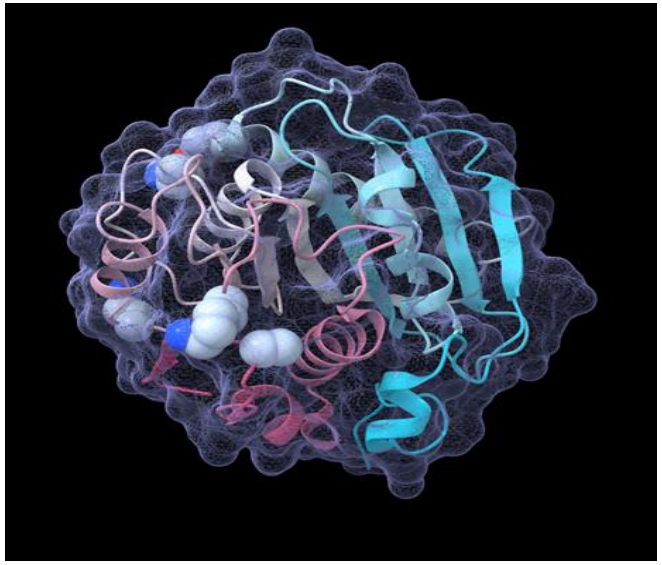
Bioengineering to Save the World

Hal Alper
The University of Texas at Austin



Everything we do leaves a footprint on our environment

Some impacts are highly visible

Some impacts are highly visible

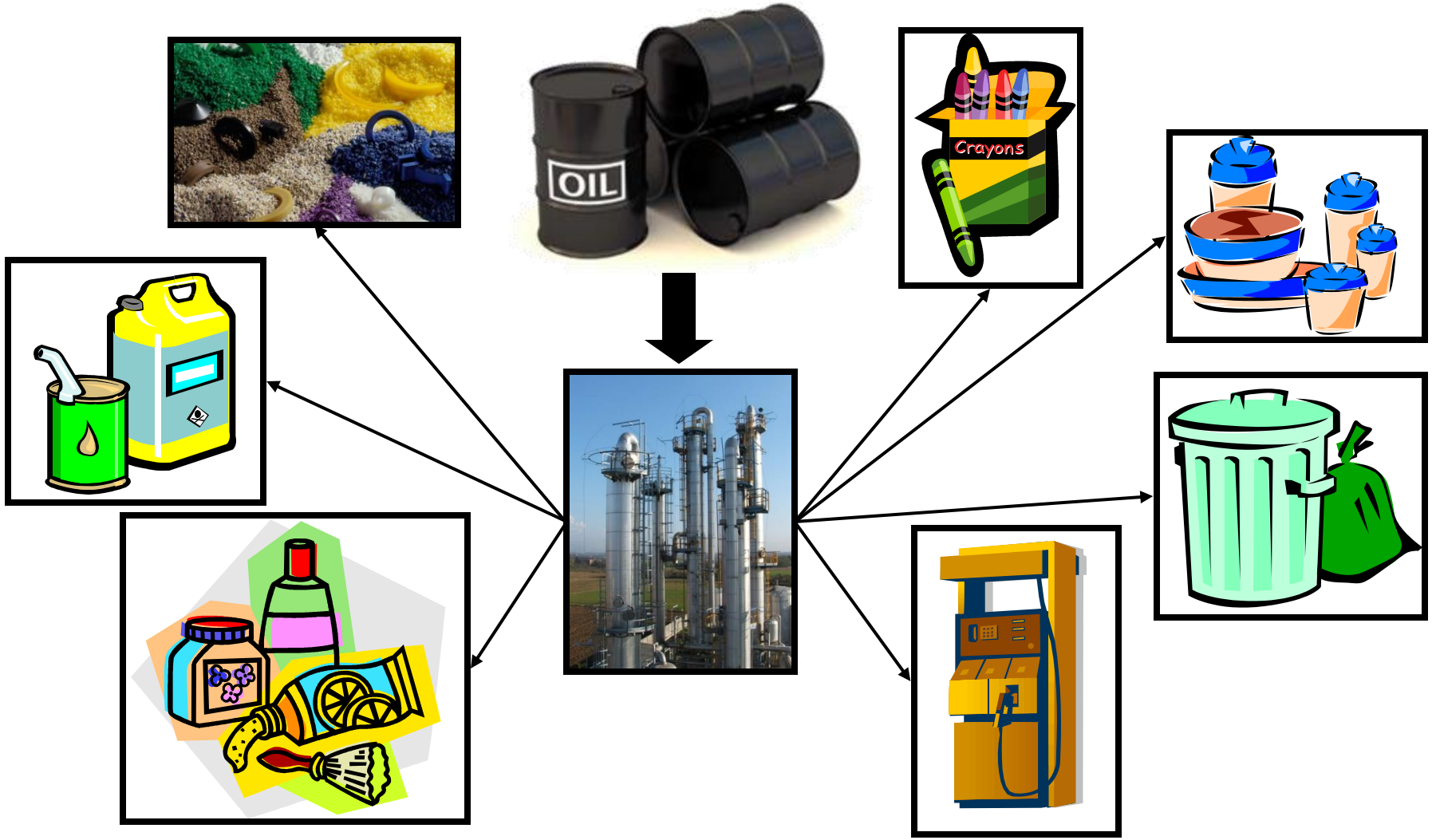
Some impacts are highly visible

Some impacts are highly visible

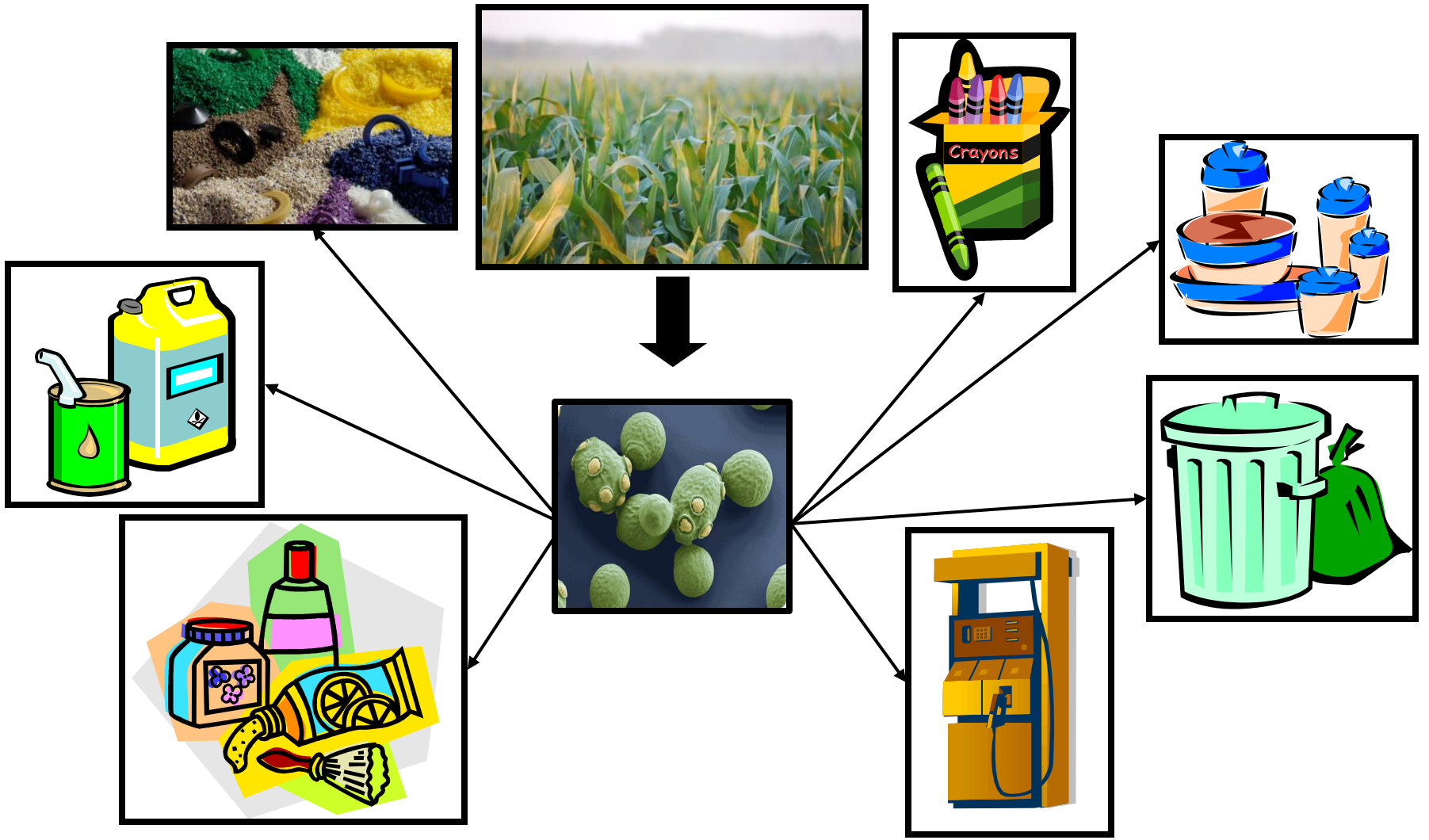
Some impacts are not easily seen

We need a more sustainable solution for our Planet

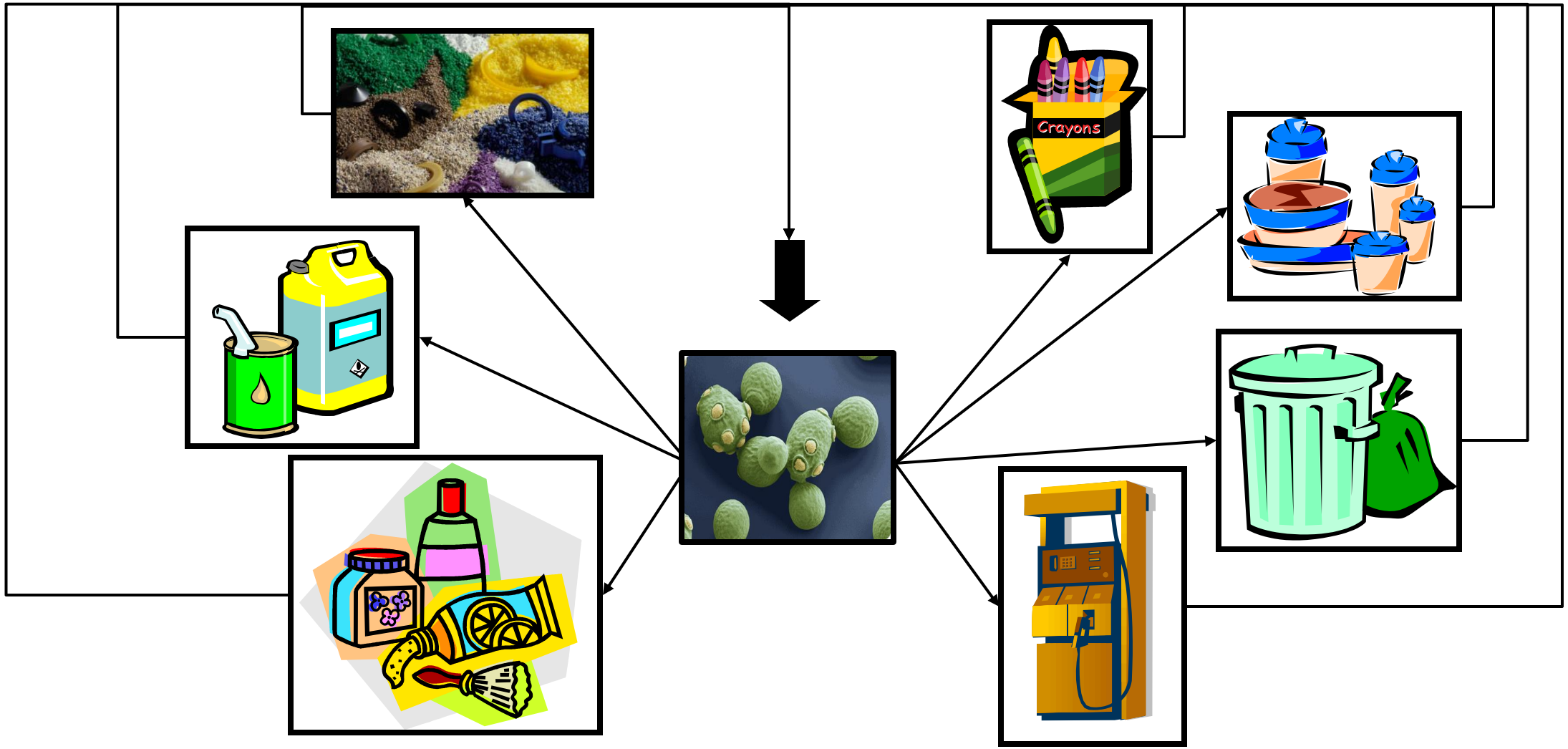
Sustainability requires a transition away from traditional chemical manufacturing



Initially we wonder whether we could “grow” these materials?

