

End-of-life strategies for cosmetic products & packaging

Degradability, Biodegradability, Compostability & Biobased (Beginning of Life)



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QUESTIONS

- What are the end-of-life strategies for cosmetic products and packaging ?
 - Closed loop (circular) systems – **anaerobic digester** (waste water treatment), **composting**, soil, recycle/repurpose
 - Eliminate or minimize leakage to oceans and land
 - Divert waste from landfills to recycle or compost
- Is “Biodegradability” an end-of-life solution for your product and packaging? – composting, anaerobic digestion, recycling, energy recovery?
 - Caution -- “biodegradable” has become a much misused and hyped term with many misleading claims in the marketplace.
- Natural vs synthetic?? -- regularly used but obsolete for today’s products
 - “biobased” appropriate terminology with biobased (carbon) content reporting – governed by ASTM ISO standards
 - USDA BioPreferred program , EU programs



Poll Question – select only one amongst the options presented

1. When you consider the term “biodegradable” on a packaging or product – What is your immediate thought process?

The product will/should biodegrade/disappear in:

(a) < 1 year (b) < 2 years (c) 5 years (d) < 50 years

2. What is the environmentally responsible end product of degradation/biodegradation?

(A) Breaks down into small inert/safe molecules

(B) The product is utilized/assimilated by the microorganisms completely

(C) The product is utilized/assimilated by the microorganisms partially – for example 50% is utilized and the remaining 50% nothing happens or breaks down into small visible (or not) molecules

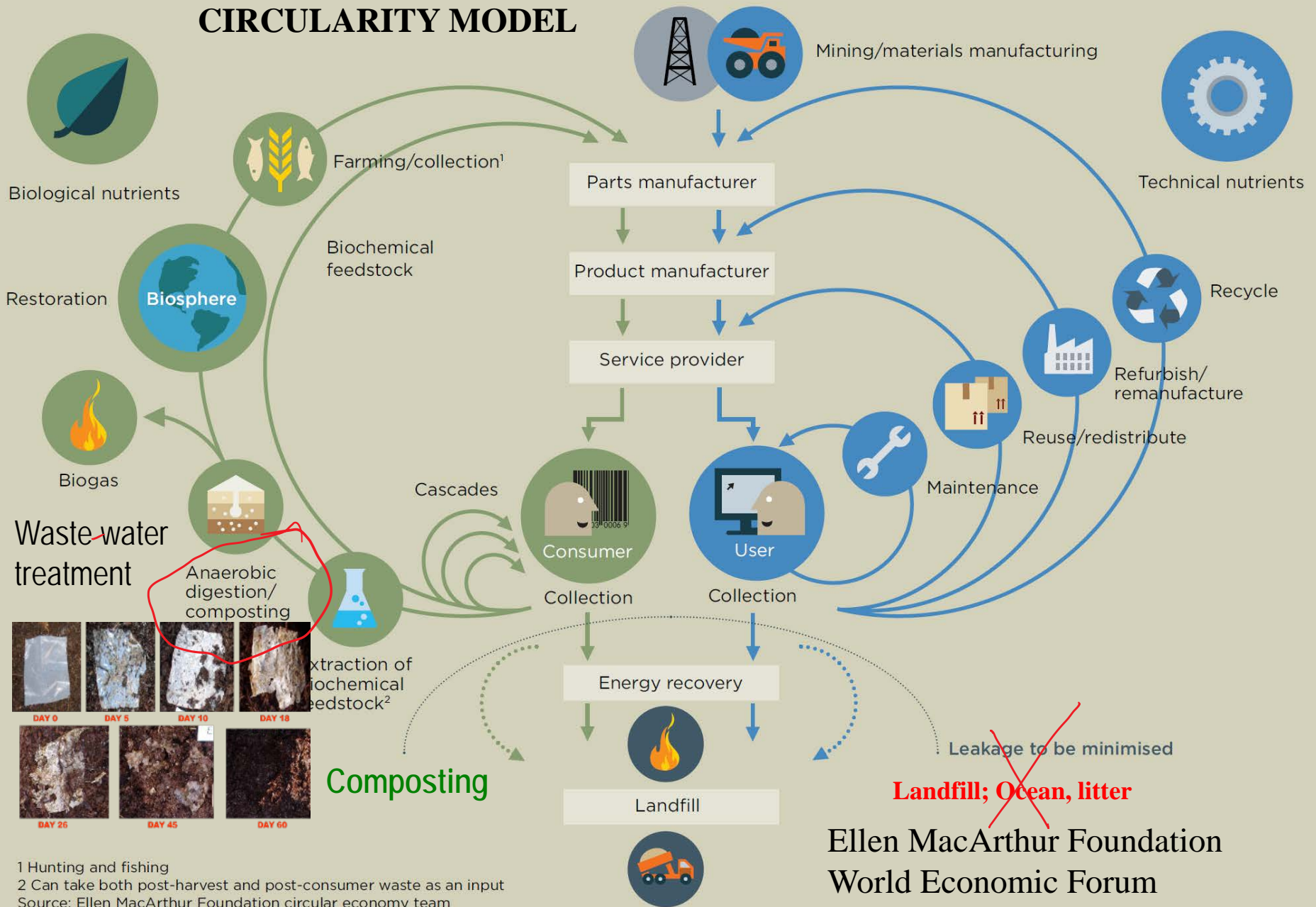
3. Biodegradability is a solution to Ocean plastics pollution

(1) YES

(2) NO



CIRCULARITY MODEL

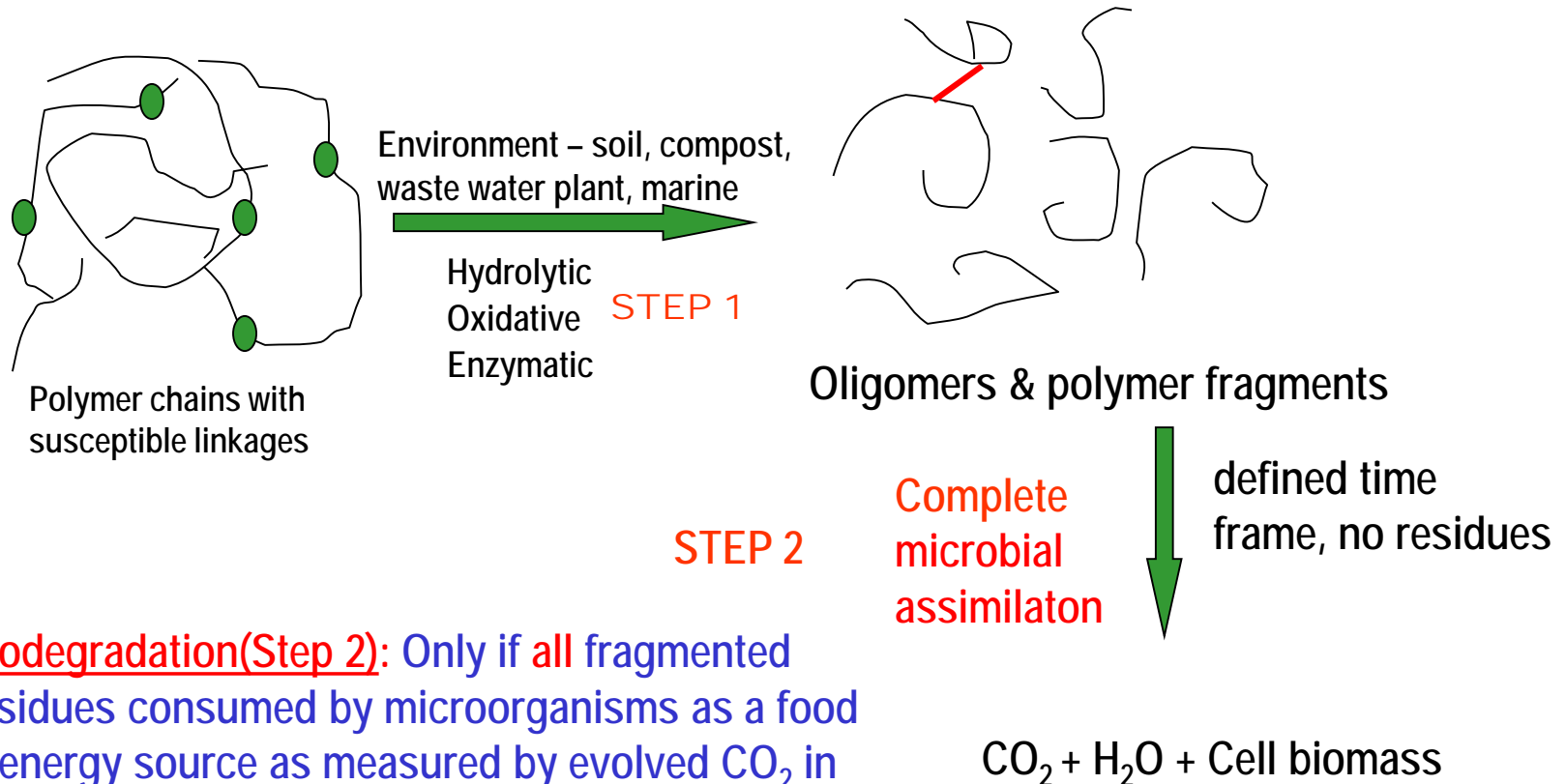


Ellen MacArthur Foundation
World Economic Forum



What does “Biodegradable” Mean?

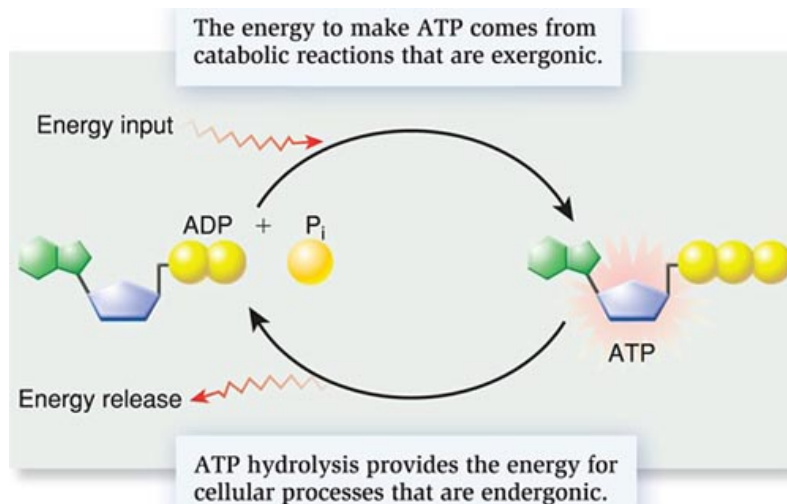
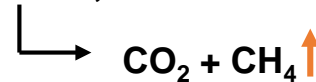
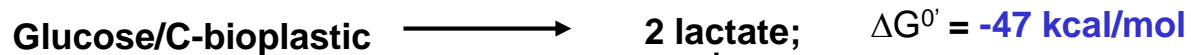
Can the microorganisms in the target disposal system (composting, soil, anaerobic digester) assimilate/utilize the carbon substrate as food source completely and in a short defined time period?

