Bioplastics and Biodegradable polymers

UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

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Comissão Europeia

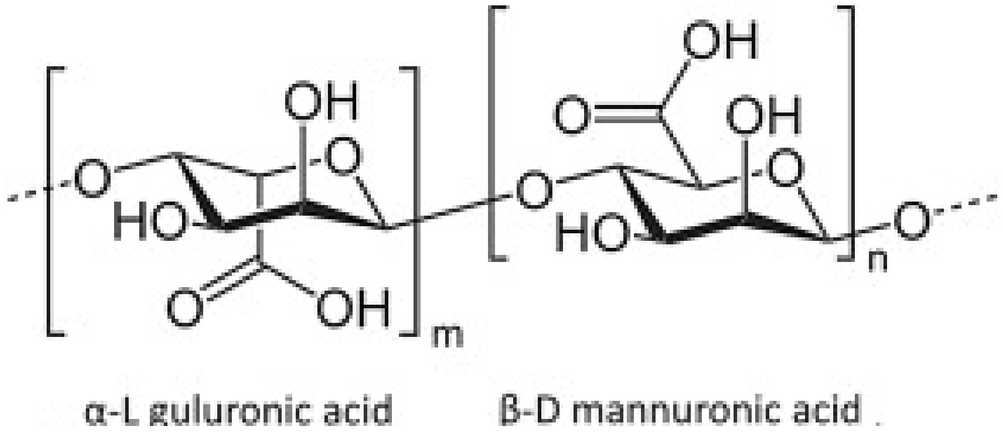
Bioplastics and Biodegradable polymers

Summary

- Bioplastics vs Biodegradable plastics
- Biodegradation in several environments
- Types of biodegradable polymers
- Sources
- Main properties
- Examples and applications

Biodegradable polymers

- Biodegradable polymers: high molecular weight molecules (macromolecules)
- Macromolecules made up of the covalent bond of low molecular weight molecules (monomers)



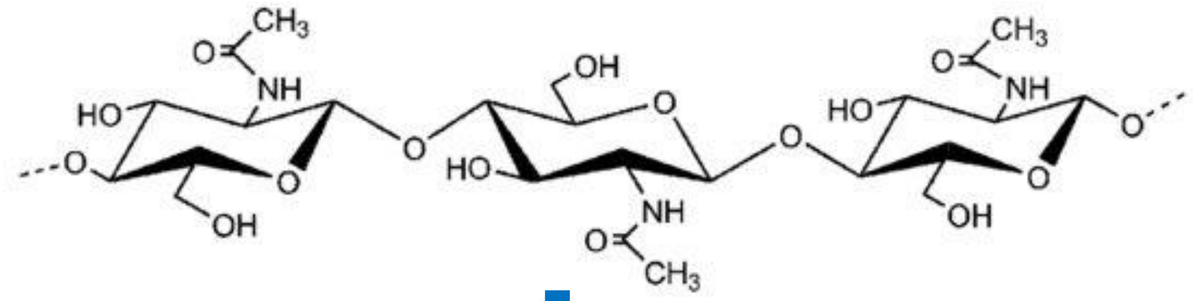
Alginate

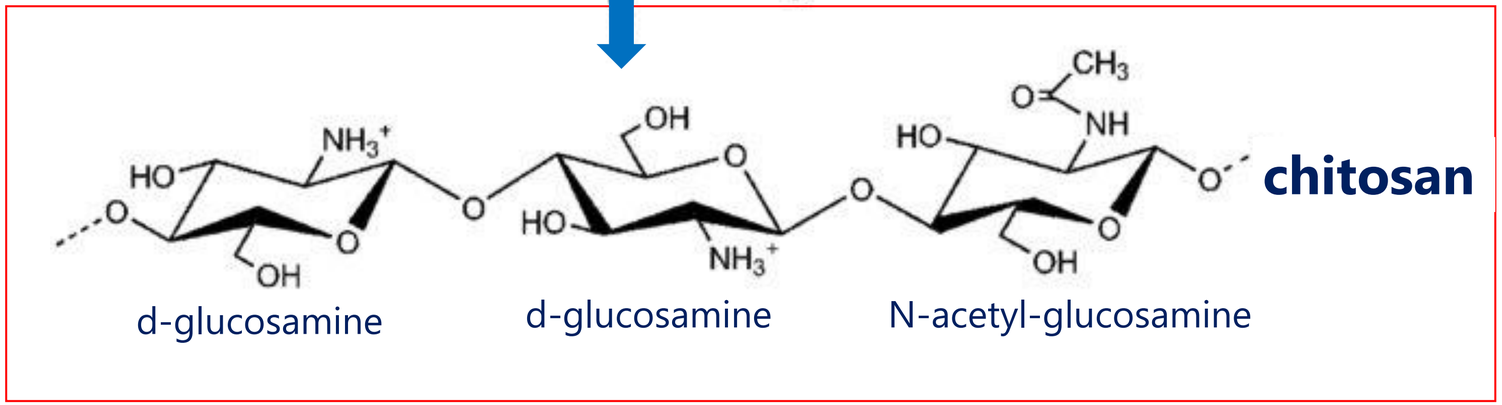
Feedstock (source)

Algae

Alginate powder

Biodegradable polymers





Feedstock (source)

Sea food shells

Chitosan powder

Biodegradation

- Biodegradation is the conversion of substrates (in this case polymers) by naturally occurring organisms (mainly microorganisms) into water, carbon dioxide, methane, biomass and minerals.
- A material or product is called **biodegradable under specific environmental conditions** if it is able to undergo, within a given time, a certain degradation process that is caused by biological activity and can be measured by a standardized test method
- The property of biodegradation does not depend on the source of a material. Instead, it is rather depended on its chemical structure.

