From Plastic waste to Plastic value using *Pseudomonas putida* Synthetic Biology

SUSCHEM ES Química Sostenible
Asamblea General SusChem-España
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The problem

Worldwide plastic production: 335 millions tons/year
European generation of plastic waste: 26 million tons/year

Emission
CO_2

Recycling 30%
Incineration 39%

Landfill and environment (rivers, oceans etc)

31%

A EUROPEAN STRATEGY FOR PLASTICS IN A CIRCULAR ECONOMY, January 2018

The problem

Use of plastic waste!

- Best case:

- Worst case:

The P4SB objective

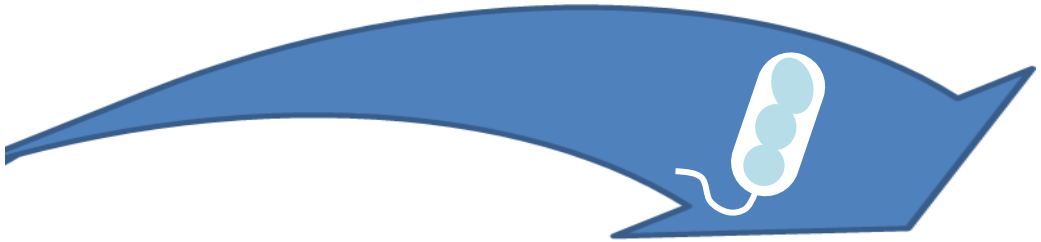
The biotransformation of non-sustainable plastic waste into sustainable value-added alternative materials

→ *use plastic waste as carbon source for biotechnology*

polyethylene terephthalate (PET)

polyurethane (PU)