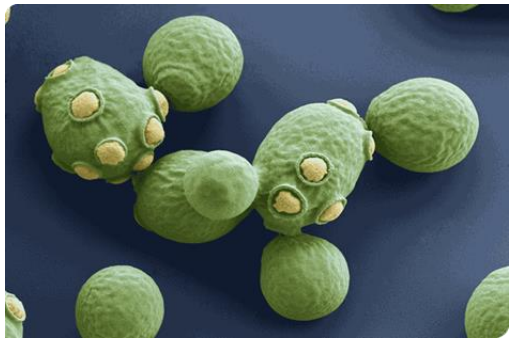


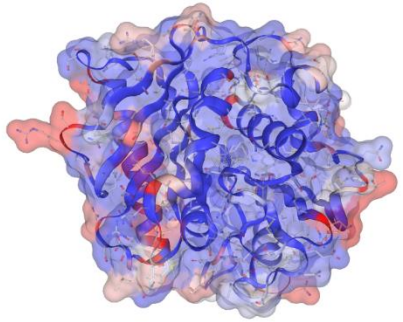
Better yet, what if “end-of-life” turns into a feedstock?



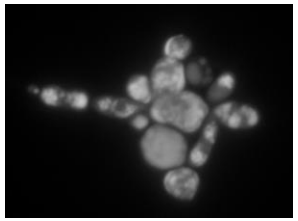
Bioengineering can convert “waste into treasure”

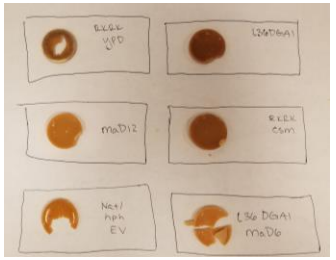
Waste Inputs

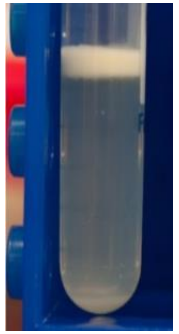




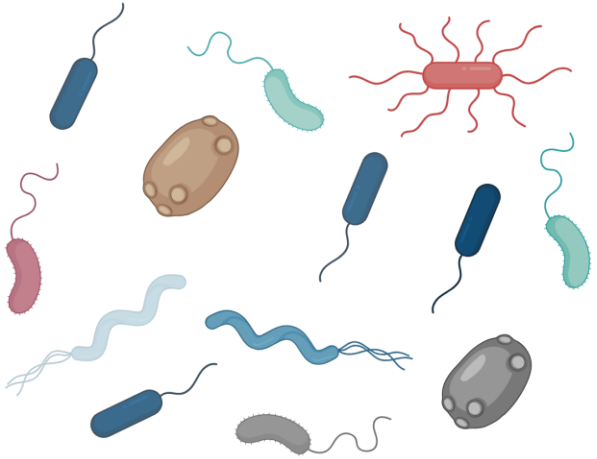
New Products

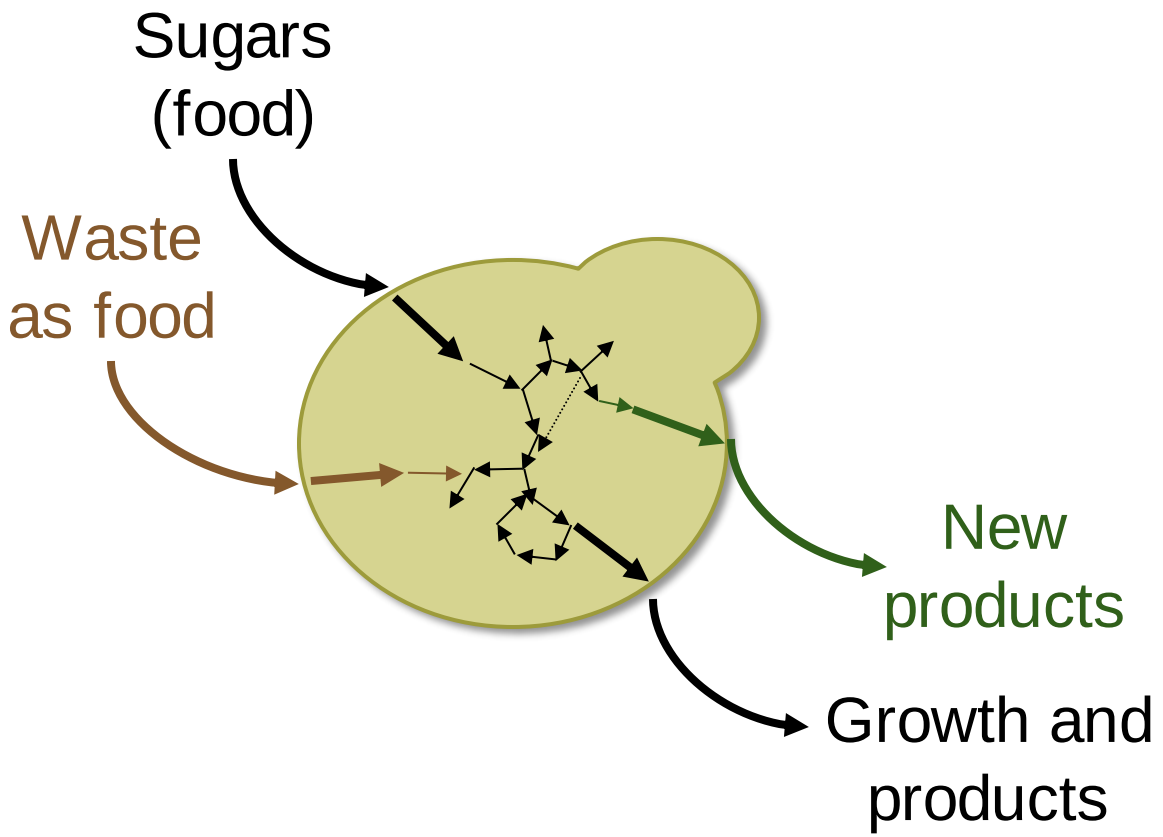




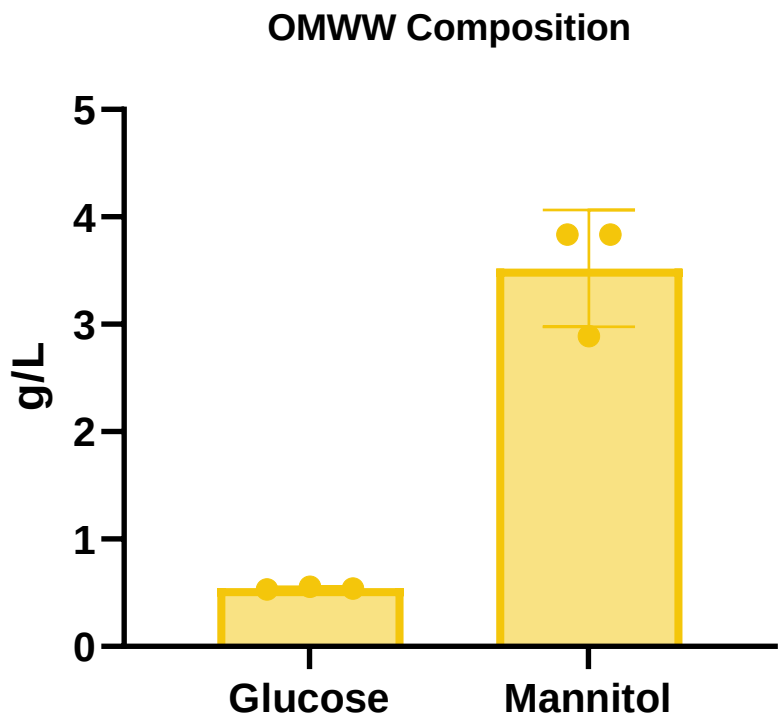


Harnessing the power of a cell to transform waste

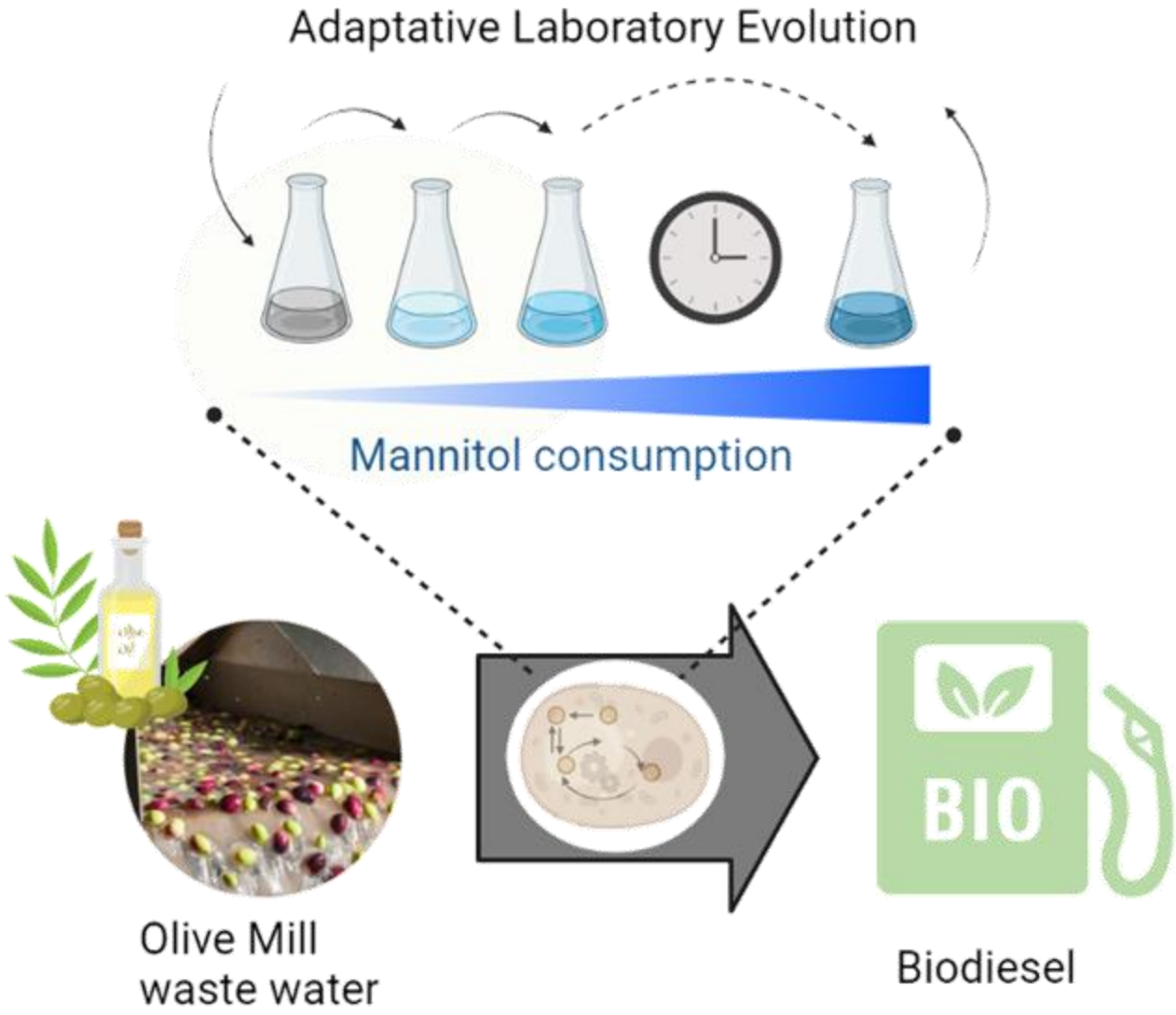




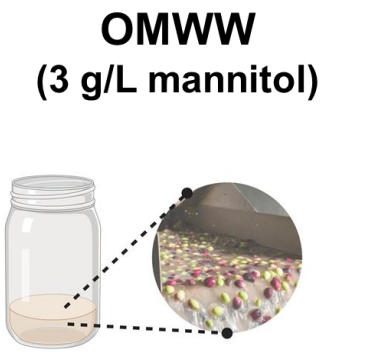
Olive mill waste water has a high organic content