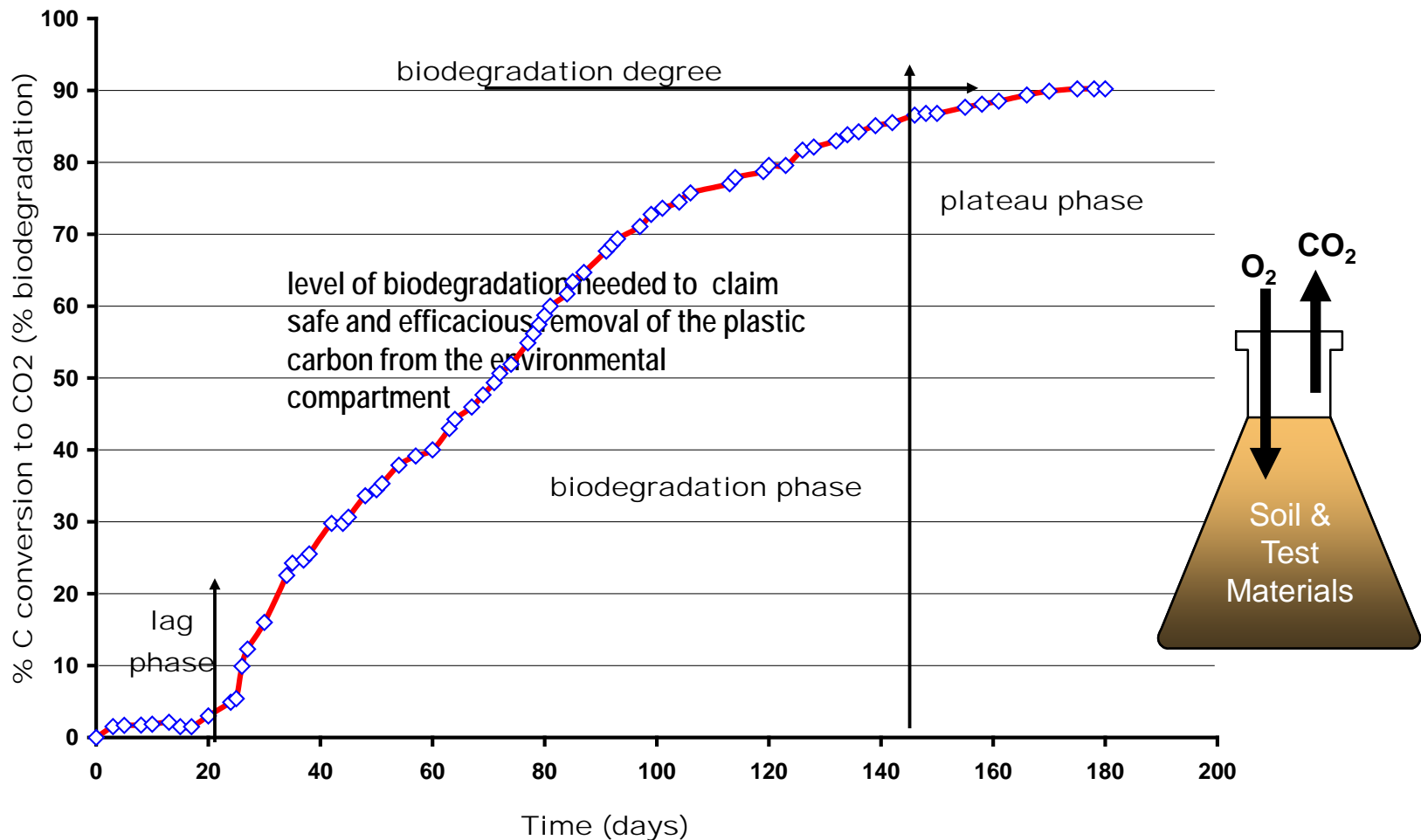


Biodegradation(Step 2): Only if **all** fragmented residues consumed by microorganisms as a food & energy source as measured by evolved CO_2 in defined time and disposal environment

Basics of microbial utilization -- biodegradability

- Microorganisms utilize carbon substrates as “food” to extract chemical energy for their life processes.
- They do so by transporting the C-substrate inside their cells and:
- Under aerobic conditions, the carbon is biologically oxidized to CO_2 releasing energy that is harnessed by the microorganisms for its life processes. Under anaerobic conditions, $\text{CO}_2 + \text{CH}_4$ are produced.
- Thus, a measure of the rate and amount of CO_2 or $\text{CO}_2 + \text{CH}_4$ evolved as a function of total carbon input to the process is a direct measure of the amount of carbon substrate being utilized by the microorganism (percent biodegradation)



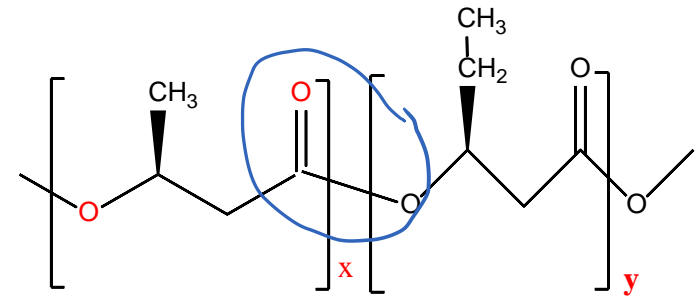
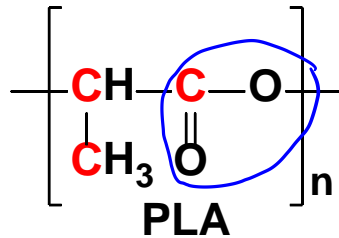
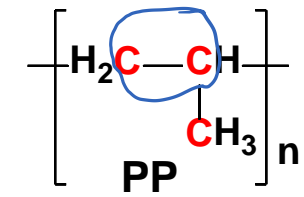
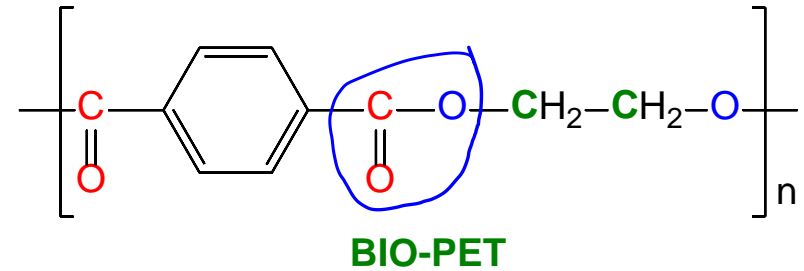
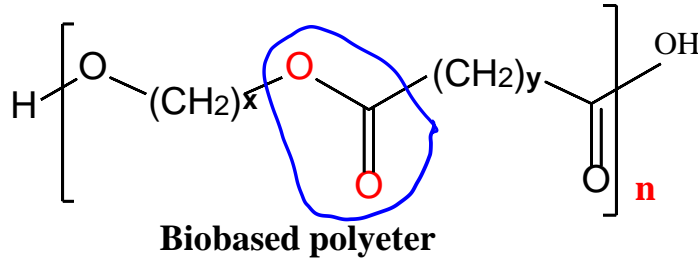
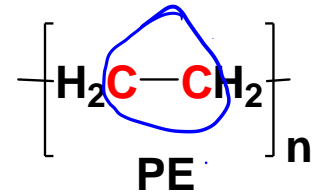


ASTM D5988; ISO 17556 -- Soil biodegradability test method

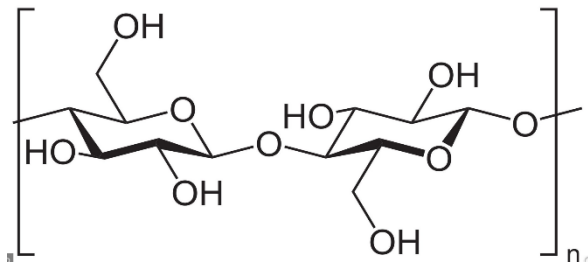
EN 17033 – soil biodegradability specifications for biodegradable mulch film

COMPOST -- ASTM D5338; ISO 14855; ISO 18606; EN 13432 AS 4736 & 5810
Specification – ASTM D6400, 6868 ; ISO 17088; EN13432

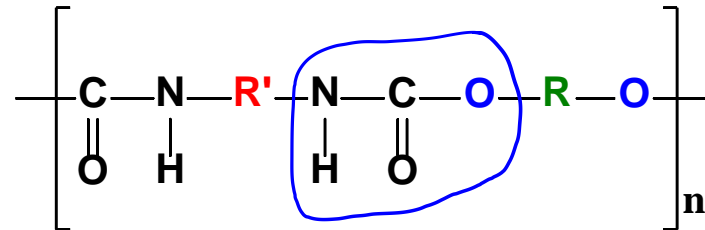
Understanding “BIOBASED & BIODEGRADABILITY” at Molecular level