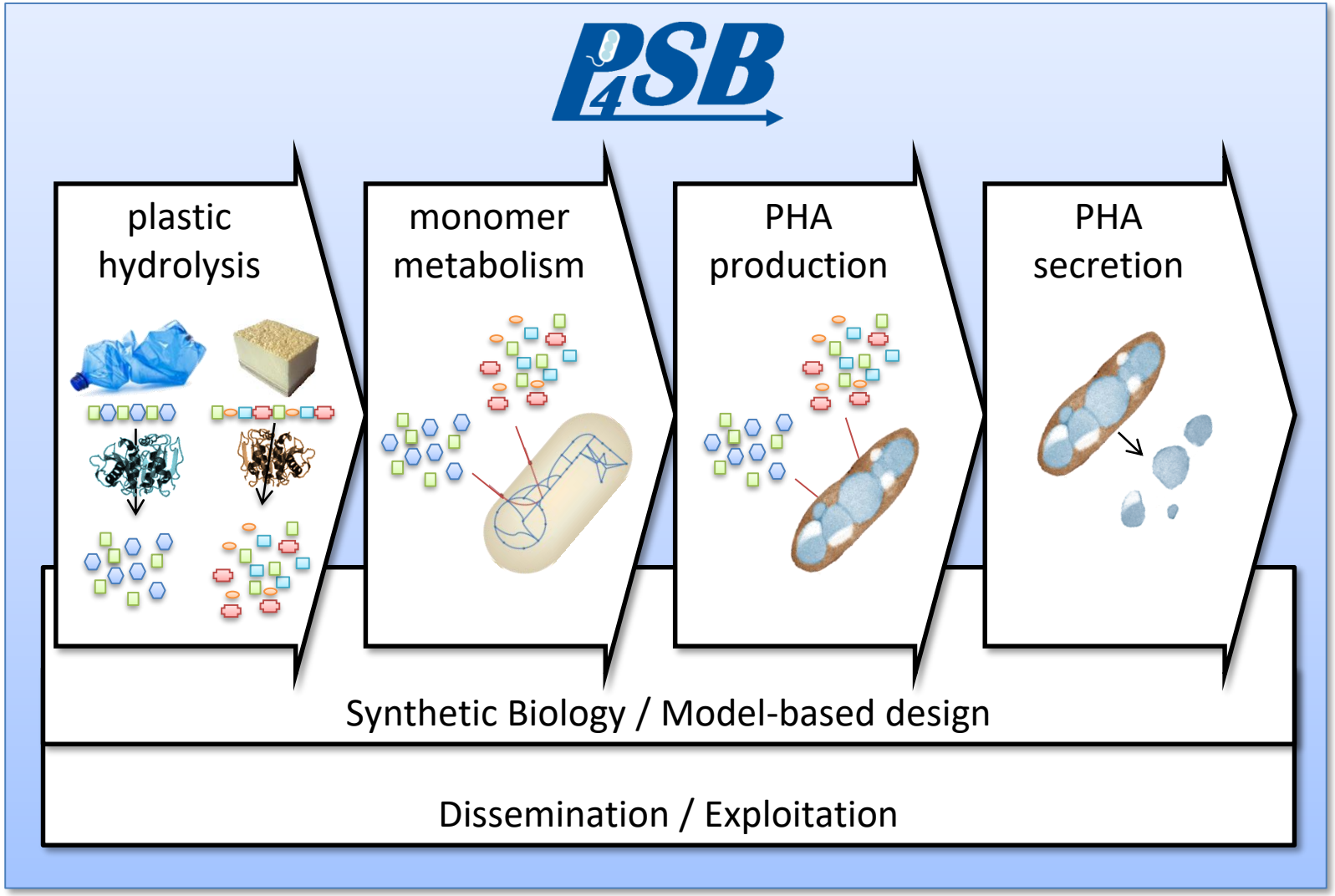
Bio-upcycling



Bioplastics

Wierckx et al., Plastic biodegradation: challenges and opportunities, 2018, *DOI: 10.1007/978-3-319-44535-9_23-1*
Drzyga & Prieto, Plastic waste management, a matter for the „community“, 2019, *Microbial Technology 12(1):66-68*