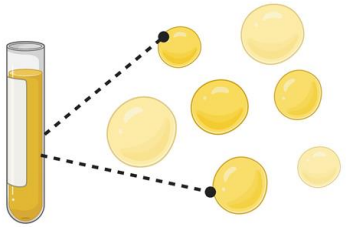
Teaching yeast cells to consume waste from olive processing



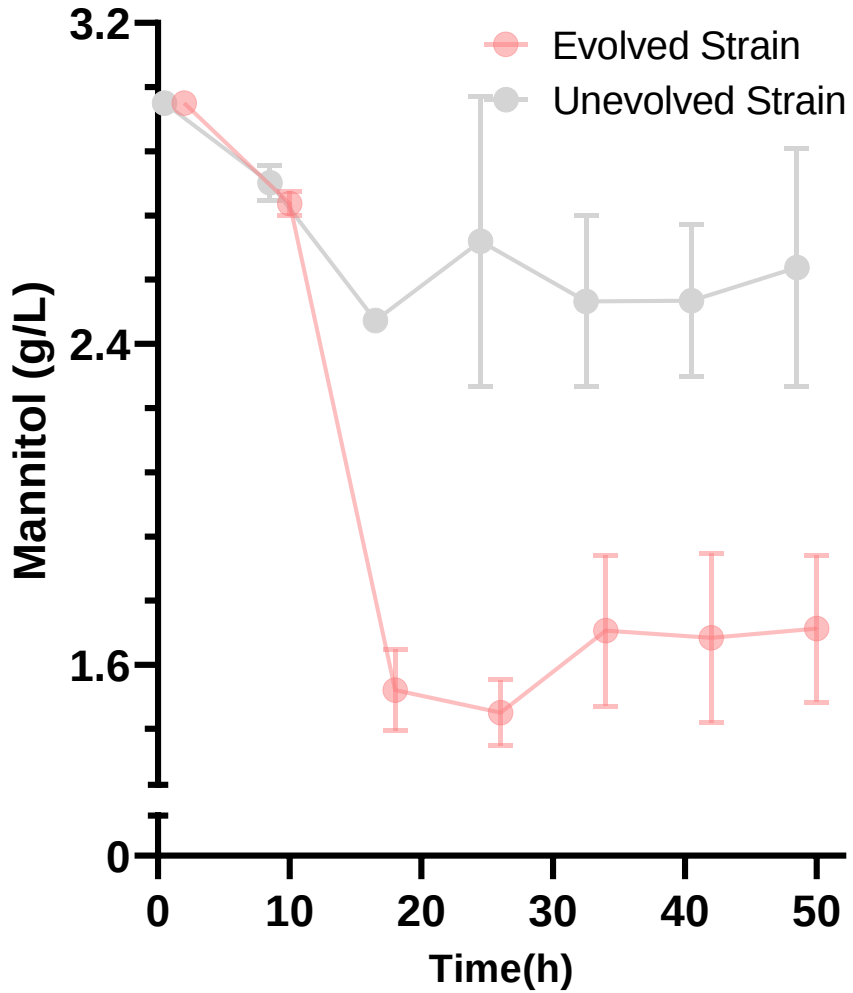
Converting waste water to fuel



Evolved *Y. lipolytica* consumption of OMWW



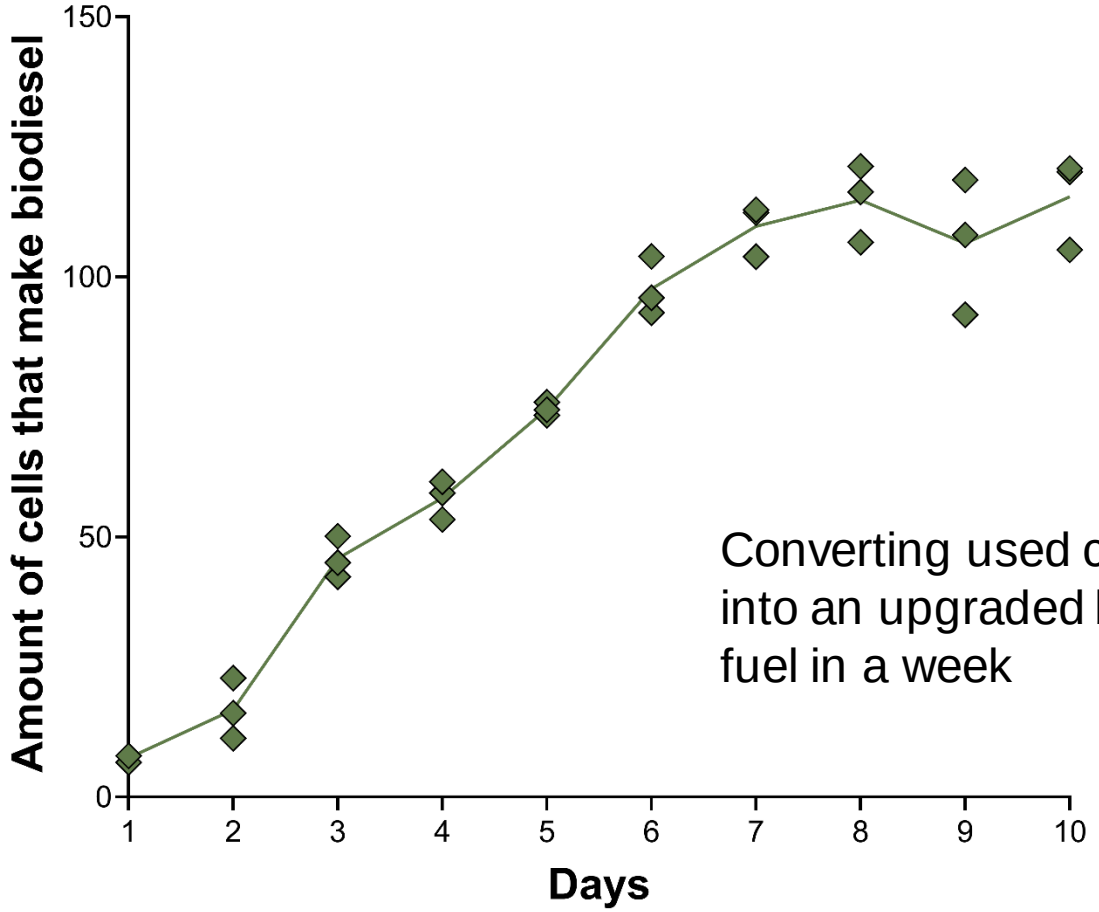
Lipids
(0.24 g/g)



Waste cooking oil is a hazardous waste

Improperly disposed waste cooking can wreak havoc in pipes

Converting locally sourced cooking oil to upgraded biodiesel



Converting used cooking oil into an upgraded biodiesel fuel in a week

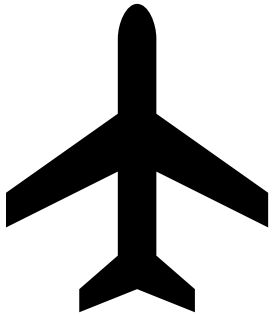
Bioreactor in Alper Lab

Nearly 400 millions tons of plastics will be produced this year

How much is 400 million tons?

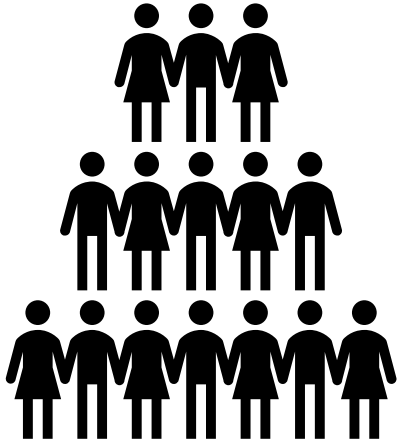
11 Million fully loaded tractor trailers

<3 Million in the US



700,000 fully loaded A380 aircraft

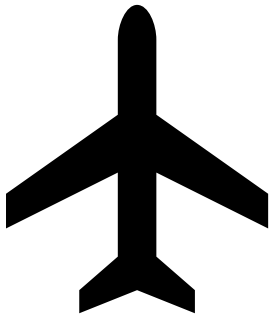
~250 manufactured



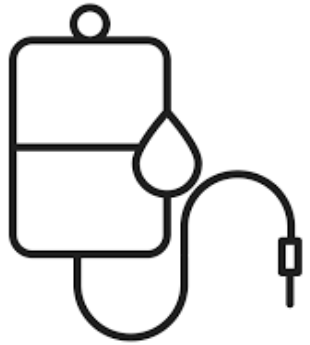
Collective weight of every human

Plastics enable many advances in our modern life

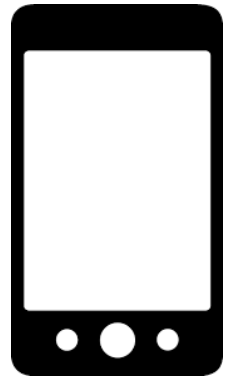
Decrease weight 30% and increased fuel efficiency >18%



Carbon-fiber reinforced plastic increase fuel efficiency 20%



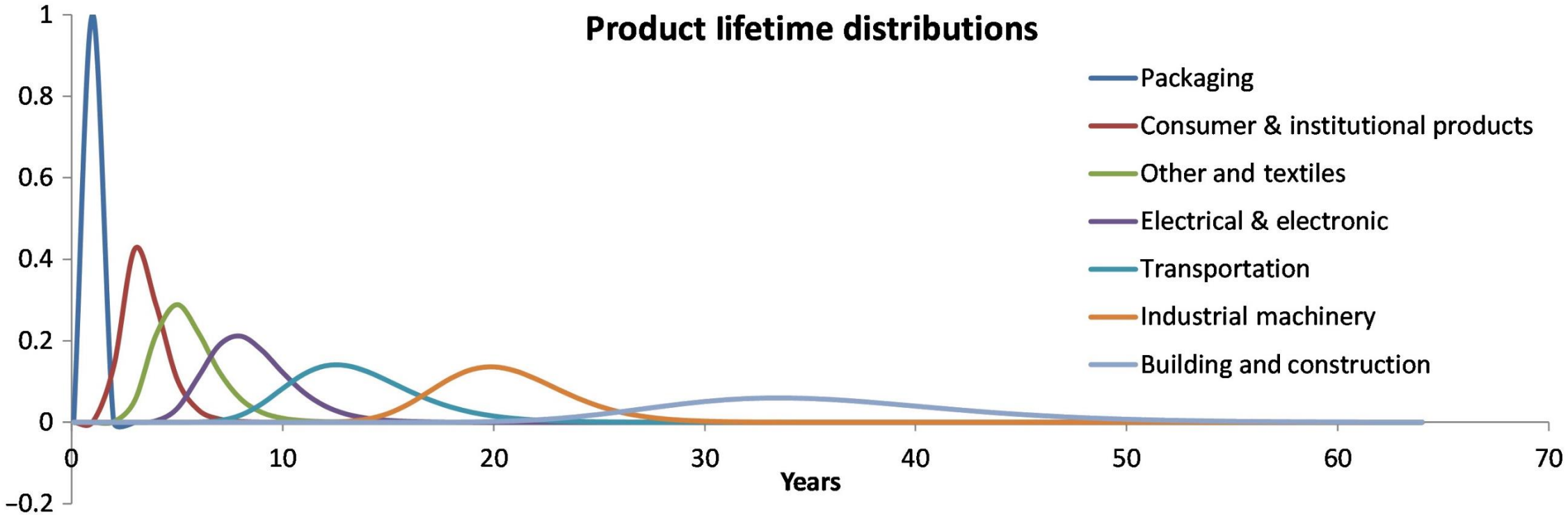
Enable modern medicine and sterilizable devices