ASTM D5210 – Standard Test Method for Determining the Anaerobic Biodegradation of Plastic Materials in the Presence of Municipal Sewage Sludge

ASTM D6400 – Standard Specification for Compostable Plastics (USA)

ASTM D5988 – Standard Test Method for Determining Aerobic Biodegradation in Soil of Plastic Materials

ISO 14852 – Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium

UNI EN 14995 - Standard Specification for Compostable Plastics (Europe)

Biodegradable polymers

Biodegradable polymers

They may or may not originate from renewable sources

Bio-based

Polymers in which 100% of its carbon comes from renewable sources

Oil-based

Produced with petrochemical based monomers

However:

The term "bio-based" does not equal "biodegradable"

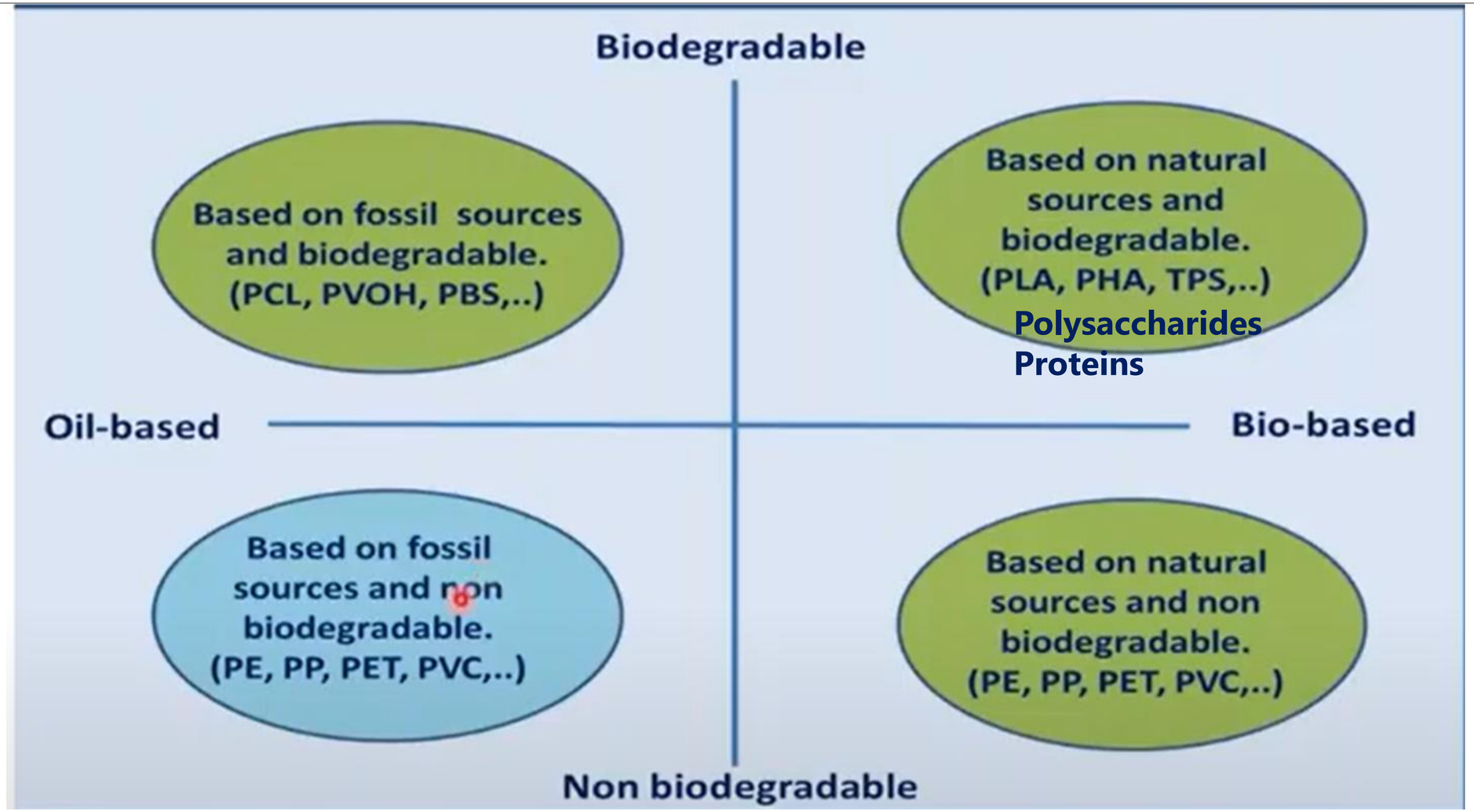
There are "bio-based" polymers that are not "biodegradable"

In addition:

Bioplastics is a term that includes: (i) polymers extracted directly from biomass, (ii) produced by microorganisms, (iii) synthetized with monomers produced by microorganisms or (iv) oil-based biodegradable polymers.

