

Poly-what?

A Translator's Guide to Polymer Science

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Topics for Today

Introduction and Goals

- What are polymers?
- What is polymer science?
- Where do polymers come from?
- What do I call them?
- What do I need to know about polymers?
- Where will polymers turn up in my work?
- Terminology resources

Introduction and Goals

A Translator's Guide to Polymer Science

After today, you should have a better idea of

what polymers are

what polymer science is

where do polymers come from

what do you call them

where you might come across polymers in your work

where can you find polymer terminology resources

What are polymers?

Mr. McGuire: I just want to say one word to you.
Just one word.

Benjamin Braddock: Yes, sir.

McG: **Plastics.**

B: Exactly how do you mean?

McG: There's a great future in **plastics**. Think about it. Will you think about it?

*Advice given to newly graduated Benjamin Braddock
(Dustin Hoffman, in The Graduate, 1967)*

What are polymers?

Polymers and plastics have gotten a bad rap

See: https://s3-eu-central-1.amazonaws.com/cartoons-s3/styles/product_detail_image/s3/cartoons/2019/09/the_plastic_age_gatis_sluka.jpg?itok=VnGvz-J

Cartoon by Gatis Šlūka

What is a polymer?

- a natural or synthetic chemical substance
- composed of repeating subunits (same or different)
- two subunits (a dimer) or three (trimer), “oligomers”
- up to 10s, 100s, 1,000s, 1,000,000s,... (n-mers)
- huge ones (macromolecules) have unique properties
- often not a single specific molecular mass/structure
- make up our foods (proteins, carbohydrates, fats)
- make up us

The word polymer

Coined in 1833 by Jöns Jacob Berzelius

(a type of isomerism; chemical structures were still undefined)

polymer (English, German, Norwegian, Swedish, Danish, Czech,...)

polimer (Albanian, Croatian, Hungarian, Polish, Uzbek, Malay, Bosnian,...)

полимер (*polimer*) (Russian, Bulgarian, Macedonian, Mongolian, Kazakh,...)

polymère (French)

polymeer (Dutch)

polymeeri (Finnish)

polímer (Catalan)

polimero (Italian, Esperanto)

polímero (Spanish, Galician)

polimeroa (Basque)

fjölliða (Icelandic)

պոլիմեր (*polimer*) (Armenian)

πολυμερές (*polymerés*) (Greek)

پوليمر (*pōlimar*) (Arabic, Pashto)

پليمر (*pōlimar*) (Farsi, Dari)

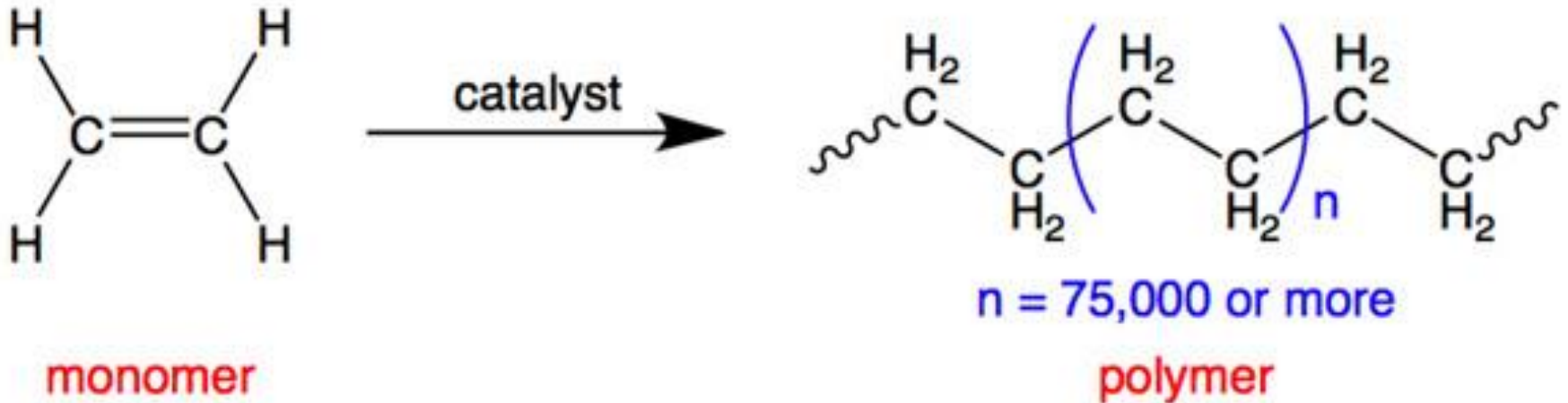
重合体 or **ポリマー** (*juugoutai / porimaa*) (Japanese)