Enable cell phone function and heat dissipation

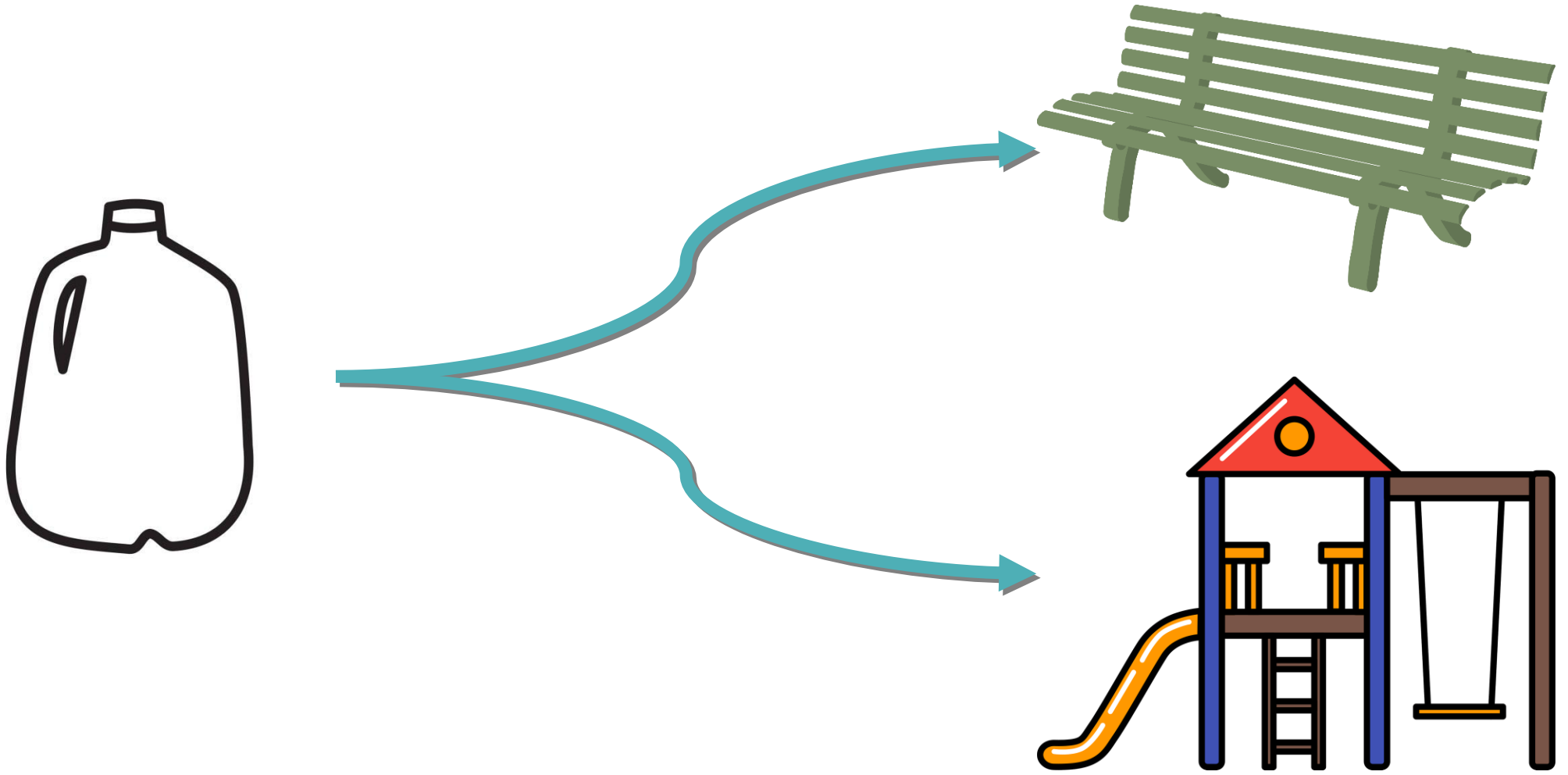
The long-lasting impact of plastics

Impact of single use varies across sectors



Geyer *et al.*, *Sci Advances*, 2017

Some plastics can be repurposed for a new life

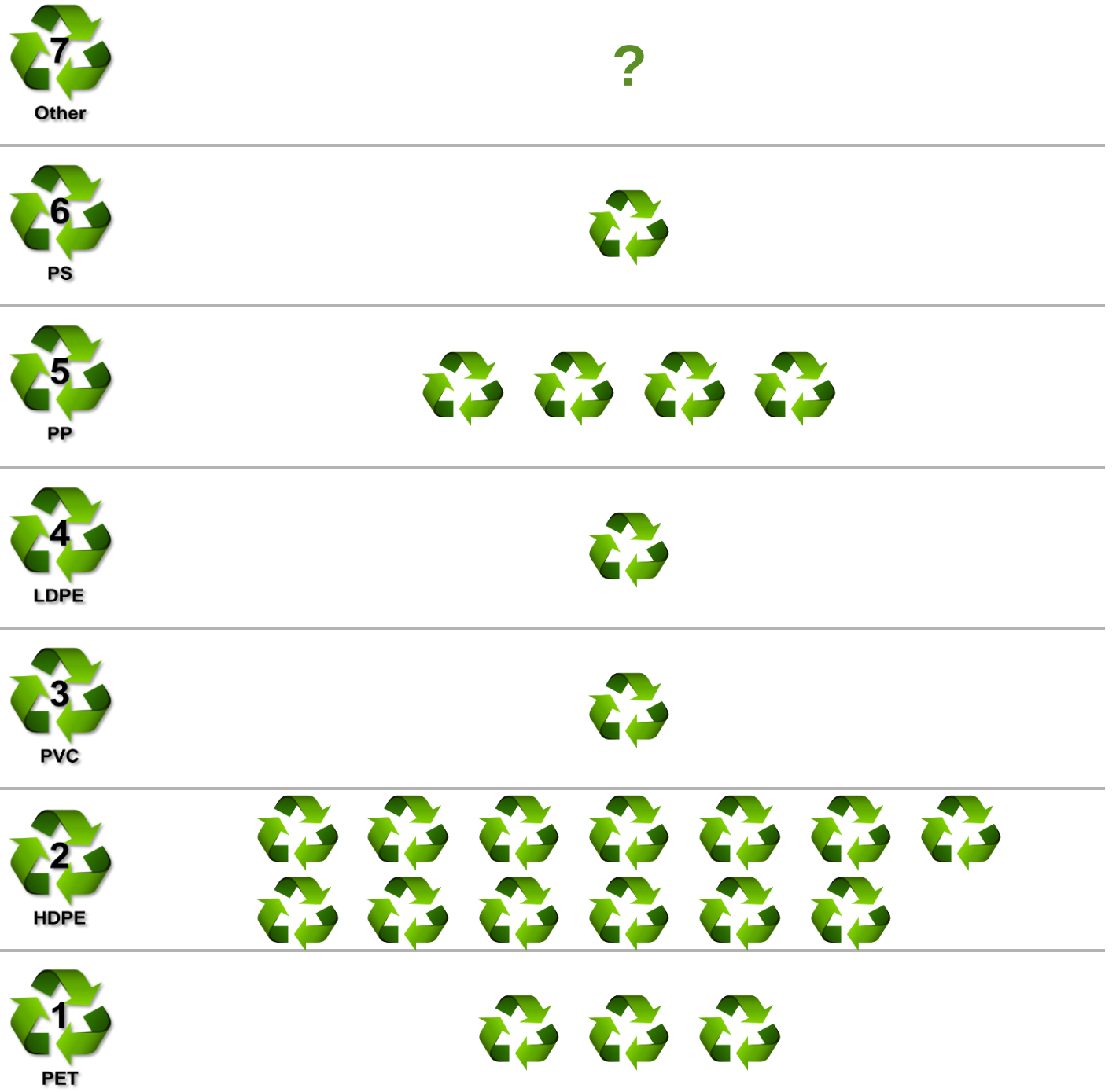


How much plastic waste is actually recycled?

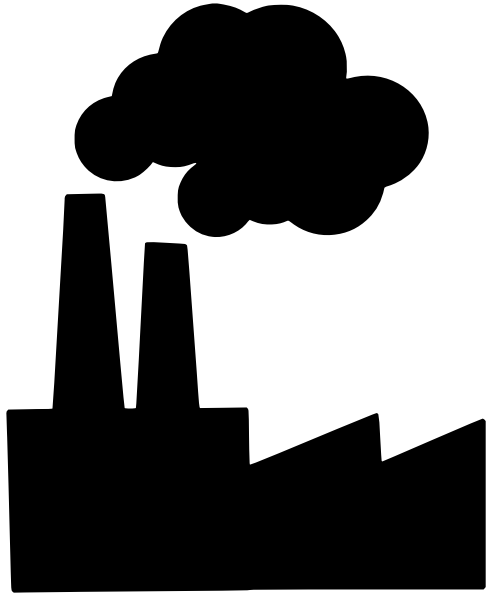
15% Collected

9% Recycled

Traditional mechanical recycling is limited



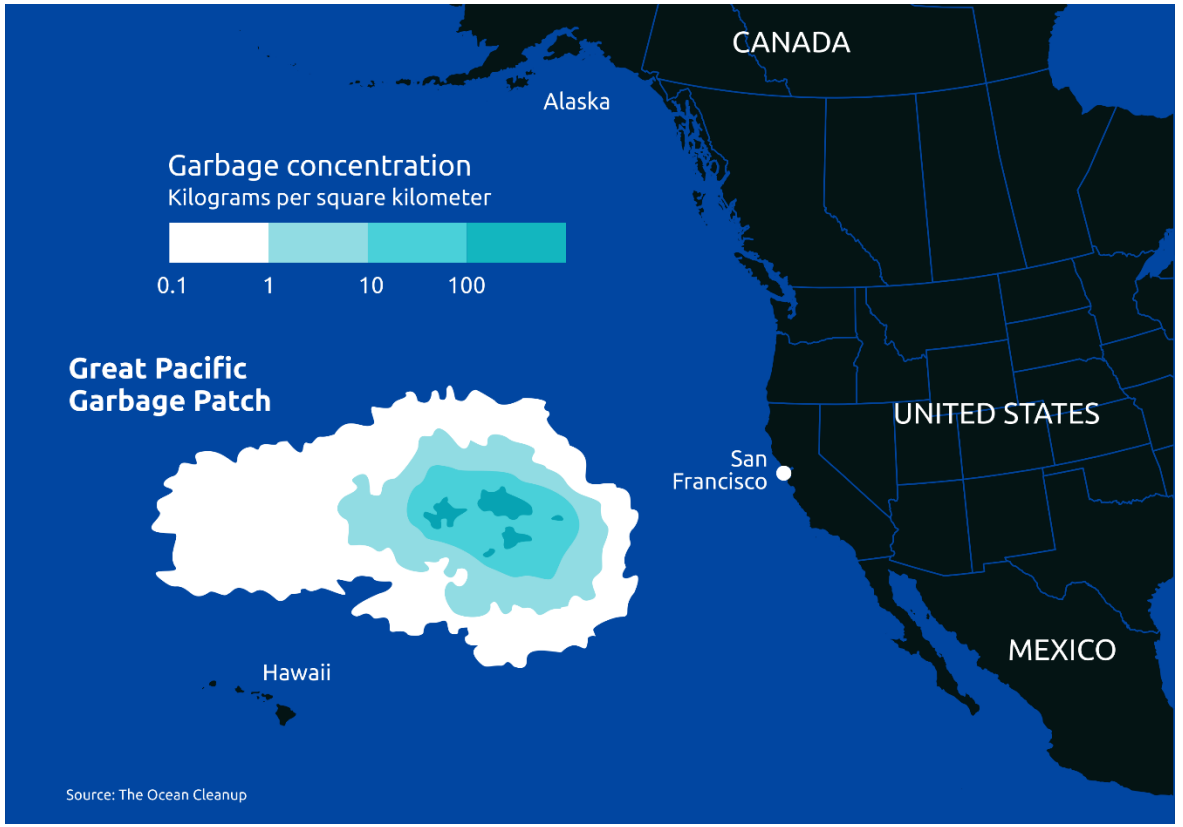
The problem with plastics are current production, end-of-life, and over-use



Plastic production, conversion, and handling emit 3.4% of global greenhouse gas emissions

OECD Global Plastics Outlook Database, 2023

The problem with accumulated plastic waste



Estimated 1.8 Trillion pieces of plastic

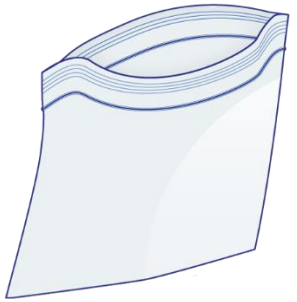
~50% of this is discarded fishing supplies

