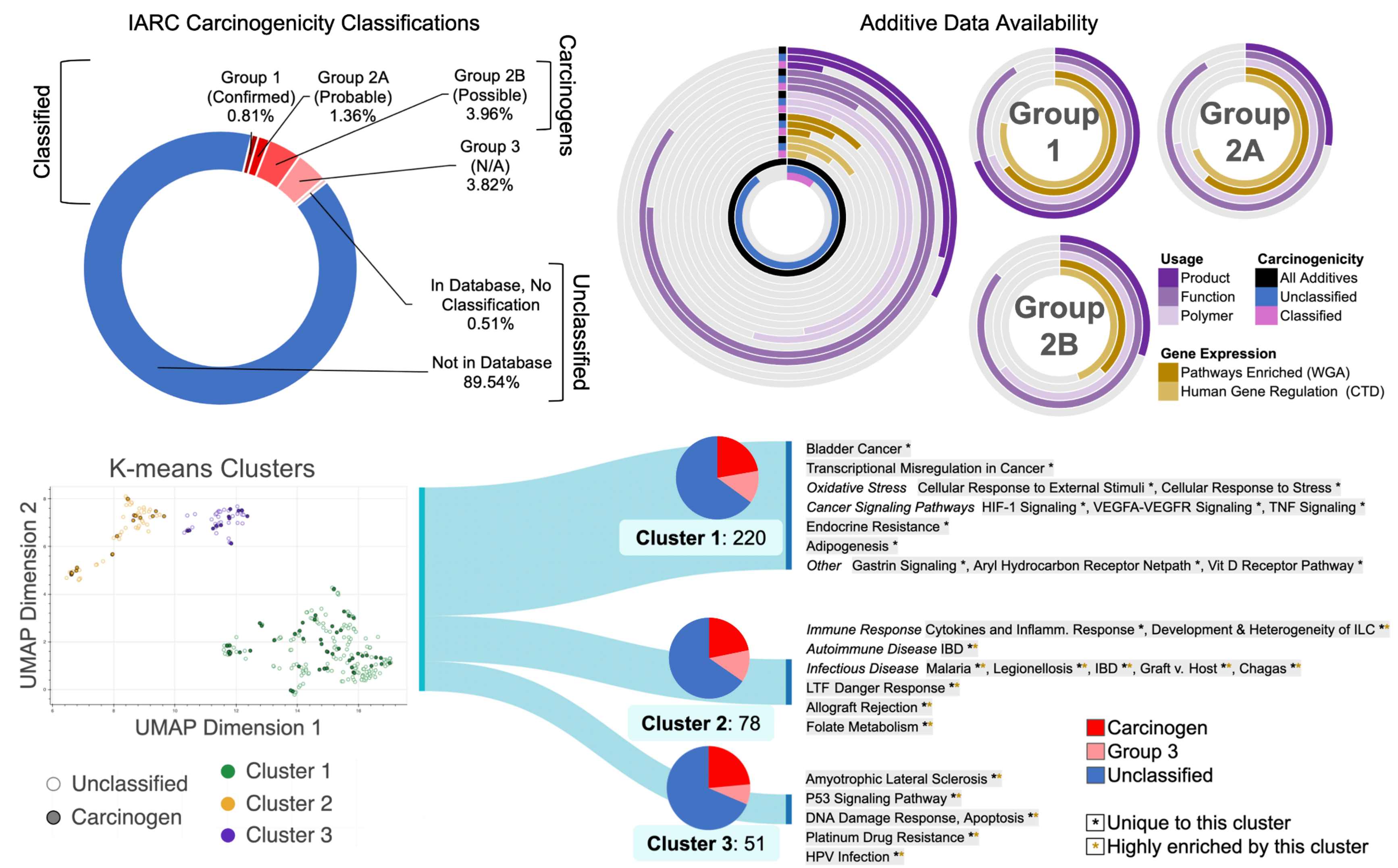
Created with BioRender.com and Canva

Research Goals

1. Understand how plastic and its chemical additives affect **human health** and innate immunity
2. **Discover plastic-degrading bacterial species** and create highly efficient and **thermostable** plastic degraders in the lab

