AWP 2-4 – Polymer Chemistry

Polymers in Life Science

University of Potsdam

Matthias Hartlieb

Summer term 2025

Overview

A) General Aspects & Definitions

B) Antimicrobial Materials

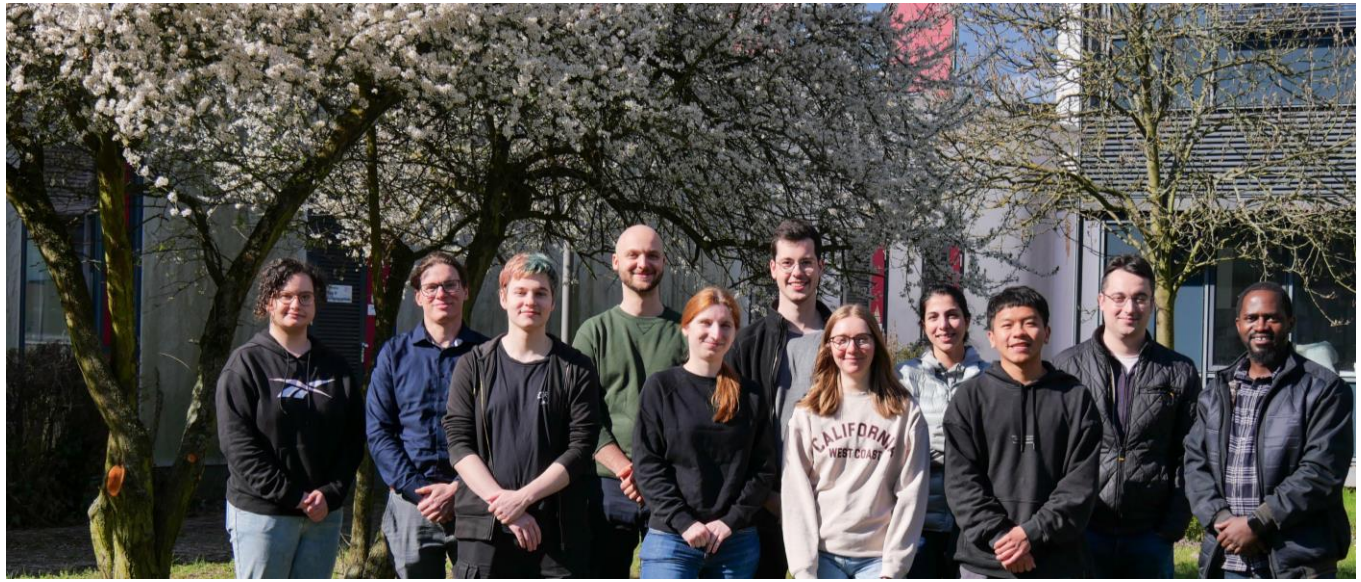
C) Nanomedicine

D) Gene Delivery

E) Regenerative Medicine

The lecturer

- Dr. Matthias Hartlieb
- Emmy Noether group leader at UP (since 2021)
- Polymeric Biomaterials group



Learning objectives

- Know about the requirements **polymers in biomedical applications**, be able to suggest tests for certain properties
- Know about key **definitions** and be able to suggest certain polymers for specialize applications based on **structure property relationships**
- Understand the danger behind **antimicrobial resistance** and be able to suggest potential solutions
- Understand the concepts of **antimicrobial polymers** and **antifouling** and be able to suggest polymers able to be used for these applications
- Be able to define the term **nanomedicine**, know core concepts of its use and be able to connect polymer properties with it
- Know about the major hurdles in the **delivery of genetic materials**, be able to suggest polymeric systems to overcome them and be able to explain how this is accomplished

AWP 2-4 – Polymer Chemistry

Polymers in Life Science – A) General Aspects

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Overview

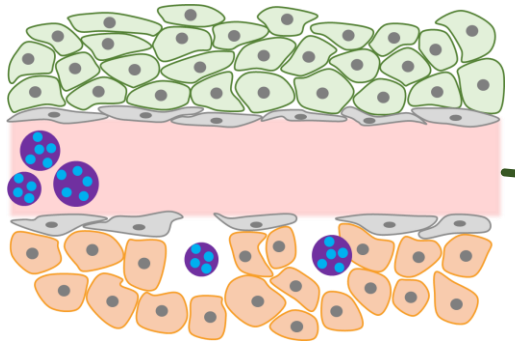
- Polymers in Life Science
- Definitions
- Approval of Biomaterials
- Biodegradation & Sterilization

Learning objectives

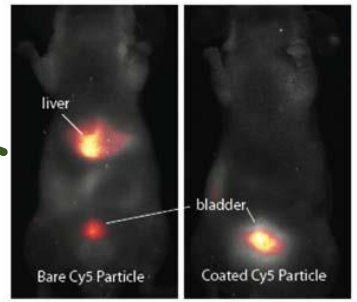
- Know and understand important definitions principal polymers in life science
- Be able to discuss the approval process of biomaterials for clinical use
- Know principal ways to determine biocompatibility and how to sterilize biomaterials