PHBV -- poly(3-hydroxybutyrate-co-3-hydroxyvalerate)
PHAs

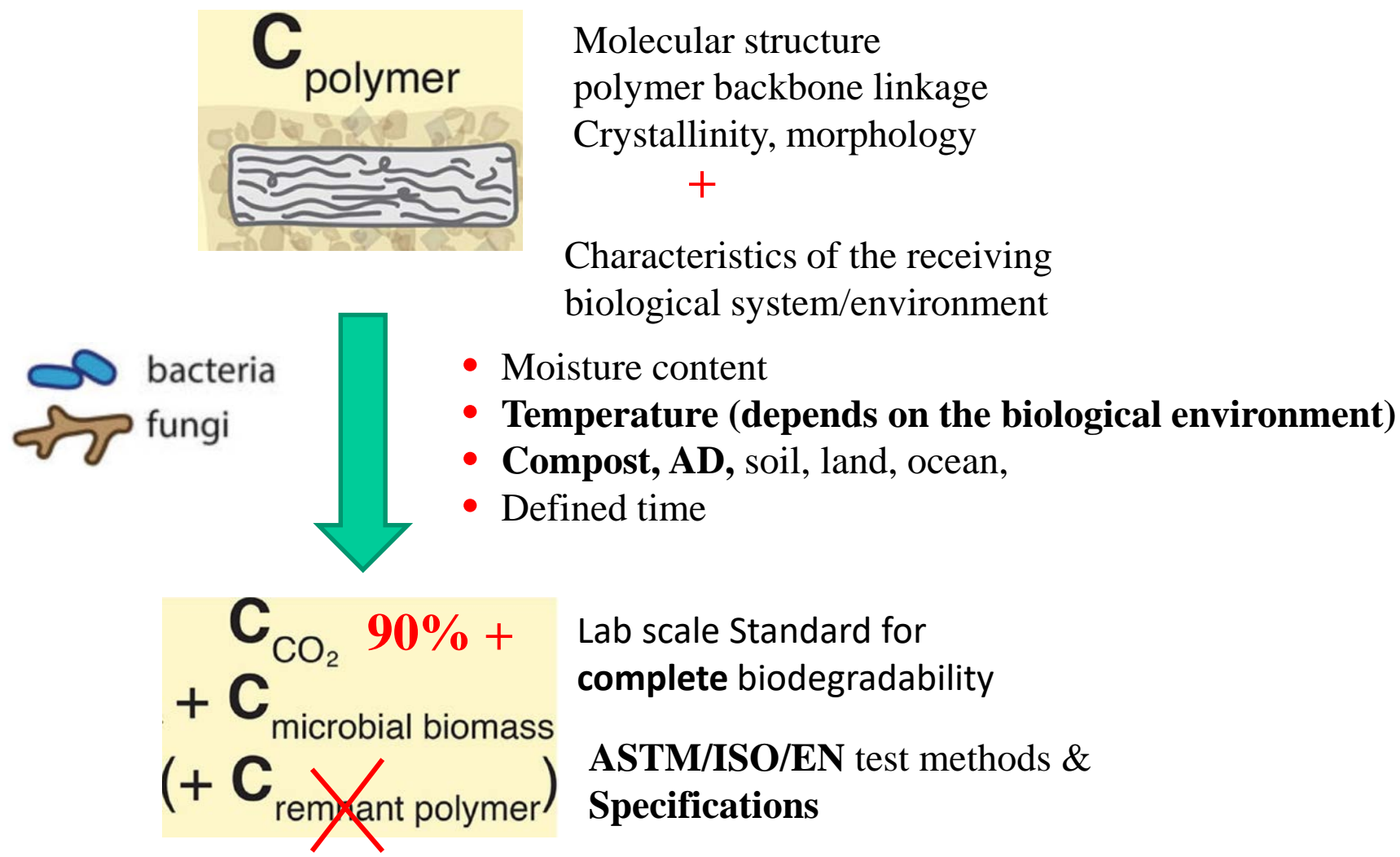


Cellulose



Biobased polyurethane

Dos and Do Nots When Assessing the Biodegradation of Plastics
Environ. Sci. Technol.2019, 53, 17, 9967-9969



Respirometric analyses may be complemented by tracing the plastic’s carbon into microbial biomass through the use of isotopically labeled plastics

Is biodegradability a solution to plastics end-of-life?

*Biodegradability in concert with managed, closed-loop disposal systems like composting/anaerobic digestion or soil (agriculture) resulting in **complete removal from the environmental compartment in a short time defined by the disposal environment** can be a viable and responsible “end-of-life” solution in harmony with the “Circularity Model.”*

“and **NOT** by reducing the lifetime of plastics that enter the environment”. X

Biodegradability is:

- (a) **Function of the physicochemical characteristic of the molecule AND the biochemical nature of the disposal (end-of-life) system**
- (b) **Compostable** defines the boundary conditions under which complete biodegradability and removal from the environment occurs.

End-of-Life

Managed, closed loop, circular

- Industrial composting
- Home/residential composting
- **Waste water –anaerobic digester – cosmetic products & textile fibers**
- Soil – agricultural mulch films & products

Leakage to the environment **X**

- Oceans – microplastics
- Land – Litter
- Landfills & open dumps – mismanaged wastes



Marine biodegradability claim – Singapore new item; Eco-business, 2018

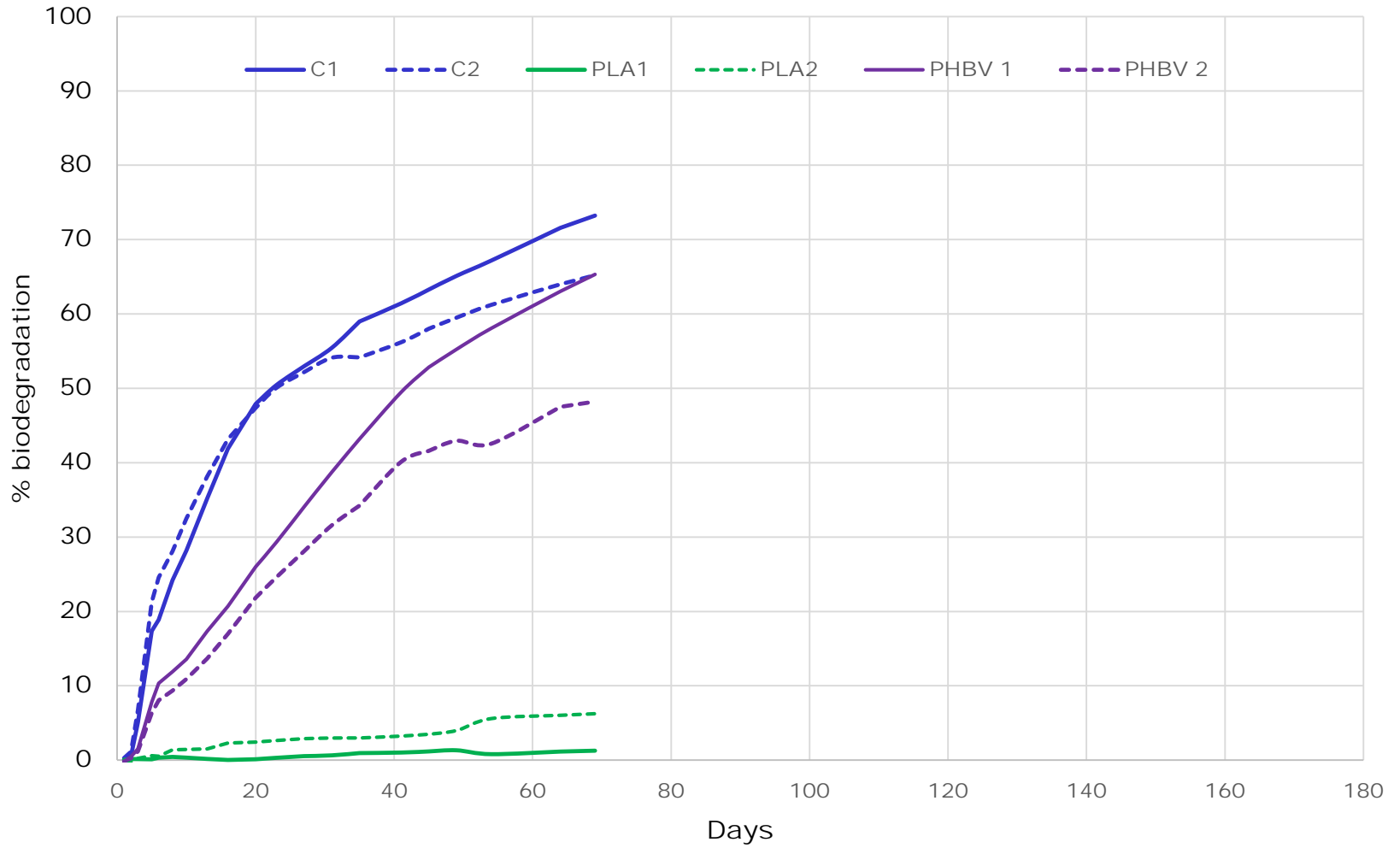
creating straws that would decompose under regular natural conditions into water and carbon dioxide before
The technology behind it—manufacturing a biodegradable material called polyhydroxyalkanoates (PHA) from edible oils and even waste cooking oil—has

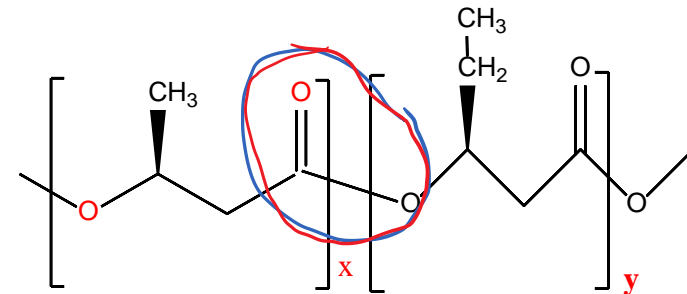
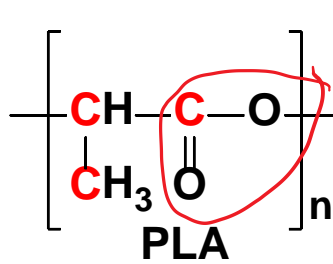
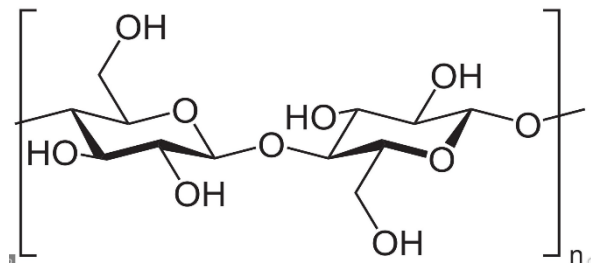


Is this a valid claim of biodegradability? – or misleading
?????



