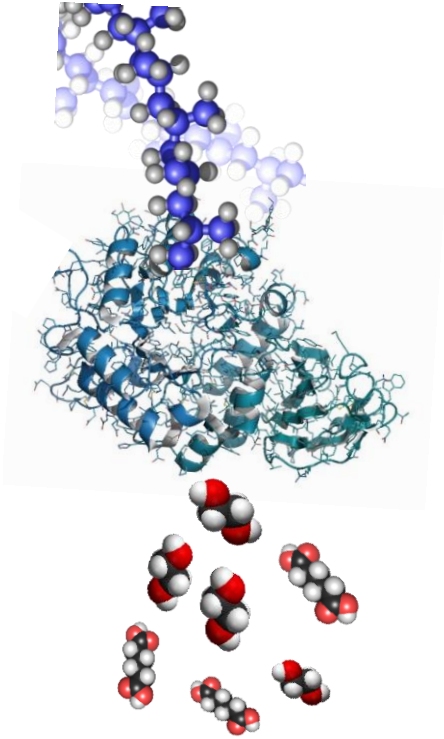
CARBIOS
Reinvent Polymers Lifecycle

CARBIOS, THE FIRST AND ONLY COMPANY TO HAVE DEVELOPPED BIOLOGICAL PROCESSES BASED ON ENZYMES TO BREAKDOWN PLASTIC WASTES INTO MONOMERS

Workshop on Plastics for a Circular Economy
US Department of Energy's (DOE's)
Bioenergy Technologies Office (BETO)

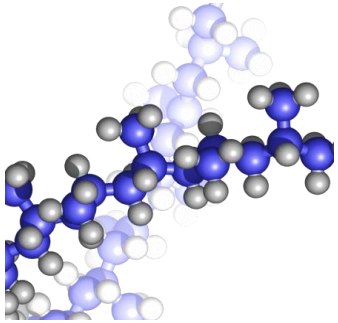


December 11-12, 201 9 Golden, Colorado

ZOOM ON PLASTICS

Petrochemical or biobased polymers, long chains consisting in monomer repetition

Monomers = building blocks



Polymer

5 main plastics on the market

PE

PP

PET

PVC

PS

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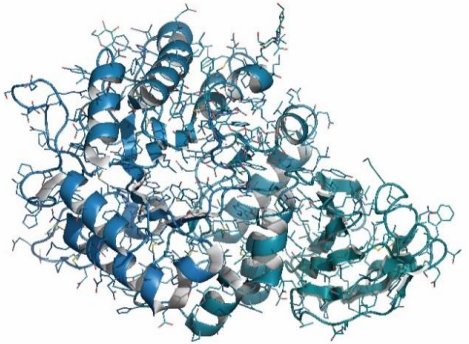
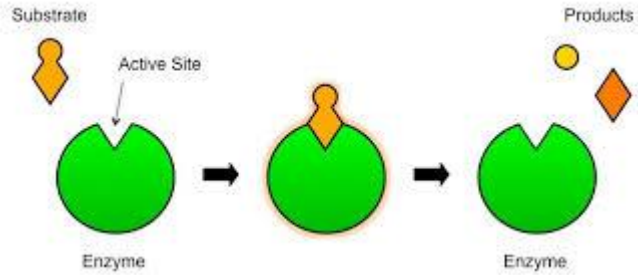
ENZYME, KEY PLAYER IN ALL BIOLOGICAL PROCESSES





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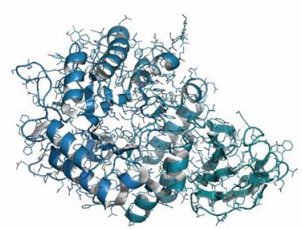
BIOLOGICAL DECONSTRUCTION OF PLASTICS

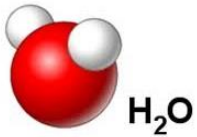
Abiotic fragmentation

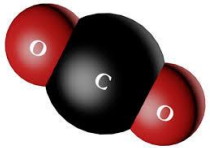
Enzyme degradation

Bioassimilation

Mineralization







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IN A FEW WORDS

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WHO ARE WE?