Where are polymers used in Life Science

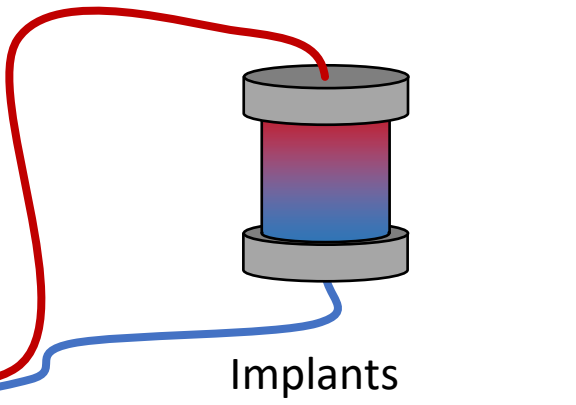
Drug delivery



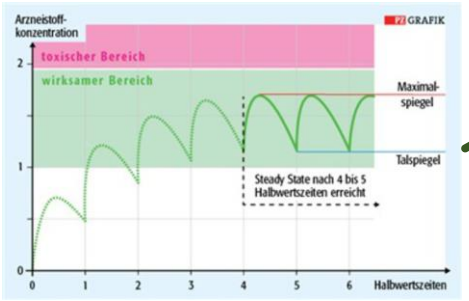
Diagnostics



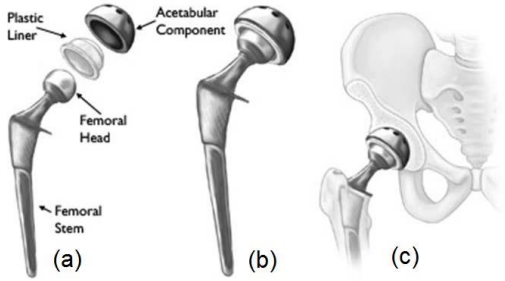
Extracorporeal devices



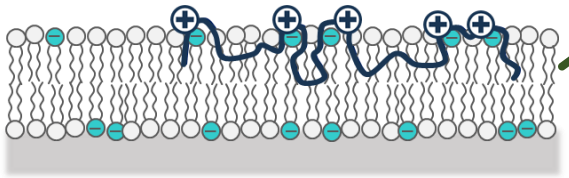
Drug release



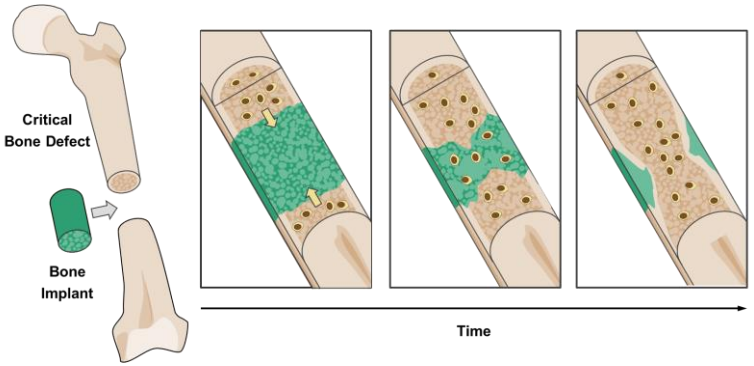
Implants



Polymeric drugs & conjugates



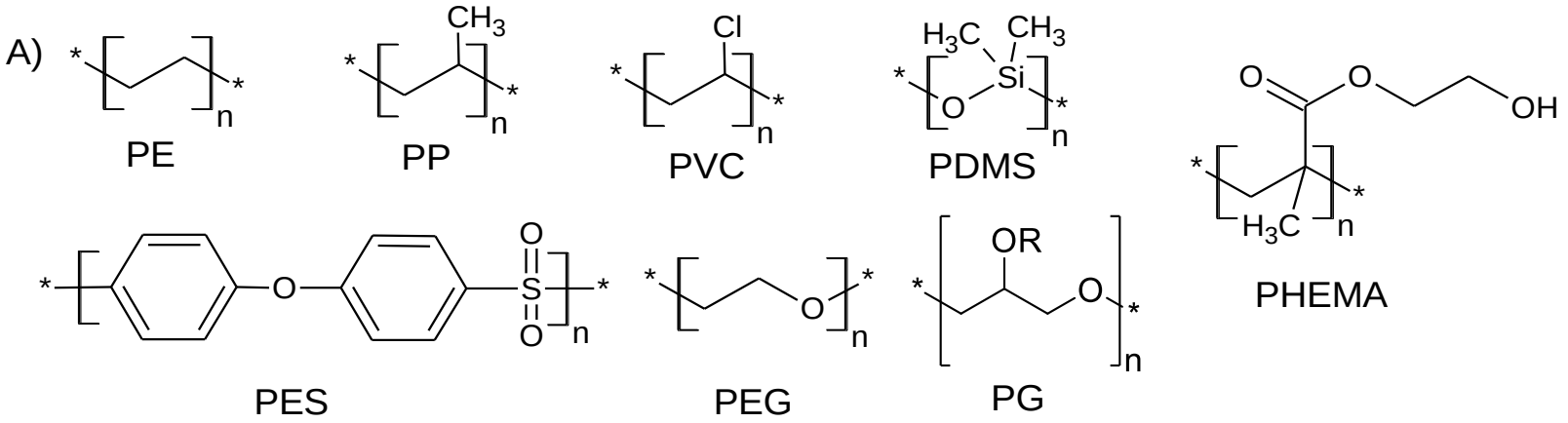
Tissue Engineering



Examples for Polymers in Biomaterials

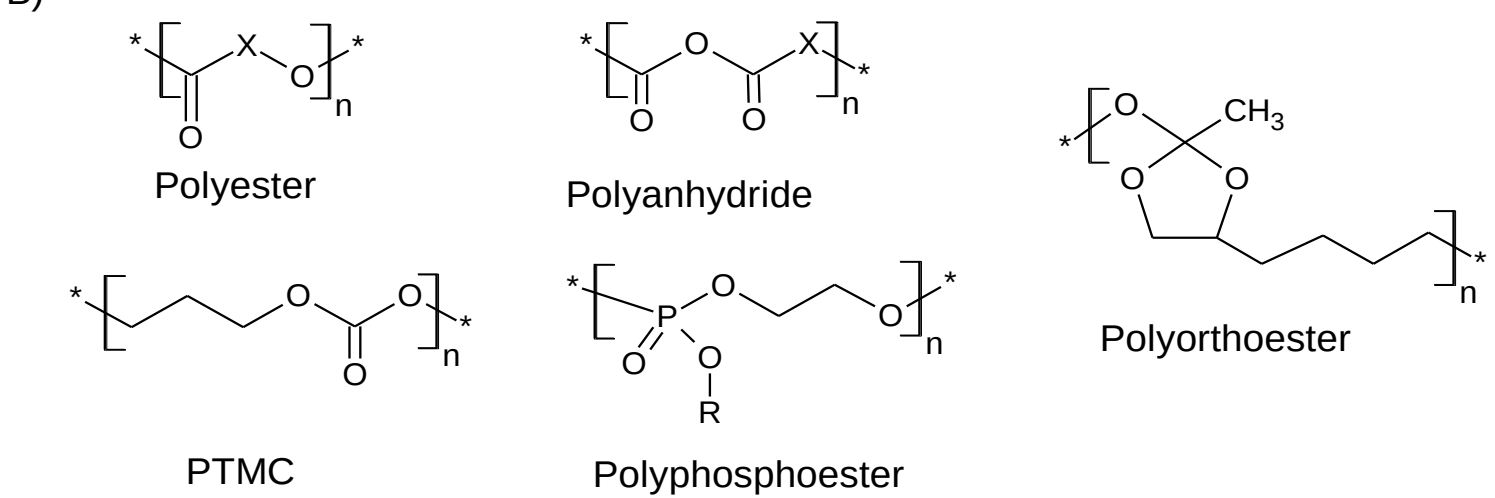
„biostable“

A)



degradable

B)



Some definitions

Biomaterial

- Material exploited in contact with living tissues, organisms, or microorganisms.
  - *Note 1: The notion of exploitation includes utility for applications and for fundamental research to understand reciprocal perturbations as well.*
  - *Note 2: The definition "non-viable material used in a medical device, intended to interact with biological systems" recommended in [6] cannot be extended to the environmental field where people mean "material of natural origin".*
  - *Note 3: This general term should not be confused with the terms biopolymer or biomacromolecule. The use of "polymeric biomaterial" is recommended when one deals with polymer or polymer device of therapeutic or biological interest.*

*Vert, M.; Doi, Y.; Hellwich, K. H.; Hess, M.; Hodge, P.; Kubisa, P.; Rinaudo, M.; Schué, F. O. (2012). "Terminology for biorelated polymers and applications (IUPAC Recommendations 2012)". Pure and Applied Chemistry. **84** (2): 377. doi:10.1351/PAC-REC-10-12-04*

Some definitions

Biocompatibility

- Ability to be in contact with a living system without producing an adverse effect.

Biodegradability

- Capability of being degraded by biological activity.
  - Note: *In vitro* activity of isolated enzymes cannot be considered as biological activity. (See biodegradation and enzymatic degradation.)