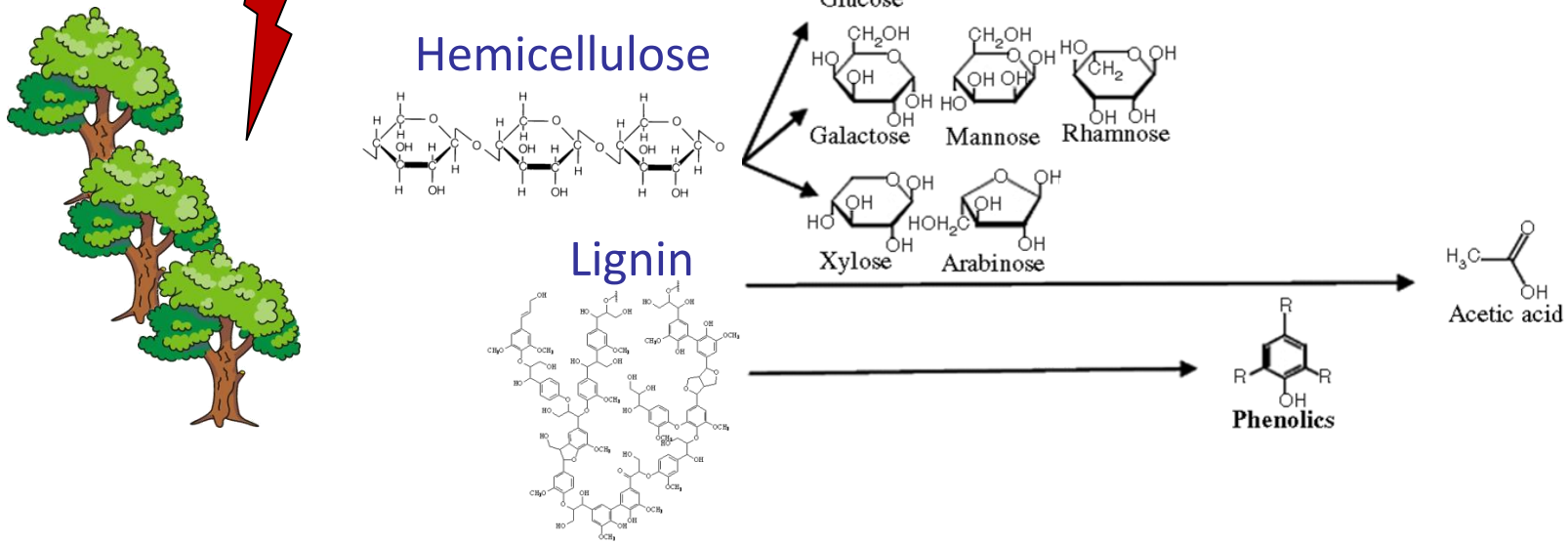
The P4SB approach

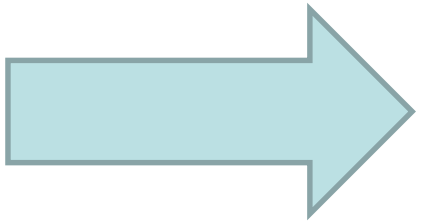


www.p4sb.eu

Analogy to lignocellulosic biotech

pretreatment **hydrolysis** **fermentation**



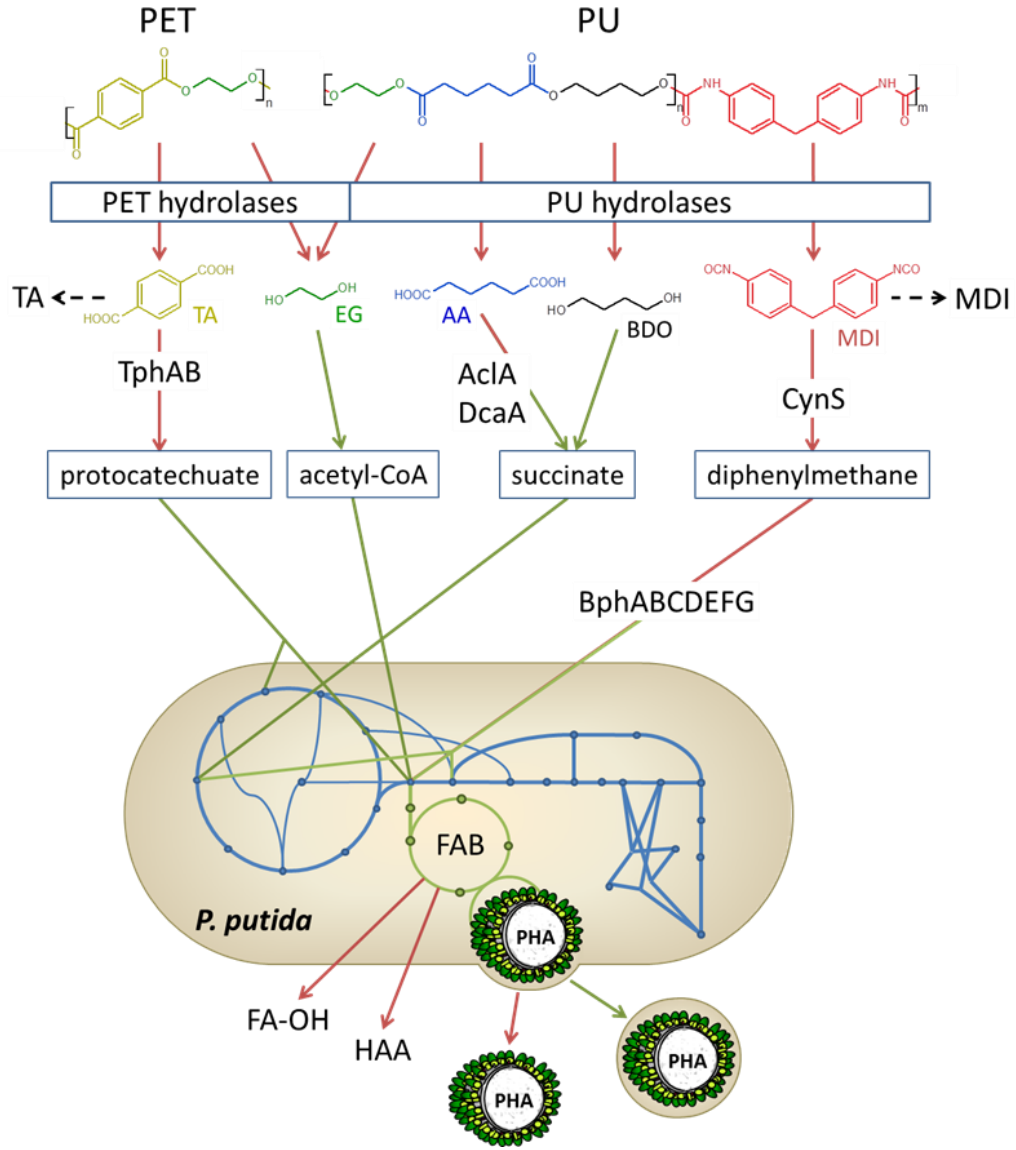


Modified from: Almeida et al. (2007) *J. Chem. Tech. Biotech.* 82:340

The P4SB approach

Intermediates:

TA, terephthalic acid
EG, ethylene glycol
AA, adipic acid
BDO, 1,4-butanediol
MDI, 4,4'-methylene diphenyl diisocyanate