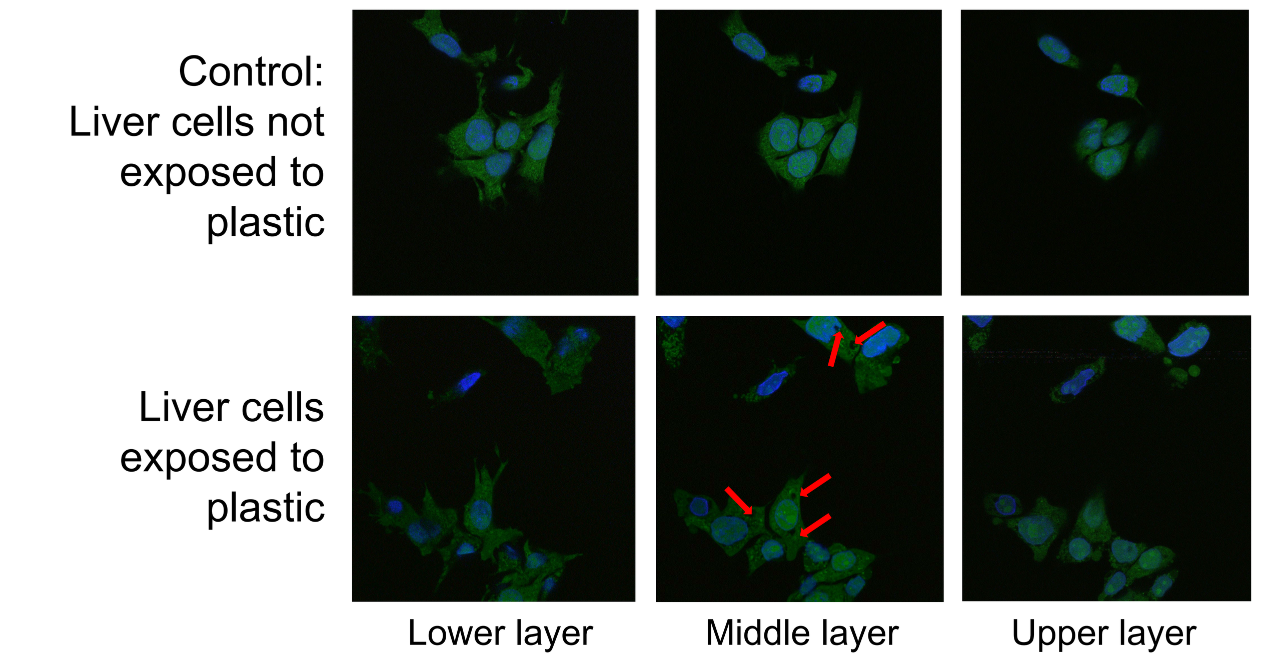
1. Plastics and their additives are potentially harmful to human health