In vitro

- Studies on microorganisms or cells outside their normal biological context

In vivo

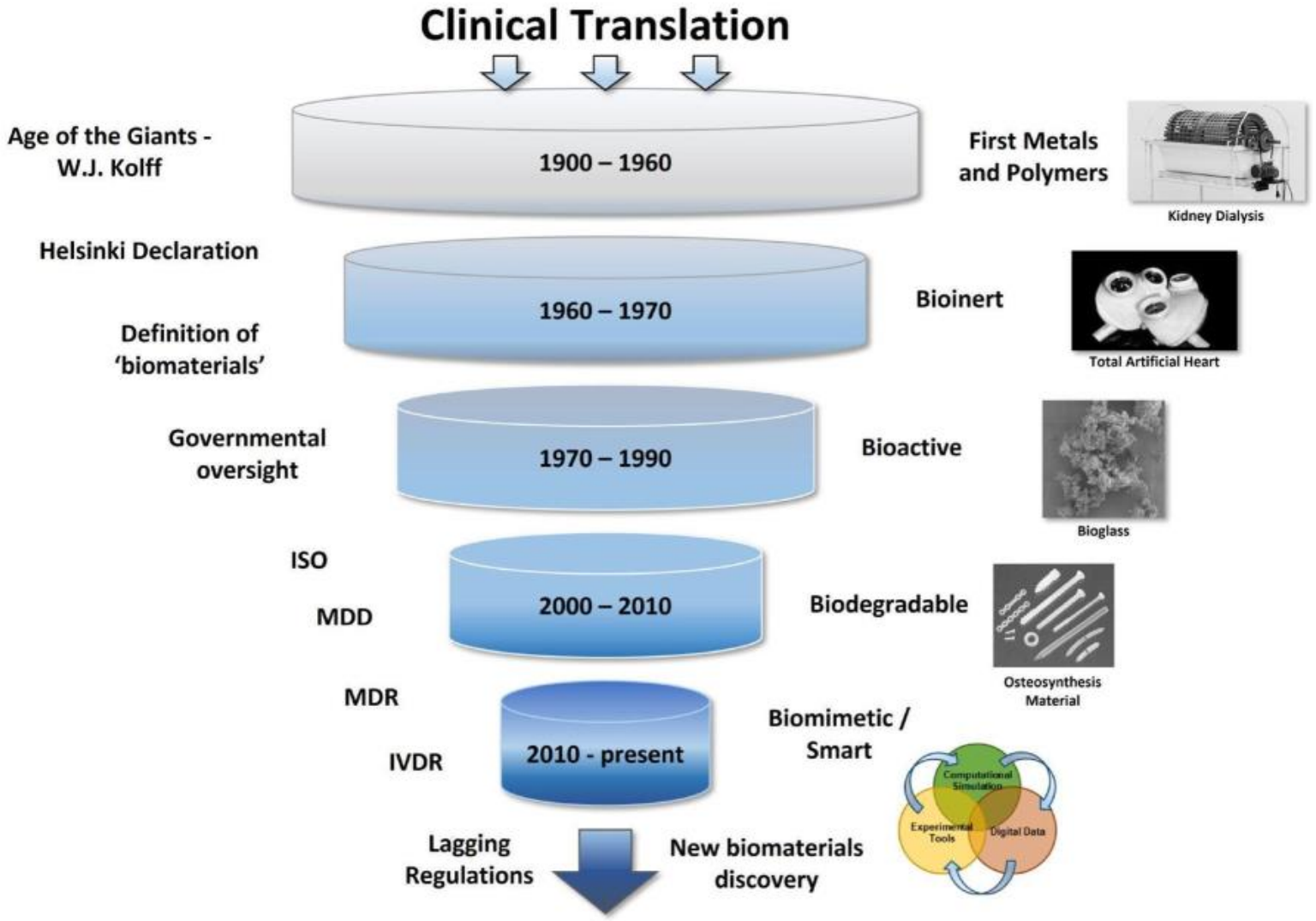
- Tested on a whole living organism (usually animal)

Ex vivo

- Tested on explanted parts of a living organism (e.g. tissue sample)

*Vert, M.; Doi, Y.; Hellwich, K. H.; Hess, M.; Hodge, P.; Kubisa, P.; Rinaudo, M.; Schué, F. O. (2012). "Terminology for biorelated polymers and applications (IUPAC Recommendations 2012)". Pure and Applied Chemistry. **84** (2): 377. doi:10.1351/PAC-REC-10-12-04*