The Ocean Cleanup, 2023

Plastic nurdles as the source of all of our materials

~1000 Nurdles

~300 Nurdles



~400 Nurdles

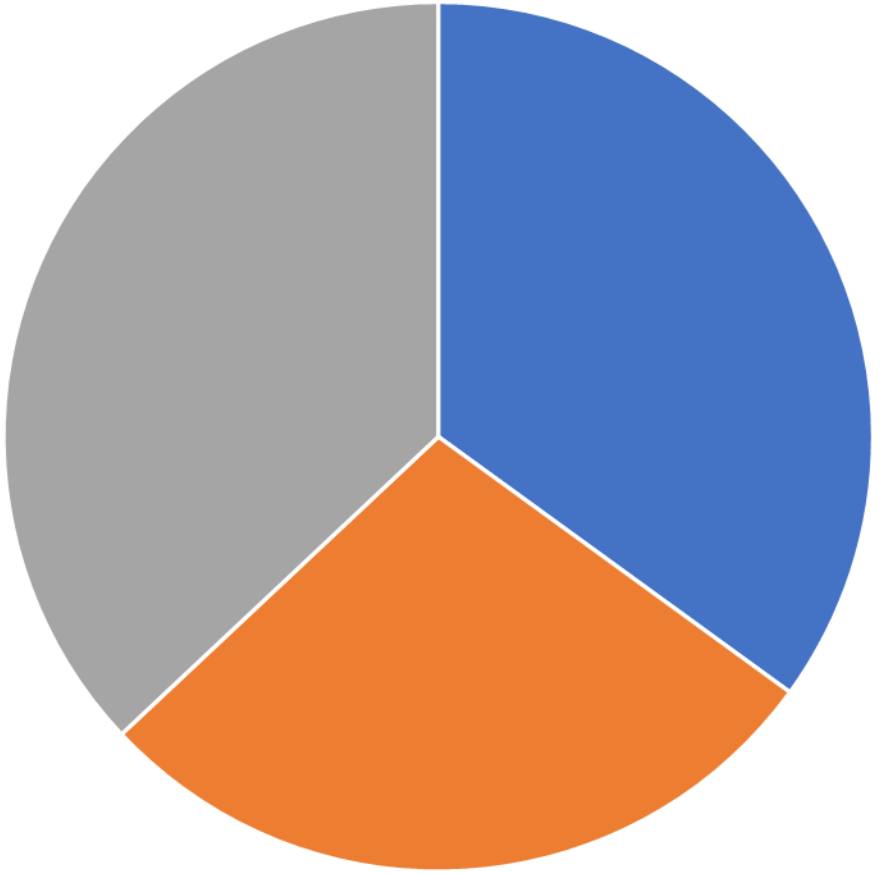
>10,000 tons of nurdles enter out waterways each year

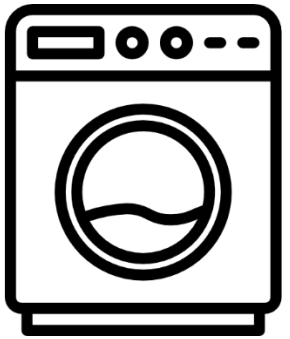
Environmental disasters highlight challenges

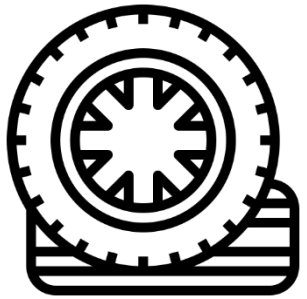
X-Press Pearl
June 2021
Sri Lanka

~2000 tons of nurdles were released

Microplastics: another impact of plastic usage (and waste)



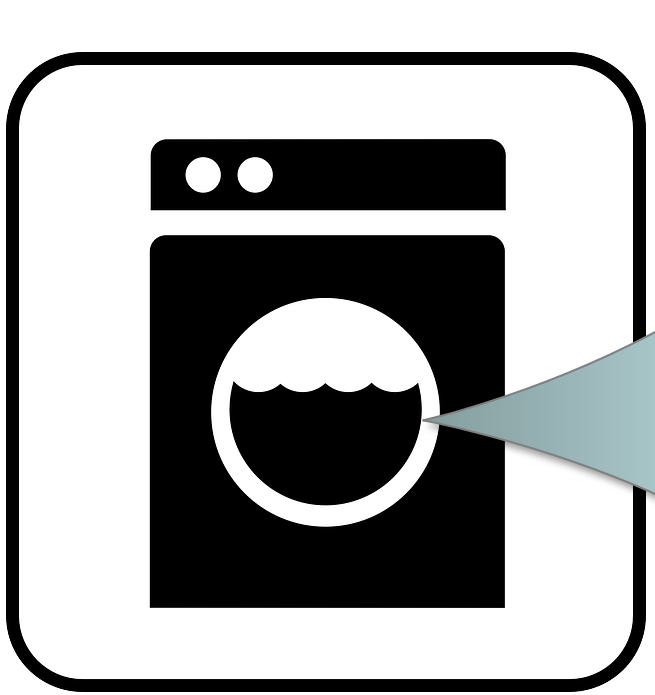




~60% of all microplastics come from two very common daily activities

Boucher *et al.* IUCN, 2017

Microplastics from the laundry



Average load :

1 gram microfibers
>700,000 particles

Most pass through water treatment facility

De Falco *et al.* Sci Rep, 2019

An estimated 1.53 Million tons / year of microplastics are released

Per person, that is equivalent to:

Boucher *et al.* IUCN, 2017

Are plastic alternatives better for the environment / climate?

In terms of CO_2 / net global warming potential:

1 HDPE plastic bag used once =

Paper bag used 3 times
LDPE bag used 4 times
Cotton bag used 131 times

Edwards *et al.*, *Env. Agency*, 2011

Are plastic alternatives better for the environment / climate?

In terms of CO_2 / net global warming potential:

1 PP plastic straw used once =

Paper straw used 5 times
Metal straw used 150 times

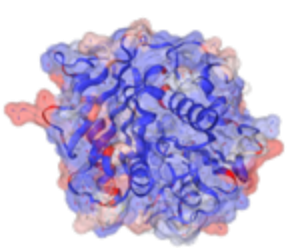
Rana *et al.*, MSU, 2020

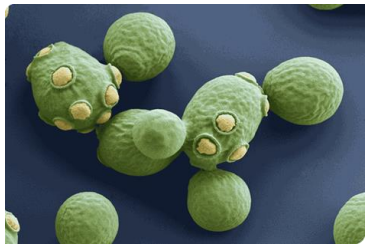
We need a sustainable, circular solution

Every single-use material has the same problem: single use

<u>Production</u>:
Precious resources, CO_2 emissions, energy

New material



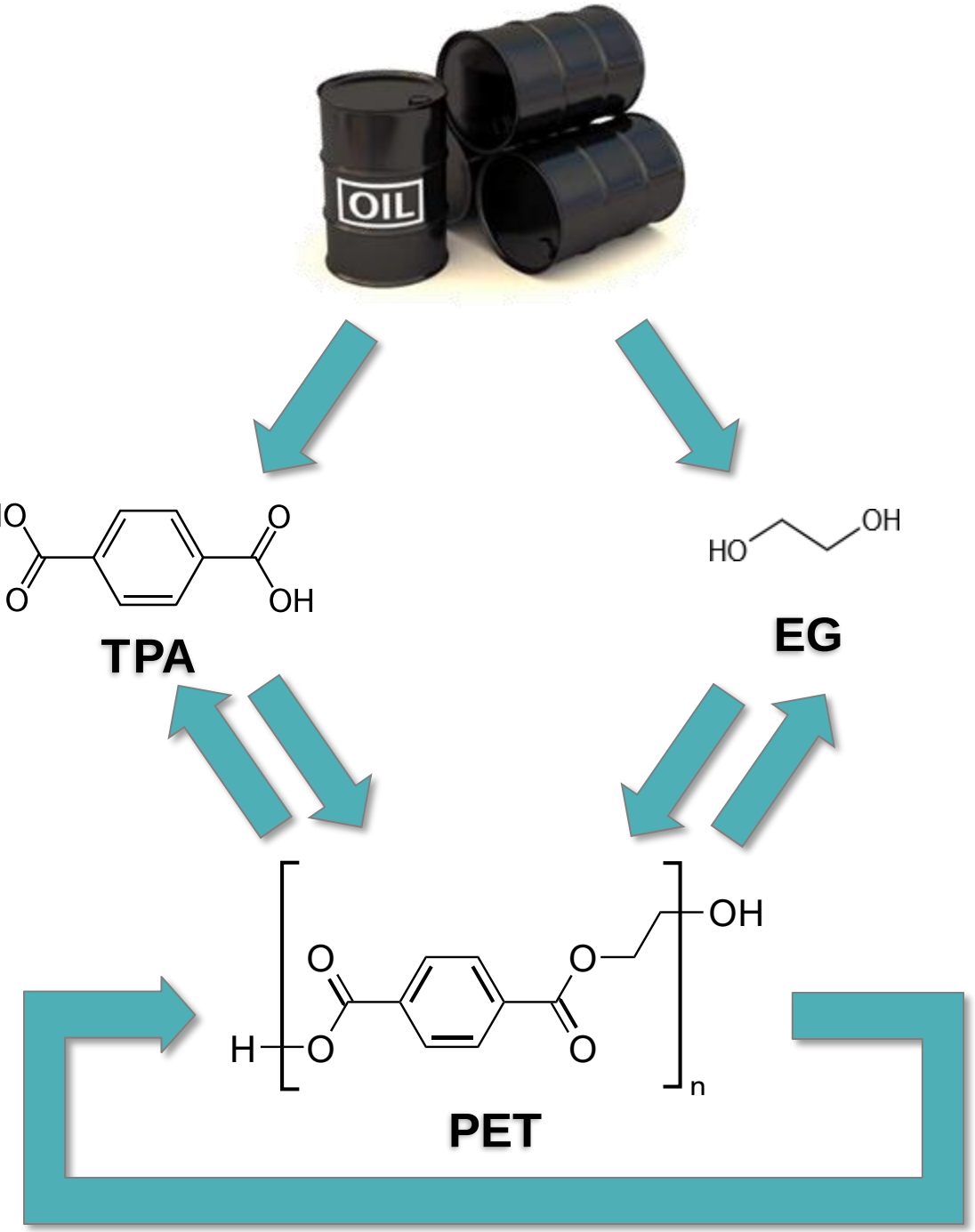


Used Material

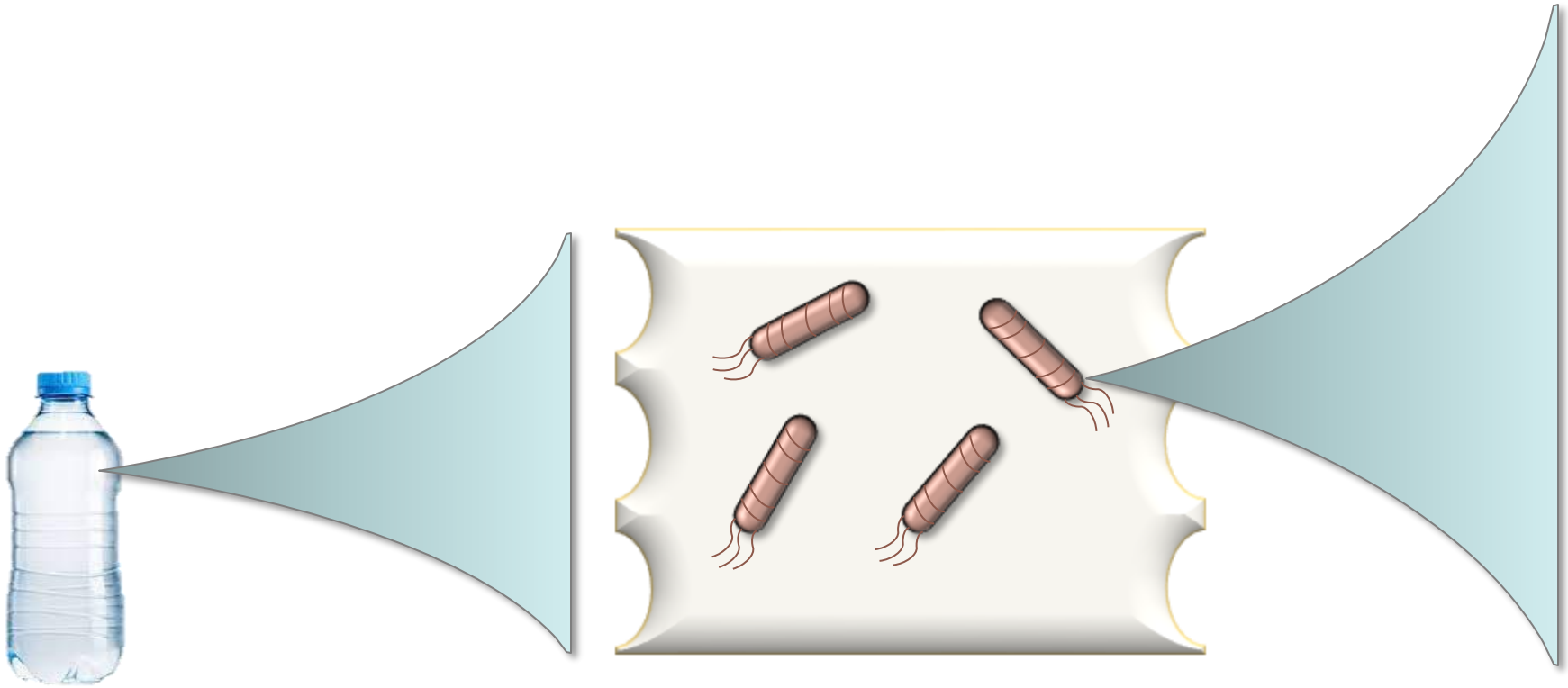
<u>Disposal</u>:
Waste, lost carbon, energy, CO_2