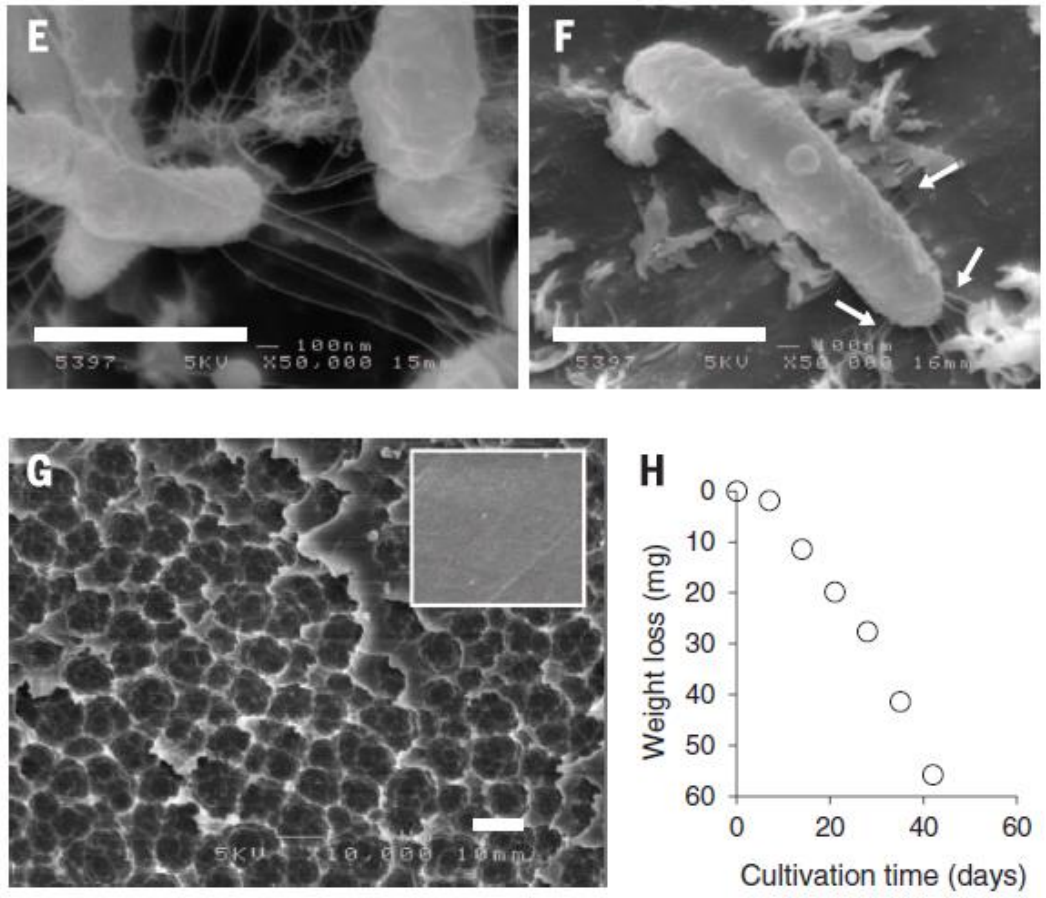


- PET and PU hydrolysis
  - Enzyme engineering
- Monomer metabolism
  - Pathway engineering
- PHA production
  - Metabolic engineering
- PHA harvest
  - Cell biology

Enzymatic PET film hydrolysis

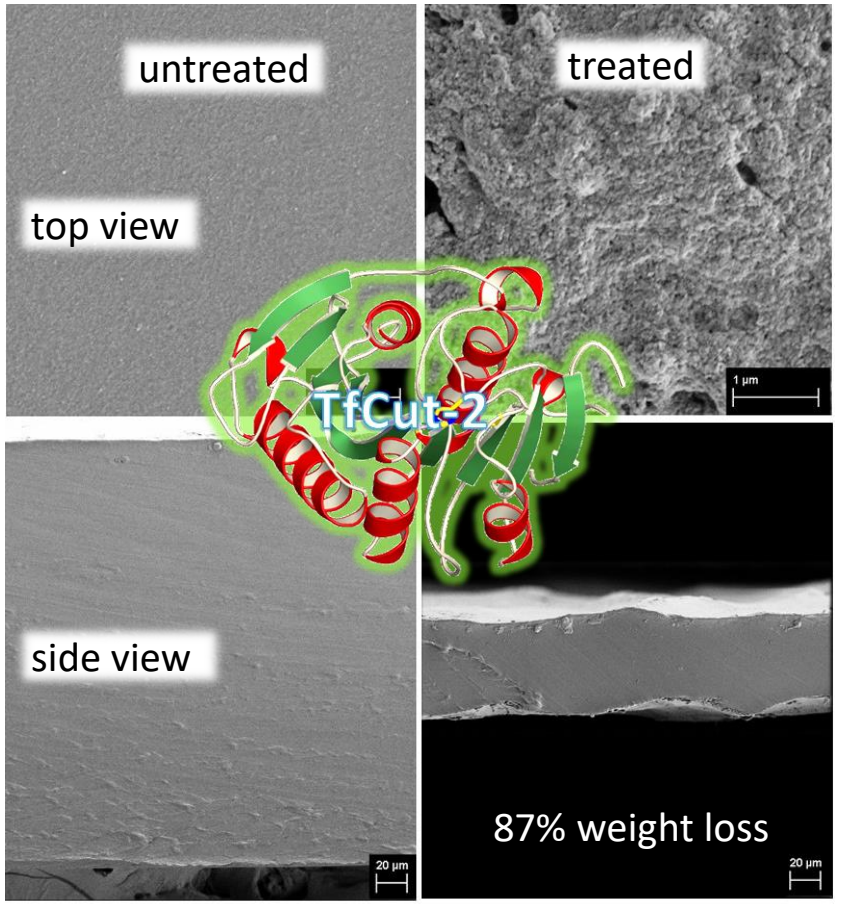
UNIVERSITÄT LEIPZIG
Wolfgang Zimmermann
Ren Wei

Ideonella sakaiensis



Yoshida et al. (2016) *Science* 351:1196

Enzymatic process (by cutinase)