A. ≥ 150 carcinogens and 2,400 chemicals of unknown carcinogenicity are used in plastics.



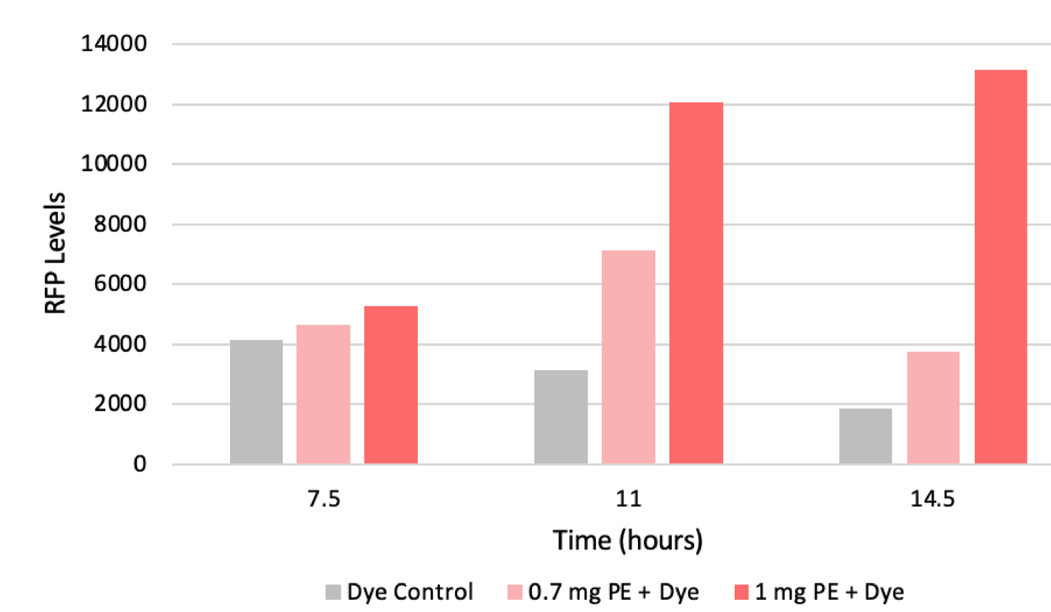
- Chemical-gene interactions are better studied for carcinogens than unclassified chemicals.
- Based on biological effects, additives break into **three distinct clusters** with near-identical distributions of carcinogens and unclassified chemicals.

B. Liver cells can internalize nanoplastics



- **Liver cells likely internalize plastic** as demonstrated by the absence of fluorescent signal within the cells (red arrows).
- **Blue signaling** = cell nucleus
- **Green signaling** = cell cytoplasm