% biodegradation (at 30°C)

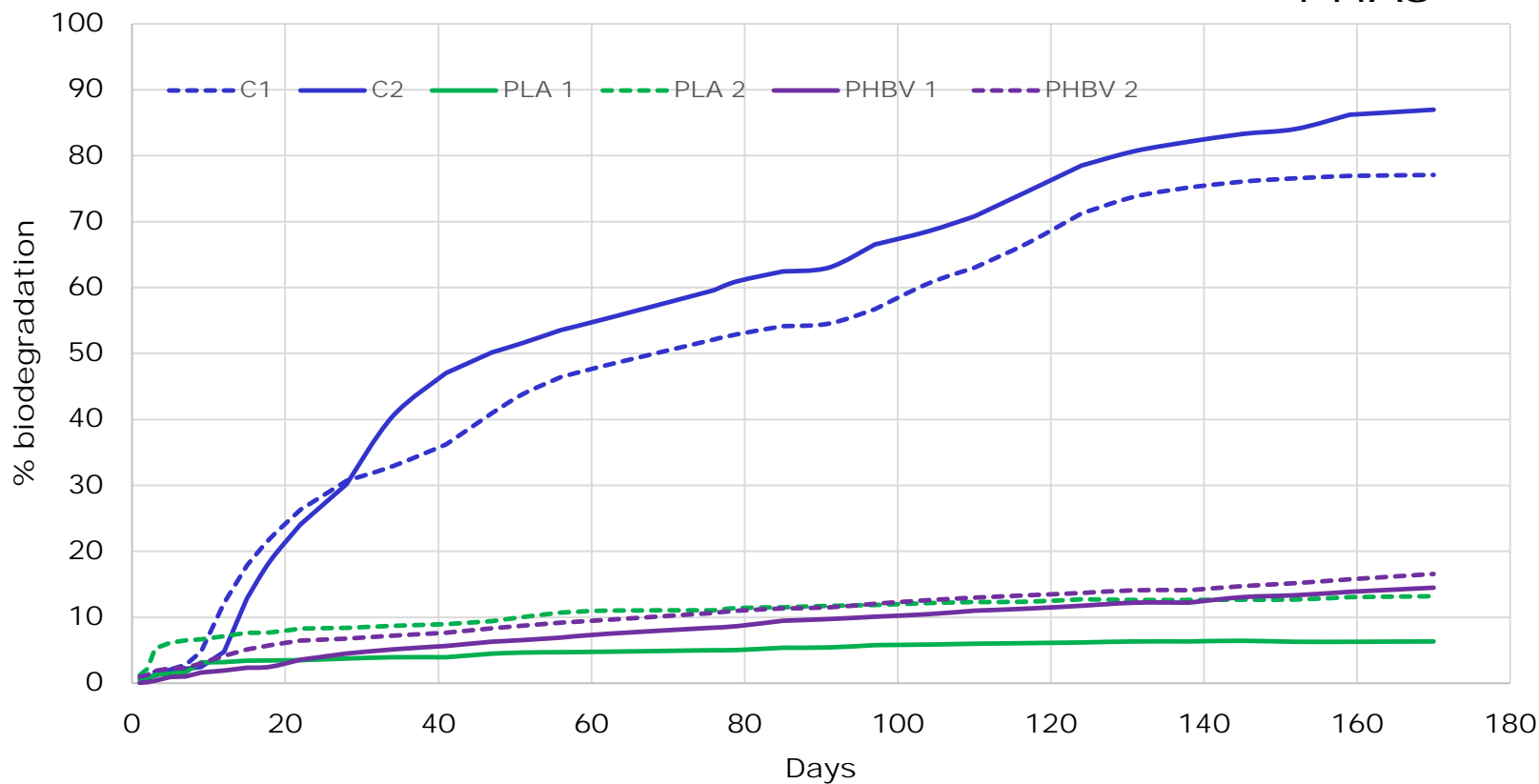




PHBV -- poly(3-hydroxybutyrate-co-3-hydroxyvalerate)

PHAs

% biodegradation (at 10°C)



IMPORTANT CONSIDERATIONS – CAUTION!

Unqualified use of the term “biodegradable” is wrong, misleading, and deceptive.

It violates the law in the State of California and U.S. Federal Trade Commission (FTC) green guides **& in Australia too**

- **Need to define disposal environment, time/rate and extent of biodegradation**
 - **qualified** biodegradability claim
 - **Integrated to Composting or AD coupled to composting**
 - **Soil biodegradability (mulch films & ag products)**
- Need **complete** microbial assimilation and removal from the environmental compartment in a short time period otherwise may have environmental and health consequences
 - **Degradable, partial biodegradable not acceptable – serious health and environmental consequences**
 - Phil. Trans. Royal. Soc. (Biology) July 27, 2009; 364

Organic/Biodegradable waste management

- Landfills – closed dumps – preserve and try to keep waste from leaking
- Uncontrolled open dumps in the emerging economies of the world
- Pockets of anaerobic environments leads to methane generation – 25X GWP
- Managed closed loop waste management infrastructures for organic/biowaste will reduce the country's GHG emissions



At least 80 percent of ocean plastic comes from land-based sources, but the actual number is probably much higher.



PLASTICS OCEAN POLLUTION

In 2010 **about 5.0 to 12.7** million tons of “mismanaged” land based plastic waste entered into the oceans from 192 costal countries within 50 km of the coast – Science , Vol 347, Issue 6223 pg 768, 2015

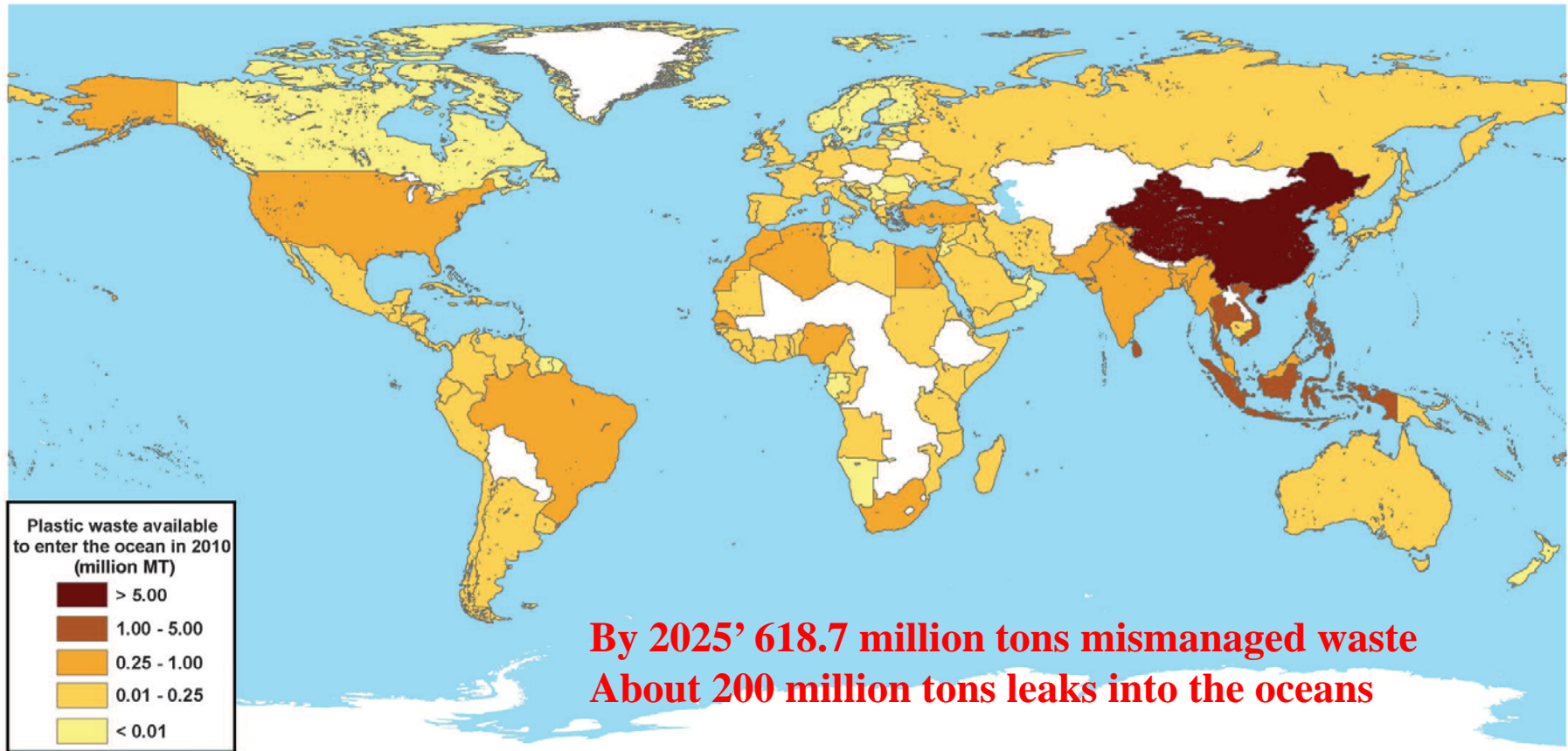
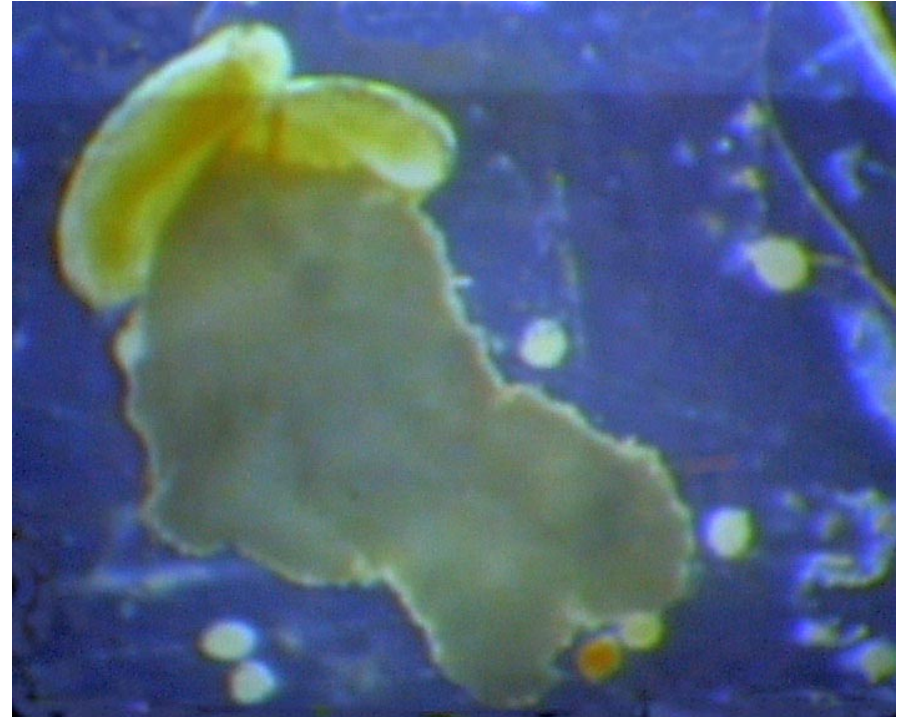


Fig. 1. Global map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast. We considered 192 countries. Countries not included in the study are shaded white.