Wei & Zimmermann (2017) *Microb. Biotechnol.* 10:1308-1322
Zimmermann & Billig (2011) *Adv. Biochem. Eng. Biotechnol.* 125:97-120
Alisch et al. (2004) *Biocatal. Biotrans.* 22:347

Enzymatic PET film hydrolysis

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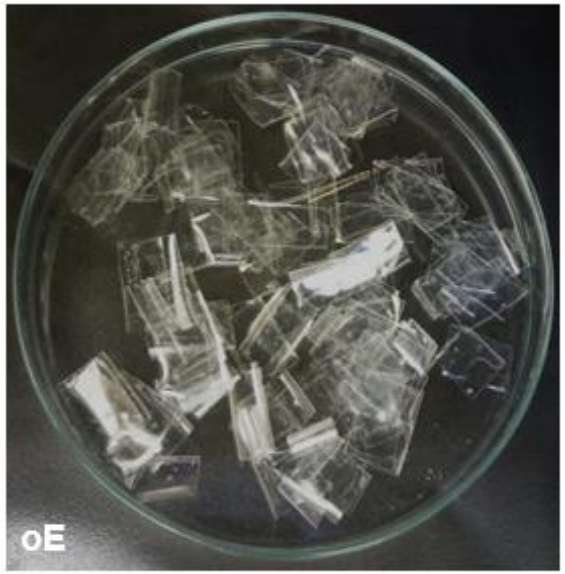
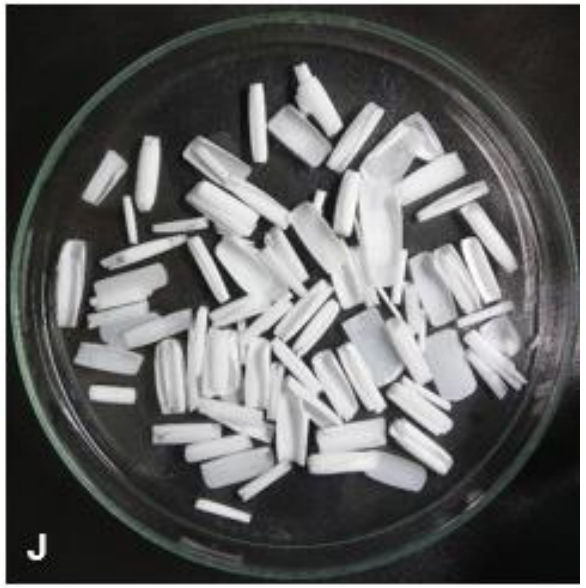


Day 0: untreated



Day 4 at 70°C: Weight loss: 72%

- Cutinase from *Thermobifida fusca*

Pseudomonas putida KT2440

Interesting host

- Well-annotated genomes
- Harmless (non-pathogenic)

High stress resistance

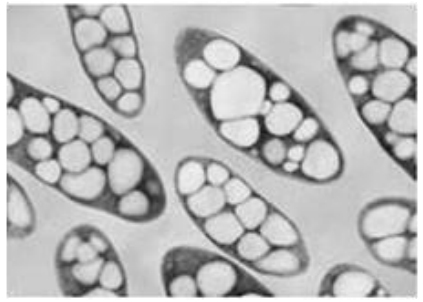
- Solvent-tolerant strains
- Oxidative/chemical stress

