MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM

Can biodegradable plastics solve the problems caused by plastic debris leaking into sea?

- Development of new biodegradable plastics based on innovative ideas: current status and further proposal for social implementation-

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Working Group 4
Sustainable Resources Circulation for Global Environment
Clean earth

ISO 14851

Green Polymer Research Lab,
Gunma University, Japan

Content

1. **Background and current status**
2. **Development concept of marine biodegradable plastics**
   - Potentially biodegradable plastics(PBP)
   - Trigger system for biodegradation of PBP
3. **Research in lab: *study examples***
   - PBP: Aliphatic polyesters are candidates in PBP
   - Switching: Abiotic stimulation(disulfide bonds)
   - Switching: Bio-stimulation(Polycaprolactone)
4. **Further proposals for social implementation**

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Environmental issues caused by marine plastic debris

Fig. 1. Plastic pollution in Kuju beach (Shimoda).

Fig. 2. Derelict fishing gear in coral reef.

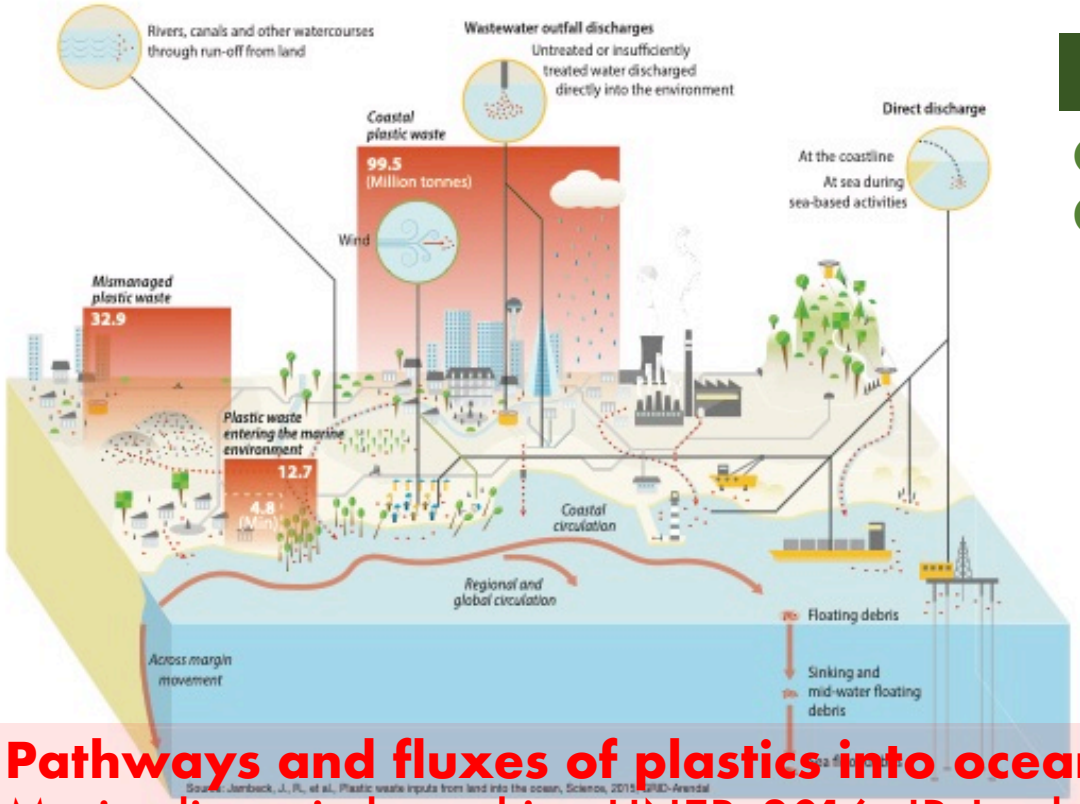
46% of plastic debris around Great Pacific Garbage Patch from fishing nets, Lebreton et al. Sci. Rep. 4(2018)4666.

Fig. 3. A sea turtle plastic straw stung
From a movie that research team of Texas A&M U posted on YouTube on 20150810.

Most plastics leaking into environments go to the oceans

What are the problems ?

1. Plastics that were originally used in the ocean would caused environmental damage at high probability(ALDFG :Abandoned Lost or otherwise Discarded Fishing Gear).
2. Most plastic waste that leaks into environments could reach to the ocean.



Pathways and fluxes of plastics into oceans

Marine litter vital graphics, UNEP, 2016. JR Jambeck, *et al*. Science, 2015.

What are the solutions ?