聚合物 (*jùhétǐ*) (Chinese)

중합체 or **폴리머** (*junghabche / pollimeo*) (Korean)

What are polymers?

A natural or synthetic chemical substance composed of repeating subunits (same or different)



Polyethylene
from addition polymerization

What are polymers?

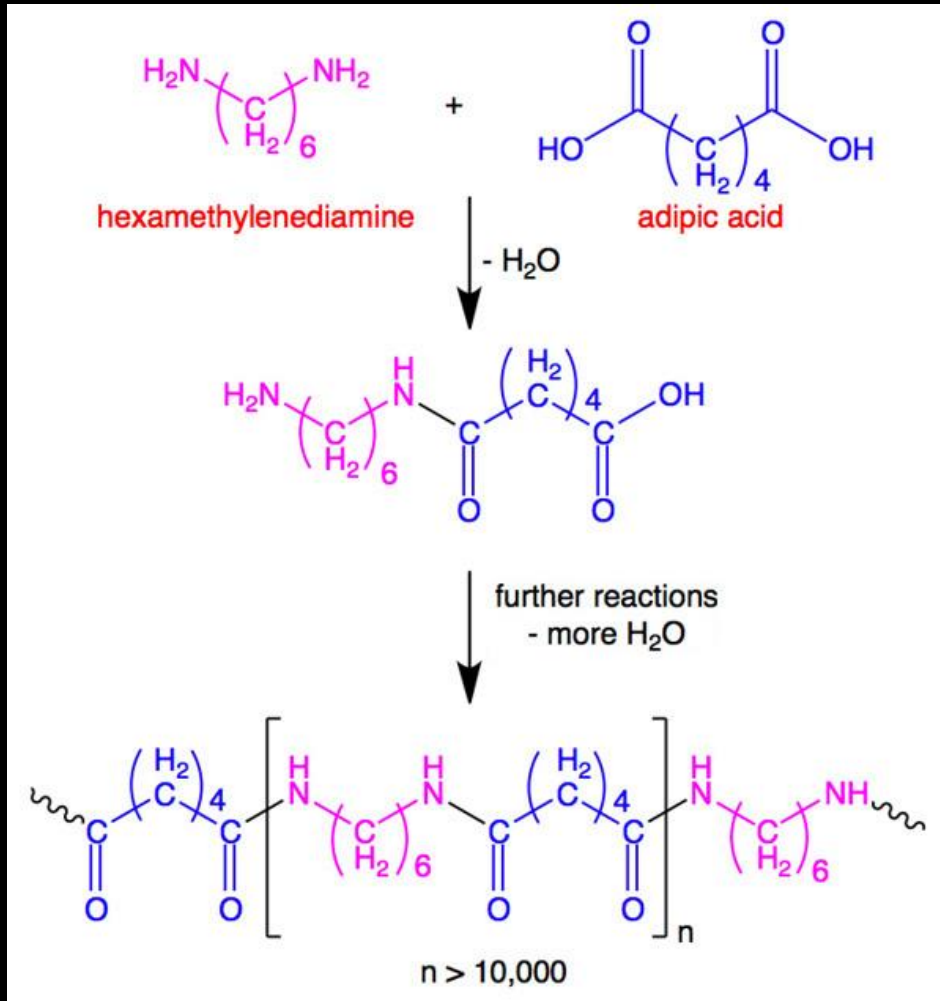
Nylon 66

from condensation polymerization

Two different monomers

are condensed to make a mixed monomer precursor

The precursor is further condensed to make the polymer



What are polymers?