More plastics in the oceans than plankton



**Colonization of microplastics loaded
with toxins
Transported up the food chain**



Rank by mass of mismanaged waste and ocean leakage (25%) – based on population living within 50 km of the coast

Million Metric Tons

Mismanaged waste Ocean Leakage

1	China	17.81	4.45
2	Indonesia	7.42	1.85
3	Philippines	5.09	1.27
4	Vietnam	4.17	1.04
5	India	2.88	0.72
6	Nigeria	2.48	0.62
7	Bangladesh	2.21	0.55
8	Thailand	2.18	0.54
9	Egypt	1.94	0.48
10	Sri Lanka	1.92	0.48
11	Malaysia	1.77	0.44
12	Pakistan	1.22	0.31

DIVERT MISMANAGED WASTE TO COLLECTION & RECYCLING

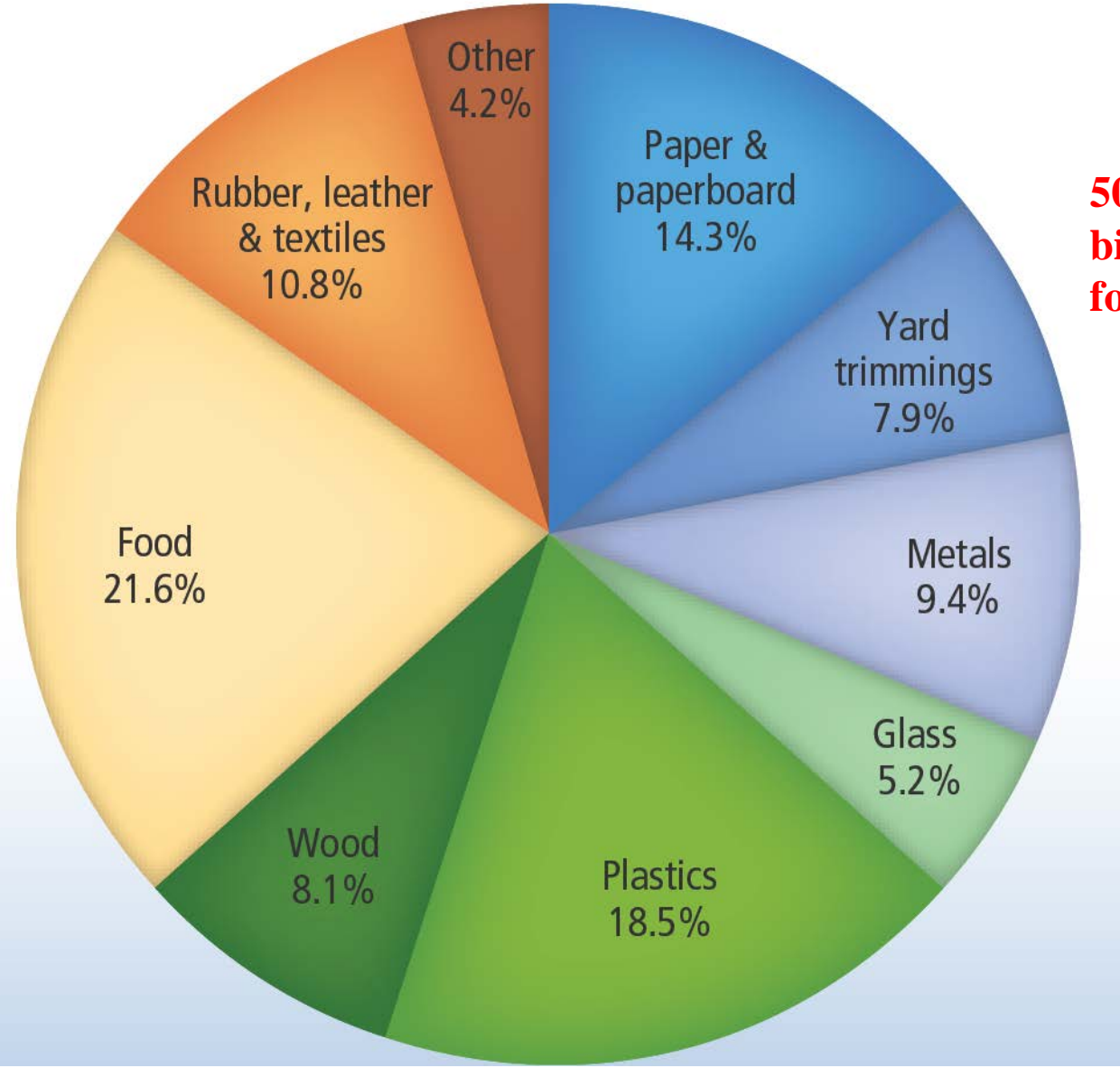
Organics including compostable plastics for recovery by composting, anaerobic digestion

Durable Plastics recovery through mechanical and chemical recycling

Science , Vol 347, Issue 6223 pg 768, 2015



MSW numbers (U.S. EPA: 2014 Fact Sheet. November 2016



**50% + is organic
biodegradable waste –
food, paper, hybrids,**



**Total MSW Landfilled (by material), 2014
136 Million Tons**

Certified/ Verified Compostable Plastics is the “enabling technology” to efficiently and efficaciously **divert food and other organic wastes** from landfills (NA) & open dumps to environmentally responsible end-of-life solutions like composting.

“Compostable” defines the boundary conditions under which complete biodegradation (microbial utilization) needs to be validated using ASTM/ISO International Standards

Enabler for the “Circularity Model”

Enabler for “Organics Recycling”

- **Recovery of 1.84 MMT of MSW biodegradable organic wastes through composting results in 1.74 MMT CO2 equivalents of GHG**
 - **Only 5% of foodwaste generated is recovered through composting, rest goes into landfills to generate methane with its 25X GWP impact**

Cosmetic products and textile fiber washings – AD process in waste water treatment



Twins @ Target Field



Newest MLB ballpark to embrace a *systems approach to waste diversion*

Compostable packaging and front of house compost collection now complement other sustainability initiatives such as water and energy conservation

A simple two bin system throughout the ballpark captures bottles and cans in one bin and everything else in another

Because “everything else” is almost all compostable, contamination is kept to a minimum and a ***diversion rate of over 90% is within reach***

Organic stream is sent to a county transfer station that sends material to The Mulch Store and Full Circle Organics compost facilities



Organic Collection Programs

Small & Large Businesses, Universities, Schools, Festivals.....



100% reusable, recyclable or compostable plastic packaging by 2025

FOLLOW THEIR LEAD



- **Eliminate** problematic or unnecessary plastic packaging and move from single-use to reuse packaging models
- **Innovate** to ensure 100% of plastic packaging can be easily and safely reused, recycled, or composted by 2025
- **Circulate** the plastic produced, by significantly increasing the amounts of plastics reused or recycled and made into new packaging or products



Narayan

THE MISUSE OF BIODEGRADABILITY AS AN EOL OPTION

- Oxo-biodegradable catalysts and organic/enzyme additives render C-C backbone polymers like PE, PP, PS completely biodegradable or biodegradable in landfills -- **abound in the marketplace and press**
- Articles have appeared in literature and widely covered in print and E-media of macro-organisms like meal worms and wax moth eating plastics as solutions for plastic waste management.
- CNN news reported “the gut bacteria in worms can transform plastic into safe biodegradable waste”; News headlines proclaimed “Styrofoam-Eating Mealworms Could Happily Dispose of Plastic Waste”.
- Another one said “The Indian meal-moth, can degrade polyethylene”.

Caterpillars & mealworms are NOT the ^{^ next} new biodegradable magical solution to plastic waste management? Nor are the oxo-biodegradable or enzyme additives plastics

&

BIODEGRADABILITY IS NOT A EOL SOLUTION for dumping or leakage of plastics (mismanaged waste) to Oceans & Land (litter)



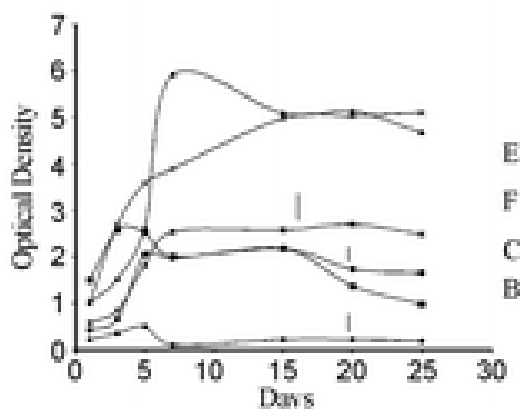
MISUSE OF BIODEGRADABILITY CLAIMS

- *Chem. Commun.*, 2002, (23), 2884 - 2885

- A hypothesis was developed, and successfully tested, to greatly increase the rates of biodegradation of polyolefins, by anchoring minute quantities of glucose, sucrose or lactose, onto functionalized polystyrene (polystyrene-co-maleic anhydride copolymer) and measuring their rates of biodegradation, which were found to be significantly improved

- PRESS

- **Sugar turns plastics biodegradable.** Bacteria make a meal of sweetened polythene and polystyrene.



Increase in rates of biodegradation for sugar linked polystyrene

weight loss of only 2-12%,

Only sugar is being assimilated, PE chain intact – Is this a genuine example of biodegradable plastic?



Example – A false and misleading “biodegradable” claim



Amazon.com agreed to pay **\$1,512,400** in civil penalties and investigative costs to settle the case. The judgment also includes an injunction that prohibits Amazon from unlawfully selling or offering for sale plastic products labeled as “biodegradable” or using similar terms, or selling or offering for sale plastic products labeled as “compostable” without appropriate certification. Amazon also agreed to make an additional payment of \$50,000 to CalRecycle to fund testing of plastic products marketed to consumers as compostable or degradable.

Walmart -- \$1 million settlement

Costco -- \$0.5 million settlement

BASICS

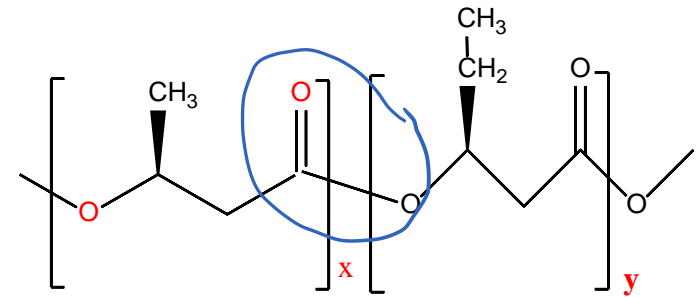
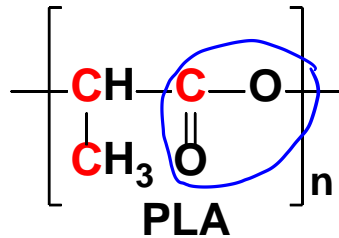
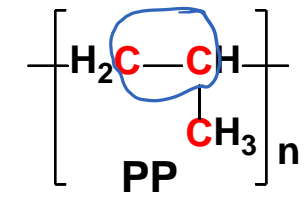
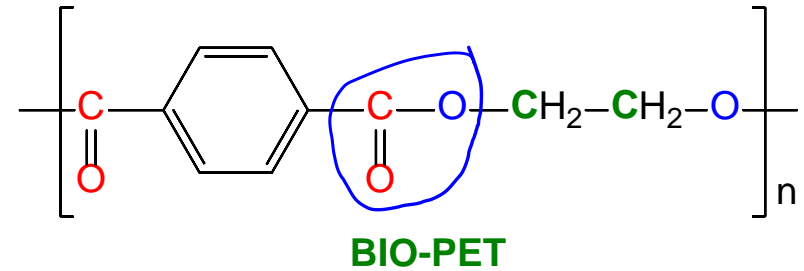
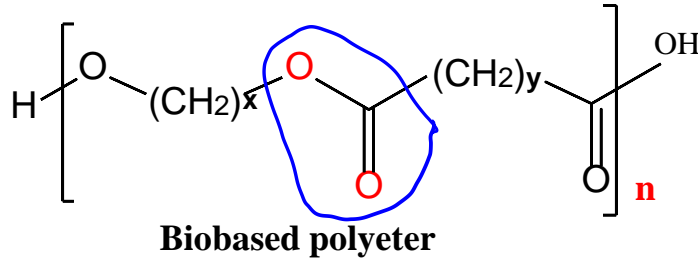
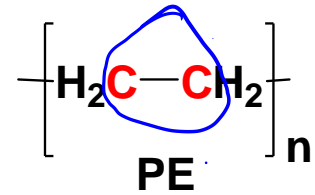
1. BIOBASED represents the “beginning of life”
 - Asks about the “origins” of the carbon in the molecule/product
 - petro/fossil vs plant-biomass feedstock
 - Natural vs Synthetic – not appropriate
2. biodegradable-compostable represents the “end-of-life”.
 - (a) Function of the physicochemical characteristic of the molecule AND the biochemical nature of the disposal (end-of-life) system
 - (b) Need to define the disposal (end-of-life) system, time, rate and extent of biodegradation.
 - (c) Compostable defines the boundary conditions under which complete biodegradability and removal from the environment occurs.
3. BioPlastics encompasses both terms – biobased & biodegradable-compostable