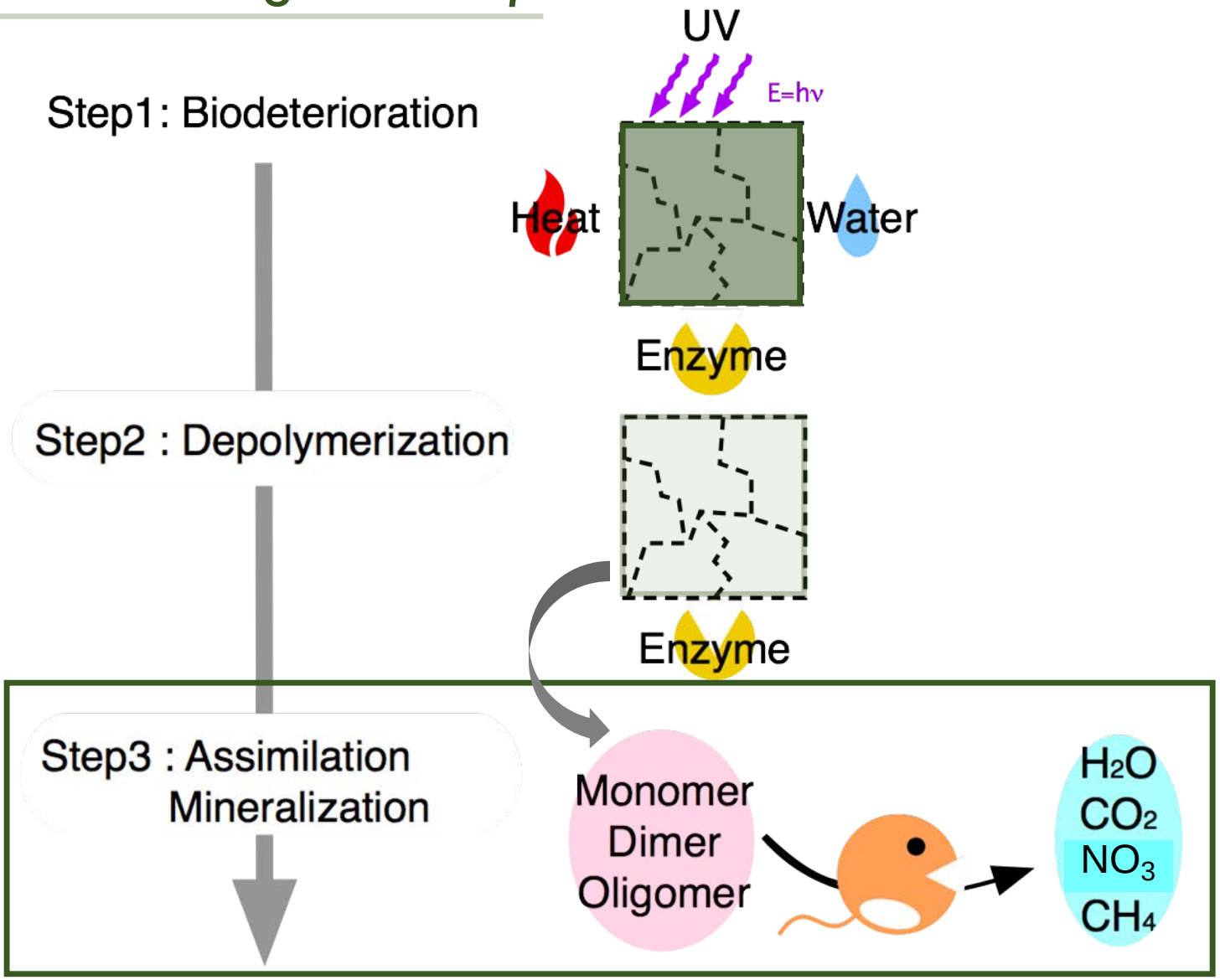
Osaka Blue Ocean Vision
G20 OSAKA Summit

1. Recovery
2. Innovation
3. Empowerment

⇨ *Development of new biodegradable plastics*

Biodegradable plastics would solve such issues.

What is Biodegradable plastics?



Chemosphere, 2008, **73**, 429.

Biodegradability of biodegradable plastics in environments (including marine environments).

Polymers	Environmental degradability		
	Excellent	Depending on site	Poor
PHAs	Soil Freshwater Brackish water **Seawater** Aerobic sludge Anaerobic sludge Compost	-	-
PESu	Soil Freshwater Compost Activated sludge	-	Seawater
PBSu	Compost	Soil	Seawater Activated sludge Freshwater
PBAT	Compost	Soil	Freshwater Seawater
PLA	Compost	Soil	Seawater
PCL	Soil Freshwater **Seawater** Compost	-	-

Now most biodegradable plastics we can buy do not degrade in marine environments except for PHAs and PCL.

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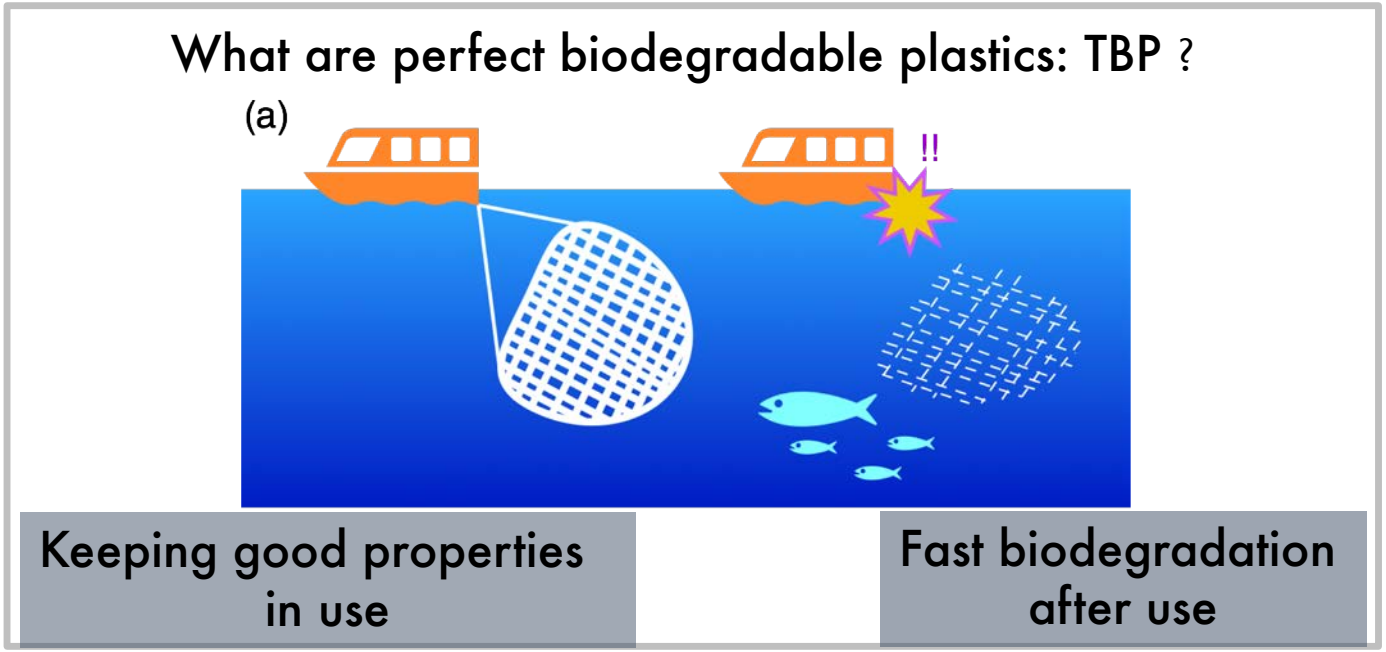
Biodegradable plastics have conflicting elements

Specific use :
Uncollectible after use (Agricultural and fishing gears, e.t.c.)