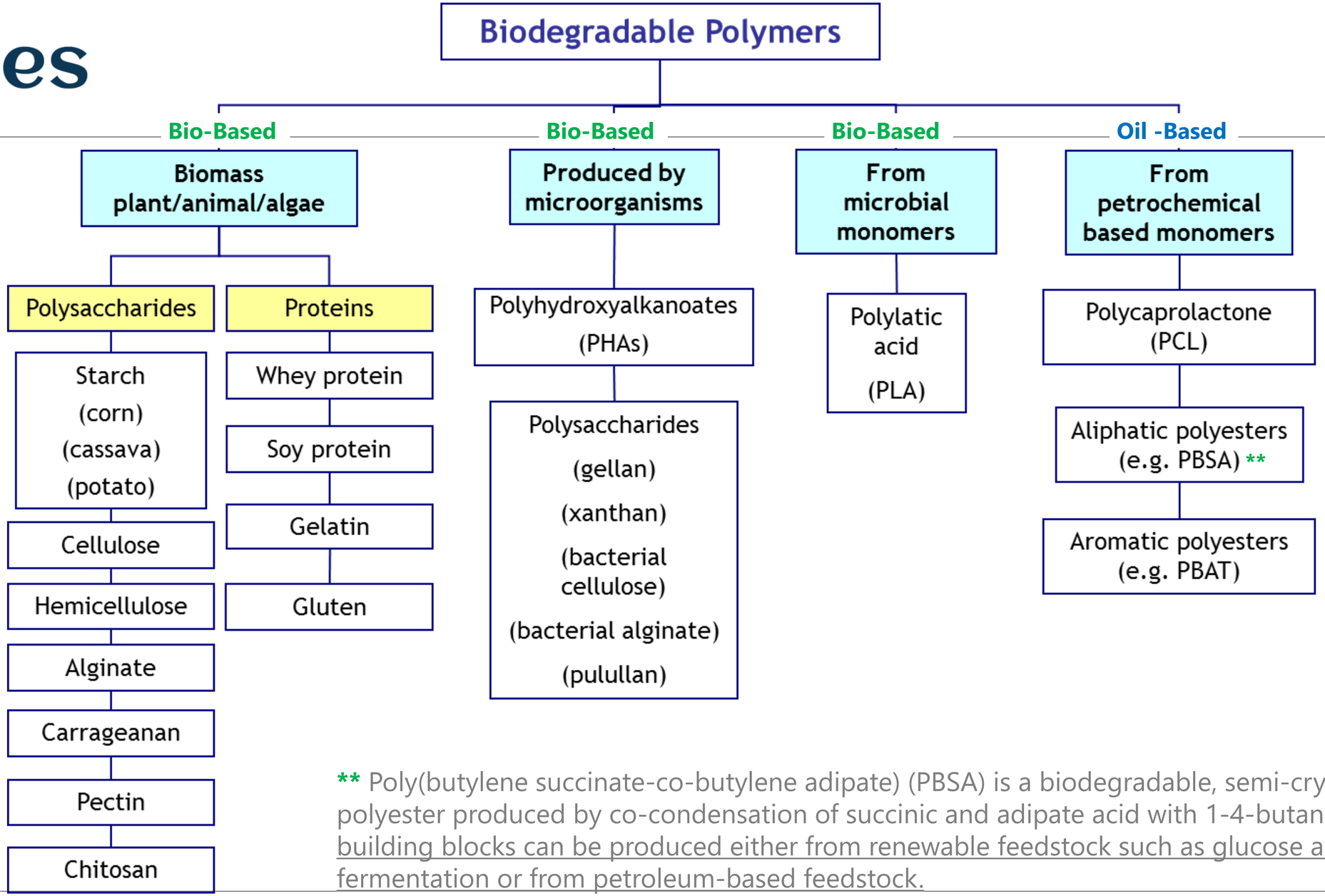
https://bioplasticseurope.eu/about

Biodegradable and non-biodegradable polymers



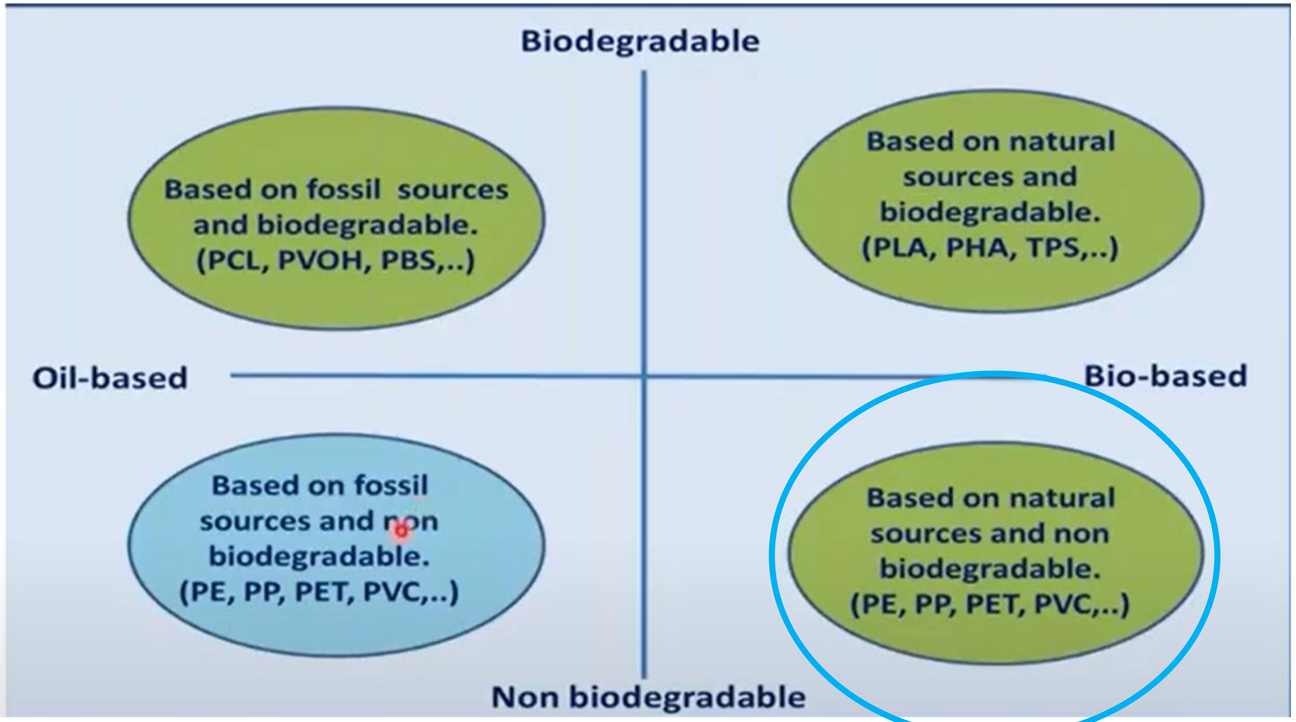
Bioplastics

Traditional petrochemical based non-biodegradable polymers

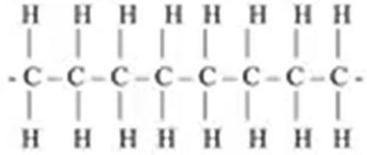


** Poly(butylene succinate-co-butylene adipate) (PBSA) is a biodegradable, semi-crystalline polyester produced by co-condensation of succinic and adipate acid with 1-4-butanediol. All three building blocks can be produced either from renewable feedstock such as glucose and sucrose via fermentation or from petroleum-based feedstock.