Polystyrene

See: <http://vivienecoello.com/wp-content/uploads/2020/05/Capturesty.png>

Or, easier on the eyes:

See: <https://a3511.files.wordpress.com/2018/10/pschain.gif>

What are polymers?

Oxytocin, a natural nonamer (9 subunits)

See:

https://en.wikipedia.org/wiki/Oxytocin#/media/File:Oxytocin_with_labels.png

The “love molecule”

high levels of plasma oxytocin have been correlated with romantic attachment
popular specialty tattoo

What is polymer science?

Polymer chemistry

synthesis and properties of polymers, and reactions on polymers, forming blends

Polymer physics

physical properties (mechanical, thermal, electronic, magnetic, optical, acoustic, etc.) of polymer materials

Polymer characterization

analysis of chemical structure & morphology, determination of physical properties based on composition and structure

What is polymer science?

Related fields

Polymer engineering

designing and implementing applications (vehicles, protective clothing, electronics, weapons, etc.) of polymer materials

Polymer medicine

medical, clinical, and pharmaceutical applications (artificial tissues, prostheses, instruments, etc.) of polymer materials

Materials science

Resource recovery

Where do polymers come from?

Polymerization

polymérisation (FR)

Polymerisation (DE)

重合 (*juugou*) (JA)

polimerización (ES)

the process by which many smaller chemical units are combined by generating new covalent bonds to form a larger (usually linear) molecule

Addition: smaller units are joined together by directly forming new bonds

Condensation: smaller units are joined together by cleaving out portions of each unit and making new bonds

Where do polymers come from?

monomer

monomère (FR)

Monomer (DE)

モノマー (*monomaa*) (JA)

単量体 (*tanryoutai*)

monómero (ES)

a molecule which can undergo polymerization and contribute constitutional units to the resulting polymer

oligomer

oligomère (FR)

Oligomer (DE)

オリゴマー (*origomaa*) (JA)

oligómero (ES)

a molecule comprising ≥ 2 monomers and itself can undergo polymerization and contribute to the resulting polymer

What's in a name?

Polymer nomenclature

Standards have been established by the Chemical Abstracts Service (**CAS**) and the International Union of Pure and Applied Chemistry (**IUPAC**)

These standards are frequently ignored

IUPAC Compendium of Polymer Terminology and Nomenclature

<https://iupac.org/wp-content/uploads/2016/01/Compendium-of-Polymer-Terminology-and-Nomenclature-IUPAC-Recommendations-2008.pdf>

What's in a name?

To name a polymer:

ethylene => polyethylene

styrene => polystyrene

methyl methacrylate => poly(methyl methacrylate)

ethylene glycol => poly(ethylene glycol)

!!! Not polyethylene glycol !!!

!!! Not polymethyl methacrylate !!!

...but it's a losing battle

What is a copolymer?

copolymer

copolymère (FR)

(K)Copolymer (DE)

コポリマー (*koporimaa*)
共重合体 (*kyoujuugoutai*) (JA)

copolímero (ES)

**the substance produced when ≥ 2
types of monomer are joined
together to form a macromolecule**

copolymerization

copolymérisation (FR)

(K)Copolymerisation (DE)

共重合 (*kyoujuugou*) (JA)

copolimerización (ES)

**the process of joining ≥ 2 types of
monomer together to form a
macromolecule**

What's in a name?

To name a copolymer:

Copolymer structure	Connective	Nomenclature
Unspecified or unknown	- <i>co</i> -	poly(A- <i>co</i> -B)
Random (has a Bernoullian distribution)	- <i>ran</i> -	poly(A- <i>ran</i> -B)
Statistical (obeys known statistical laws)	- <i>stat</i> -	poly(A- <i>stat</i> -B)
Alternating (for two monomer units)	- <i>alt</i> -	poly(A- <i>alt</i> -B)
Periodic (regular arrangement of constitutional units)	- <i>per</i> -	poly(A- <i>per</i> -B- <i>per</i> -C)
Block (linear block arrangement)	- <i>block</i> -	polyA- <i>block</i> -polyB
Graft (side chains polyB linked to main chains polyA)	- <i>graft</i> -	polyA- <i>graft</i> -polyB

From:

A concise guide to polymer nomenclature for authors of papers and reports in polymer science and technology (IUPAC Technical Report) [De Gruyter]

[https://www.degruyter.com/document/doi/10.1515/pac-2018-0602/html#j_pac-2018-0602_tab_002_w2aab3b7c68b1b6b1ab1b1b3b4Aa]

What's in a name?