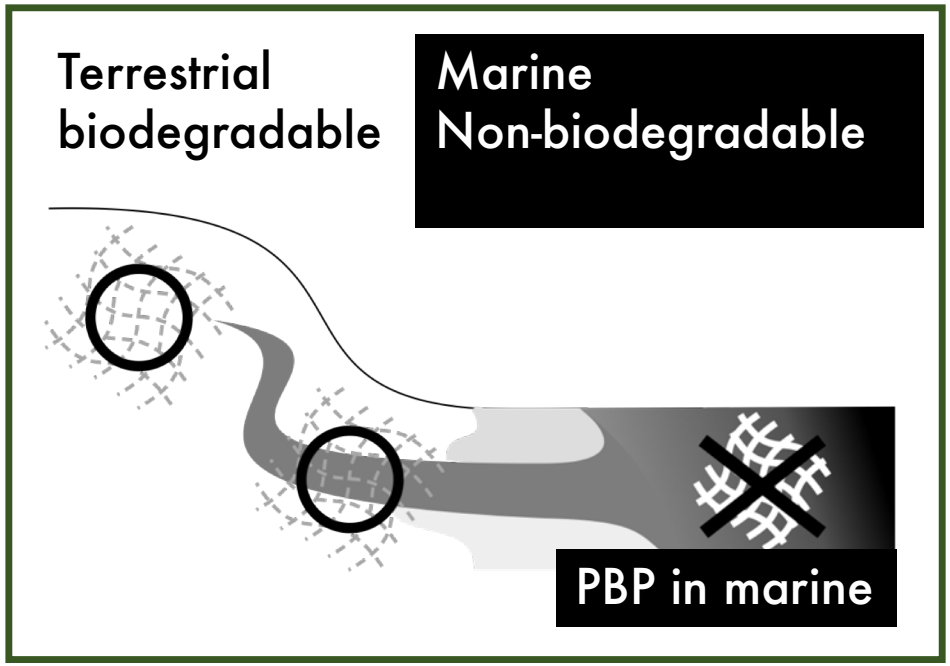


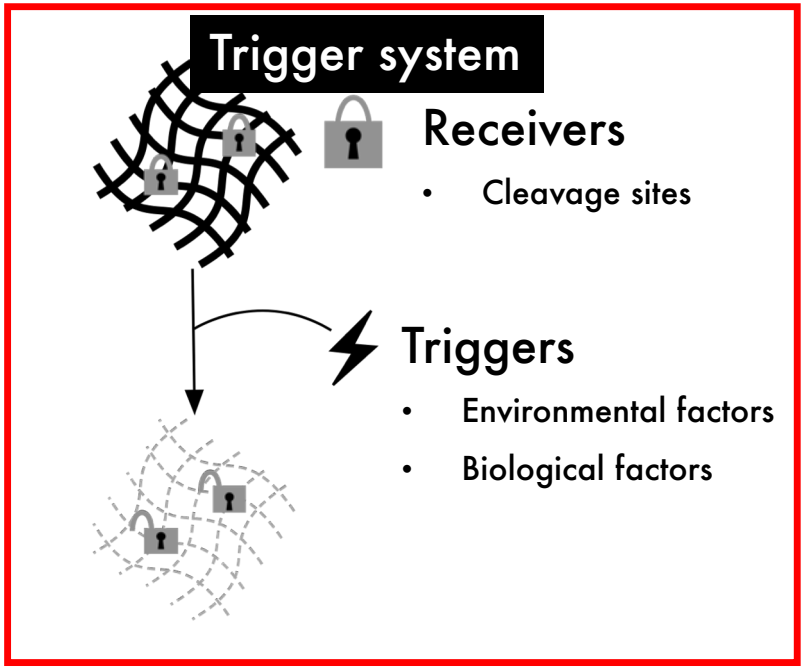
Difficult goals

To make perfect biodegradable plastics,
initial time of biodegradation must be controlled.

It is defined as "Timing biodegradable plastics: **TBP**",
which has a **switch function** to start degradation.

Proposal: To create TBP, "Potentially biodegaradable plastics: PBP" and "Trigger system" could be used.





Biodegradability of PBP depends on environments

Biodegradation starts by "Trigger system".