2011
Creation

2013
IPO Euronext Growth Paris

2019
14.5 M€ capital increase (of which 10.5 M€ from Copernicus, Michelin and L'Oréal)

- **28** employees
- **2** innovative bioprocesses
- **32** patent families

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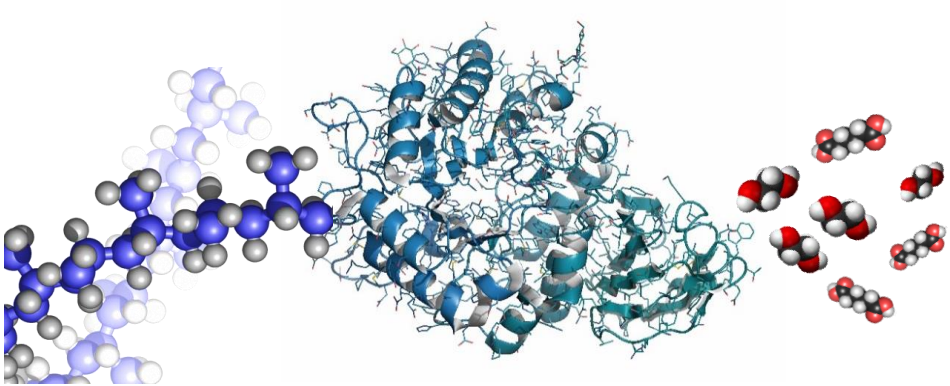
ENZYMES TO FULLY BREAKDOWN POLYMERS



Polymers

(plastics and textiles)

Carbios enzymes

Monomers

(building blocks)

BIODEGRADATION ZERO WASTE

INFINITE RECYCLING

REVOLUTIONARY PROCESSES FOR INFINITE RECYCLING AND BIODEGRADATION OF PLASTICS AND TEXTILES

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AN EXPERIENCED MANAGEMENT TEAM

Jean-Claude LUMARET

Founder & CEO

40 years experience in the agro-industry at an international level and expert in intellectual property

- **TWB (Toulouse White Biotech):** Chairman
- **METABOLIC EXPLORER**: VP Strategy & Innovation (Member of the Executive Committee)
- **ROQUETTE:** Director, Business Intelligence, Director BU Fermentation and Industrial Chemistry, Director, Intellectual Property and Regulatory Affairs
- Chemical Engineer, Lyon University, European Trademark Expert, CEIPI Center for International IP Study, Strasbourg

Martin STEPHAN

Deputy CEO

30 years of experience in the chemical industry

- **CHEMOURS:** Global Director of the Fluorotelomers business, EMEA Director, Sourcing, Logistics & Real Estate
- **DU PONT DE NEMOURS**: Global Product Manager, Business and Market Manager, Sales Director
- **ATOFINA**: Global Business Manager Fluorotelomers
- **ELF ATOCHEM**: Various positions in Finance
- MS in Business Management, HEC Paris, BA Economics Paris University.

Prof. Alain MARTY

CSO

International expert in enzymology and biological processes

- **INSA** Institut National des Sciences Appliquées, Toulouse : Professor and Head of a research group
- **AERES** Agence d'Evaluation de la Recherche et de l'Enseignement Supérieur and **ANR** Agence Nationale de la Recherche: Evaluator (France's National Education Research Agencies)
- PhD in Biology, Biochemical Engineer, University of Toulouse

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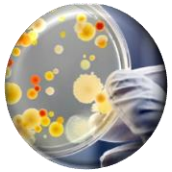
A PRAGMATIC INNOVATION MODEL

RESEARCH | LABORATORY | PILOT | INDUSTRY




EXTERNAL RESEARCH | DEVELOPMENT BY CARBIOS | INDUSTRIAL PARTNERSHIP

cnrs
INRA SCIENCE & IMPACT
twb White Biotechnology center of excellence
tbi Toulouse Biotechnology Institute Bio & Chemical Engineering

La Région Auvergne-Rhône-Alpes
ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie
bpifrance