To name a copolymer:

Poly(methacrylonitrile-**co**-propene)

Poly[(butyl acrylate)-**ran**-(ethyl acrylate)]

Poly(ethene-**stat**-propene-**stat**-styrene)

Poly[(adipic acid)-**alt**-(butane-1,4-diol)]

Poly(oxirane-**per**-tetrahydrofuran)

Polyacrylonitrile-**block**-poly(buta-1,3-diene)-**block**-polystyrene

Polyisoprene-**graft**-poly(methacrylic acid)

From:

A concise guide to polymer nomenclature for authors of papers and reports in polymer science and technology (IUPAC Technical Report) [De Gruyter]

[https://www.degruyter.com/document/doi/10.1515/pac-2018-0602/html#j_pac-2018-0602_tab_002_w2aab3b7c68b1b6b1ab1b1b3b4Aa]

What do copolymers look like?

See: <https://garantiplastik.ir/wp-content/uploads/2020/05/copolymers-types-01.jpg>

From: Huang, J.; Turner, S. R. Polymer **2017** 116 572-586

Graft copolymer

copolymère greffe (FR)

Pfropfcopolymer (DE)

グラフト共重合体 (*gurafuto kyoujuugoutai*) (JA)

copolímero de injerto (ES)

See:

https://upload.wikimedia.org/wikipedia/commons/9/90/Graft_copolymer_3D.svg

Minihaa, CC0, via Wikimedia Commons

[https://upload.wikimedia.org/wikipedia/commons/9/90/Graft_copolymer_3D.svg]

What are polymer materials?

a polymer material can be a polymer, a copolymer, or combinations thereof

polymer blend

mélange de polymères (FR)

Polymermischung (DE)

ポリマーブレンド
(*porimaa burendo*)

(JA)

混合高分子
(*kongou koubunshi*)

mezcla de polímeros (ES)

polymer alloy

alliage de polymères (FR)

Polymerlegierung (DE)

ポリマーアロイ
(*porimaa aroi*)

(JA)

ポリマー合金
(*porimaa goukin*)

aleación de polímeros (ES)

What are polymer blends?

A mixture of two or more polymers

Can be immiscible, compatible, or miscible

- immiscible: components form 2 phases (~emulsion)
- compatible: inter-component attractive interactions
- miscible: components form a single phase

Each type of material exhibits properties different from those of either component alone, more flexibility in engineering material properties

What do I need to know about them?

We already saw what polymers and their mixtures are, where they come from, and how to name them

What else is there?

How they are characterized

How are polymers characterized?

polymers:

- resemble other molecules, only much bigger!
- don't have a single molecular mass
- don't necessarily have a uniform structure
- can have macromolecular “local effects”
- can have tertiary structure (channels, coils, sheets, folds, cross-links, etc.)

How are polymers characterized?

primary parameters measured:

- **molecular mass**
- **molecular structure**
- **morphology**
- **thermal properties**
- **mechanical properties**

Molecular mass

actually measure averages:

weight-average molecular mass (M_w)

sum of factors (weight fraction) × (mass of that weight fraction)

number-average molecular mass (M_n)

total weight of all molecules in the sample (w) divided by the number of molecules

These are determined from light scattering, colligative properties, and size exclusion chromatography (SEC) / gel permeation chromatography (GPC)