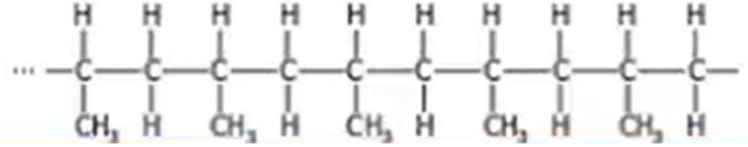
Biodegradable and non-biodegradable polymers



Bio-PE: Ethylene is obtained by the catalytic dehydratation of bio-ethanol, followed by normal polymerizations.



Bio-PP: the ethylene obtained from bio-ethanol is dimerized to produce n-butene. The n-butene is then reacted with the ethylene to produce bio-PP. A similar production route is possible using butanol from sugar fermentation.



Frequently used bio-based or biodegradable polymers

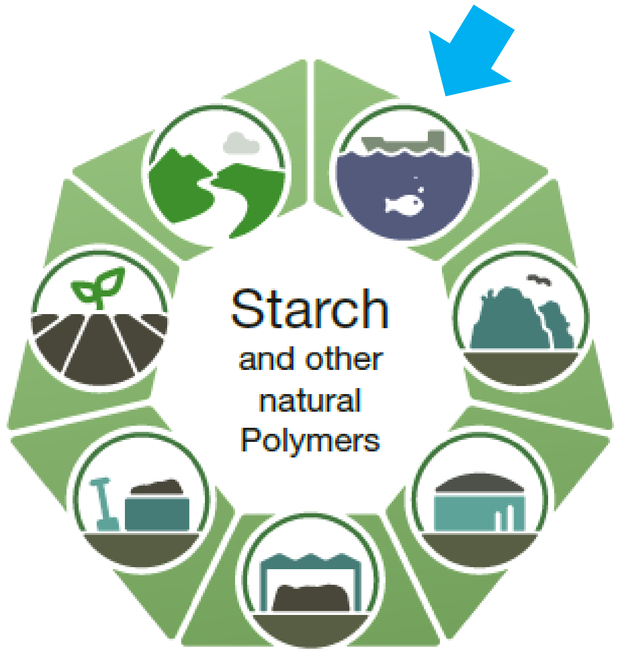
Abbreviation	Name	Bio-based	Biodegradable
PA	Polyamide	✓	
PBAT	Polybutylene adipate terephthalate		✓
PBS	Polybutylene succinate	✓	✓
PCL	Polycaprolactone		✓
PE	Polyethylene	✓/×	
PET	Polyethylene terephthalate	✓/×	
PHA	Polyhydroxyalkanoate	✓	✓
PHVB	Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)	✓	✓
PLA	Polylactic acid	✓	✓

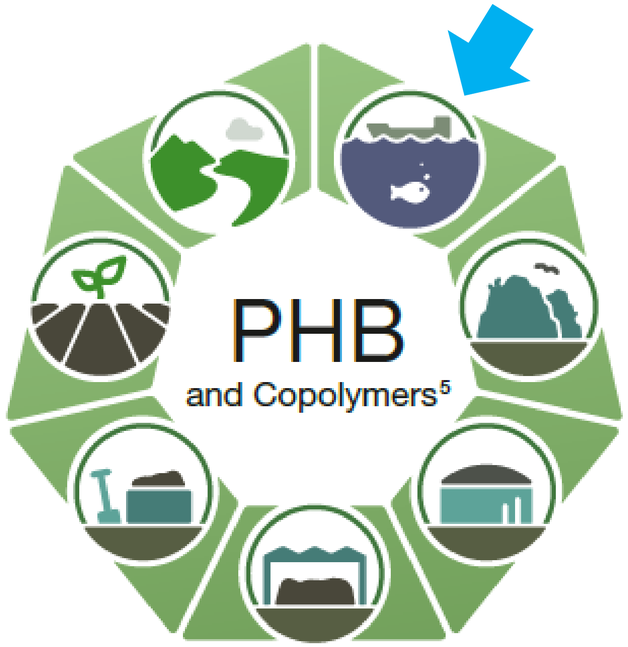
Biodegradation

proven biodegradability

proven biodegradability under certain conditions or for certain grades

biodegradability not proven





Polyhydroxyalkanoates

Polylatic acid

Biodegradable-Polymers-in-Various-Environments.pdf

MARINE ENVIRONMENT
Temperature 30°C,
90% biodegradation within
a maximum of 6 months
(Certification: TÜV AUSTRIA OK
biodegradable MARINE (ISO under
preparation))

FRESH WATER
Temperature 21°C,
90% biodegradation within
a maximum of 56 days
(Certification: TÜV AUSTRIA OK
biodegradable WATER)

SOIL
Temperature 25°C,
90% biodegradation within
a maximum of 2 years
(Certification: TÜV AUSTRIA OK
biodegradable SOIL; DIN Certco
DIN-Geprüft biodegradable in soil)

HOME COMPOSTING
Temperature 28°C,
90% biodegradation within
a maximum of 12 months (Certification:
TÜV AUSTRIA OK compost HOME; DIN
Certco DIN-Geprüft Home
Compostable)

LANDFILL
No standard specifications or
certification scheme available,
since this is not a preferred
end-of-life option