Limagrain from earth to life
novozymes Rethink Tomorrow

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ENZYMATIC RECYCLING OF PET

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POLYESTER PET

70 Mtons in 2017
(4% growth p.y.)

60% TEXTILE

40% PLASTIC

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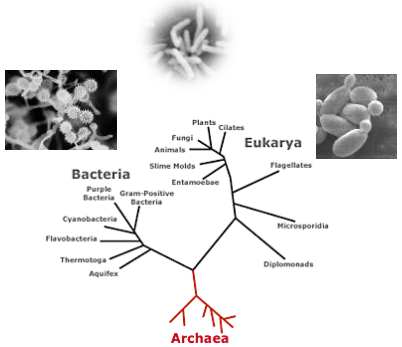
UPCYCLING PET WASTE

	CONVENTIONAL RECYCLING	CARBIOS UPCYCLING ENZYMATIC TECHNOLOGY
 Trays  Textiles	0%	100%
 Complex Opaque bottles Colored bottles		100%
 Clear bottles		100%

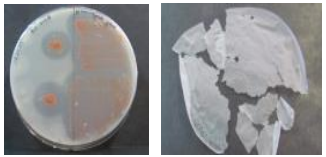
A SOLUTION FOR ALL KIND OF PET WASTE FLOWS

STRATEGY FOR PET RECYCLING



Microbial diversity analysis

SCREENING

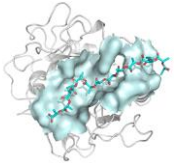


ENZYME IDENTIFICATION

Candidate enzymes

ENZYME PRODUCTION

ENZYME ENGINEERING



ENZYME WITH OPTIMIZED THERMOSTABILITY AND ACTIVITY

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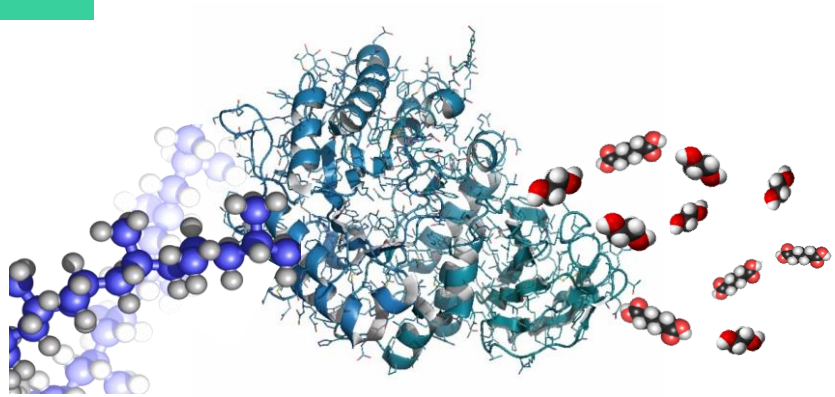
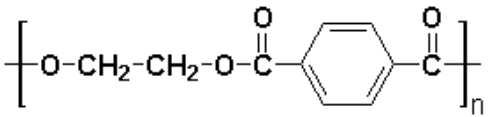
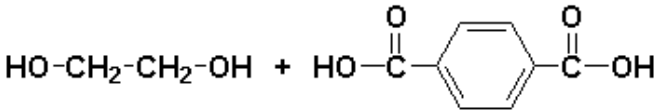
ENZYME CATALYSES THE PET HYDROLYSIS



PET | Depolymerase ENZYME | MONOMERS



poly(ethylene terephthalate)