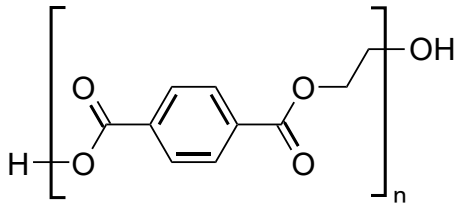
How to close the loop:

Re-thinking PET recycling to enable infinite reusability

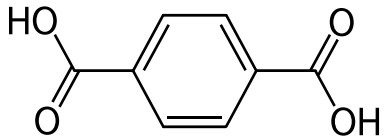


Nature has slowly found a way…

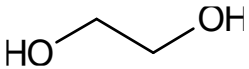




PET



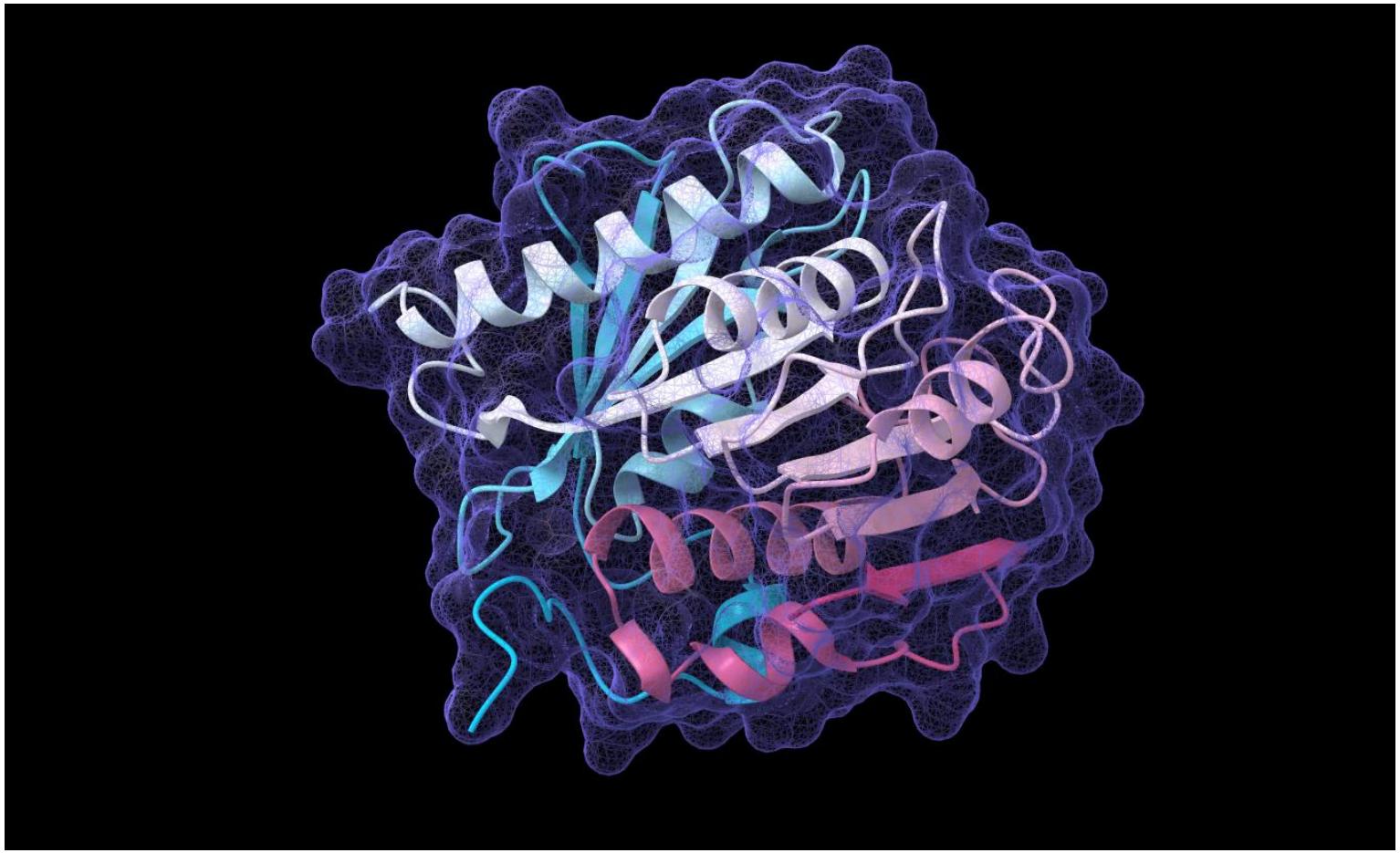
TPA



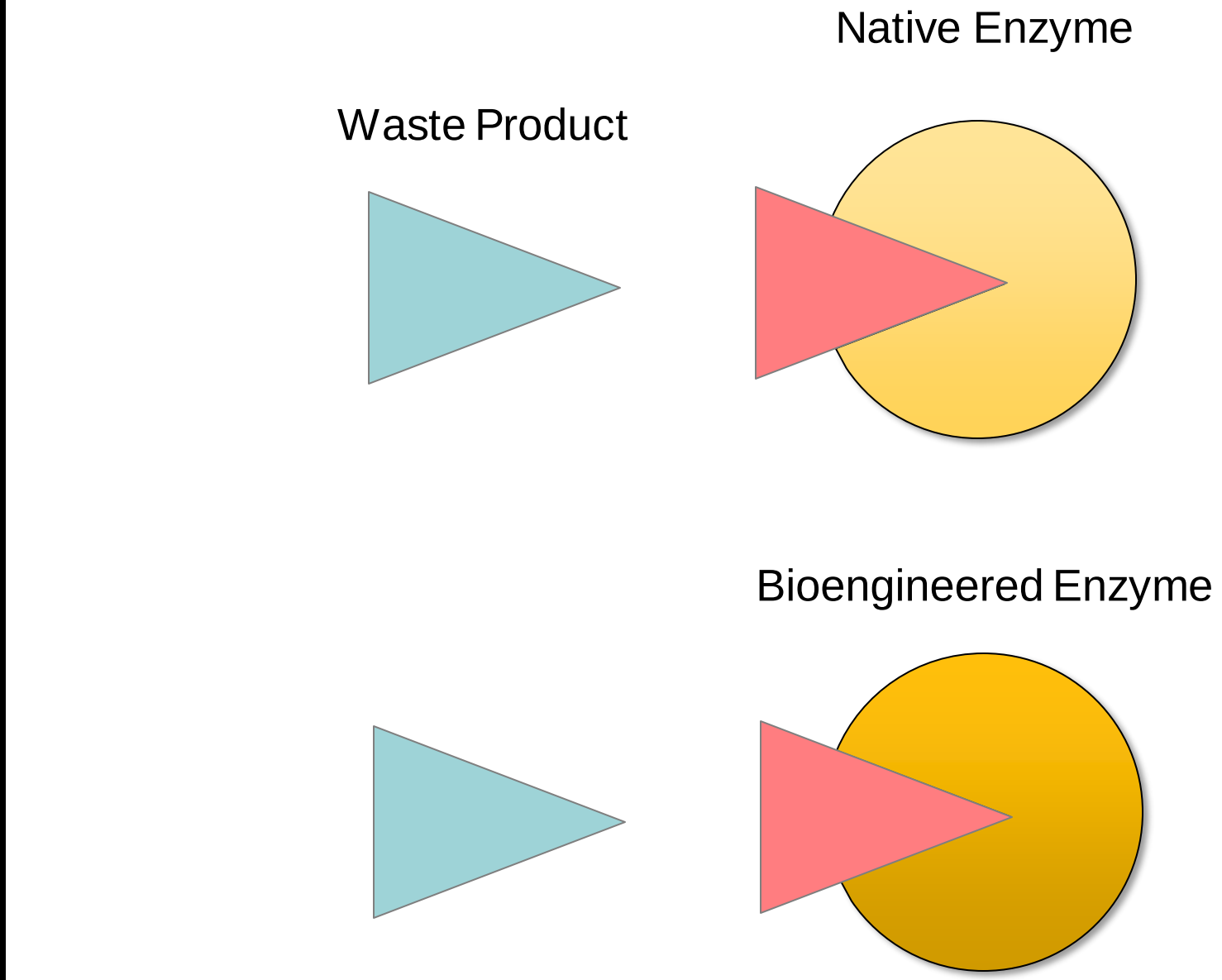
EG

Ideonella sakaiensis first identified in 2016

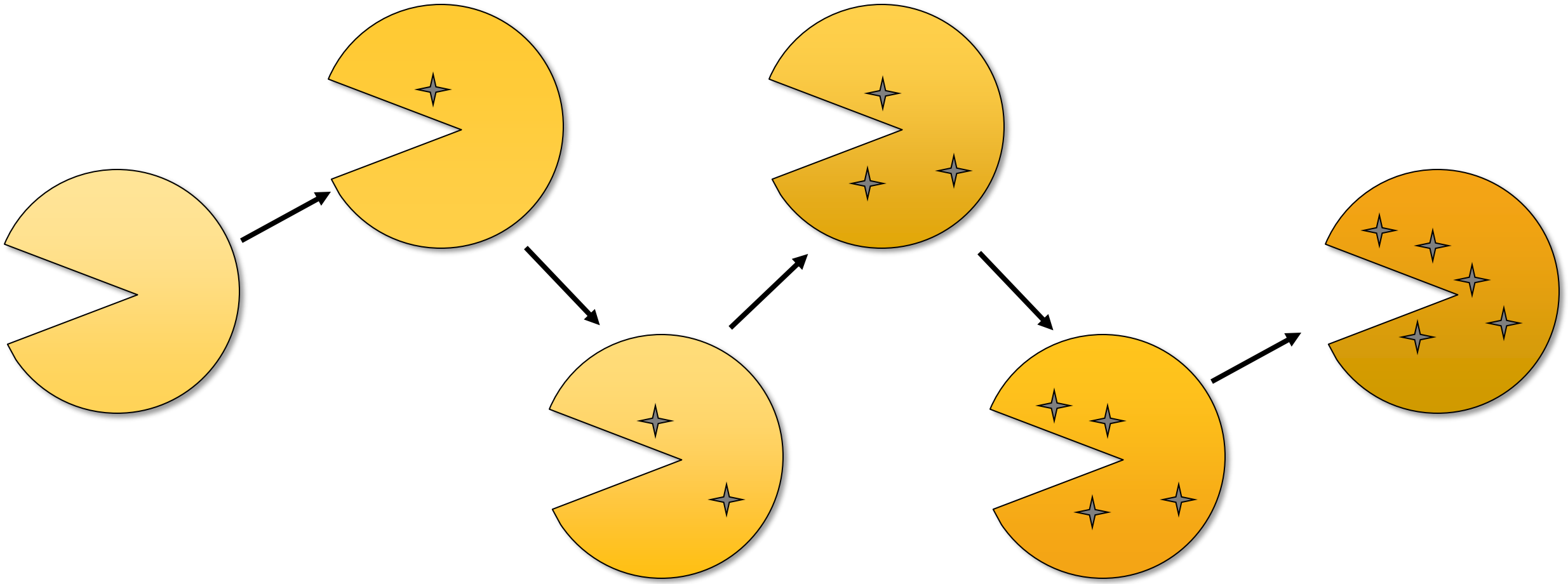
…all thanks to an enzyme name PETase.