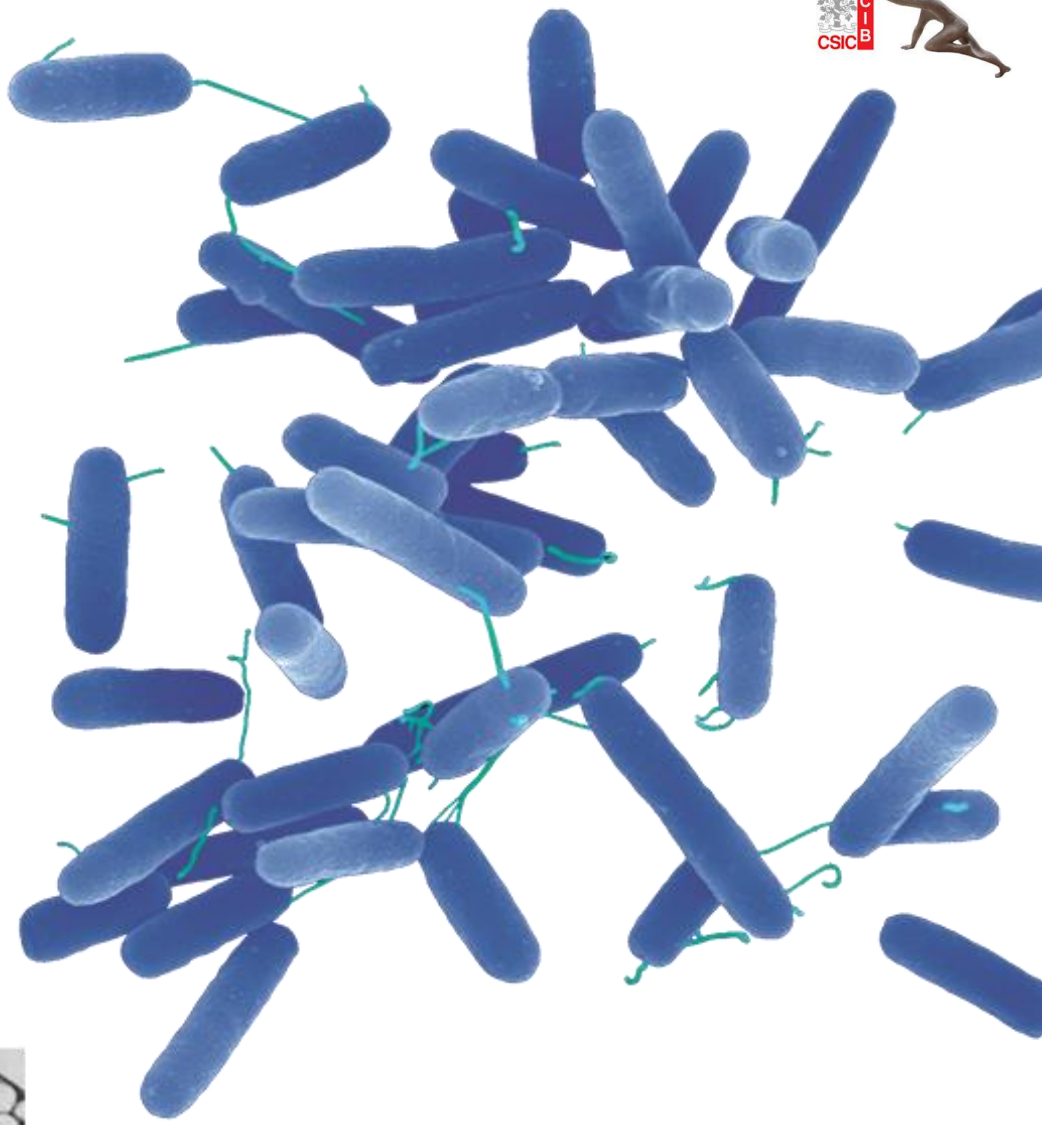
Versatile metabolism

- Sugars, glycerol, aromatics, aldehydes

Natural bioplastic (PHA) producer

- Storage polymer

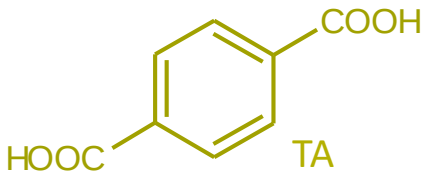


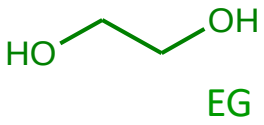


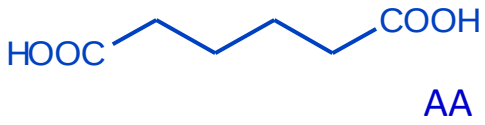
© Dennis Kunkel microscopy

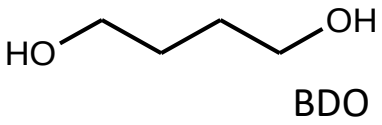
PHA production from plastic monomers

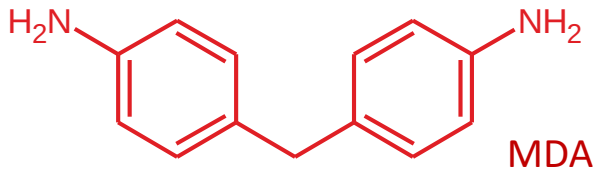
Kevin O'Connor
Shane Kenny
Tanja Narancic