ethylene glycol | terephthalic acid

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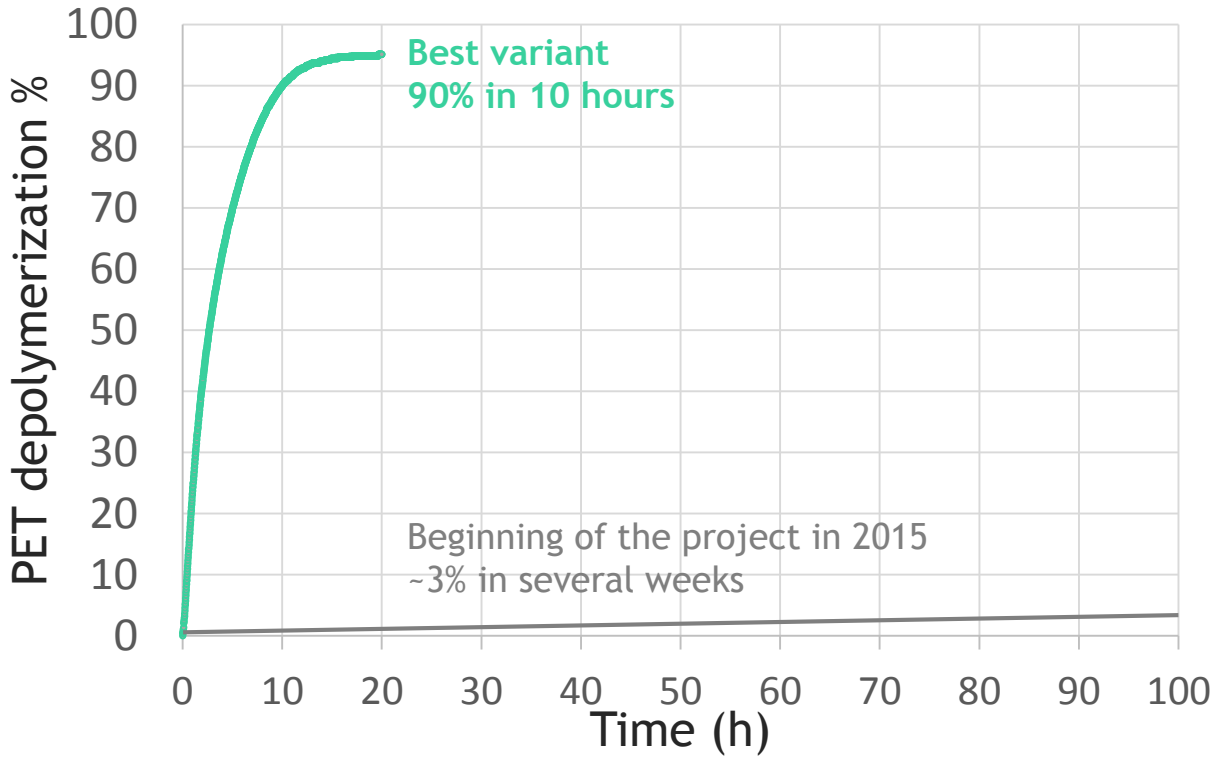
KEY FACTOR:
A PERFORMANT ENZYME



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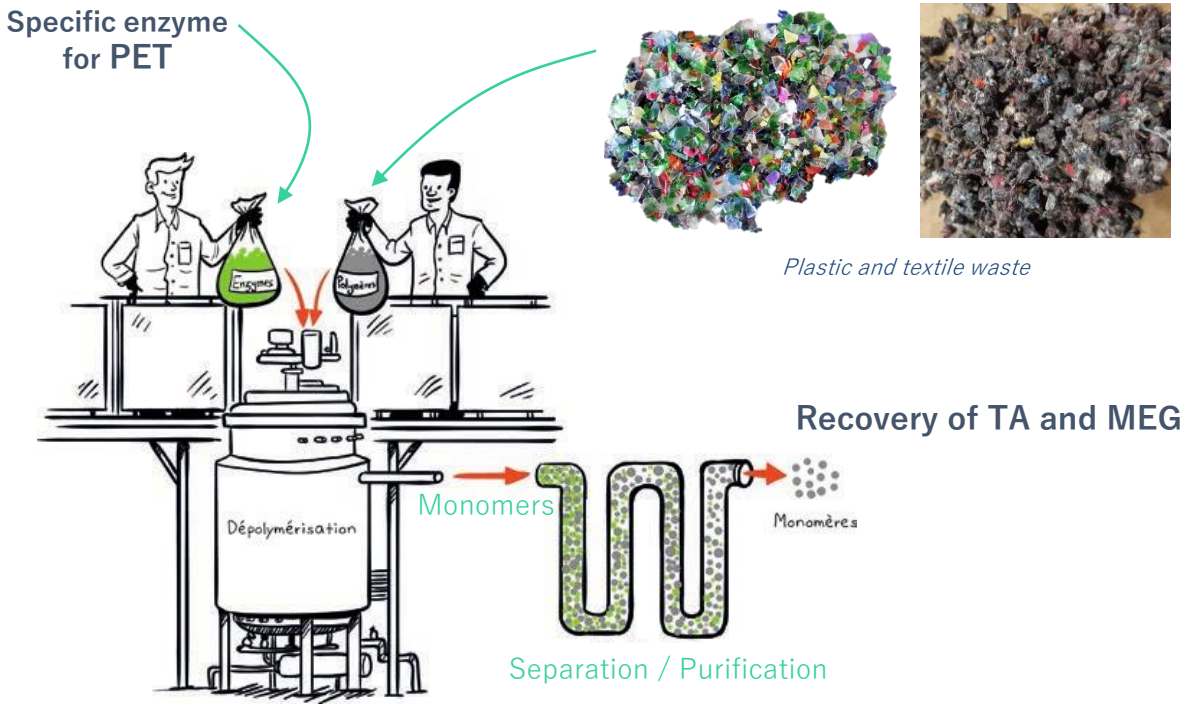
PRINCIPLE OF PET ENZYMATIC RECYCLING



