Plastic Pollution: Health Impacts and Bioremediation Solutions

Duke UNIVERSITY | BASS CONNECTIONS

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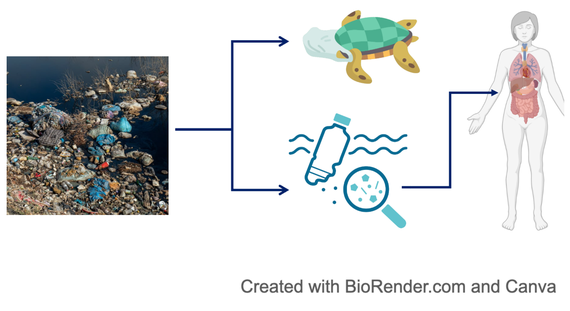
Bass Connections in Energy & Environment

Introduction

- Millions of tons of plastic enter the environment each year, harming wildlife and ecosystems.
- Chronic ingestion of plastics are a danger to our health
- Bioremediation, a process using living organisms to break down pollutants, has shown promise in helping combat the plastic issue. [1, 2]



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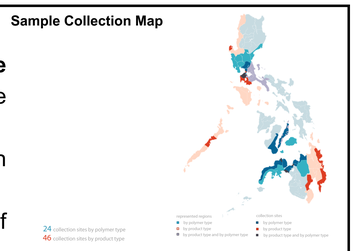
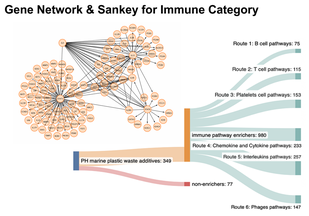
Research Goals

1. **Discover** plastic-degrading bacterial species and **create** highly efficient and thermostable plastic degraders in the lab
2. **Understand** how plastic and its chemical additives **affect** human health and innate immunity
3. **Identify** and **create** policy to help curb plastic pollution and **educate** future scientists about plastic bioremediation efforts

Plastic additives have many potential health effects.

- We uncovered **associations between additives and the top polymer types** prevalent in the Philippines marine plastic waste
- About **53% of additives** examined exhibit associations with **cancer pathways and endocrine & immune disruptions**
- Associated genes show **disproportionate enrichment** of the IL-4 and IL-13 pathways
- Enriched endocrine pathways linked to **adipogenesis** and **lipid accumulation**
  - elevated risk of **obesity** in coastal communities
  - impact of **hormone sensitizers** show additives can **increase** our body's responsiveness to other endocrine-disrupting chemicals





Bioremediation Solutions

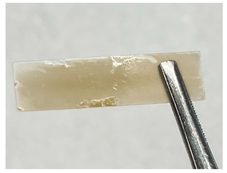
Developing a thermostable bacterial strain to degrade plastic more efficiently at higher temperatures.

- ☑ Transform thermostable bacteria with plastic-degrading enzyme
- ☑ Validate plastic degradation
- ☐ Optimize conditions
- ☐ Build bioreactor for plastics

Thermostable bacteria *T.Thermophilus*

+

Thermostable PET degrading enzyme cut190[3]

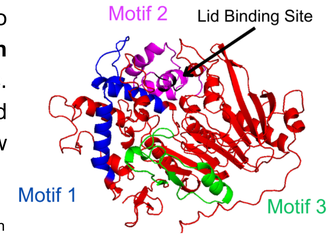


Biofilm growth of *T.thermophilus* transformed with, plastic-degrading enzyme, cut190, on PET

Using a novel computational pipeline to identify plastic degraders.

Given a set of proteins we know to degrade plastics, we can **search** for similar sequences in databases. **Verification** of sequential and structural similarity yields new plastic degraders!

Annotation of functional regions and motifs in Ideonella, a well-known plastic degrader



BLAST — Searching for similar sequences → **Phylogenetics** — Confirming sequential similarity based on evolution → **AlphaFold & PyMol** — Visualization and confirming structural/functional similarity

Engineering an extracellular fusion enzyme for enhanced PET degradation.

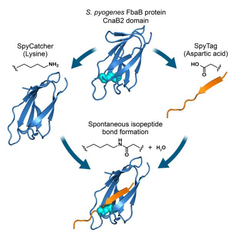
Design a **paired recombinant bacteria system**

- Excrete enzymes able to link extracellularly to create an efficient PET degrading fusion enzyme
- Modified with **pelB** signal sequence and **Spy Tag/Catcher**

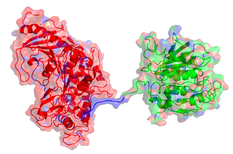
Leaf Compost Cutinase (LCC) is a hydrolase found to to be a highly efficient PET degrader. [MS].

We **bioengineered two *E. coli* strains** to export LCC and MHETase

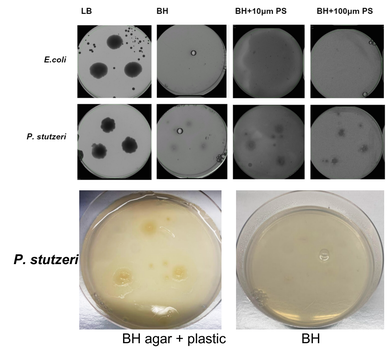
- pelB allows cytosolic export of enzymes
- bioconjugation domain pair causes the two enzymes to bind



LCC-MHETase Fusion



Validating *P. stutzeri* utilization of polystyrene on agar plates.



We mixed polystyrene microspheres with carbon-free Bushnell Haas (BH) agar and inoculated with *P. stutzeri* and *E. coli* (control). Growth suggests **metabolism** of polystyrene as a sole carbon (food) source.

P. stutzeri, the novel bacterial species we identified, can consume polystyrene microspheres as a carbon source. Future experiments will test *P. stutzeri* on consumer grade Styrofoam.

Plastic policies lack information on additives, but educational outreach can improve local action

How effective are policies and other efforts aimed at mitigating plastic pollution and its associated health risks?

1. **Examine** plastics policies in the Nicholas Institute's Plastics Policy Inventory and assess how often plastic additives are addressed
   a. **Conducting** a database search of plastics policies in the Inventory
2. **Understand** how high school students perceive current systems in their local communities that aim to reduce plastic pollution
   a. **Develop** a program for high school students to participate in an audit and waste cleanup
      i. What plastics we encounter the most, what additives are found in those plastics, and the health concerns of those additives
      ii. Students will complete a survey before and after to see if any perceptions regarding plastic pollution have changed

Future Applications

- Identify and validate new plastic-degrading bacteria for other plastic types (LDPE, PVC, and PP) through bioinformatics and in-vitro techniques
- Improve the efficiency of natural plastic degraders
  - Thermostable Transformations of *Thermophilus*
  - Quantify enzyme's plastic-degrading activity and presence of pelB primers
  - Increasing potential of *P. stutzeri* in plastic degradation

References

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