Biobased does NOT necessarily equate to biodegradable/compostable

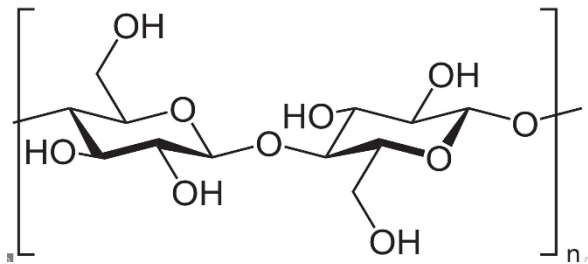
Biodegradable-Compostable are NOT necessarily Biobased



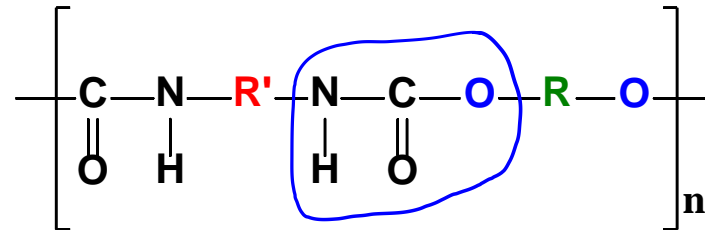
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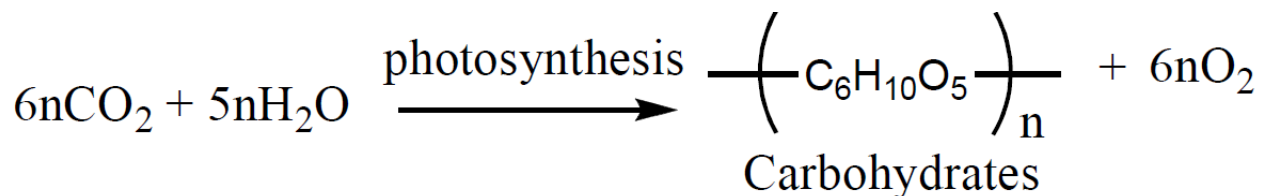
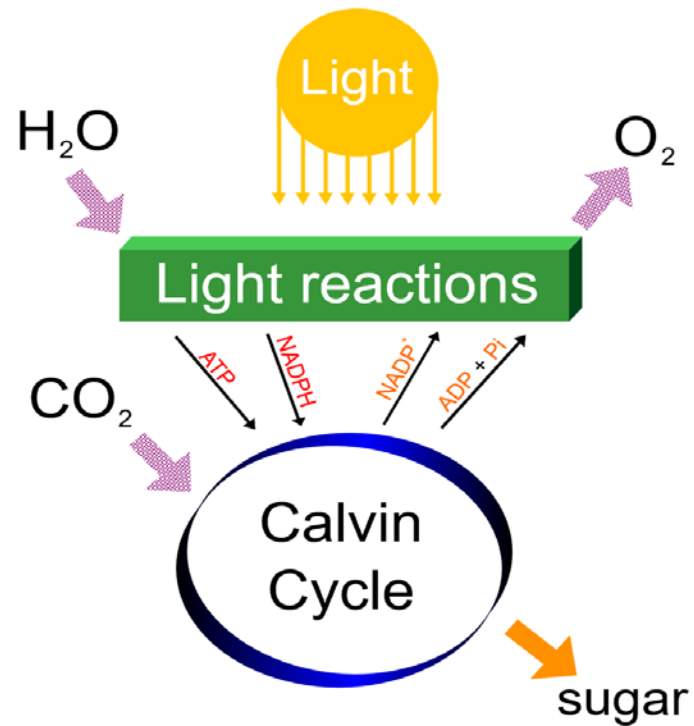
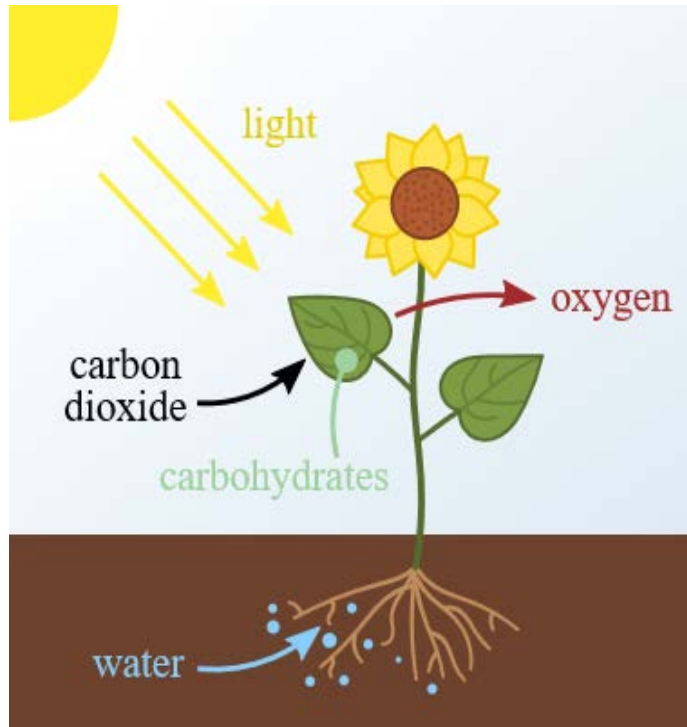
Cellulose



Biobased polyurethane

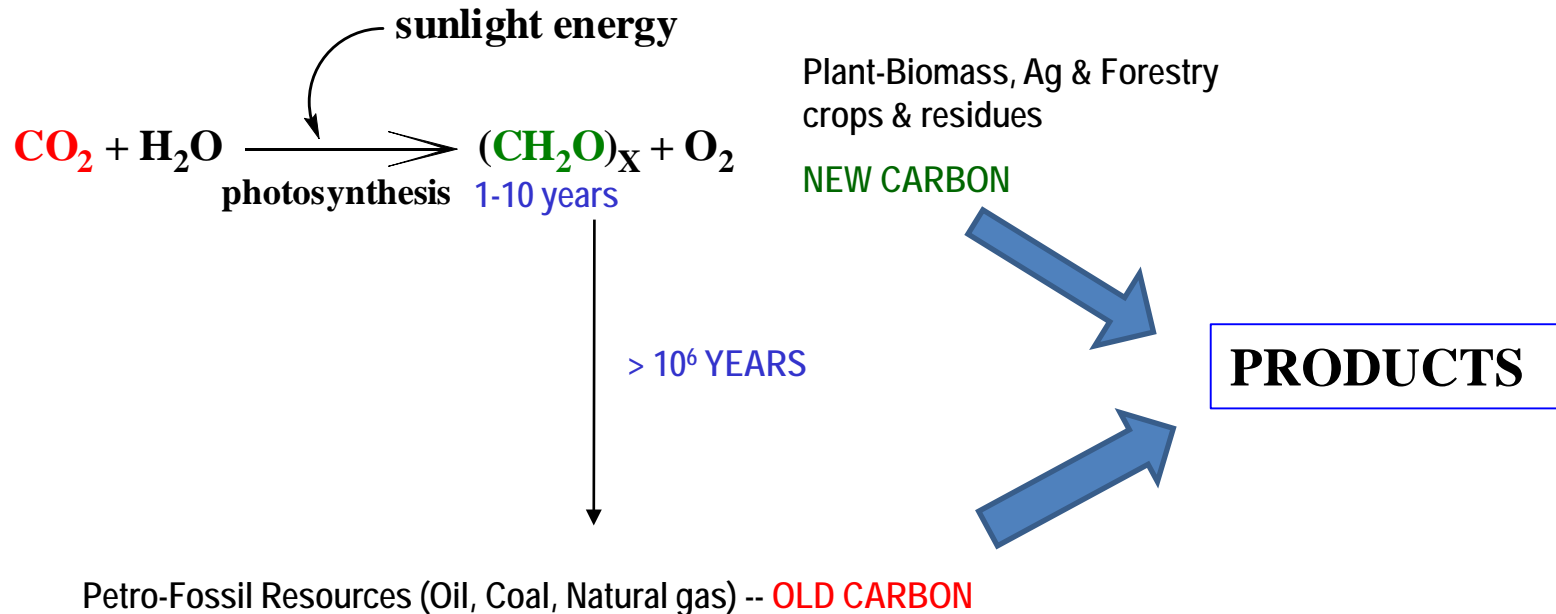
ASTM D6868; ISO 16620 (Pt 2) -- Fundamentals

biobased –containing organic carbon of renewable origin from agricultural, plant, animal, fungi, microorganisms, marine or forestry materials living in a natural environment in equilibrium with the atmosphere.



ASTM D6868; ISO 16620 (Pt 2) -- Fundamentals

biobased –containing organic carbon of renewable origin from agricultural, plant, animal, fungi, microorganisms, marine or forestry materials living in a natural environment in equilibrium with the atmosphere.