Plastic and textile waste

ADVANTAGES OF THE ENZYMATIC PROCESS:

100% Recycling

Enzyme selectivity { *- no need of sophisticated sorting*
- recycling of complex waste (PET/PE; PET/PA; PET/cotton)

Low T° (60-70° C), atmospheric pressure, no organic solvent

=> A game-changing answer to the unmet needs of companies and consumers

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ENZYMATIC RECYCLING

New products

Collection

Plastic and textile waste

ULAR MY

Grinding

Flakes

Pretreatment

Enzymatic depolymerization

Separation and purification

Repolymerization

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HUGE TOLERANCE IN FEEDSTOCKS

All this waste can now be recycled

Trays

Clear & colored bottles

Opaque bottles
(TiO2 –carbon black)

Textiles

PET/PE
(8% of PE)

Bottles for carbonated drinks
PET/PA (7.5% of PA)

NO INHIBITION OF THE ENZYME BY

- → Colorants
- → Pigments
- → Carbon black
- → TiO_2
- → Comonomers IPA, CHDM
- → Other polymers : PE, PVC, PA

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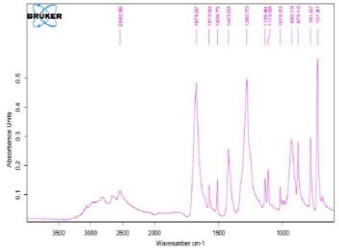
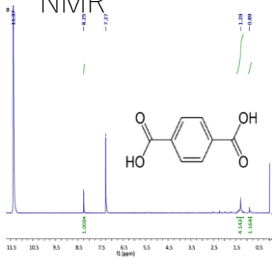
A HIGH-QUALITY RECYCLED PET

CTA

FTIR



NMR



Carbios CTA (purity > 99.5%)

PROOF of CONCEPT
of the REPOLYMERIZATION

FIRST BOTTLES

CLOSED LOOP: COLORED PLASTIC BOTTLE TO CLEAR PLASTIC BOTTLE

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PET RECYCLING: DEVELOPMENT PHASES

FIRST BOTTLES MADE WITH PET COMING FROM CARBIOS' PROCESS

2025

2023/2024
INDUSTRIAL PLANT

H2-2022
FIRST PET LICENSE DEAL CUT

H1-2021
START OF DEMO PLANT

2019
PET Contortium

L'ORÉAL

Nestlé Waters
The Healthy Hydration Company™

PEPSICO

SUNTORY
BEVERAGE & FOOD EUROPE

Pilot
2018-2021

✓Pre-pilot
2016-2017

✓Lab. scale
2014-2015

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PET BRAND OWNERS CONSORTIUM

April 2019 : a plastic consortium

CARBIOS Reinvent Polymers Lifecycle

L'ORÉAL

Nestlé Waters

PEPSICO

SUNTORY BEVERAGE & FOOD EUROPE

- ✓ A four-year agreement
- ✓ Accelerate the technology's readiness and bring it to full industrial scale
- ✓ Increase the availability of high-quality recycled plastics
- ✓ Demonstrate the technical, economic and environmental efficiency of Carbios' technology
- ✓ Support the structuring of an industrial value chain for an efficient supply of consumer-grade PET

SUSTAINABLE DEVELOPMENT GOALS

Tomorrow : a textile consortium?