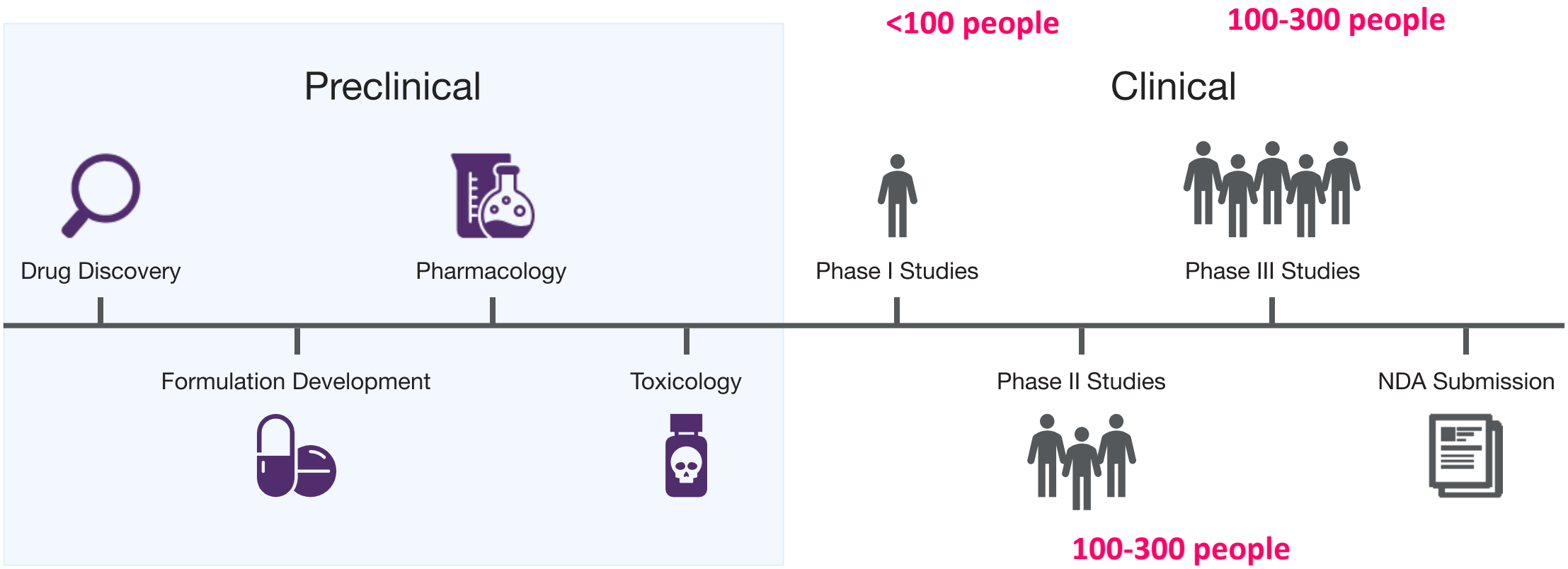
Approval of biomaterials



- Over time more consideration for ethics and the fate of test subjects (human but also animals)
- This led to decreasing numbers in translation into clinics
- Requirements for larger studies (better statistics) lead to high costs of approval (multi-million €)
- Every new material needs to start from the beginning..

Jurczak KM, van der Boon TAB, Devia-Rodriguez R, Schuurmann RCL, Sjollema J, van Huizen L, De Vries JPM, van Rijn P. Recent regulatory developments in EU Medical Device Regulation and their impact on biomaterials translation. Bioeng Transl Med. 2024, 10, e10721

Clinical trials (for drugs)



Phase 0 – pharmacokinetics with 10 people

Is it safe?

Is it working?

Is it better than available treatment?

How to determine Biocompatibility

- Cell tests (cytotoxicity, hemotoxicity, ..)
- (Organoids/Explants)
- *In vivo* in animals (Toxicity, Pharmacokinetics, Activity)
  - Mouse/rat models
  - For some applications pigs or dogs
- In human trials (phase 0)
- Clinical phase 1-3
- Phase 4 (monitoring)

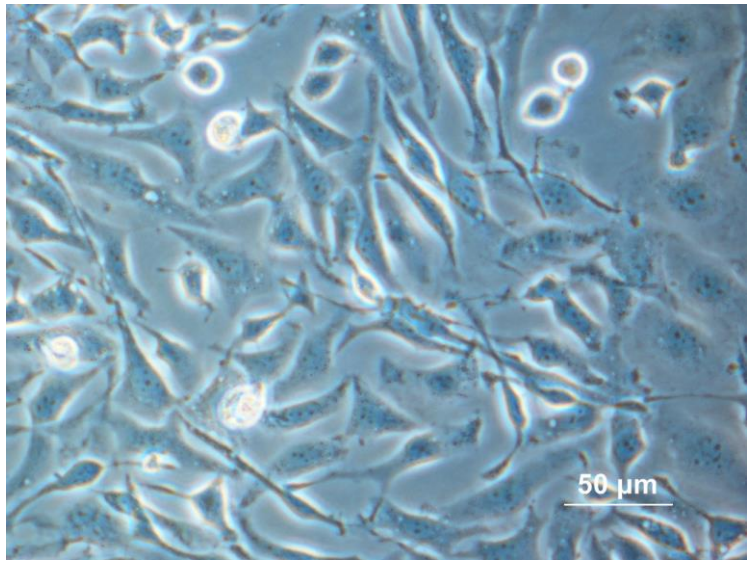
„There is no such thing as a biocompatible Material“

David F. Williams:
There is no such thing as a biocompatible material
Biomaterials **2014,** *35*, 10009-10014.