+

TBP

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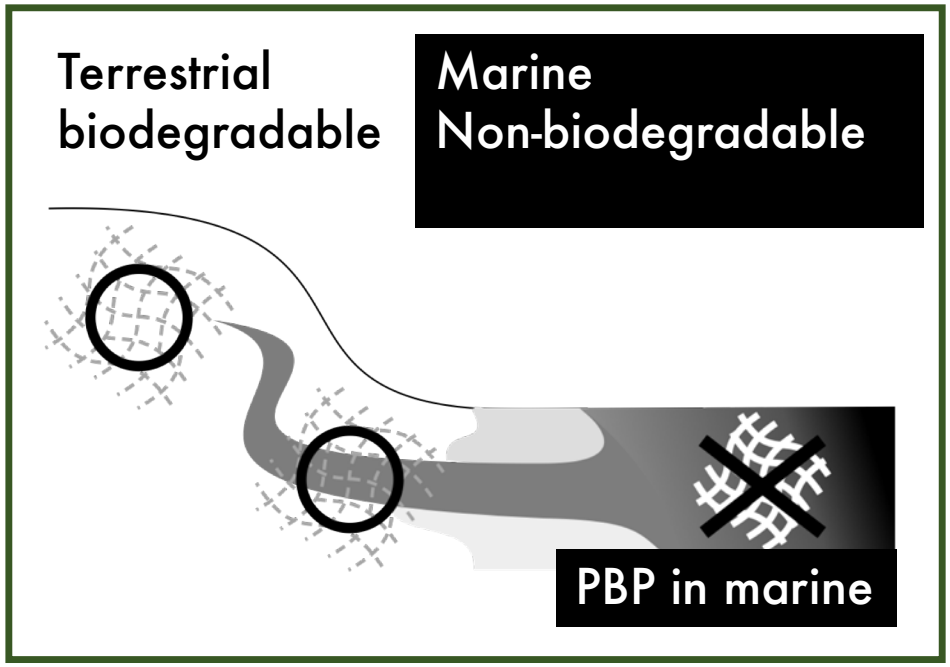
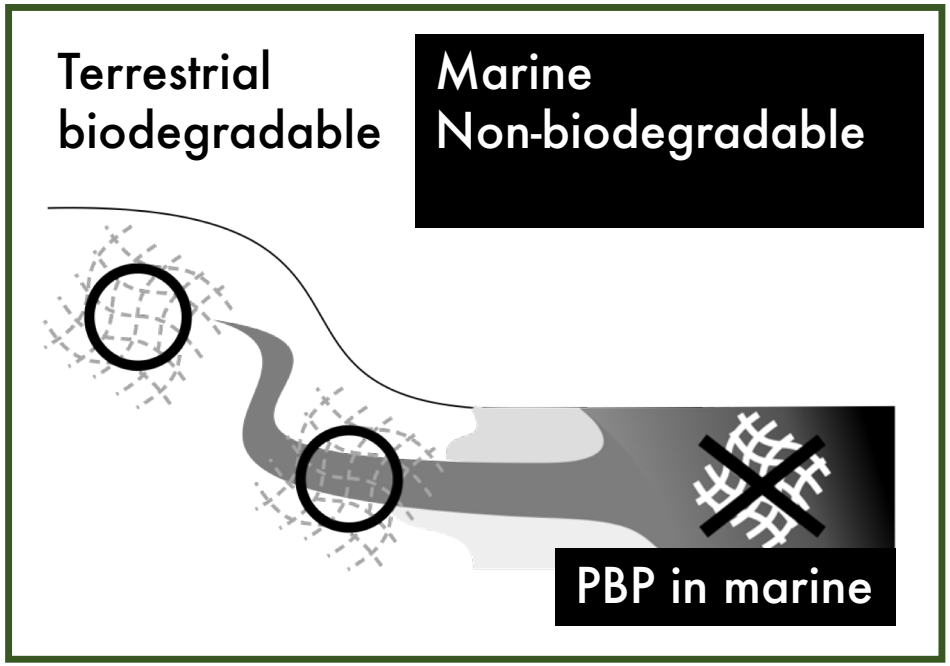


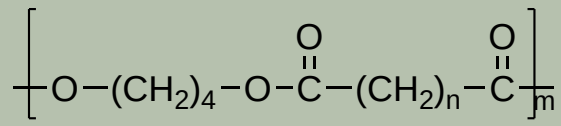
Biodegradability of PBP depends on environments

Biodegradation starts by "Trigger system".

Most aliphatic polyesters would be promising candidates for PBP

Polym Degrad Stabil 138, 18-26, 2017



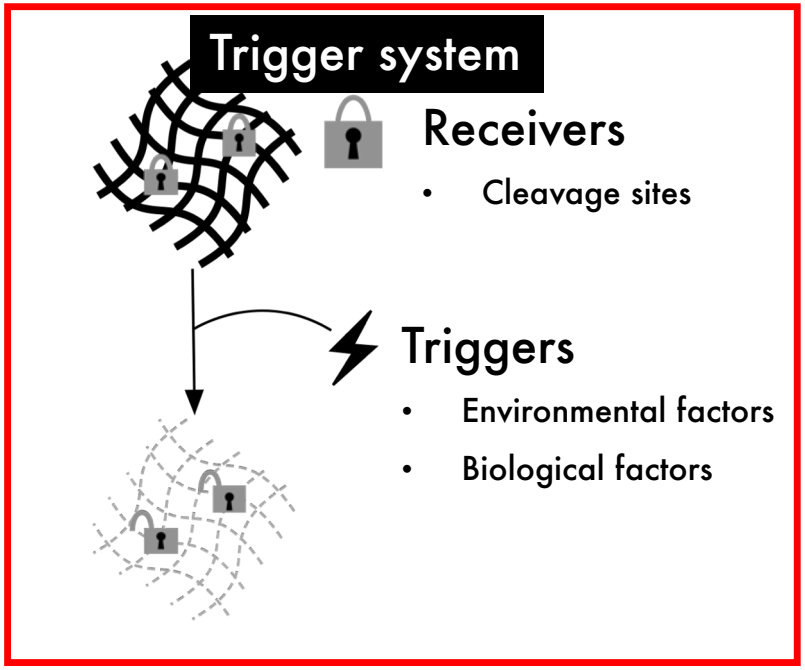


Poly(butylene *n*-alkylene dicarboxylate)
(PBAD)

PBADs could not induce degrading enzymes. Biodegradabilities of them would be related to abundance of respective degrading microbes.

We conclude that PBADs are some kind of **PBP**, of which the onset of biodegradation can be controlled.

To create TBP, "Potentially biodegaradable plastics: PBP" and "Trigger system" could be used.



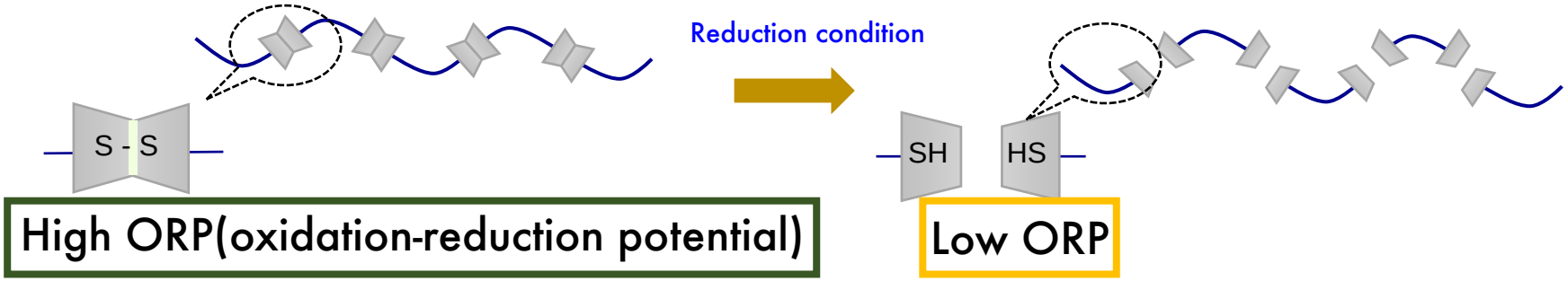
Biodegradability of PBP depends on environments

Biodegradation starts by "Trigger system".