CARBIOS Reinvent Polymers Lifecycle

GLOBAL KEY PLAYERS TEAM UP TO BOOST RECYCLABILITY OF PET PRODUCTS

BIODEGRADABLE PLA

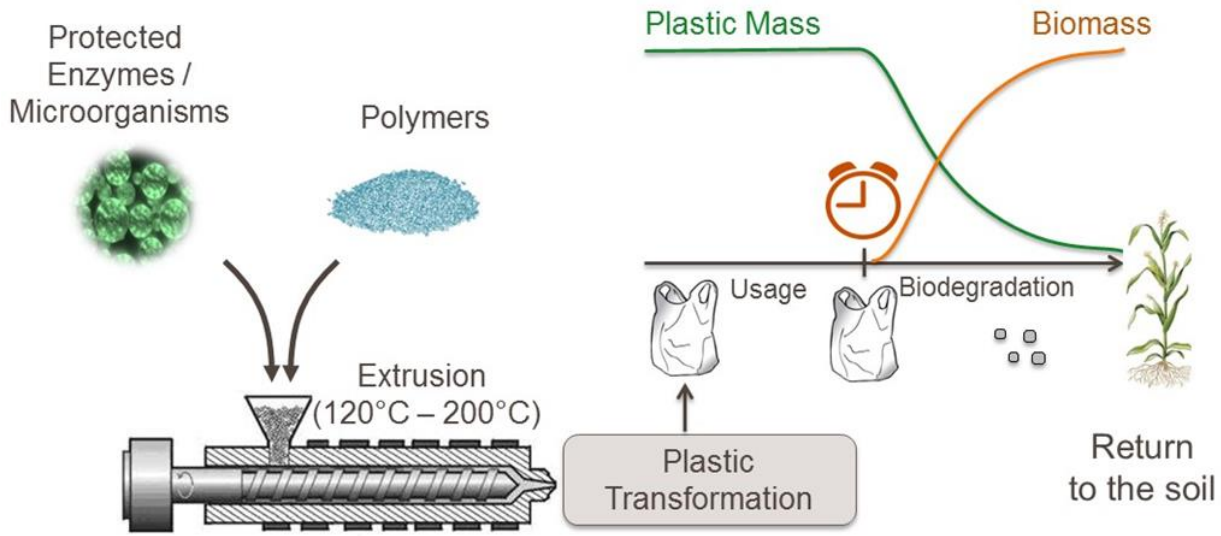
CARBIOLICE

Biodegradability is the future

CARBIOLICE PRODUCTION UNIT

PRINCIPLE OF ENZYME INCORPORATION

OBTENTION OF A BIODEGRADABLE PLASTIC



CHALLENGES:

- Enzyme resistance to high temperature of extrusion
- Control of biodegradation kinetics

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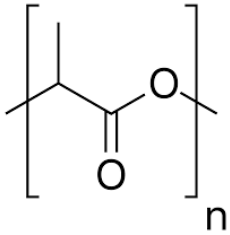
INDUSTRIALIZATION

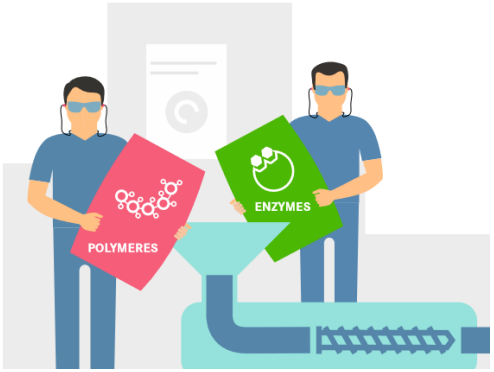


Polylactic acid (PLA)