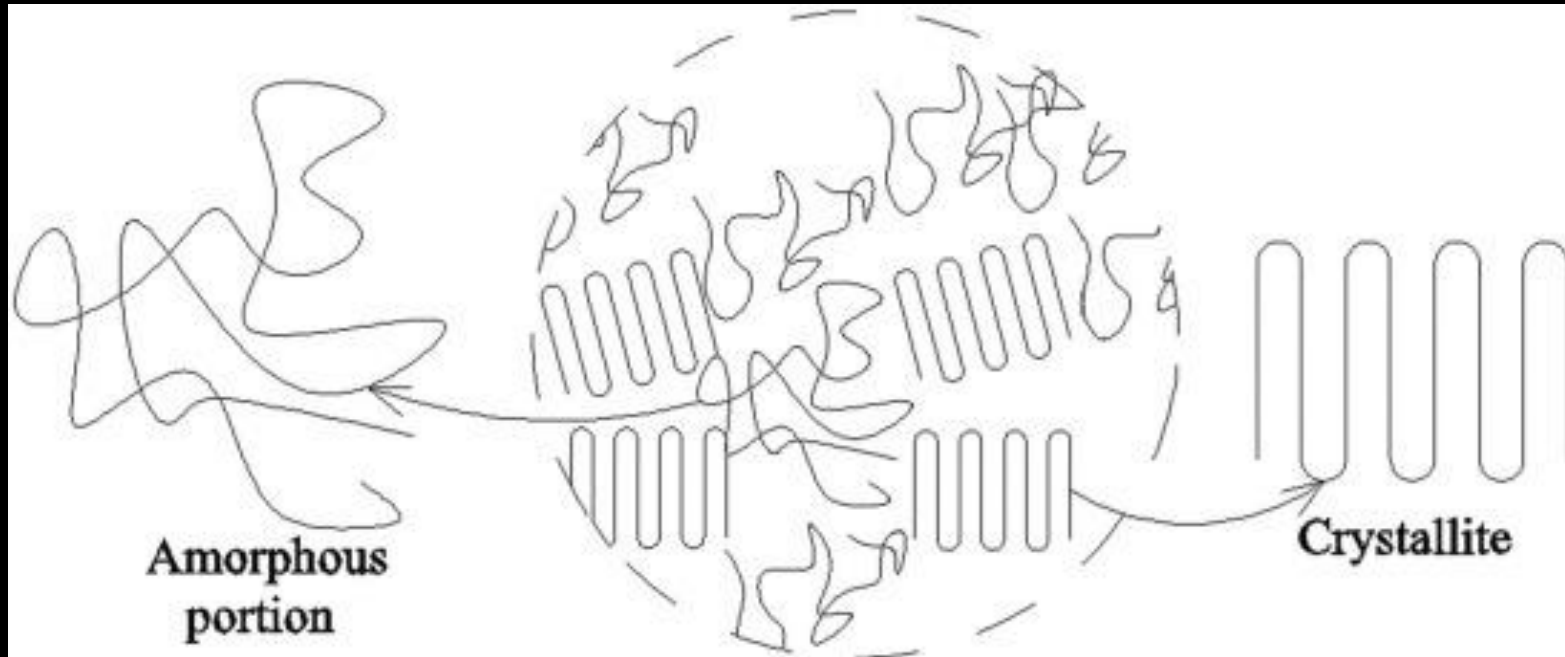
Molecular structure

similar to identifying structure and functional groups in small molecules:

techniques such as UV-visible spectroscopy, IR spectroscopy, Raman spectroscopy, NMR spectroscopy, ESR spectroscopy, X-ray diffraction, and mass spectrometry are used to identify common functional groups and structural features.

Morphology

analyzing a sample for local effects: amorphous and crystalline domains, other 3° structural features:



main technique is X-ray diffraction

Thermal properties

melting (freezing) point (T_m)

solid/crystalline \Leftrightarrow liquid/amorphous

glass transition point (T_g)

hard, brittle, glassy state \Leftrightarrow viscous/rubbery state

**melting point
freezing point**

température de fusion
température de congélation

(FR)

Schmelztemperatur
Gefriertemperatur

(DE)

融点 (*yuuten*)
凝固点 (*kyoukoten*)

(JA)

temperatura de fusión
temperatura de congelación

(ES)

glass transition point

température de transition vitreuse (FR)

Glasübergangstemperatur (DE)