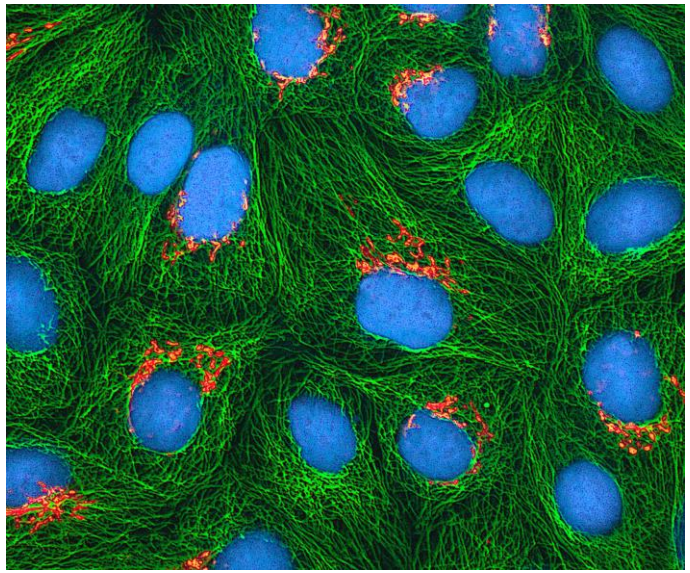
Cell culture

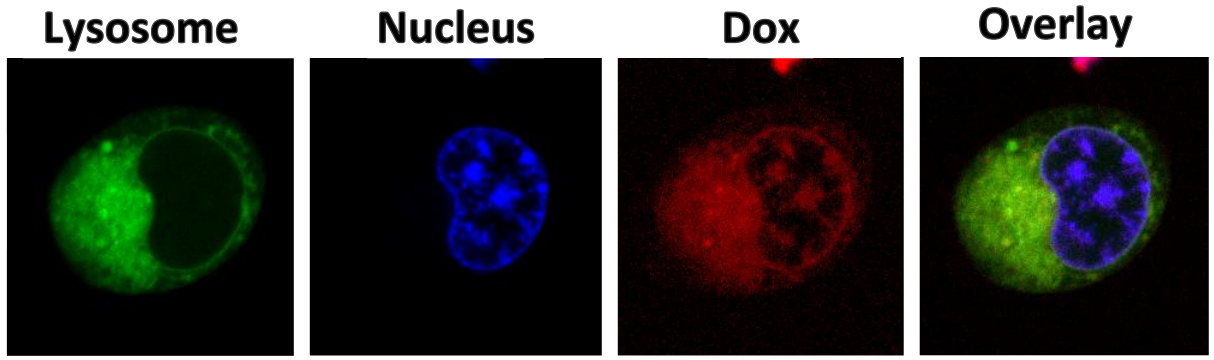
Incubator
(37°C, some CO_2)

CHO cells (cell line)



HeLa cells (cell line)
Fluorescene microscopy
(blue = nucleus, green = microtubuli, red = golgi ap.)

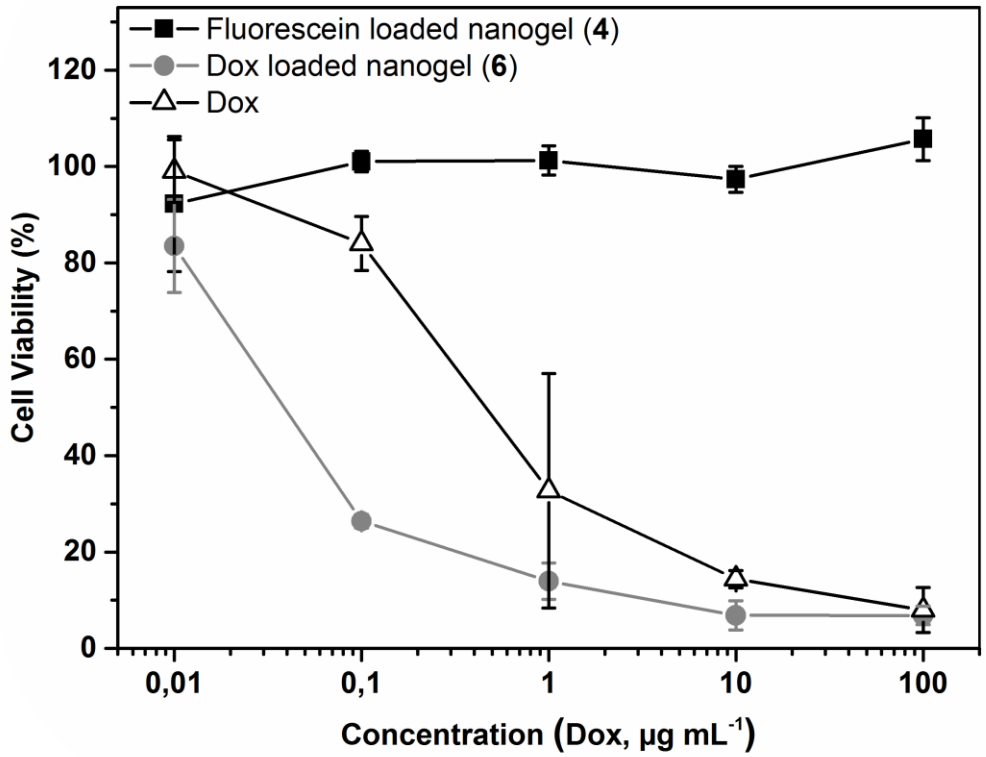




https://de.wikipedia.org/wiki/Zellkultur
Hoelzer D, Leiske MN, Hartlieb M, Bus T, Pretzel D, Hoeppener S, Kempe K, Thierbach R, Schubert US. Oncotarget. 2018 Apr 27;9(32):22316-22331

