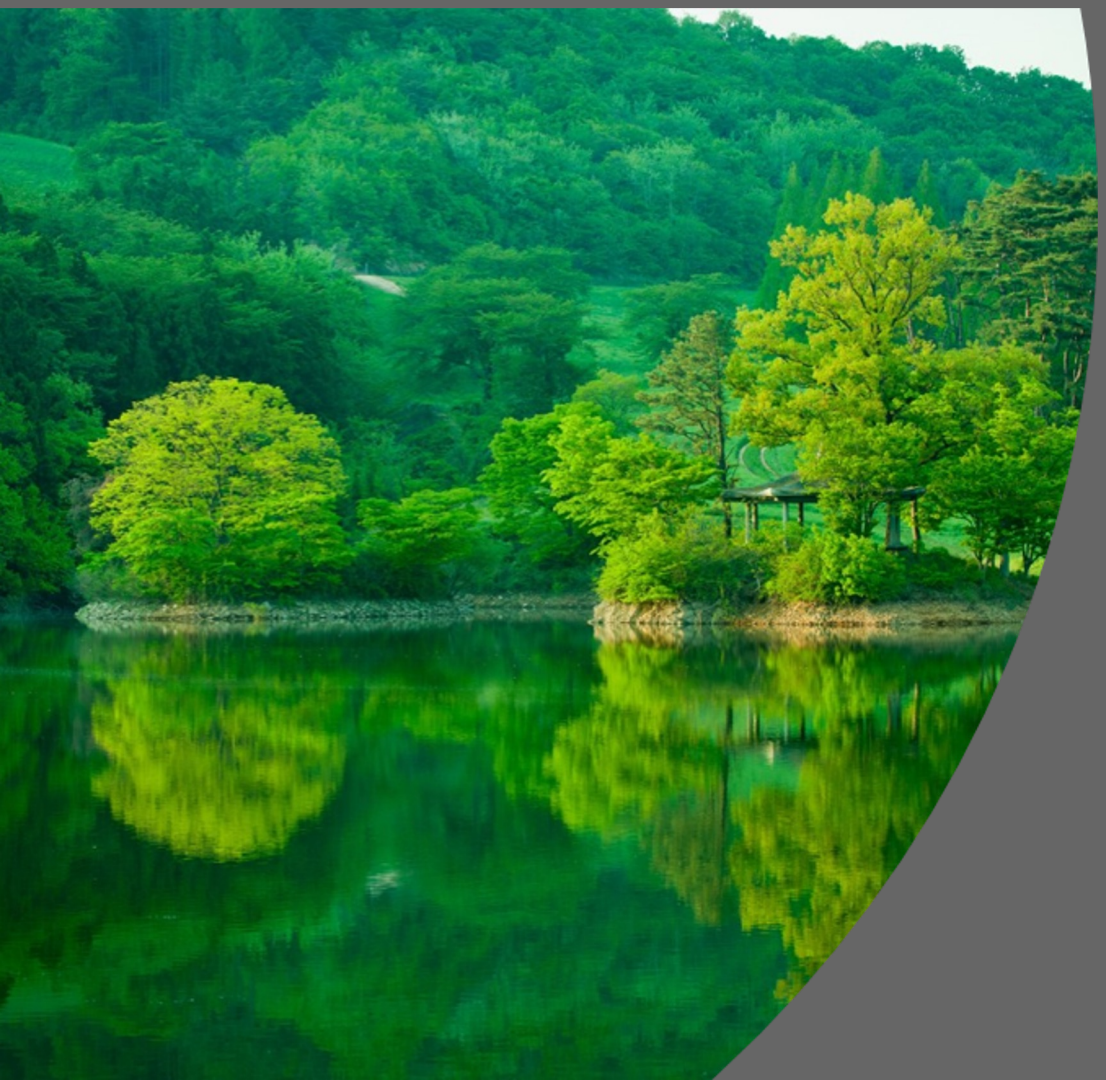


Natural Polymers

- *Cracking the Code, if we can*

Transitioning to a Sustainable, Circular Economy for Plastics Workshop

U.S. Department of Energy's (DOE) Bioenergy Technologies Office (BETO) &
Advanced Materials and Manufacturing Technologies Office (AMMTO)