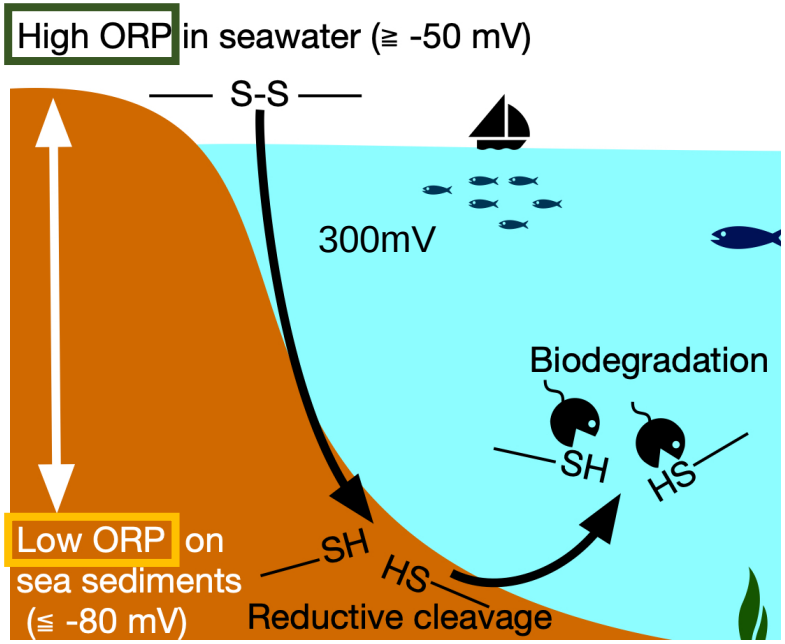
- *Abiotic-stimulation*
- *Bio-stimulation*

Biodegaradable switch provided to PBP by *Abiotic*-stimulation using environmental factors.

Polym Degrad Stabil 137, 67-74, 2017



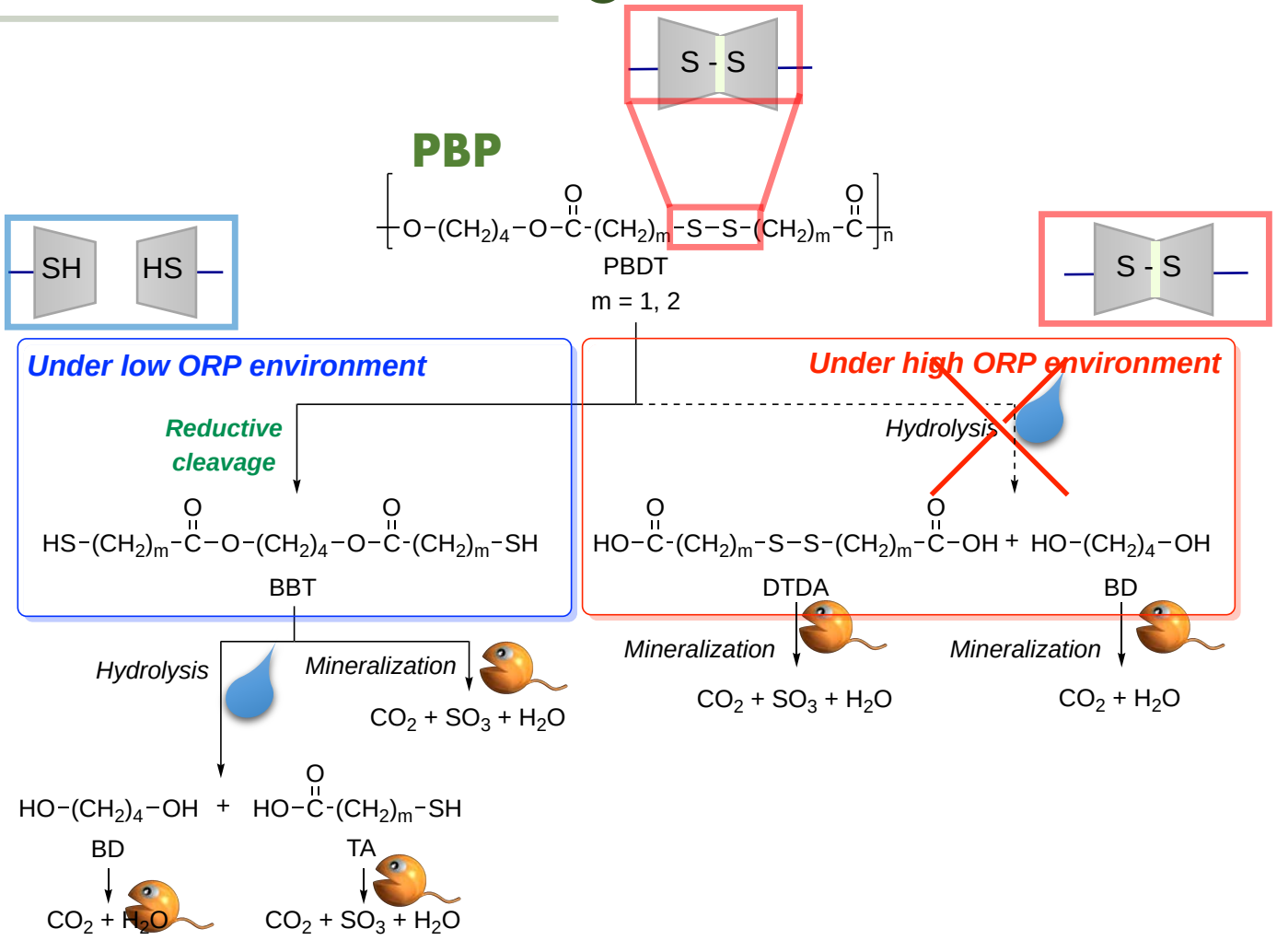
—— S-S —— : Plastics with disulfide bonds



Switching mechanism:

1. The polymers were stable at high ORP.
2. The polymers started cleavage of SS after reaching sea sediments (switch on).
3. After that, degradation products were mineralized completely.