Cytotoxicity (MTT assay)

- Measure the CC_{50} – the compound concentration of 50% viability
- Usually a Dose-response or Hill fit is used to determine



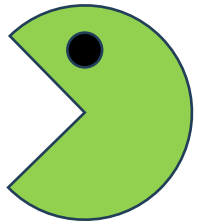
Biodegradation

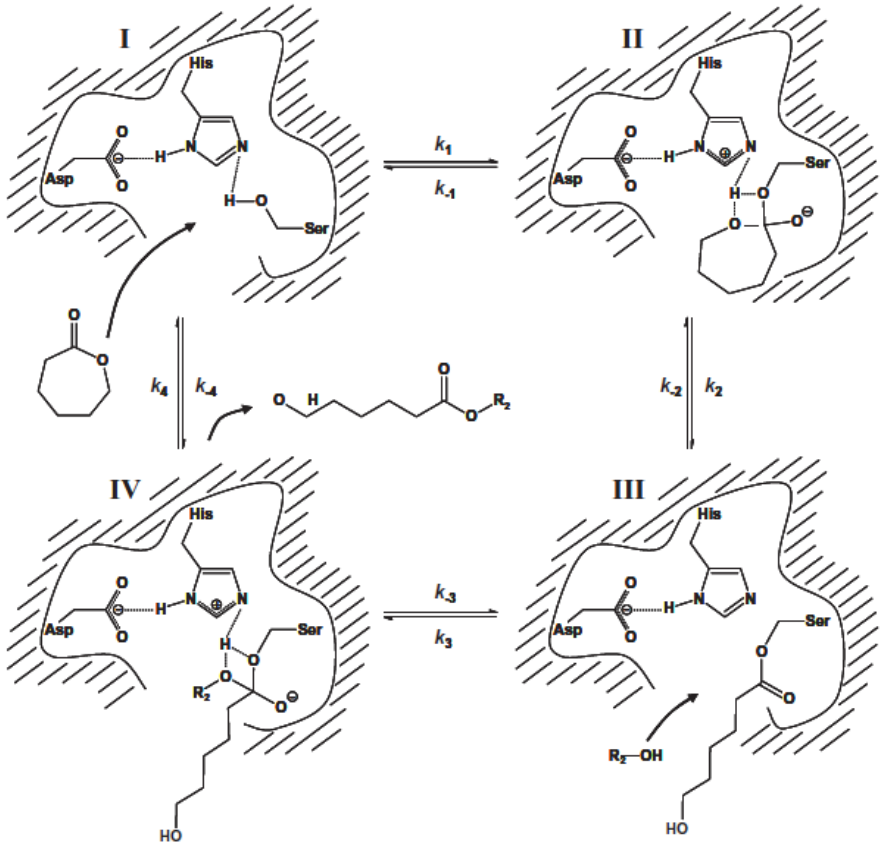
- Step-wise disintegration of materials by a biological entity

Bioresorption

- Material degradation by cellular activity or dissolution of material within biological medium

- Both are usually connected to enzymatic activity.