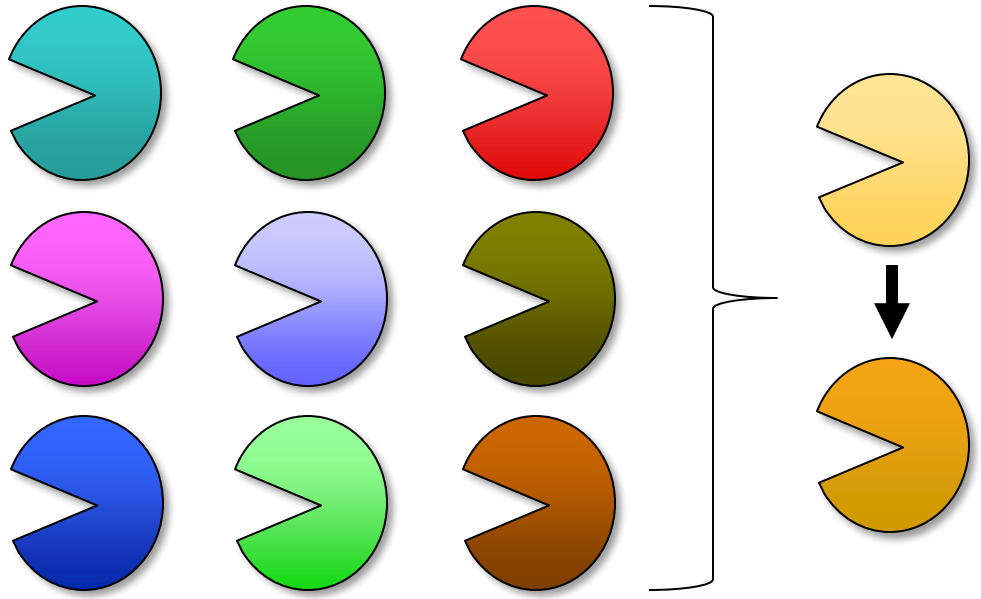
Harnessing the power of an enzyme to transform waste

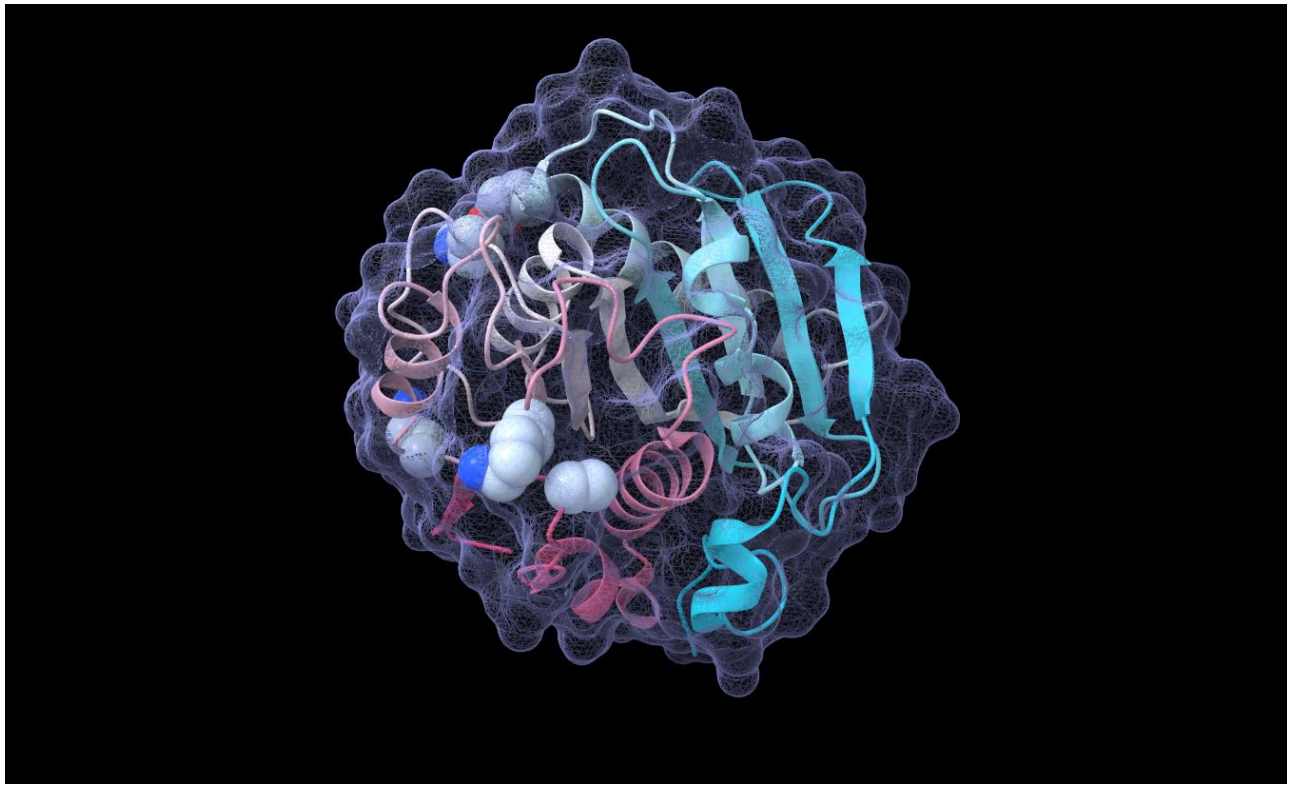


A machine-learning based approach



Re-designing PETase using a machine learning model

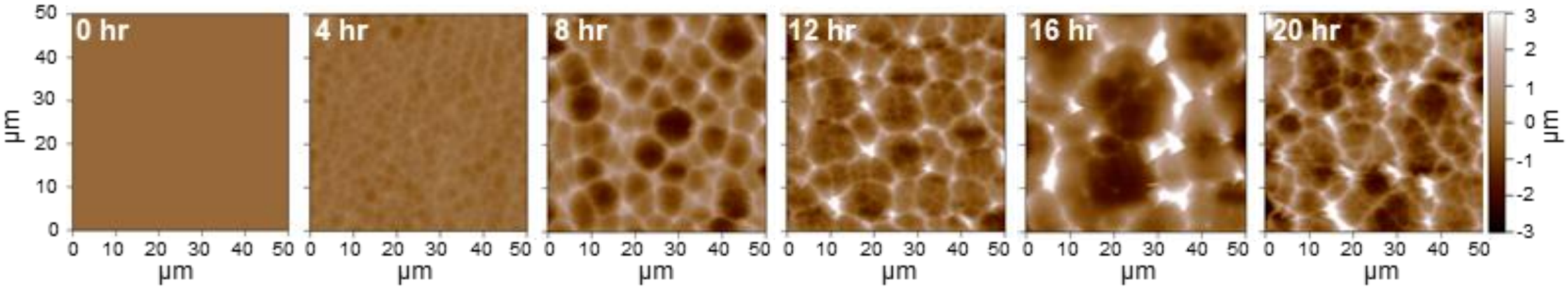




Work in collaboration with:
Drs. Ellington, Lynd, and Zhang
UT-Austin

Lu *et al.*, *Nature*, 2022

FAST-PETase breaks down plastic at the molecular level

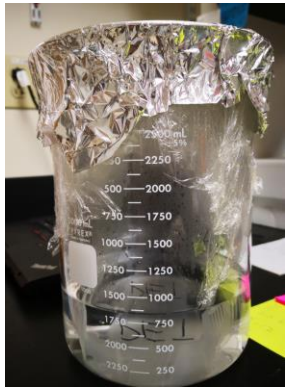


Depolymerization across a wide-range of PET plastics

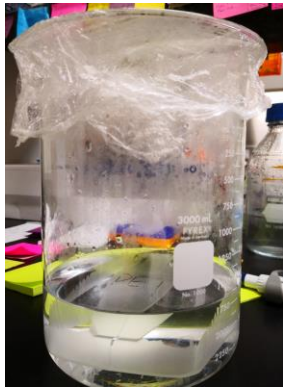
Scaling up the enzymatic degradation process