Dr. Jun Wang
June 9, 2023

Dual Problems of Plastic

Pollution

Carbon Emission

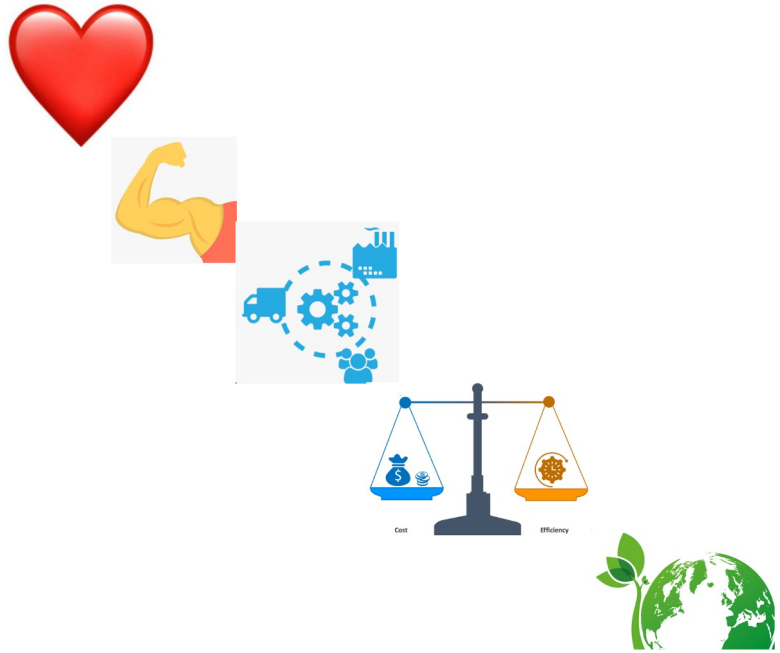
GHG emissions from the production, recycling and disposal of plastics could account for **19%** of Paris Climate agreement's total allowable emissions in 2040 – IISD

End-of-life problem

Origin of life Problem
(feedstock & Production)

CPGs’ Needs on Sustainable Materials

- Address consumers’ unmet needs/demands
  Products or services to make people’s life better
- Meet the expected functionalities
  mechanical, barrier, aesthetics, etc
- Availability, stable and secured supply
  Minimum negative impact to the business
- Cost-effectiveness
  Life cycle consideration
- Social responsibility
  Driving social impact, preserving our environment.



Plastics perform well in 4 of the above 5

Current Solutions

Let's fix the problems of plastics and make better plastics

Synthetic polymers (plastics) were not originally designed with end-of-life in mind, nor with the resource scarcity

Recycling

Current circular economy of plastics - try to close the loop, mechanical or chemical recyclings

Currently 9% plastics are recycled

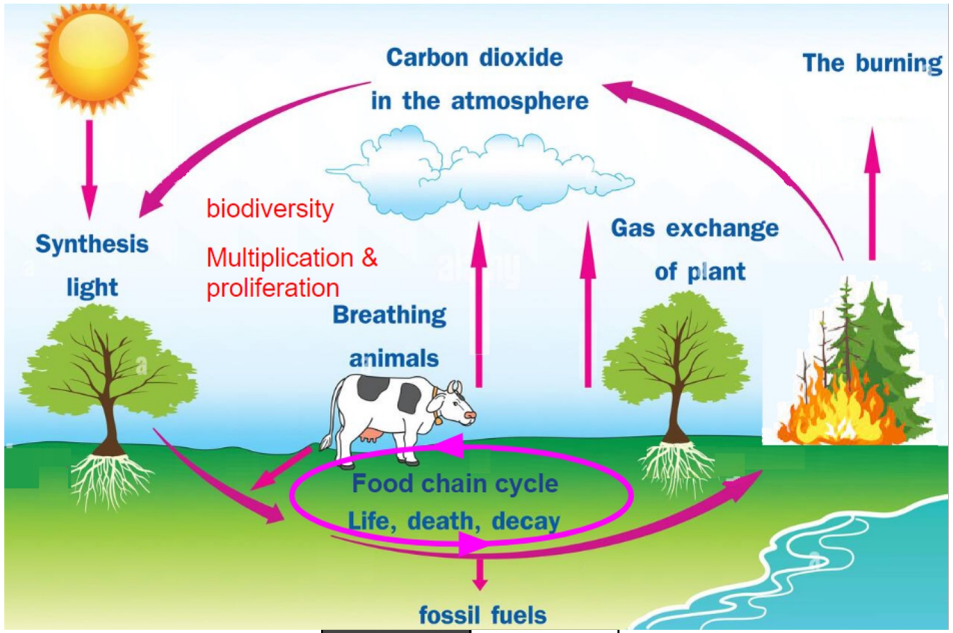
Biobased

Cost is high

Biodegradable

No collection infrastructure

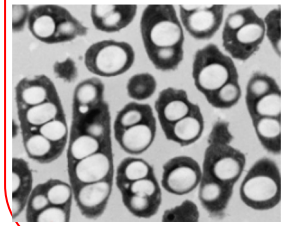
A Better Loop - Carbon Loop



√	√

Amazing Natural Polymers

Natural Ester Chain - PHA

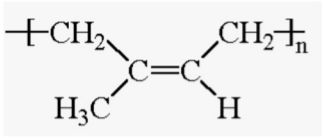


Biodegradability in different environments

	Marine Biodegradable	Fresh Water Biodegradable	Soil Biodegradable	Home Compostable	Landfill Biodegradable	Anaerobically Digestable	Industrially Compostable
PHA	✓	✓	✓	✓	✓	✓	✓
PBSA			✓	✓			✓
PBAT			✓	✓			✓
PLA						✓	✓

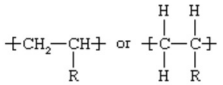
Natural C-C Chain - Natural Rubber

Latex



Chemical structure of cis-polyisoprene, the main constituent of natural rubber.