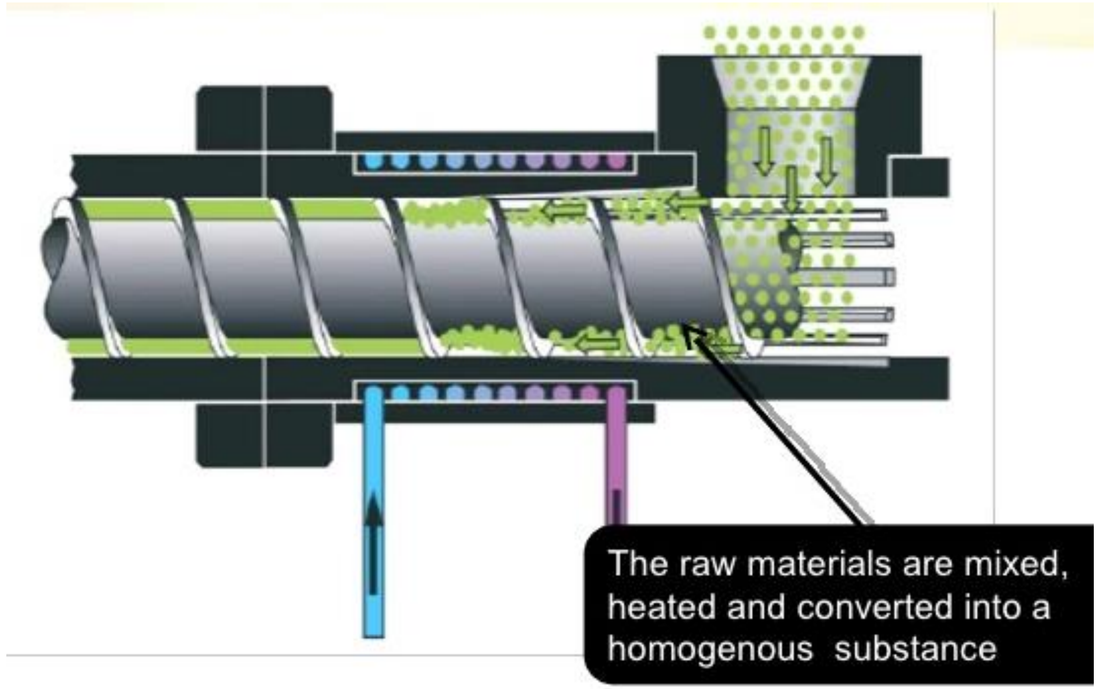
ANAEROBIC DIGESTION
Termophilic 52°C / mesophilic 37°C;
standard specification not yet
available, but 90% generally
considered as completely
biodegradable

INDUSTRIAL COMPOSTING
Temperature 58°C,
90% biodegradation within
a maximum of 6 months
(Standard: EN 13432)