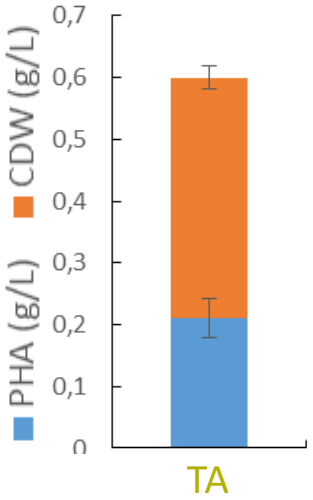


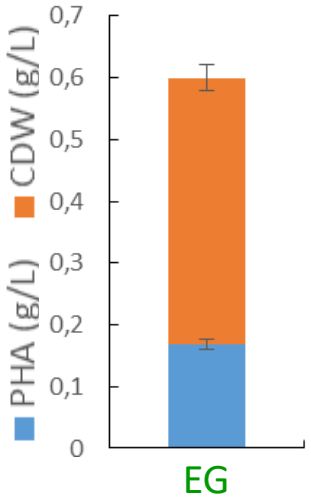


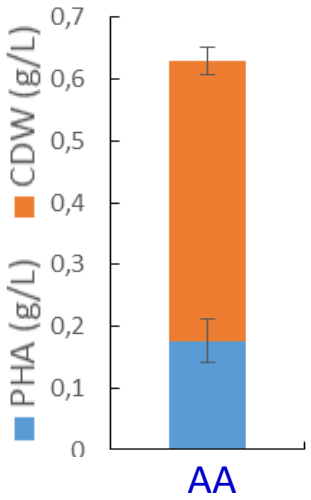


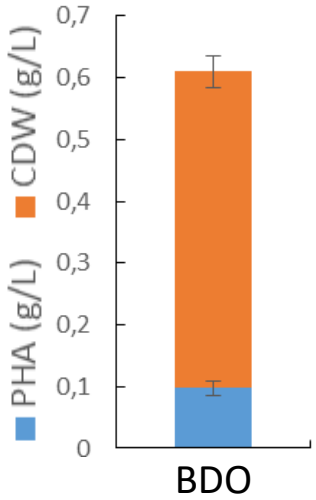


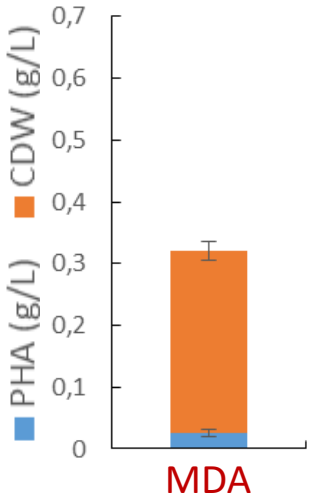


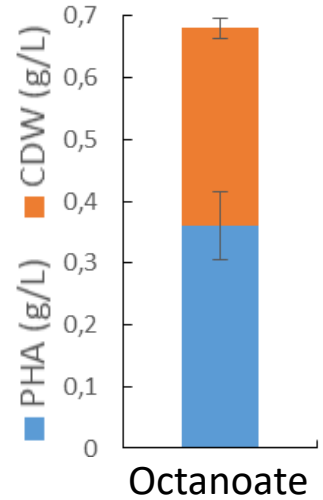




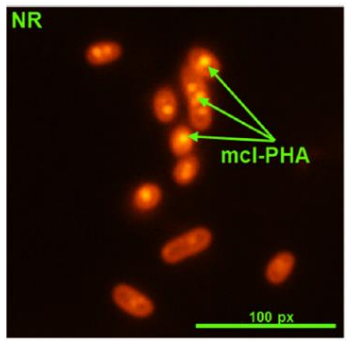




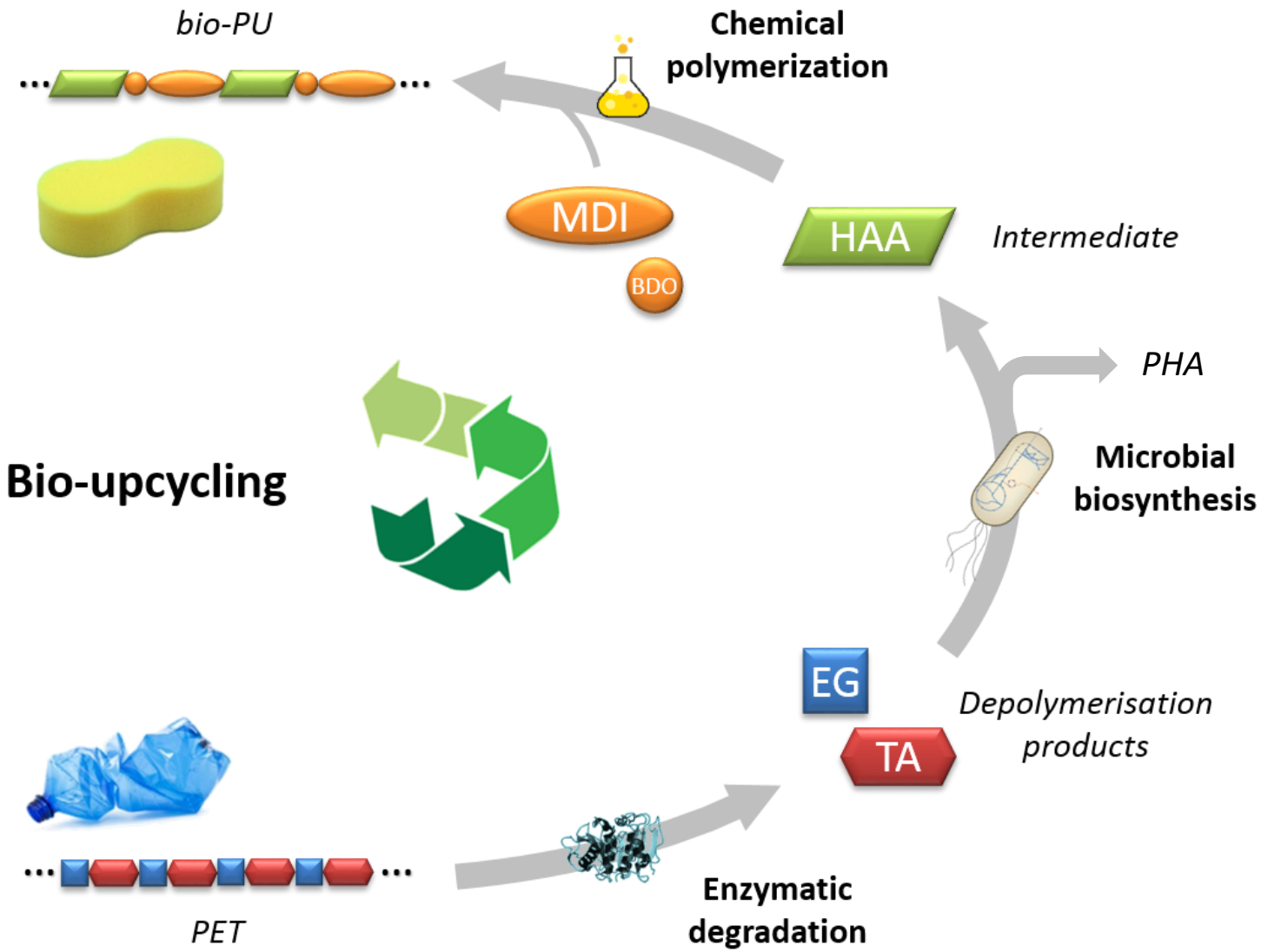




Octanoate as positive control



Concluding: new work-flow / new value chain



hydroxyalkanoyloxy-alkanoate (HAA)

Wierckx et al., Plastic waste as a novel substrate for industrial biotechnology, *Microbial Biotechnology*, 2015, 8:900–903

Outlook 1:

technologies & processes

enzymatic *microbial*

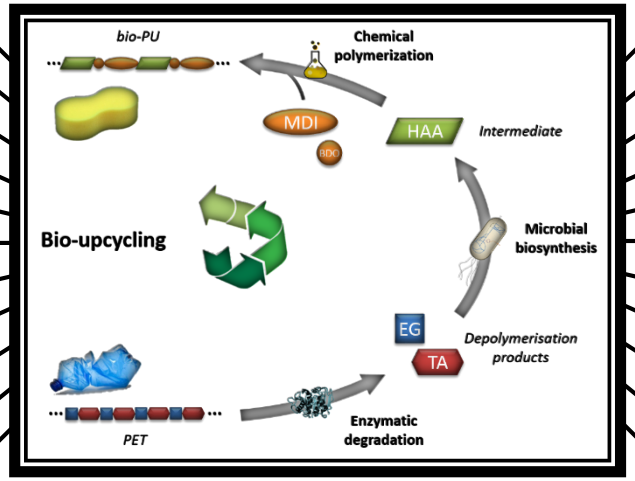
thermochemical *chemo-catalytic* *separation*

polyesters
- PET
- PEF
- PCL
- PLA
- PHA

polyurethanes
- PU