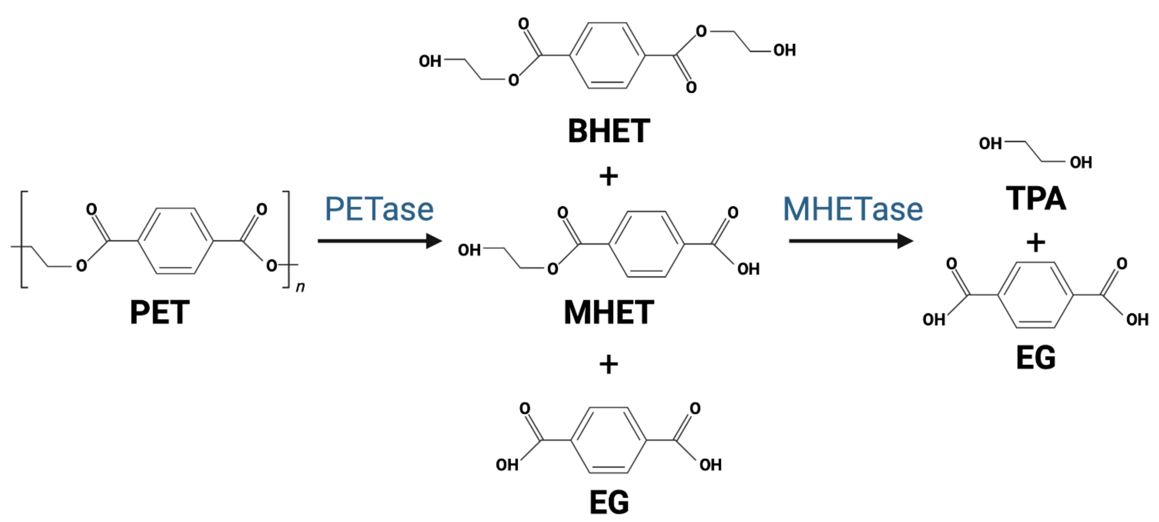
C. Macrophages phagocytose nanoplastics



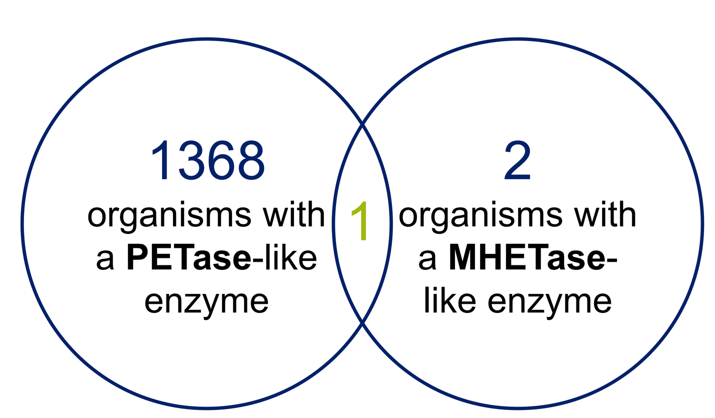
- Human macrophages phagocytose nanoplastics, causing a pH-sensitive red dye (RFP) to fluoresce.
- When exposed to greater amounts of plastic, fluorescent signal increased, indicating a **correlation between rate of phagocytosis and quantity of plastic.**

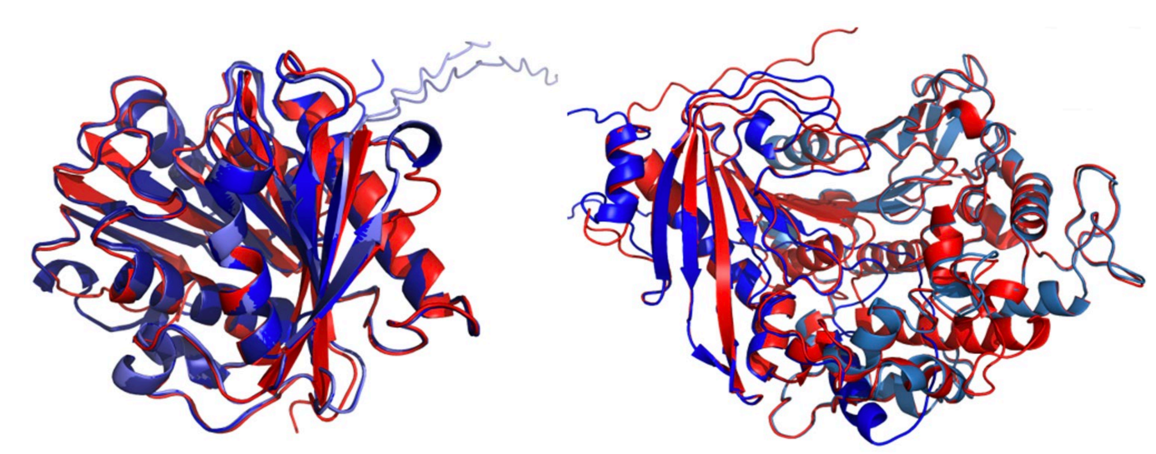
2. Our team is discovering new plastic-degrading bacteria and improving the efficiency & thermostability of existing plastic degraders

A. We identified *Pseudomonas stutzeri* as a potential plastic degrader.



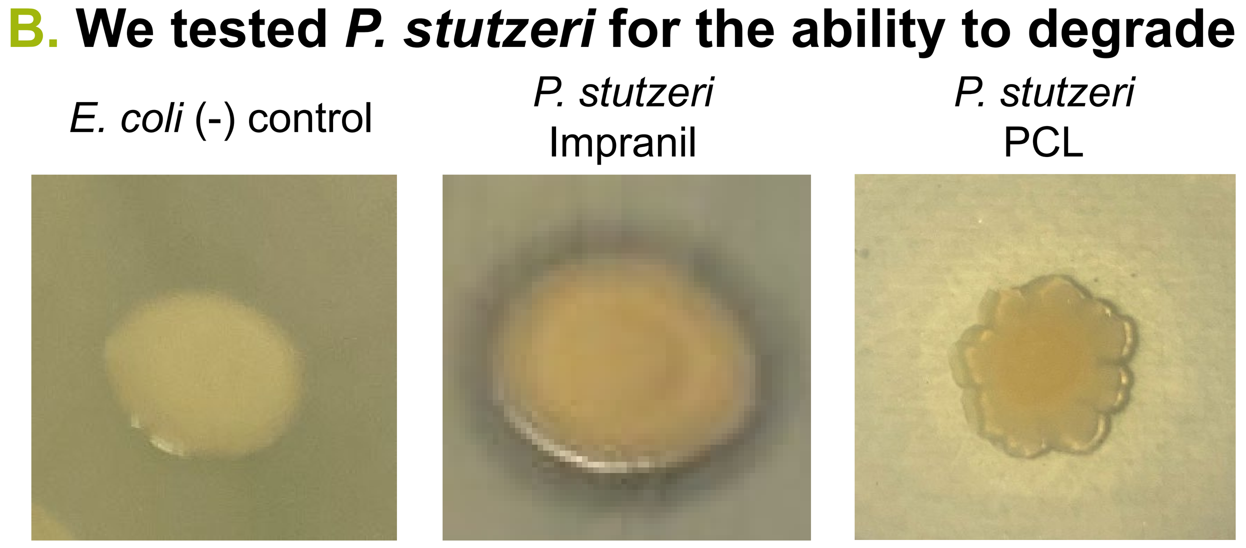
The known plastic-degrader *Ideonella sakaiensis* uses PETase and MHETase to degrade polyethylene terephthalate (PET)[3].