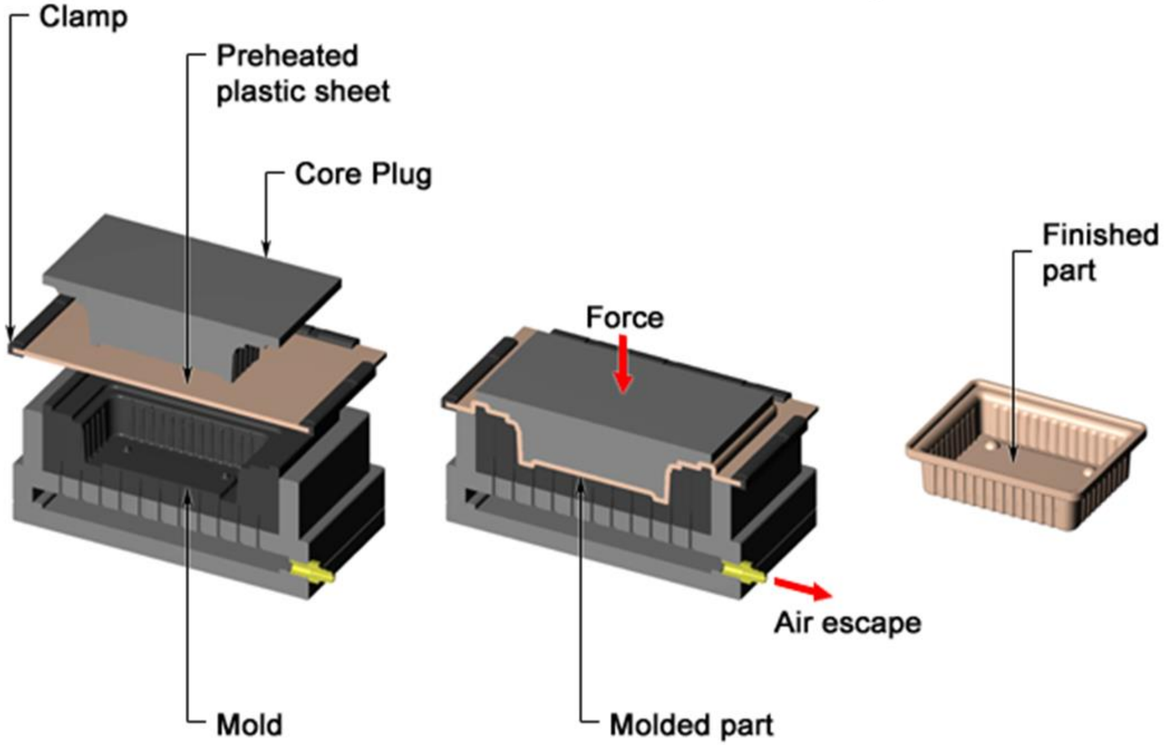
Biodegradable polymers

Some of biodegradable polymers are of Thermoplastic

Extrusion



Thermoforming



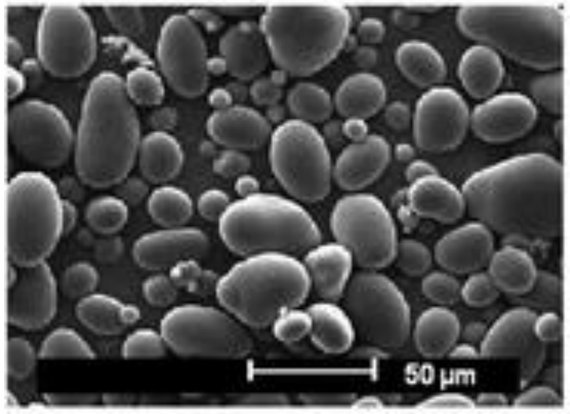
Biodegradable polymers

Starch

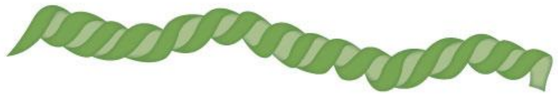
corn

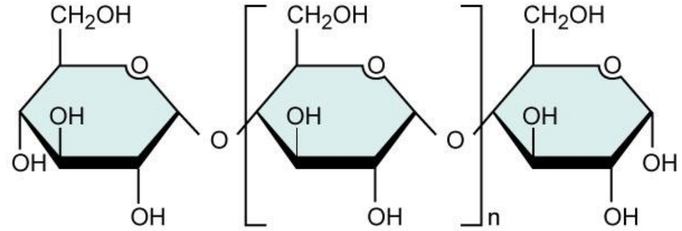
potato

cassava

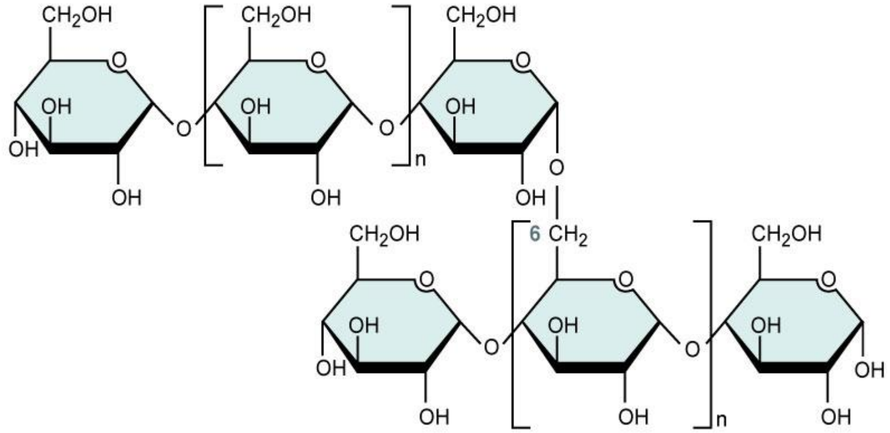


Amylose



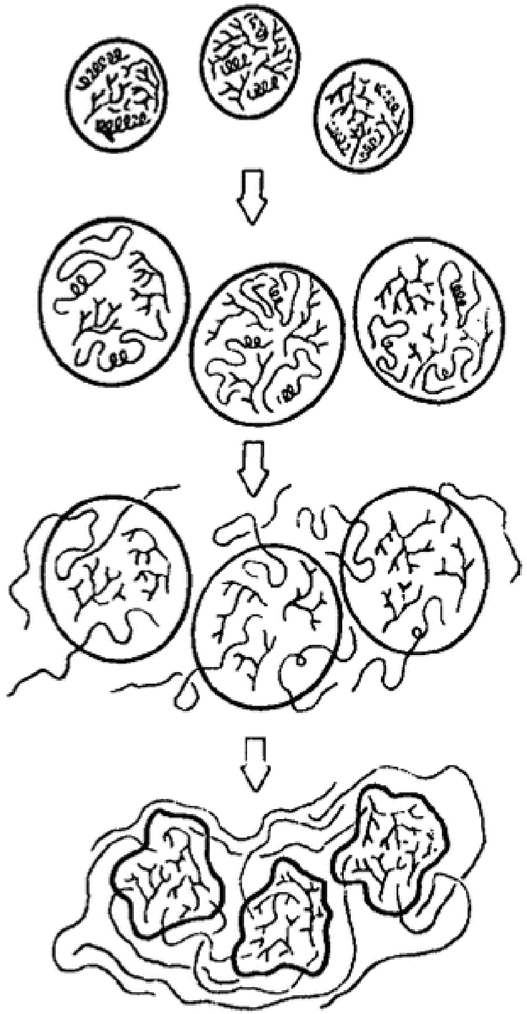


Amylopectin



Biodegradable polymers

Starch Gelatinization

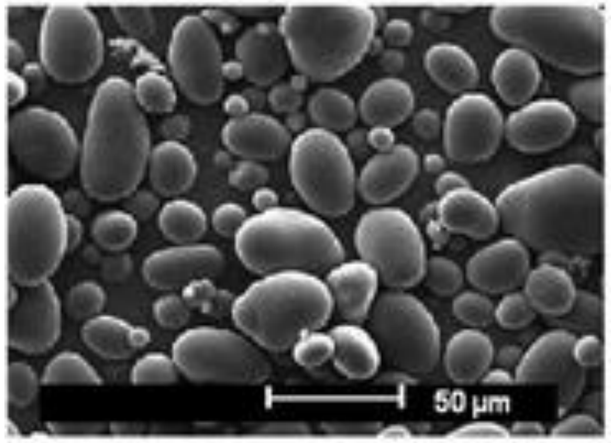


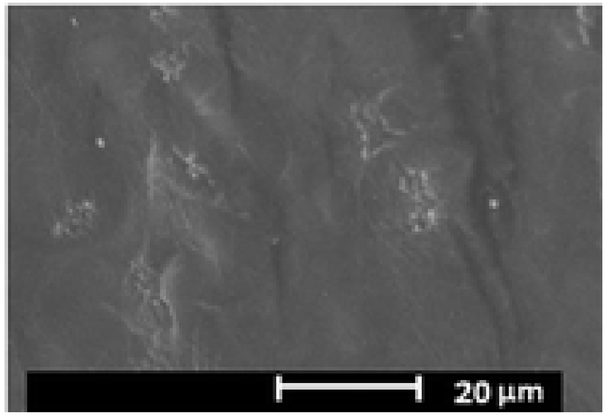
Raw starch granules made up of amylose (helix) and amylopectin (branched)

Addition of water breaks up amylose crystallinity and disrupts helices.
Granules swell

Addition of heat and more water cause more swelling.
Amylose begins to diffuse out of granules.