Scale-up of a plastic container breakdown at 50 ºC using FAST-PETase

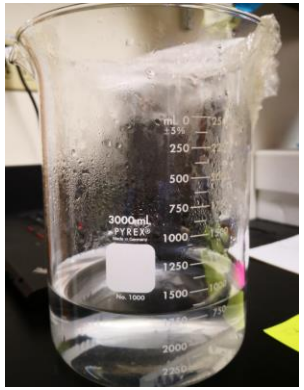
0 hr



10 hr

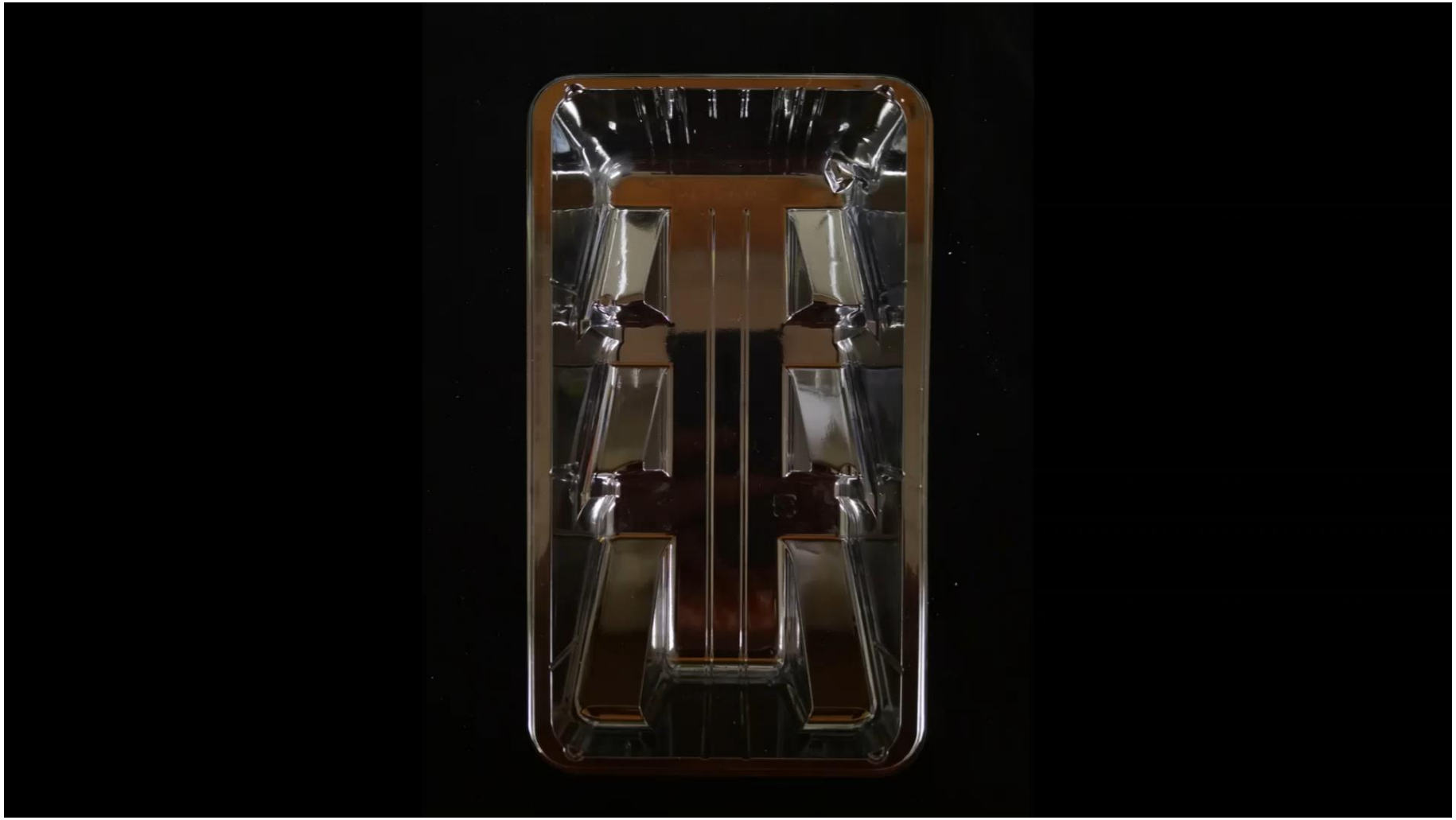


20 hr



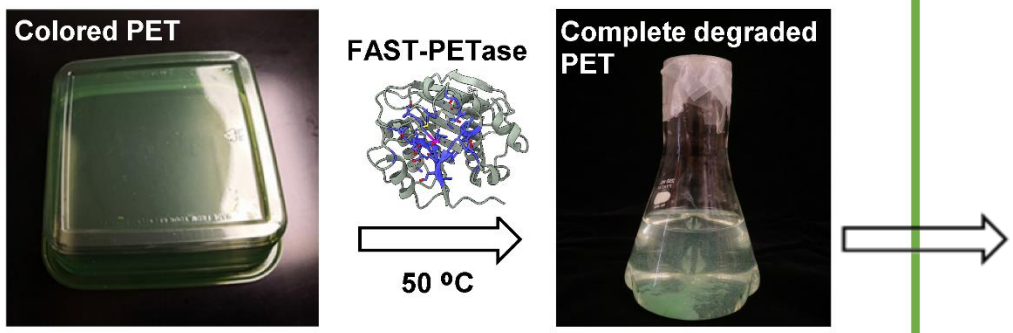
30 hr

Time-lapse of plastic degradation by enzyme

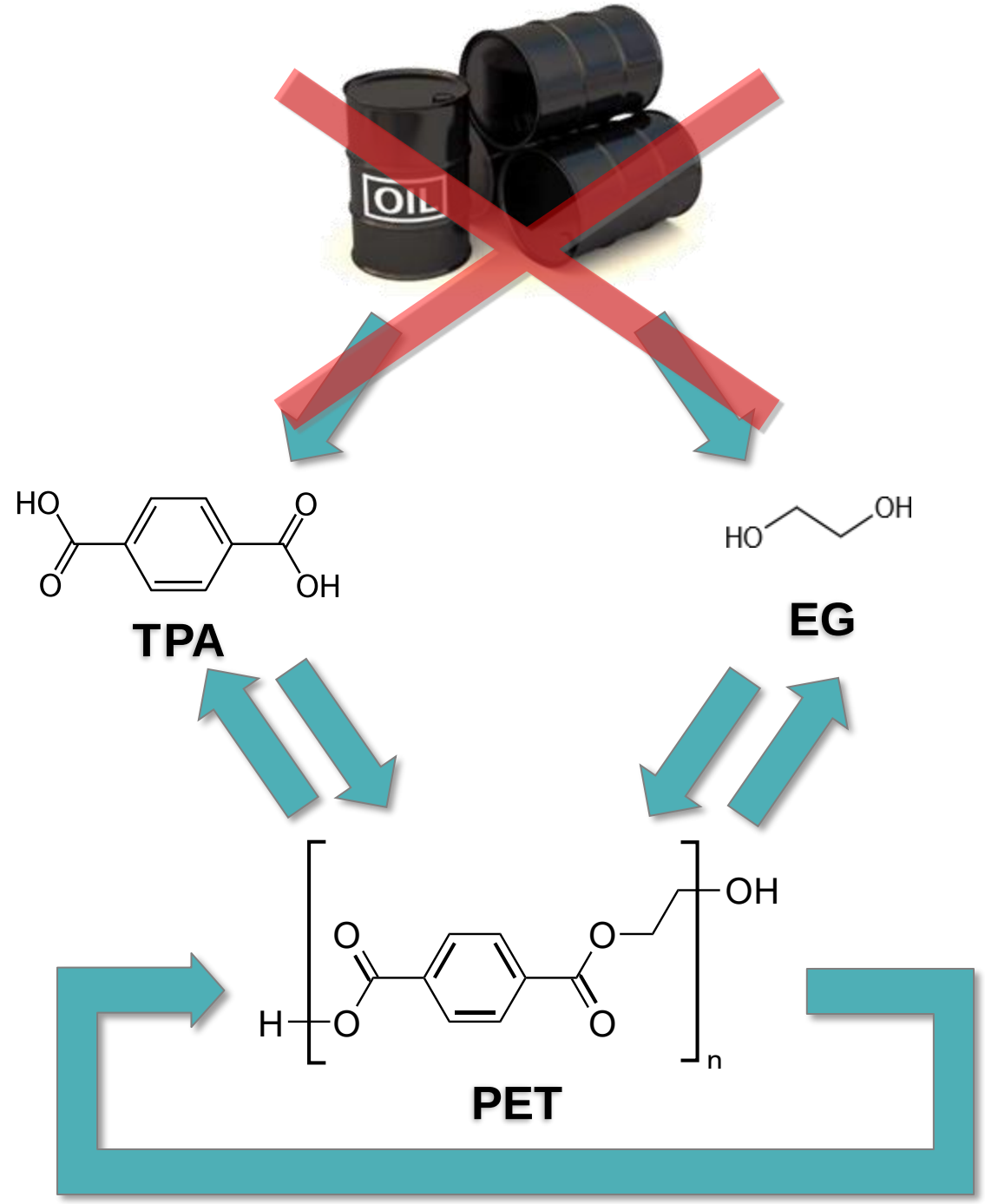


Obtaining full-circularity for PET

Biological depolymerization

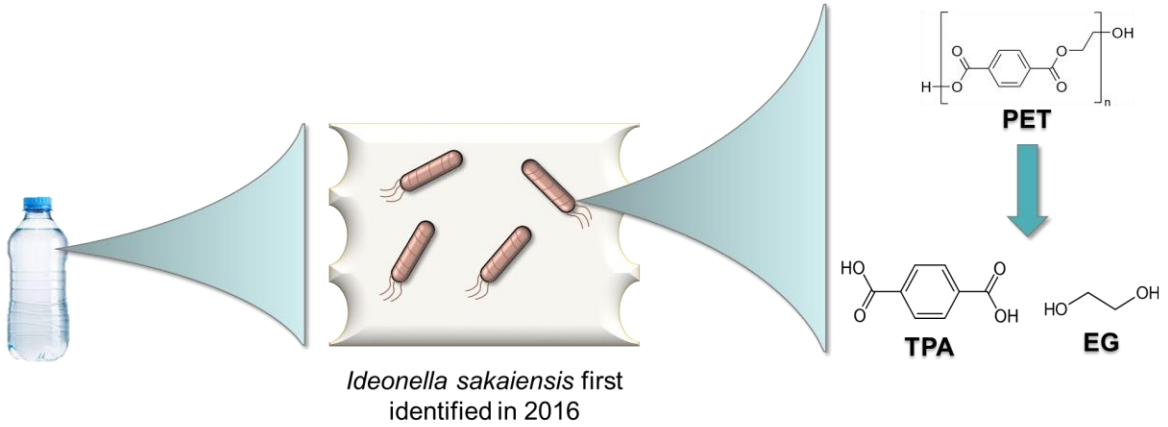


Enzyme technologies can enable infinite re-use of PET



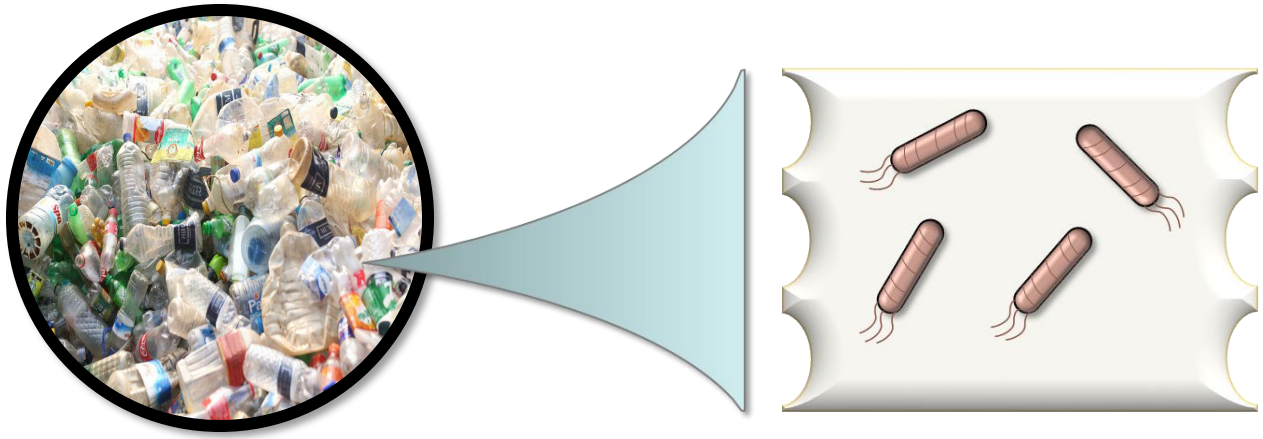
New organisms to degrade all plastics

The discovery of 1 microbe opened up so many possibilities for PET…..

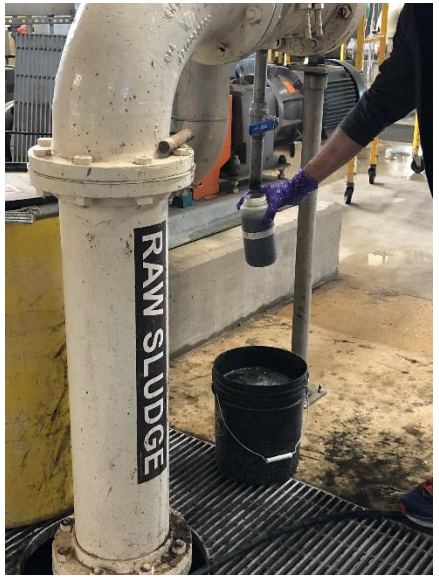


Ideonella sakaiensis first identified in 2016

…..Now we have the potential to discover the “1 microbe” for other plastics.



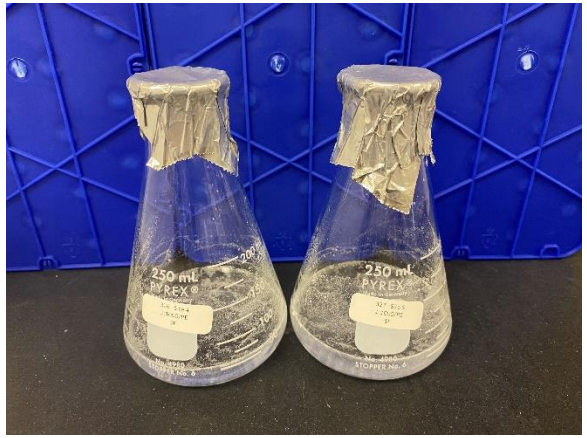
Moving forward:
“Bioprospecting” for new organisms



In the quest to identify new microbes

PET

PE



PVC

PMMA

PHB

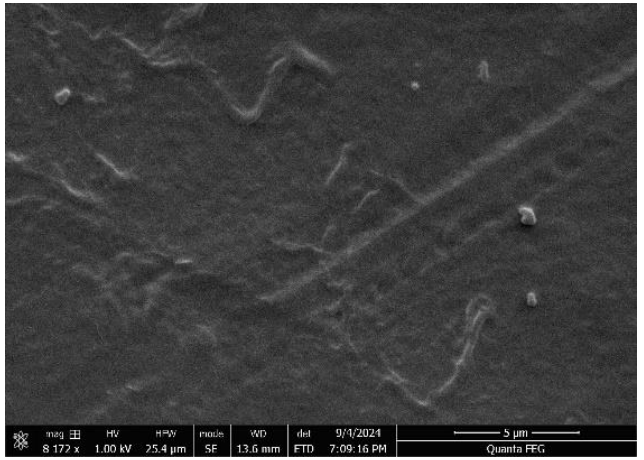
Solving the issue for all single-use materials

Production:
Precious resources, CO_2 emissions, energy

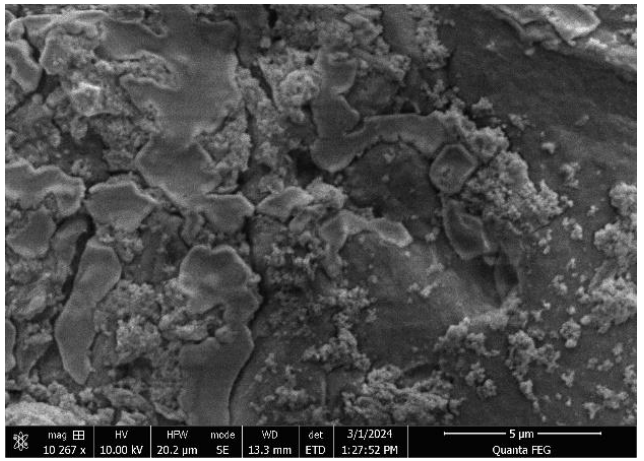
New material

Used Material

Disposal:
Waste, lost carbon, energy, CO_2



Raw Plastic (control)



Microbial degradation

Everything we do leaves a footprint on our environment...

…but the promise of bioengineering can save the World

The Alper Laboratory

Promoting Sustainable Biotech Alper Lab

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Bioengineering to Save the World

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