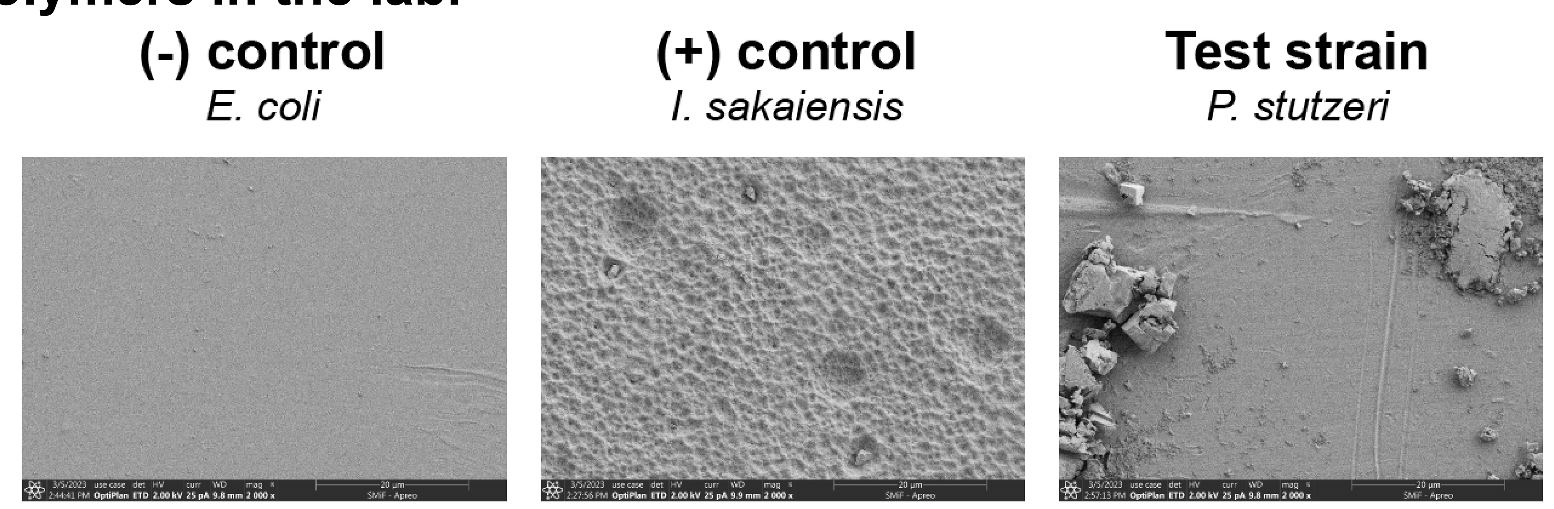


Using bioinformatics, we identified a soil bacterium (*P. stutzeri*) that contains both PETase- and MHETase-like enzymes. The PETase (left) and MHETase (right) enzymes of *I. sakaiensis* and *P. stutzeri* have similar structures. **We hypothesized that *P. stutzeri* is a plastic degrader.**