polyamides
- PA6.6
- PA11

polyvinyls
- PE
- PP
- PS



biopolymers
- PHA
- bio-PU

(glyco)lipids
- rhamnolipids
- HAA
- fatty acids

aromatics
- phenol
- styrene
- *p*-OH-benzoate

org. acids
- itaconate
- malate
- succinate

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Drzyzga & Prieto, Plastic waste management, a matter for the „community“, 2019, *Microbial Technology 12(1):66-68*

Outlook 2:

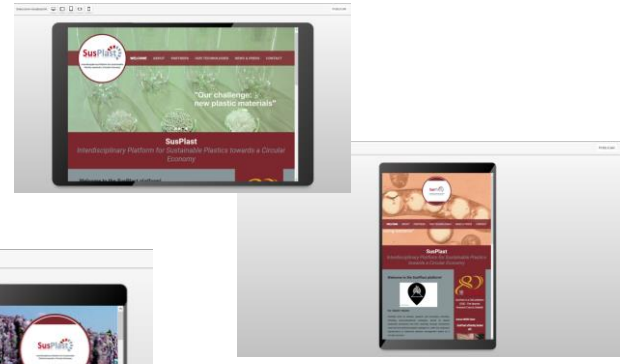
From P4SB (2015 - 2019) to mix-up | 降塑再造 mixed plastics biodegradation and upcycling using microbial communities (2019 - 2023)

Both H2020 projects are part of:

Find us at: www.susplast-csic.org

SusPlast

Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy



Acknowledgements


P4SB consortium

Funding by

Horizon 2020

Thank you for your attention!