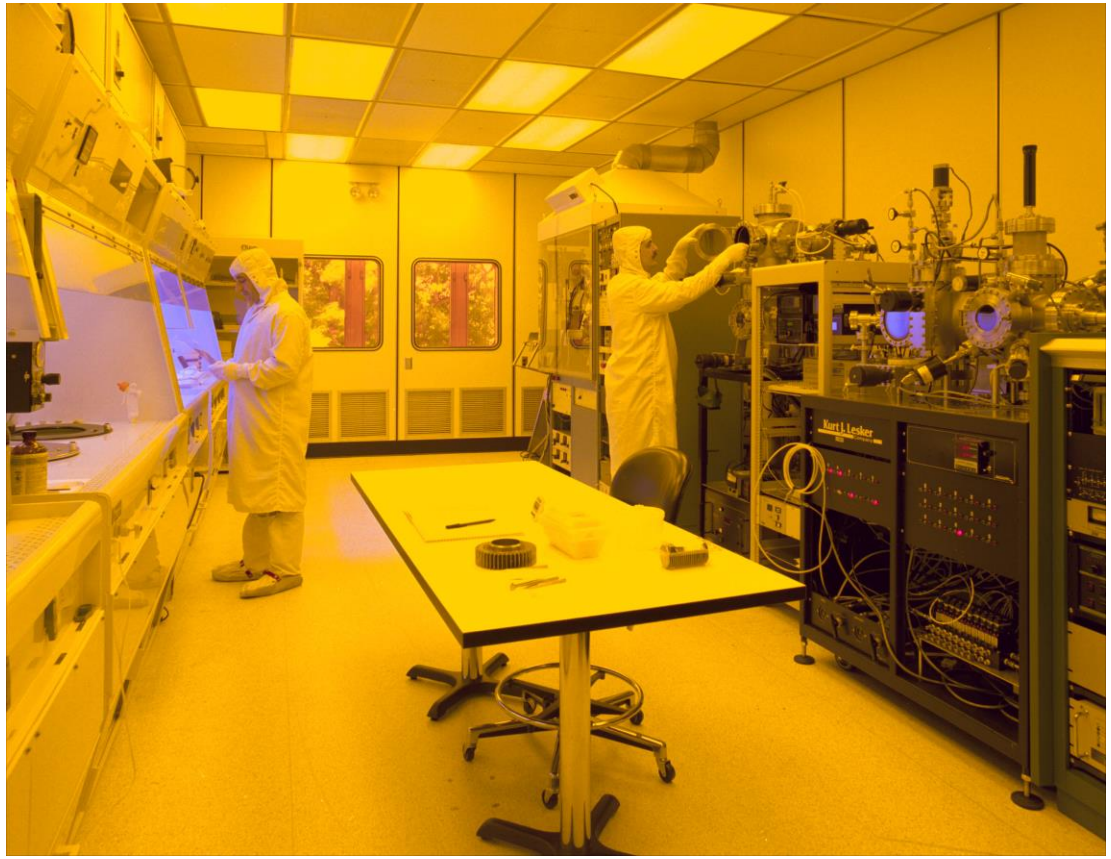




Handbook of Ring-Opening Polymerization, Wiley, 2009

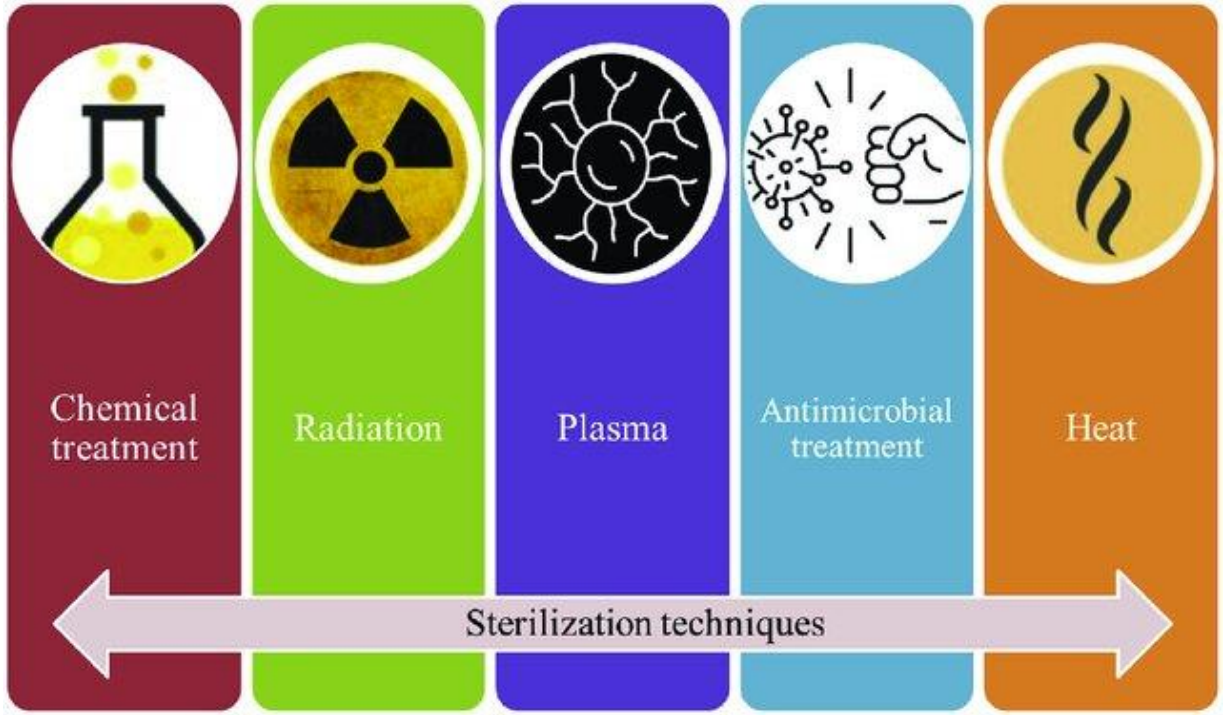
Sterilization/medical grade

Cleanroom



https://en.wikipedia.org/wiki/Cleanroom#/media/File:Clean_room.jpg

Sterilization



Production under **GMP** (Good Manufacturing Practice) conditions

Take-home message

- In **virtually all aspects of medicine** and life science polymers play an important role
- Terms like **biopolymer** and **biomaterials** should be used with care and knowledge
- **Biocompatibility** can be assessed by multiple tests
  - ***in vitro*** (e.g. cytocompatibility)
  - ***ex vivo*** (e.g explants)
  - ***in vivo*** (e.g. pharmacokintics)
- **Biodegradation** has to be considered in the application of biomaterials
- Anything for clinical use has to be sufficiently **sterile**