Biobased carbon content measurement -- Principle

^{12}C (98.89%); ^{13}C (1.1%);

^{14}C (1×10^{-10})

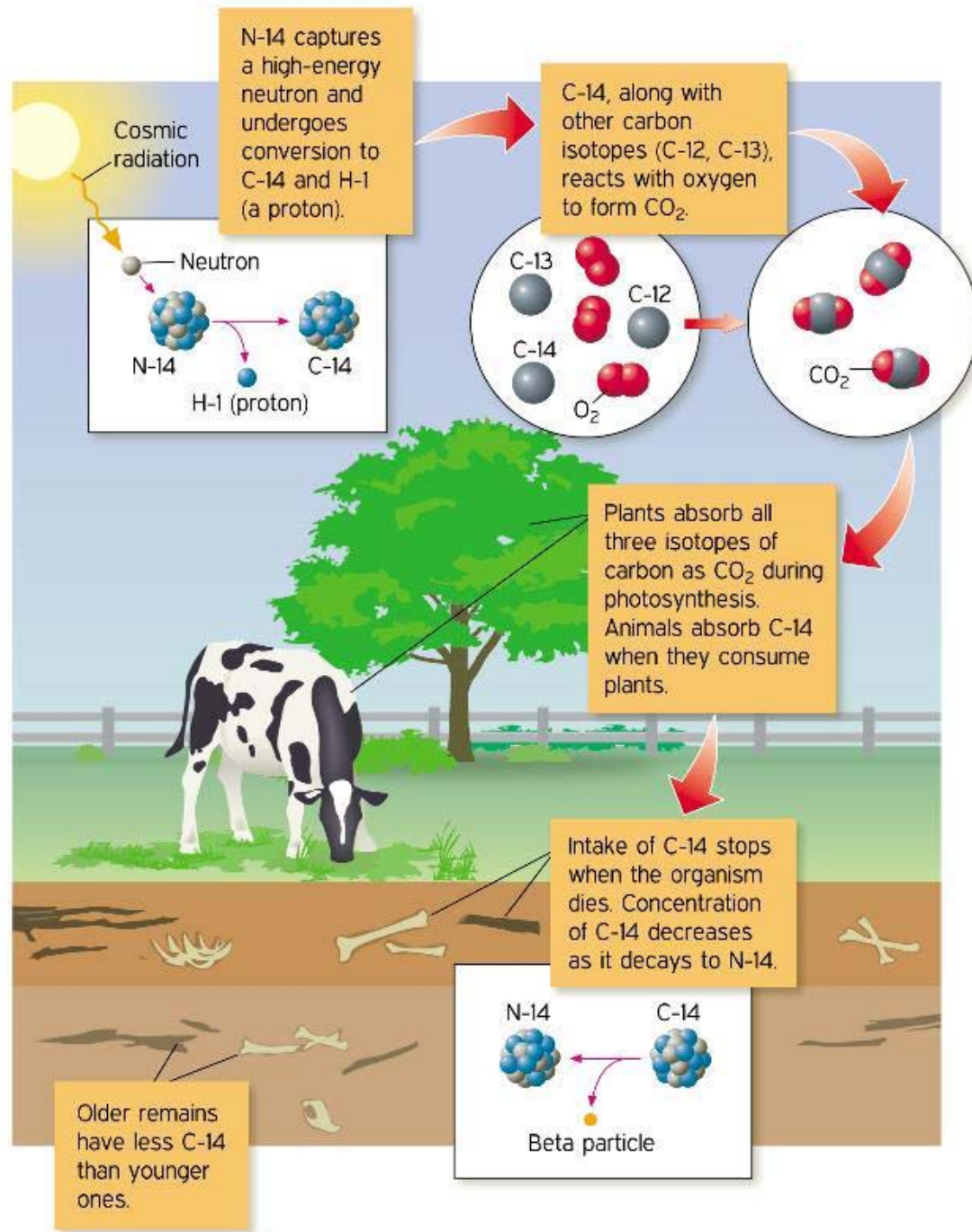
$^{14}\text{C}/^{12}\text{C} = \sim 10^{-12}$ in the atmosphere

in equilibrium with plant-biomass

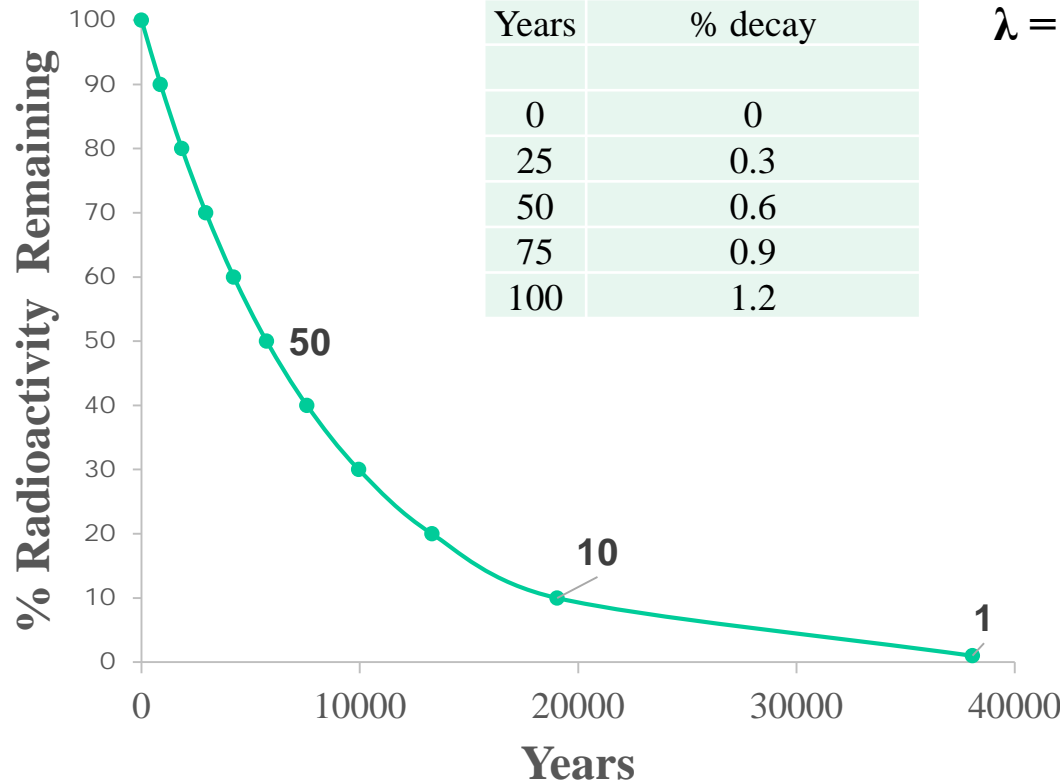
living systems

Biobased carbons will have the same ^{14}C radioactivity as in plant biomass and in the atmosphere – providing a tracer for carbon in the environment to product molecule

^{14}C $t_{0.5} = 5730$ years; so fossil carbons have no ^{14}C carbons remaining -- zero radioactivity



Radioactive decay of C14



$$(-dN/dt = \lambda * N)$$

$$N = N_0 * \exp(-\lambda * t)$$

$$\lambda = \ln 2 / (t_{1/2}) ; t_{1/2} = \mathbf{5730 \text{ years}}$$

Products containing biobased carbons -- carbon originating from "living systems (plant biomass) in a natural environment in equilibrium with the atmosphere" will retain the same isotopic ratio for 100 years.

Comparing the isotopic ratio of the test product with a 100% biobased standard product provides the amount of biobased carbons in the test product. Fossil carbons will have zero radioactivity left as they are formed over millions of years.

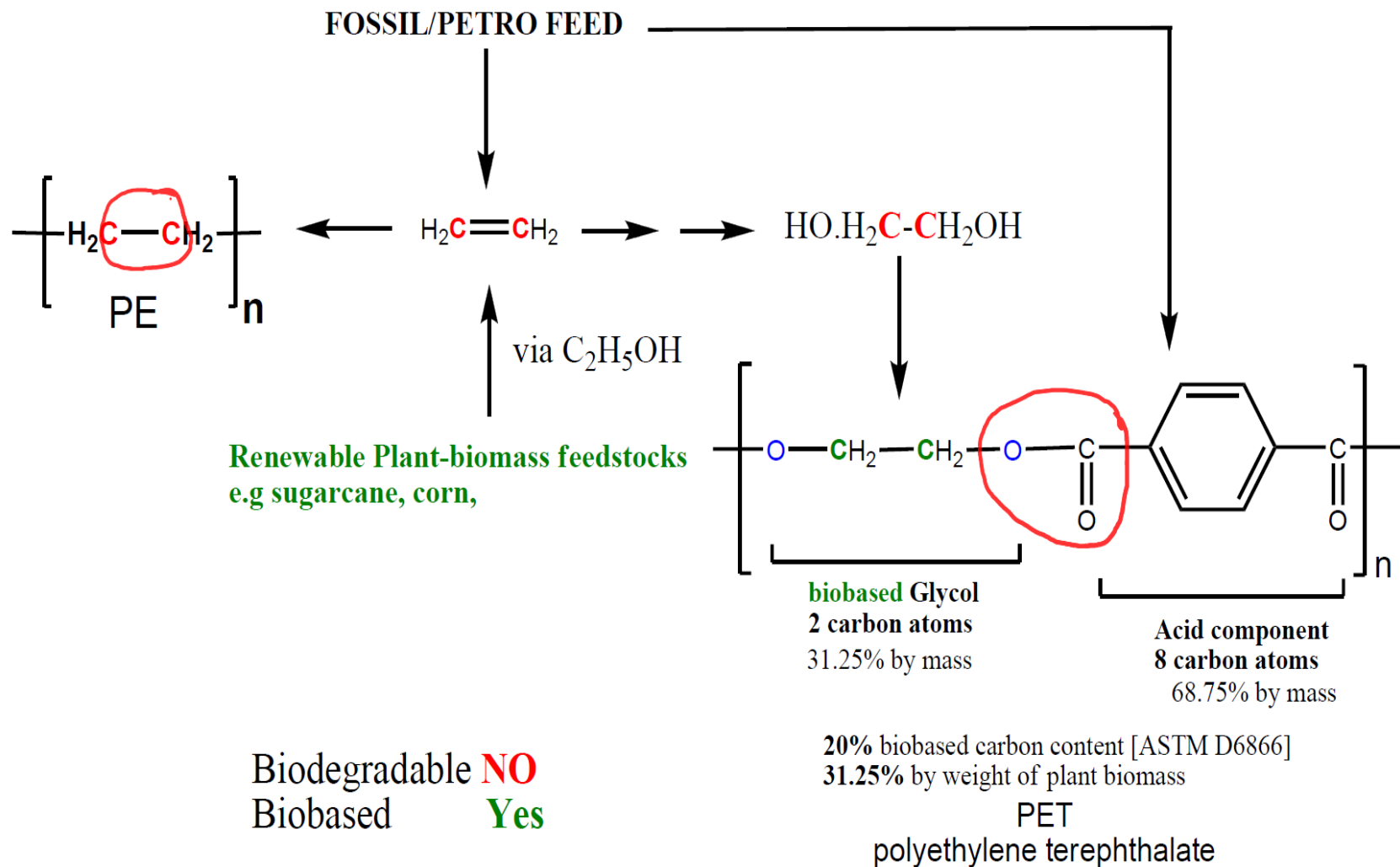
Percent **biobased** (organic) **carbon** content = mass of **biobased** (organic) carbon / total mass of carbon * 100

Percent **biogenic** (organic+inorganic) **carbon** content = mass of **biogenic** (organic+inorganic) carbon / total mass of carbon * 100

ASTM D6866; ISO 1660 Pt 2



Natural vs Synthetic – Use biobased and specify biobased carbon content



USE BIOBASED & FOSSIL BASED TERMINOLOGY!!!