Natural rubber is susceptible to degradation by a wide range of bacteria.

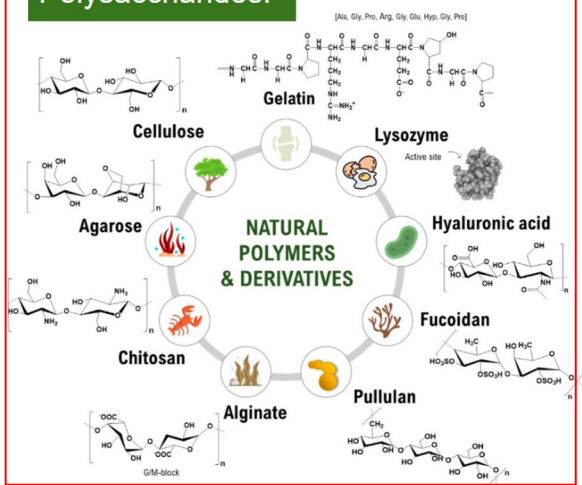


Synthetic polyolefins: PE or PP, etc.

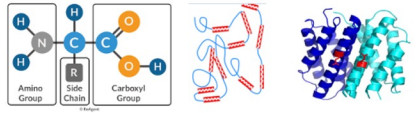
Not degradable

Backbones

Polysaccharides:



Proteins: polypeptide and amino acids



Lignin:

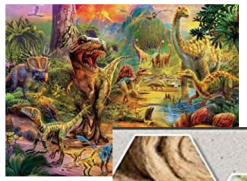
Natural Polymer Definition

Natural polymers are polymers

- Whose backbones are created by nature
- Can degrade in any natural environment and
- Their large-scale production and degradation after end-of-life do not negatively impact the environment.
- Meanwhile, natural polymers emit a minimum amount of greenhouse gas during their life cycle.

- In addition, if they are collected, natural polymers can also be recycled, (e.g., paper).

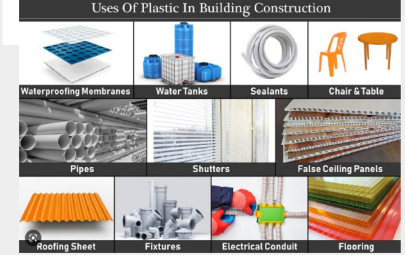
Change the Mindset



Millions of years

- Investment
- Knowledge
- Creativity
- Boldness
- Luck

Natural polymers: Biodegradability is a built-in property



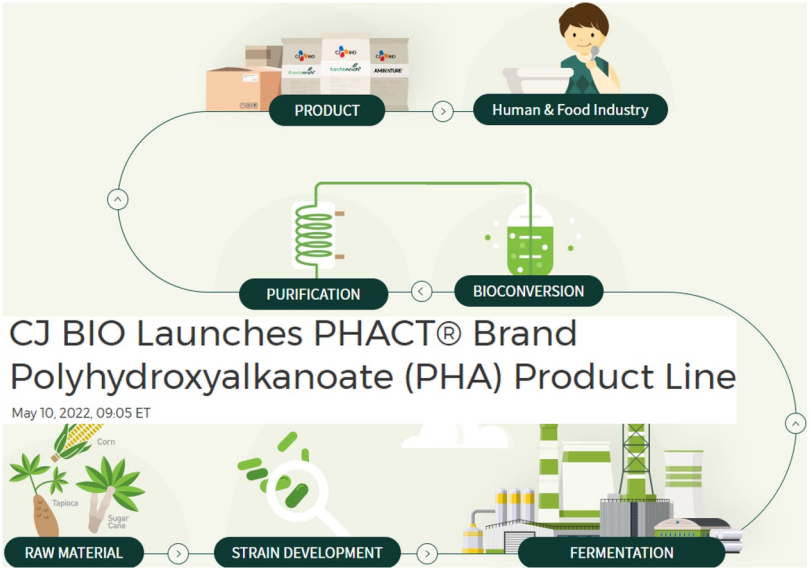
Emerging Natural Polymers as Industrial Mass Produced Materials

Turn “S” to “N”, Plastic ->

PLANTIC™
kuraray EVAL

Plantic’s primary feedstock is a natural corn starch

CJ BIO



NPC

Call to rethink and redesign plastics
Learn and start from natural polymers
Form a Natural Polymers Consortium