Granules, now containing mostly amylopectin, have collapsed and are held in a matrix of amylose forming a gel





Biodegradable polymers

Starch based items

Foams

Films

Trays

Non-biodegradable Polystyrene foams vs biodegradable starch foams
https://www.youtube.com/watch?v=wdWRx05P4I0

Biodegradable polymers

Polyhydroxyalkanoates (PHAs)

Produced by bacteria

Accumulated inside cells in granules

Energy reserves

Carbon sources: sugars, volatile organic acids, glycerol (preferably present in residues and by-products)

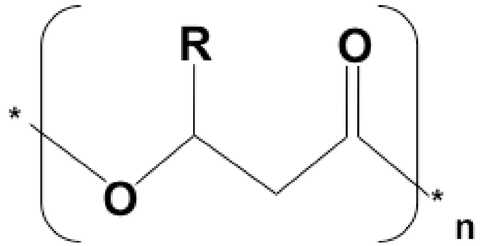
- **Thermoplastic**
- **Hydrophobic**

PHAs after extraction and purification

Biodegradable polymers

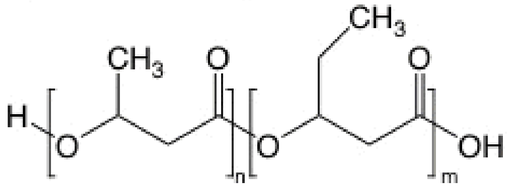
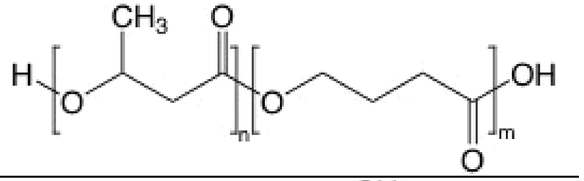
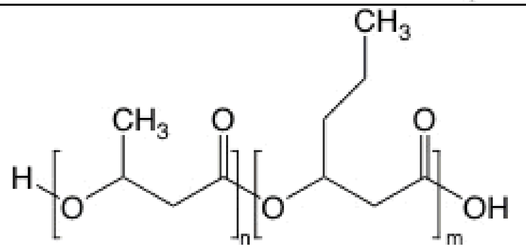
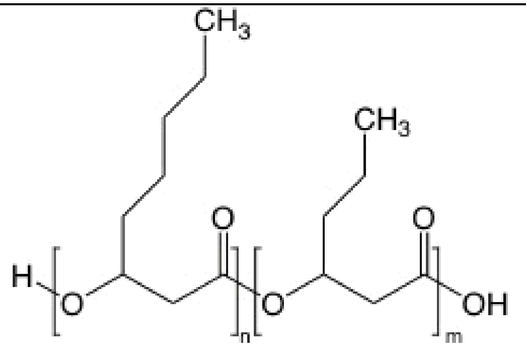
Polyhydroxyalkanoates (PHAs)

Homopolymers



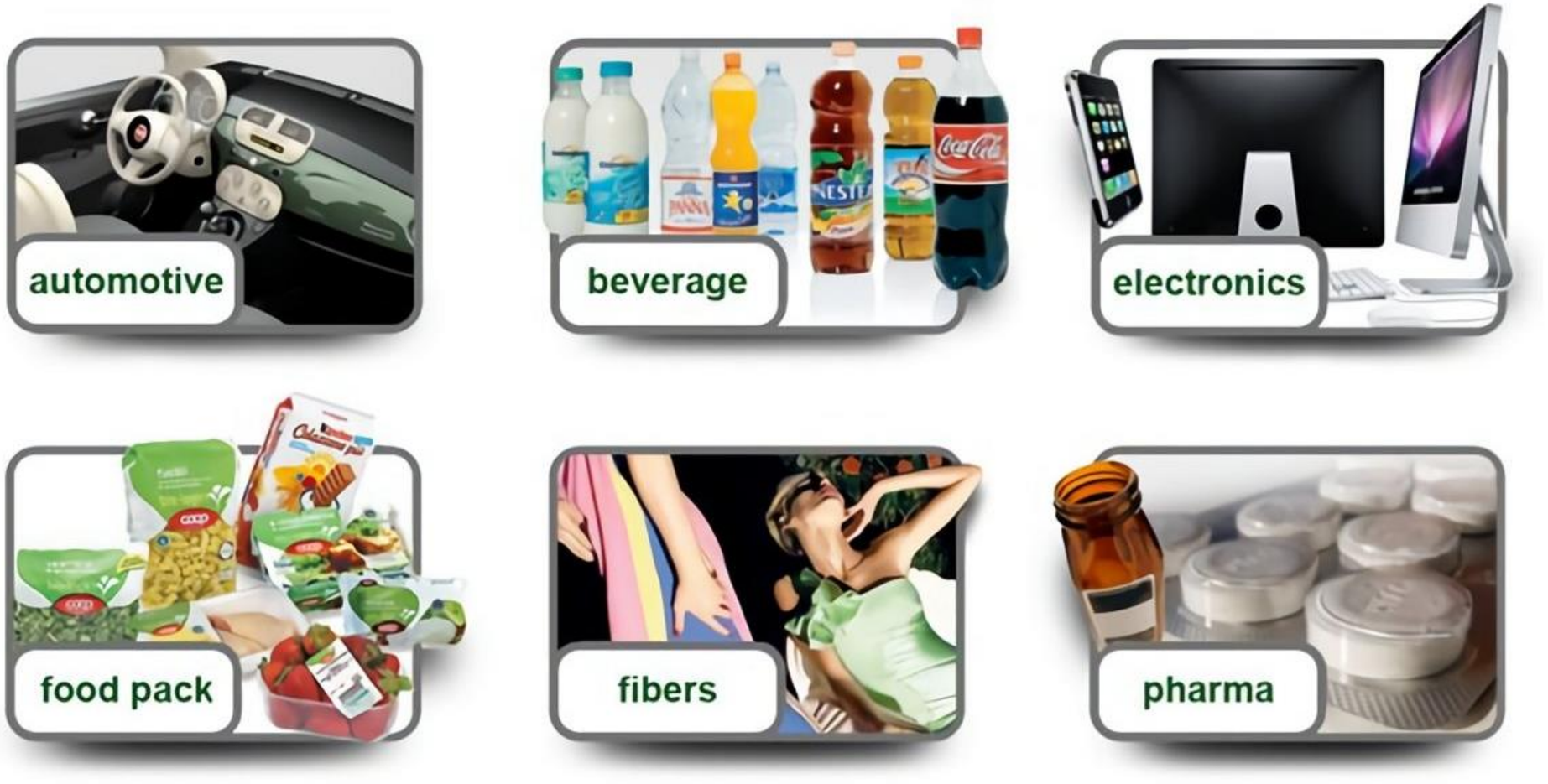
R group	Chemical Name
Hydrogen	Poly-3-hydroxypropionate
Methyl	Poly-3-hydroxybutyrate
Ethyl	Poly-3-hydroxyvalerate
Propyl	Poly-3-hydroxyhexanoate
Pentyl	Poly-3-hydroxyoctanoate