ガラス転移点 (*gurasu ten'iten*) (JA)

temperatura de transición vítrea (ES)

Thermal properties

determination by

thermogravimetric analysis (TGA)

measures the mass of a sample over time as the temperature changes; provides information about phase transitions, absorption, adsorption, and desorption; and chemical phenomena such as chemisorptions, thermal decomposition, and solid-gas reactions (e.g., oxidation or reduction)

Thermal properties

See: <https://www.researchgate.net/profile/Vahideh-Shahedifar/publication/258157660/figure/fig6/AS:297667935653893@1447980974629/Thermogravimetric-analysis-TGA-and-derivative-thermogravimetric-DTG-curves-of-30ATH.png>

thermogravimetric analysis (TGA)

analyse thermo-gravimétrique (ATG) (FR)

thermogravimetrische Analyse (TGA) (DE)

熱重量分析 (*netsujuuryoubunseki*) (JA)

análisis termogravimétrico (ATG) (ES)

TGA/DTGA of a cotton/vinyl ester composite

from: Shahedifar, V.; Amir Masoud Rezadoust, A. M. J Reinf Plast Compos **2013** 32(10) 681-688

Thermal properties

determination by

differential scanning calorimetry (DSC)

measures the difference in the amount of heat required to increase the T of a sample and reference, with both maintained at nearly the same T throughout the experiment; detects melting/freezing and glass transitions

Thermal properties

See: <https://www.creative-proteomics.com/images/Differential-Scanning-Calorimetry.jpg>

differential scanning calorimetry (DSC)

calorimétrie différentielle à balayage (CDB) (FR)

dynamische Differenzkalorimetrie (DDK) (DE)

示差走査熱量測定 (*shisasousanetsuryousokutei*) (JA)

calorimetría diferencial de barrido (CDB) (ES)

From: <https://www.creative-proteomics.com/support/dsc-based-analysis-service.htm>

Mechanical properties

many specific tests, main ones are:

tensile strength:

the maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material, measured in units of force per unit area

Young's modulus of elasticity:

a measure of the ability of a material to withstand changes in length when under lengthwise tension or compression; equal to the ratio of the longitudinal stress (increase in length when stretched) to the strain (resistance to bending), measured in units of force per unit area

Mechanical properties

See “Tensile Strength” at: <https://www.boedeker.com/Technical-Resources/Technical-Library/ASTM-Property-Testing-Overview>

tensile strength

résistance à la traction	(FR)
Zugfestigkeit	(DE)
引張強度 (<i>hipparikyoudo</i>)	(JA)
resistencia a la tensión	(ES)

Mechanical properties

See: <https://spark.iop.org/sites/default/files/image/equipment-to-measure-stiffness-of-material.gif>

Young's modulus

module de young, module d'élasticité (FR)

Elastizitätsmodul (DE)

ヤング率 (*yangu ritsu*) (JA)

módulo de Young, módulo de elasticidad (ES)

Polymers are also characterized by their persistence/degradability

*durability has been considered an advantage
but too much durability is a disadvantage*

*polymer materials must perform well during
their intended service life*

*but safe recovery, reuse, recycling, or
disposal thereafter is important*

Polymers designed for biodegradability

See:

https://upload.wikimedia.org/wikipedia/commons/2/21/Biodegradable_Polymers_Flow_Chart_3.png?1639502454913

Polymers designed for biodegradability

See:

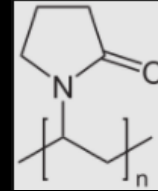
https://upload.wikimedia.org/wikipedia/commons/e/e5/Lactic_acid_polymerization.png

*two routes to prepare the polyester poly(lactic acid)
biodegrades in the environment*

From: https://en.wikipedia.org/wiki/Biodegradable_polymer

Where will polymers turn up in my work?

polyvinylpyrrolidone (PVP), also commonly called polyvidone or povidone, is a water-soluble polymer used as a binder in pharmaceutical tablets, and has been used as a temporary plasma volume expander in trauma victims



See: <https://injectionmouldingworld.com/wp-content/uploads/2020/12/Plastics-in-Automotive.png>

polymers
in
automobiles

body armor made with Kevlar® fiber with application in the military, emergency response teams, and law enforcement staff, reducing the chance of bodily injury or death caused by physical, ballistic, stab, and slash attacks.