Biodegaradable switch provided to PBP by *Abiotic*-stimulation using environmental factors.



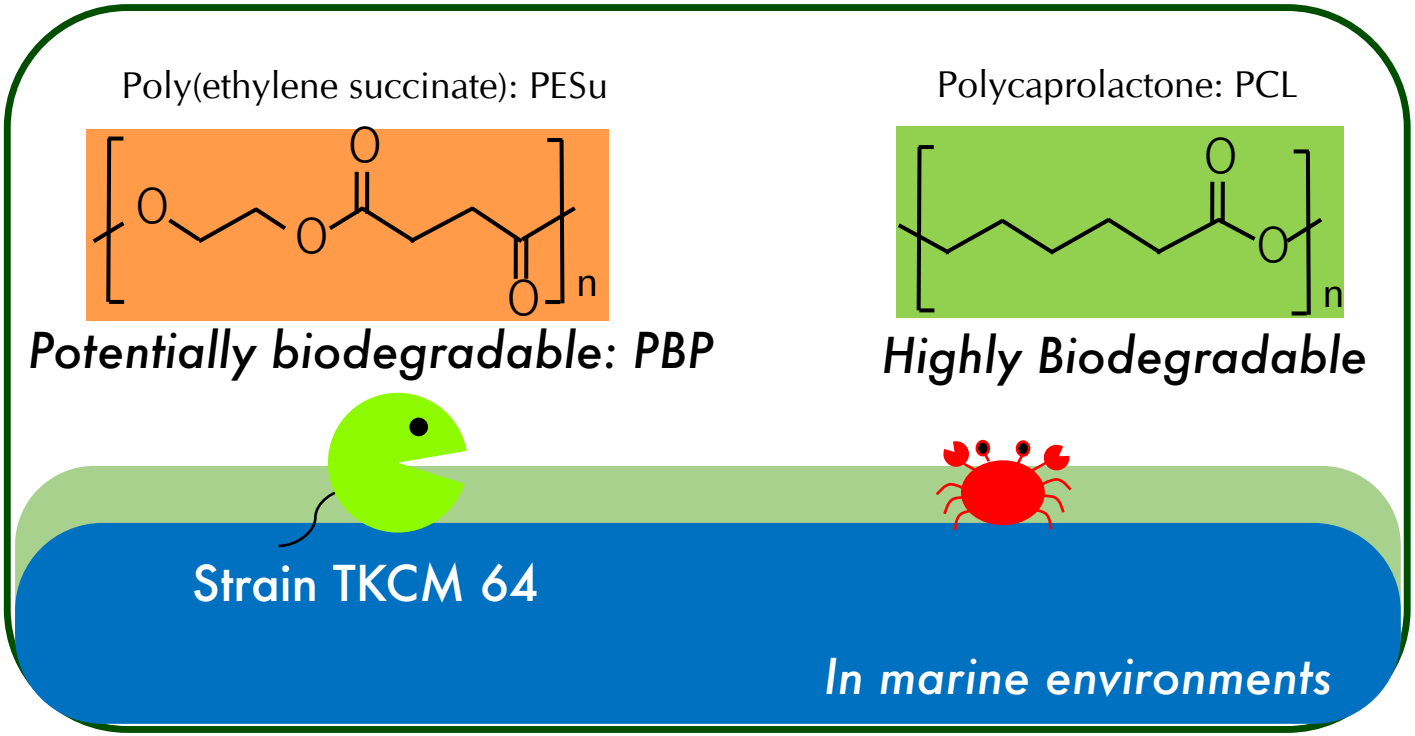
POC

In marine environments

TBP would be created by PBP (PBADs with SS)+ Abiotic trigger (low ORP) .

Biodegaradable switch provided to PBP by *bio*-stimulation using biological factors.

Polym Degrad Stabil 149, 1-8, 2018.