Commercial launch in 2020

Enzyme

novozymes
Rethink Tomorrow



Enzymated masterbatch

Transformer / Brand owner

Applications

Consumer

Home compost

CARBIOLICE
Biodegradability is the future

Creation in 2016

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CARBIOS

Limagrain
Céréales Ingrédients

bpifrance

FURTHER POSSIBLE DEVELOPMENTS ON OTHER PLASTICS

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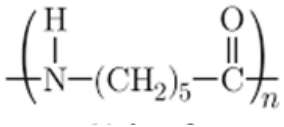
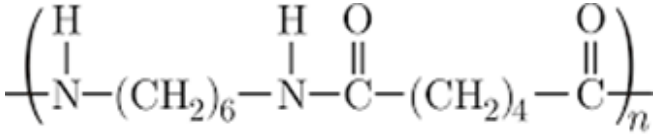
POLYESTERS AND THEN …



PA6



PA6.6

Polyamides

Enzymes described to hydrolyse them

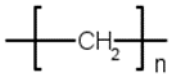
Need for enzyme improvement to develop a recycling process

Polyolefins and other C-C backbone polymers

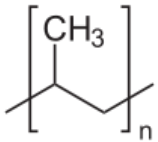
Microorganisms described to degrade them in a very limited extent

Oxidation enzymes implied => diversity of degradation products

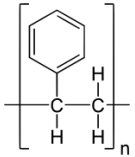
Need for enzyme improvement and polymer ecoconception



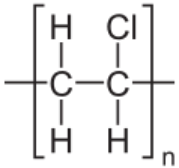
PE
PolyEthylene



PP
PolyPropylene



PS
PolyStyrene



PVC
PolyVinyl Chloride

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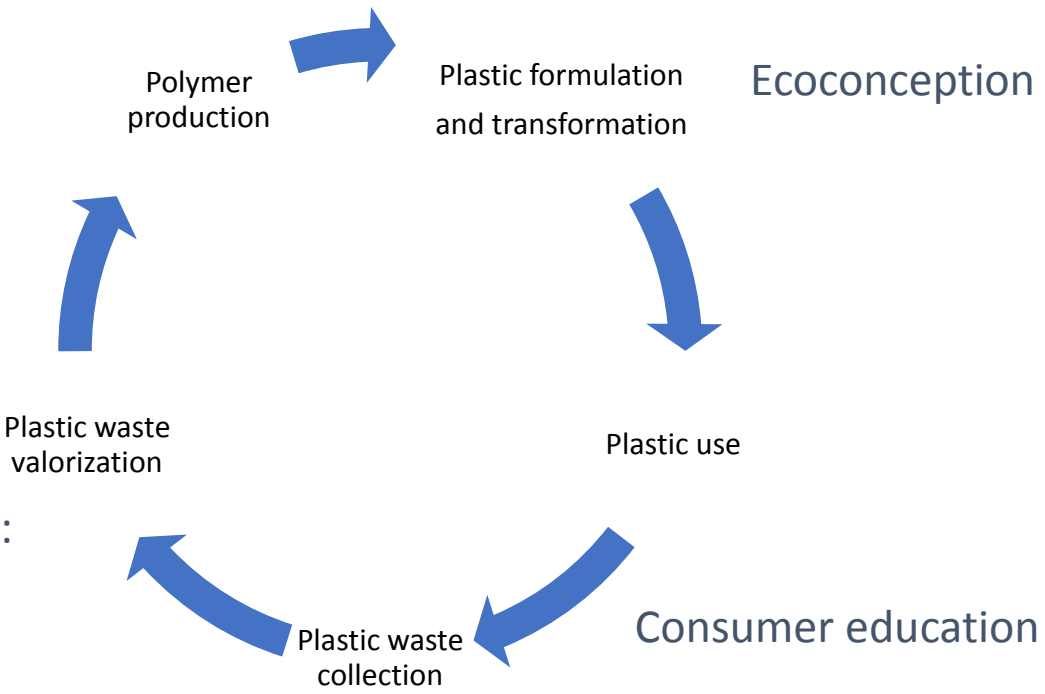
CONCLUSION



- **Biotechnologies have a great potential for plastic waste management**
- **Need for multidisciplinary approaches especially polymer chemistry / enzymology / material sciences**
- **Need for long term funding to achieve industrial solutions**

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Thank you !

“Designing the new plastic economy”

Dec. 2019

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Deputy CEO martin.stephan@carbios.fr
Innovation Manager frederique.guillamot@carbios.fr