See:
https://www.amazon.com/Tactical-Paintball-Adjustable-Protector-Breathable/dp/B0859CBWJ8/ref=pd_lpo_1?pd_rd_i=B0859CBWJ8&psc=1

Where will polymers turn up in my work?

fabric labels list the constituent fibers, all of which are made from either natural or synthetic polymers



See: https://4.bp.blogspot.com/-jFHrITwhpvQ/VsCGR0TVKII/AAAAAAAAAks0/URu8Xt6Of64/s1600/katesomerville_megacserumA.jpg

polymers in cosmetics:

PEG-20 methyl glucose sesquistearate
HDI/trimethylol hexyllactone crosspolymer
polymethylsilsesquioxane

polymers in medicines:

povidone
hypromellose (hydroxypropyl methycellulose)
poly(ethylene glycol)
microcrystalline cellulose

See: <https://generics21.com/wp-content/uploads/2016/06/glucoophage.png>

Where will polymers turn up in my work?

patents:

WO2018108932 - COMPOSITION COMPRENANT UN COPOLYMÈRE DE
PROPYLÈNE HÉTÉROPHASIQUE

DE000003524369 - OPTISCHE FASER MIT POLYMETHACRYLAT-KERN
UND FLUOR-KOPOLYMER-HÜLLE

JP2017514939 - ポリラクチド-ポリブタジエン・ベースのブロック共重合
体を含むポリマー組成物

ES2659640 - COPOLÍMERO HETEROFÁSICO DE PROPILENO CON
POCAS SUSTANCIAS EXTRAÍBLES

Where will polymers turn up in my work?

*texts on environmental problems
caused by synthetic polymers*

See: https://images.squarespace-cdn.com/content/v1/5ebacd937f182412584675f4/1590019535951-QK8NWUTUTRQ2GHWAoCMT/IMG_674c4.jpg?format=750w

Where will polymers turn up in my work?

medical, clinical, surgical uses:

See: <https://glasbergen.b-cdn.net/wp-content/gallery/heart/Toon-12267.gif>

Where will polymers turn up in my work?

medical, clinical, surgical uses:

- disposable surgical instruments and supplies, dialysis membranes
- sutures, tissue adhesives and sealants, and surgical meshes
- joint prostheses, osteosynthesis materials, bone cements
- intraocular lenses, dental composites, peripheral nerve guidance conduits

Introduction and Goals

A Translator's Guide to Polymer Science

Now you should have a better idea of:

what polymers are, and how to name them

what is polymer science: chemistry, physics, characterization

where polymers come from: natural and synthetic sources

where polymers will come up in your work

where can you find polymer terminology resources

Poly-what?

A Translator's Guide to Polymer Science

Hopefully, you are now enlightened!

When you find polymers in your translation texts, you will now have a better idea how to handle them

and know what you are handling

Terminology Resources

IUPAC Gold Book Compendium of Chemical Terminology

<https://goldbook.iupac.org/>

IUPAC Purple Book Compendium of Polymer Terminology and Nomenclature

<https://iupac.org/wp-content/uploads/2016/01/Compendium-of-Polymer-Terminology-and-Nomenclature-IUPAC-Recommendations-2008.pdf>

Polymer Glossary (University of Illinois Urbana-Champaign)

<http://matse1.matse.illinois.edu/polymers/glos.html>

Glossary of Polymer Terms used in the pharmaceutical industry

<https://lubrizolcdmo.com/technical-briefs/glossary-of-polymer-terms/>

Definitions of Polymer-related Terms (Purdue University)

<https://chemed.chem.purdue.edu/genchem/topicreview/bp/1polymer/terms.html>

Guidance for monomers and polymers (European Chemicals Agency)

https://echa.europa.eu/documents/10162/23036412/polymers_en.pdf

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Word

鍊金術 炼金术

Alchimie

Alchemy

АЛХИМИЯ

Alquimia

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