B. We tested *P. stutzeri* for the ability to degrade various polymers in the lab.

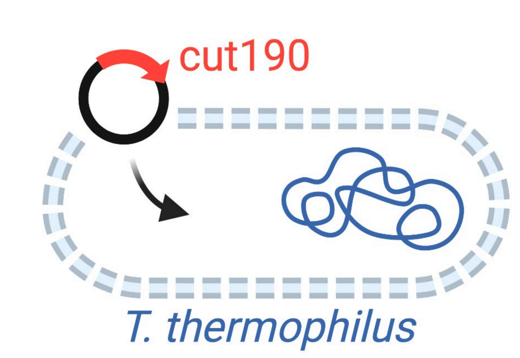


Halos around the *P. stutzeri* colonies show degradation of the polymers, Impranil and polycaprolactone (PCL), in these plate clearing assays[4].

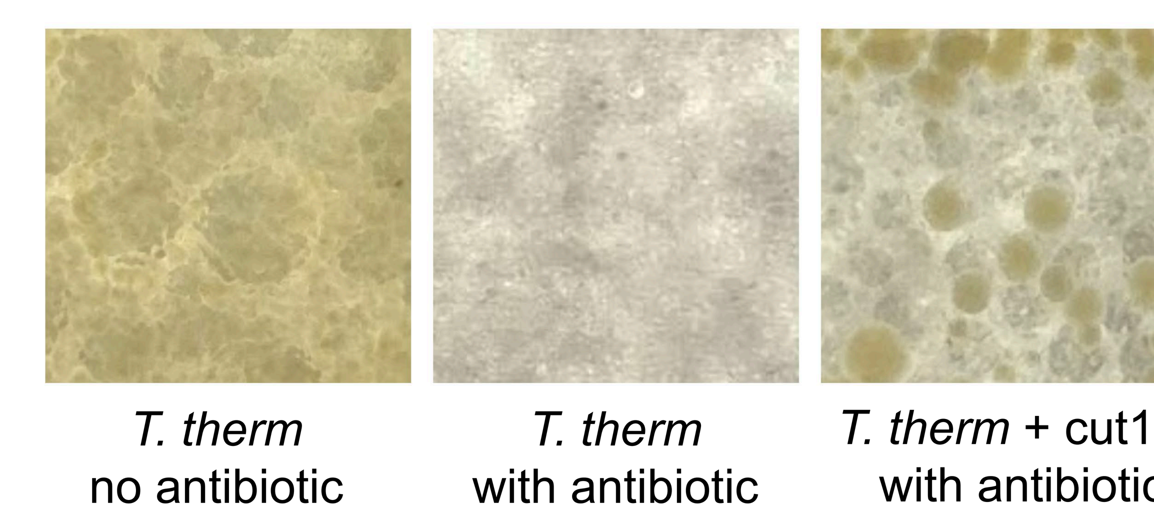


Scanning electron microscope images (5000x magnification) of PET incubated with bacteria for 1 month show that *P. stutzeri* does not degrade PET but deposits debris on the plastic surface.

C. We are developing a thermostable plastic degrader to enable bioremediation at high temperatures.



cut190 = heat-stable PET-degrading enzyme[5]
T. thermophilus = thermophilic bacterium



Antibiotic resistance shows transformation success.

Future Directions:

- **Identify new plastic-degrading bacteria for other plastic types** (PS, HDPE, LDPE, PVC, and PP)
- **Improve the efficiency of natural plastic degraders**
  - Utilize directed evolution to generate novel strains with enhanced ability to degrade plastic
  - Increase temperature range at which degradation is possible

References:

Acknowledgments: We would like to thank Bass Connections, our team leaders, and past team members, especially Jason Somarelli, William Eward, Beatrice Schleupner, Serafina Turner, Zack Weishampel, Newland Zhang, Zoie Diana, Margaret Morrison, Hailey Brighton, Sarah Plumlee, Thomas Schultz, Andrew Read, and Meagan Dunphy-Daly