Copolymers

PHA synthesized	PHA chemical structure
PHBV [poly(3-hydroxybutyrate-co-3-hydroxyvalerate)]	
P3HB4HB [poly(3-hydroxybutyrate-co-4-hydroxybutyrate)]	
PHBHHx [poly(3-hydroxybutyrate-co-3-hydroxyhexanoate)]	
PHOHHx [poly(3-hydroxyoctanoate-co-3-hydroxyhexanoate)]	

Biodegradable polymers

Polyhydroxyalkanoates (PHAs) applications



Biodegradable polymers

Polylactic Acid (PLA)

- Thermoplastic
- Hydrophobic

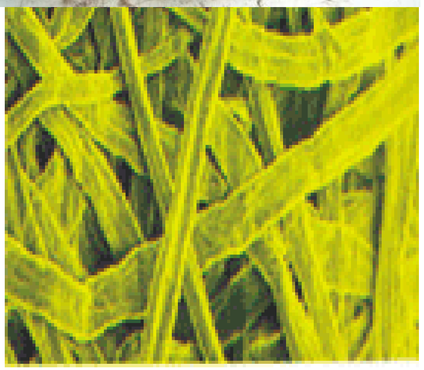
PLA produced by polymerization of lactide monomers

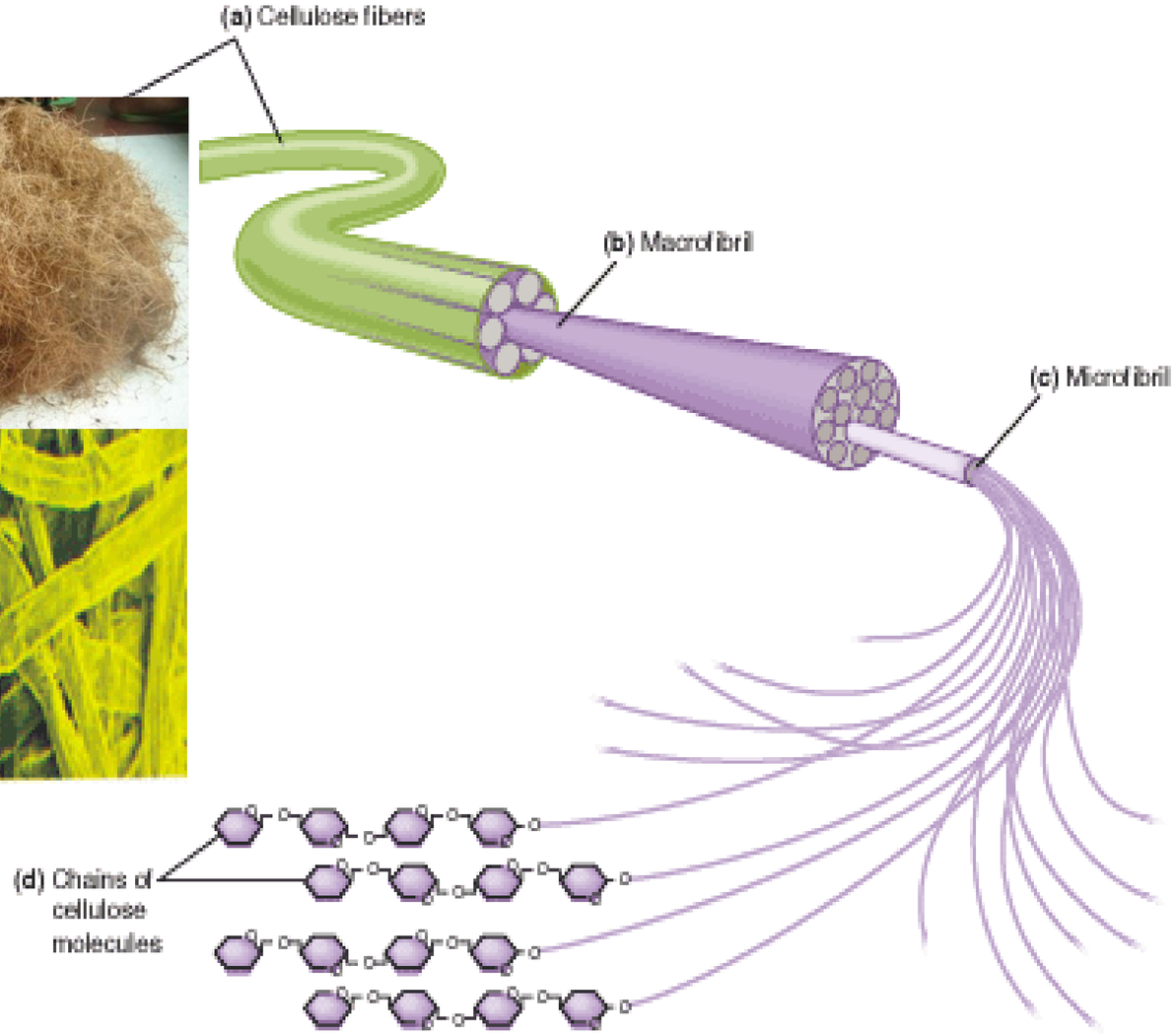
Biodegradable polymers

Cellulose

Fibers

Fibers





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Production technology of wheat straw tableware
https://youtu.be/XOl-ru6luYw

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Further reading

European Project BIO-PLASTICS EUROPE

https://bioplasticseurope.eu/project

European Bioplastics association

https://www.european-bioplastics.org/bioplastics/


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