WHY BIOBASED??

What are the benefits of replacing petro/fossil carbon with biocarbon?

- **Reduced carbon footprint**
- **Food security and creating value for rural agrarian economy**
- **Create “wealth” in rural agriculture through value-added industrial products**

CAUTION:

**Need to still address the issue of end-of-life
mechanical, chemical, biological/organic**

TAKE HOME MESSAGE

- Recent articles in literature and widely covered in print and E-media of macro-organisms like meal worms and wax moth eating plastics **as solutions for plastic waste management are misleading, troublesome and irresponsible.**
- It takes away from serious end-of-life solutions in place and being developed
- Biodegradability is not a **magical solution** for plastics waste management.
- Complete biodegradation of single use disposable plastics along with food and other biowastes in managed, closed loop disposal systems like composting and anaerobic digestion is environmentally responsible. This helps divert food and other biowastes from landfills and oceans.
 - **Certified Compostable BioPlastics**
- Degradation resulting in release of small fragments (microplastics) into the terrestrial and ocean environment has been shown to cause harm to the environment and to human health.
 - Many papers in the literature document that such fragments pick up toxins from the environment like a sponge and become a vehicle to transport toxins up the food chain.
- Use biobased, renewable carbon feedstocks (carbon footprint reductions) and in harmony with the new "Circular Economy" model





IS
BIODEGRADABILITY
A SOLUTION
TO PLASTIC WASTE POLLUTION
IN OCEAN AND ON LAND?



 **FREE** | Thursday, March 14 at 2pm ET 

 730 32 Comments 121 Shares

Attendees:
918 tuned in LIVE

** GoToWebinar recorded 901 unique login sites, but by using a post webinar survey 17 additional people were added through group self reporting data.*

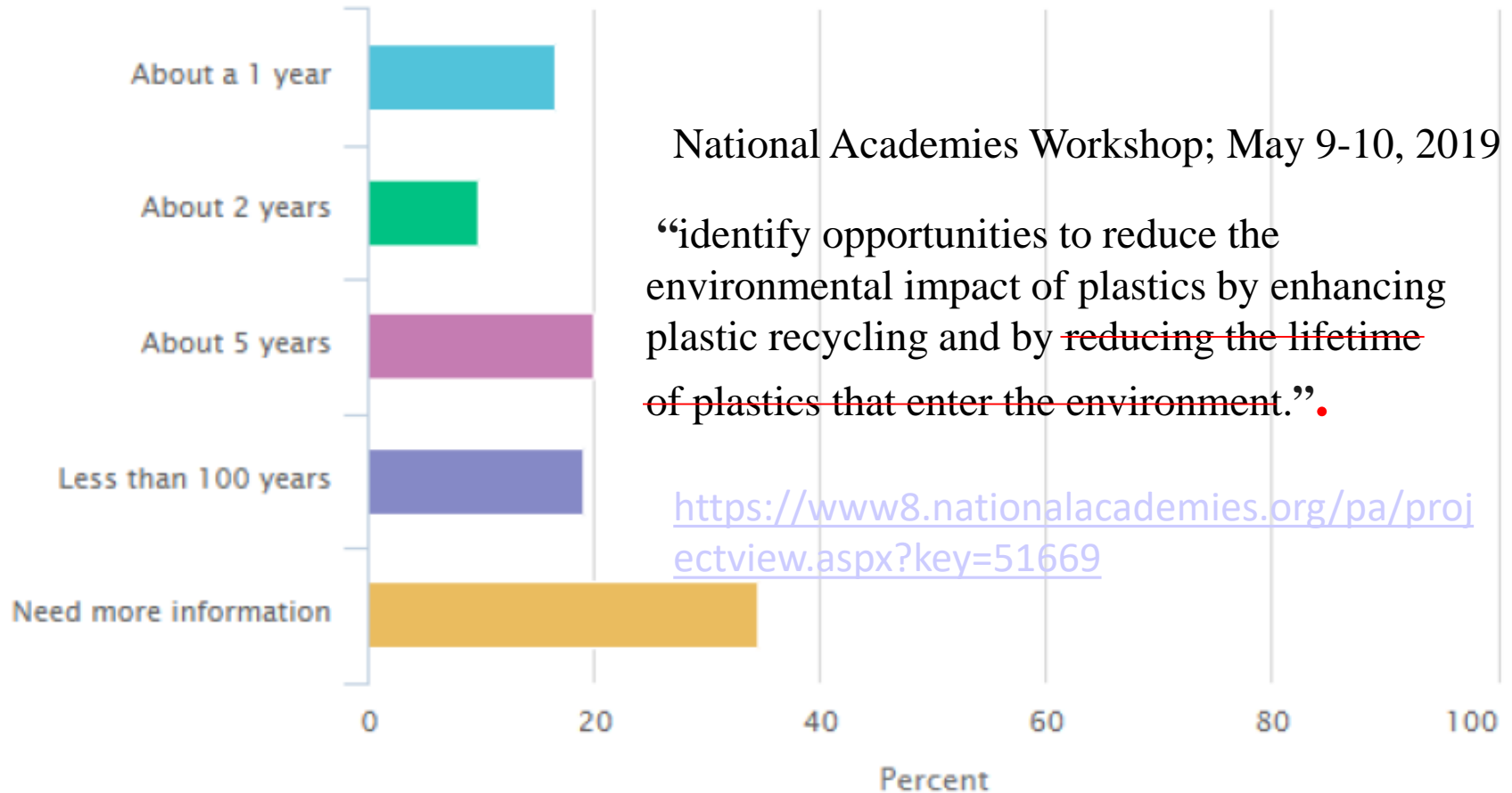
Webinar Satisfaction:

91% of the audience reported that ***“I was satisfied [or] very satisfied with today’s webinar.”***

** Possible survey answers were 5 being “very satisfied” to 1 being “very dissatisfied” out of a total of 287 survey respondents.*



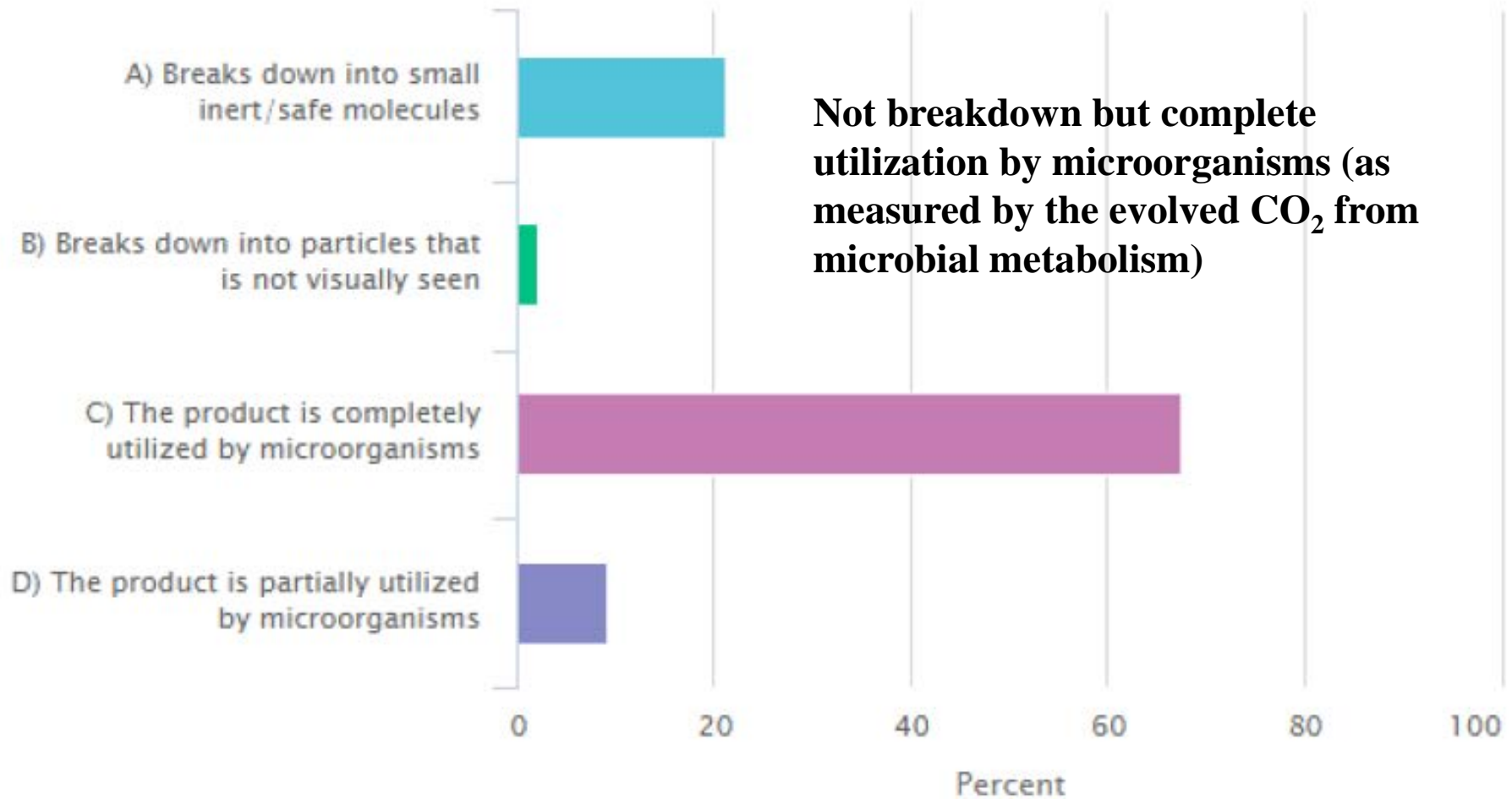
The term “biodegradable” on a plastic product means to you ≡
that it will biodegrade/disappear in:



What is the environmentally responsible end product of ≡
degradation/biodegradation?



What is the environmentally responsible end product of degradation/biodegradation?



Is biodegradability is a solution to ocean plastics pollution? ≡