Deduced carbon cycle on PCL by strain TKCM 64 in marine ecosystem

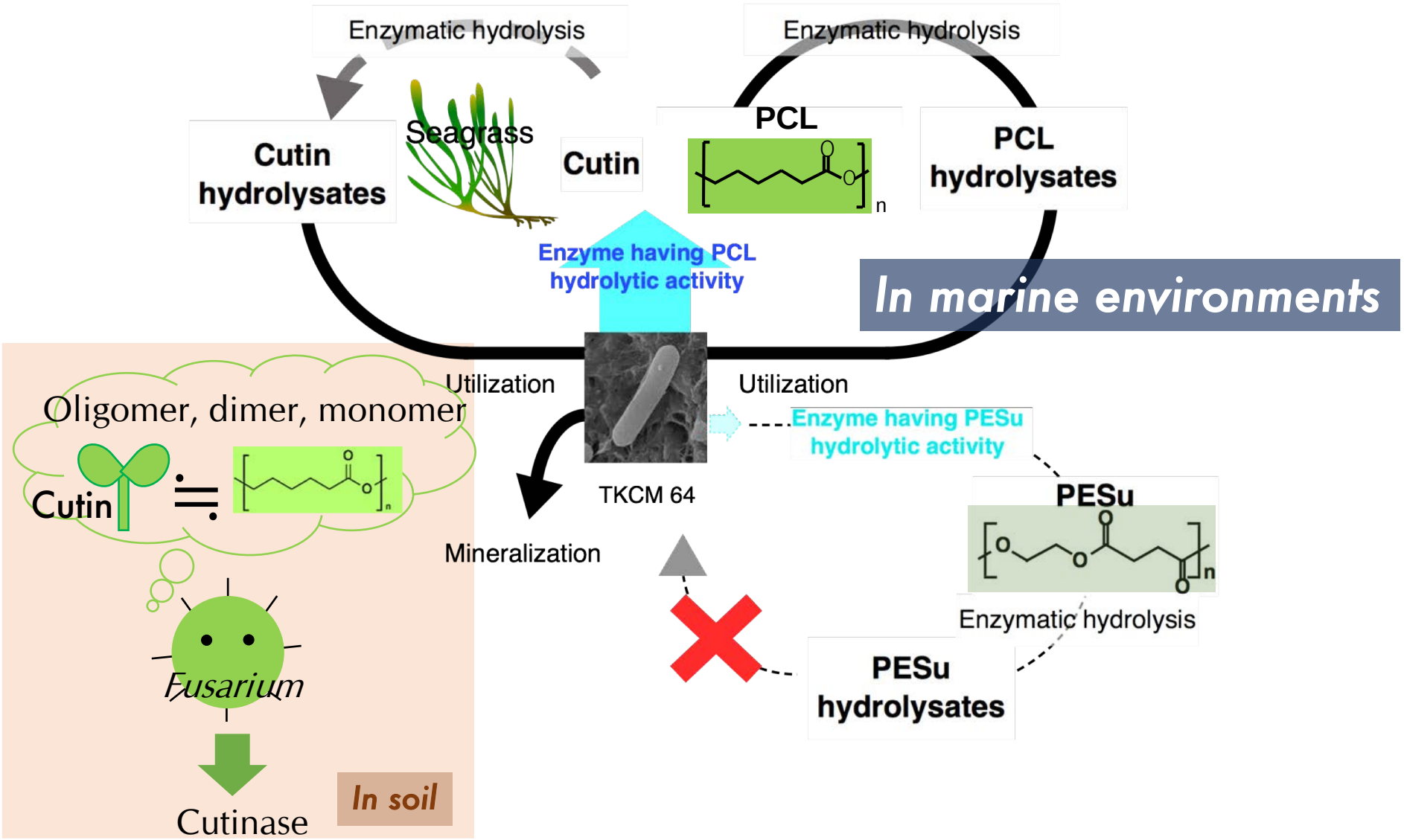
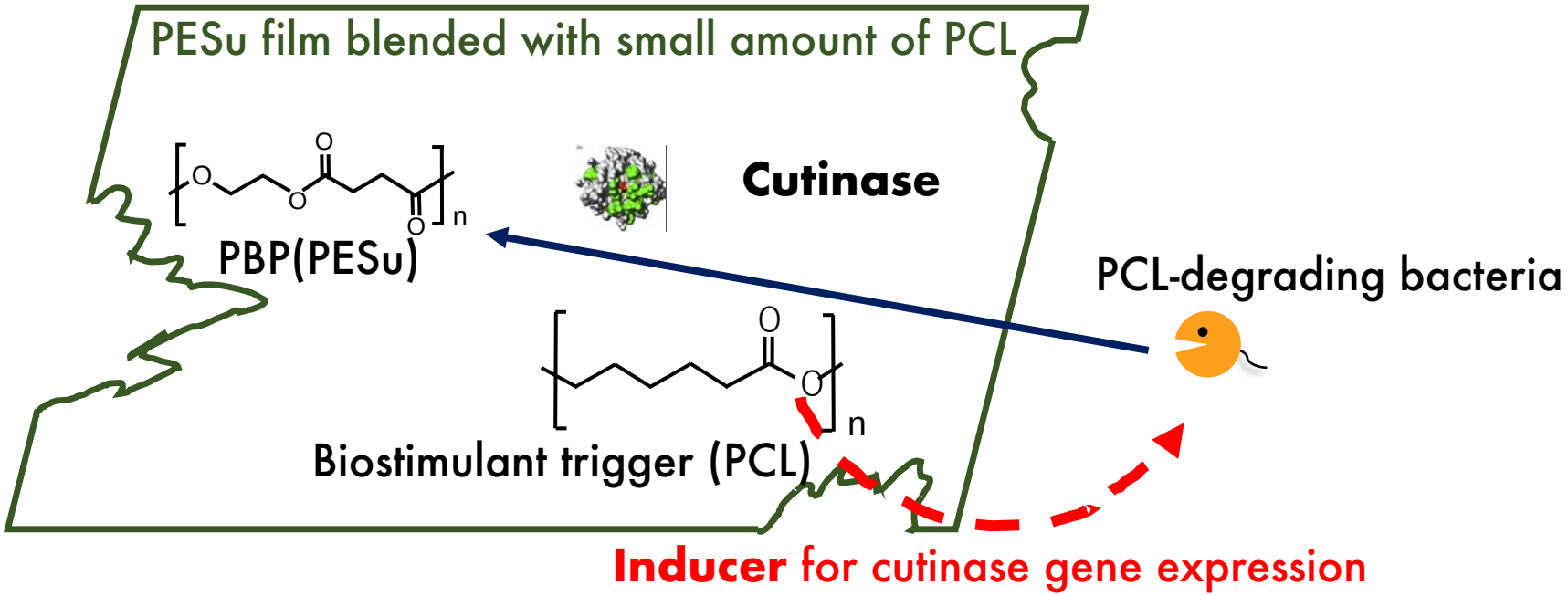


Fig. The inference of PCL and PESu-degrading mechanism in marine environments

Biodegradation of PESu could start in seawater by blending PCL



In marine environments

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In marine environments

TBP would be created by PBP (PESu)+ Biostimulant trigger (PCL) .

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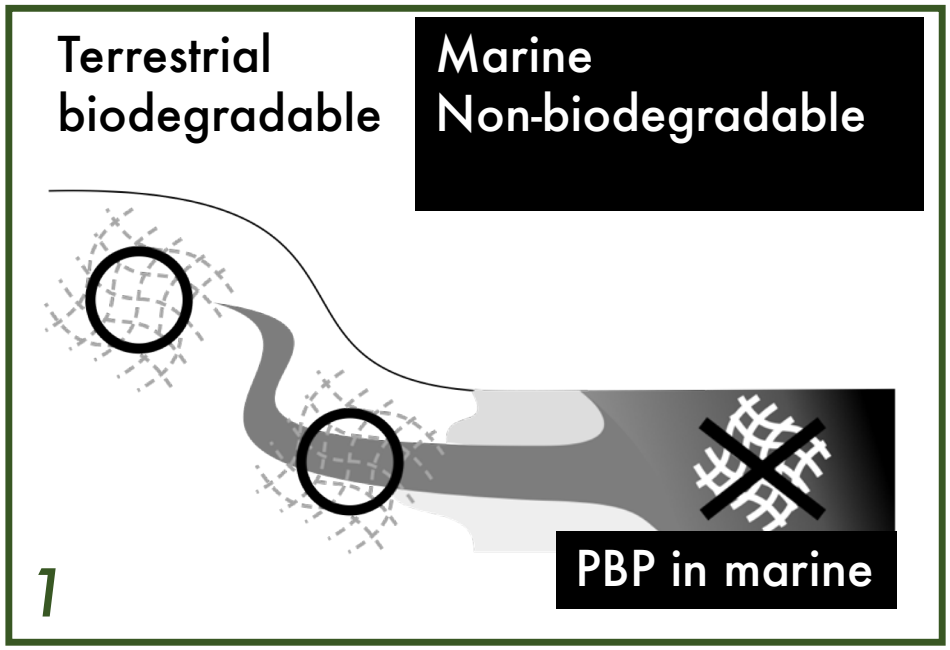
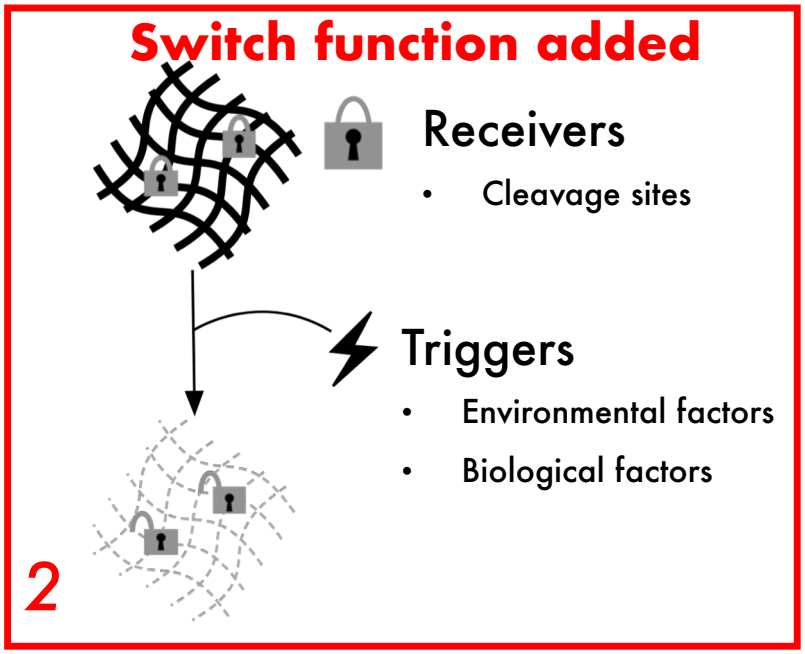
Further proposals for social implementation



PBP would determine the properties in TBP.

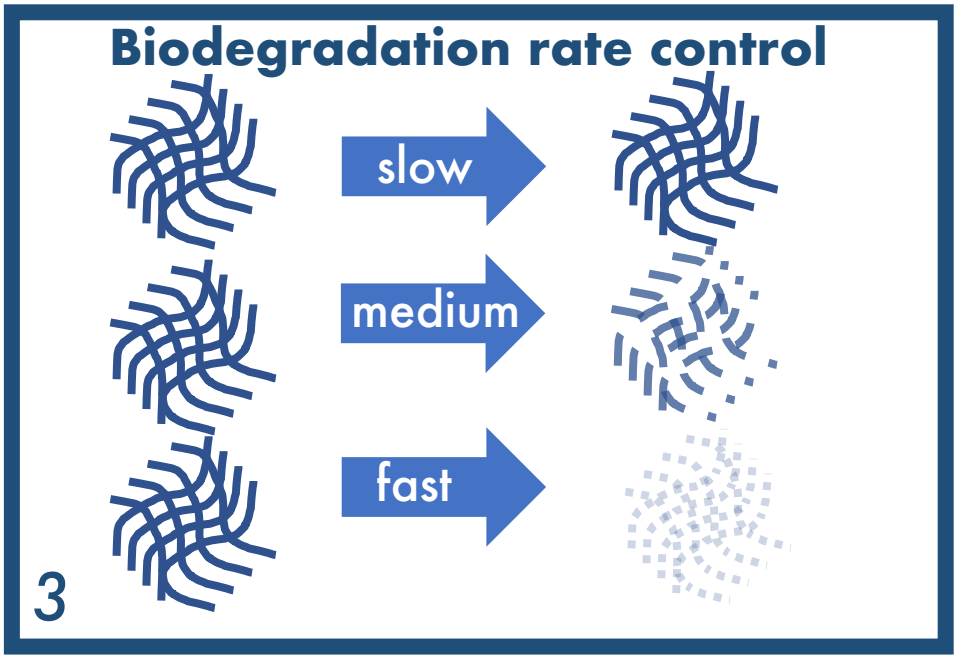
To create a variety of TBPs, we must create novel PBPs.
e.g. strength, formability, gas permeability, thermostability, e.t.c.



More variations of trigger systems should be proposed so that PBPs could start biodegradation absolutely.

e.g. by salt concentrations, temperatures, other bio-stimulants, microchips, e.t.c.

Further proposals for social implementation



Biodegradation rate could be controlled,

e.g. by control of crystallinity of polymers, primary structures, e.t.c.

by control of biofilm structures formed on the polymers(plastisphere control).

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Thank you for your attention

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