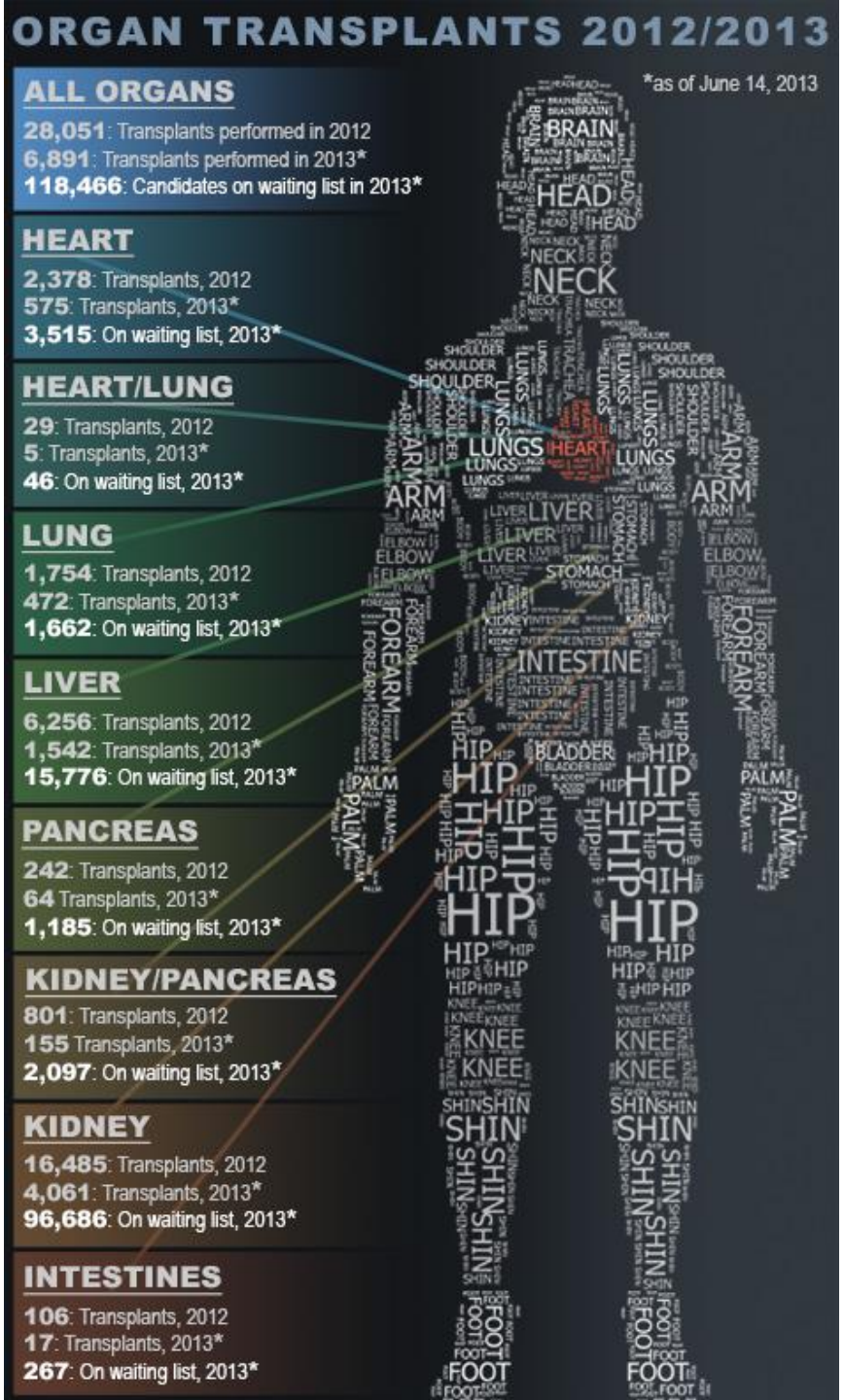
Biomaterial dalam Rekayasa Jaringan

Awal kebutuhan material dalam bidang Kesehatan:
adanya kebutuhan untuk **transplaantasi organ**



Transplantasi dan keterbatasan

- Hambatan transplantasi
  - Jumlah donor yang terbatas
  - Transmisi penyakit lewat donor organ
    - HIV
    - Hepatitis, dll

- Operasi yang dilakukan
  - Tidak selalu dapat dilakukan
  - Komplikasi, misalnya sistem imun

Transplantasi dan keterbatasan

- Mechanical devices
  - Engineering approach – rekayasa jaringan/sistem baru
  - Hal-hal yang harus diperhatikan:
    - Kompleksitas tubuh manusia
    - Berbagai fungsi
    - Living components versus non living components
    - Material :
      - Tissue based
      - Polymer
      - Metal
      - keramik

Definisi

Biomaterial is :

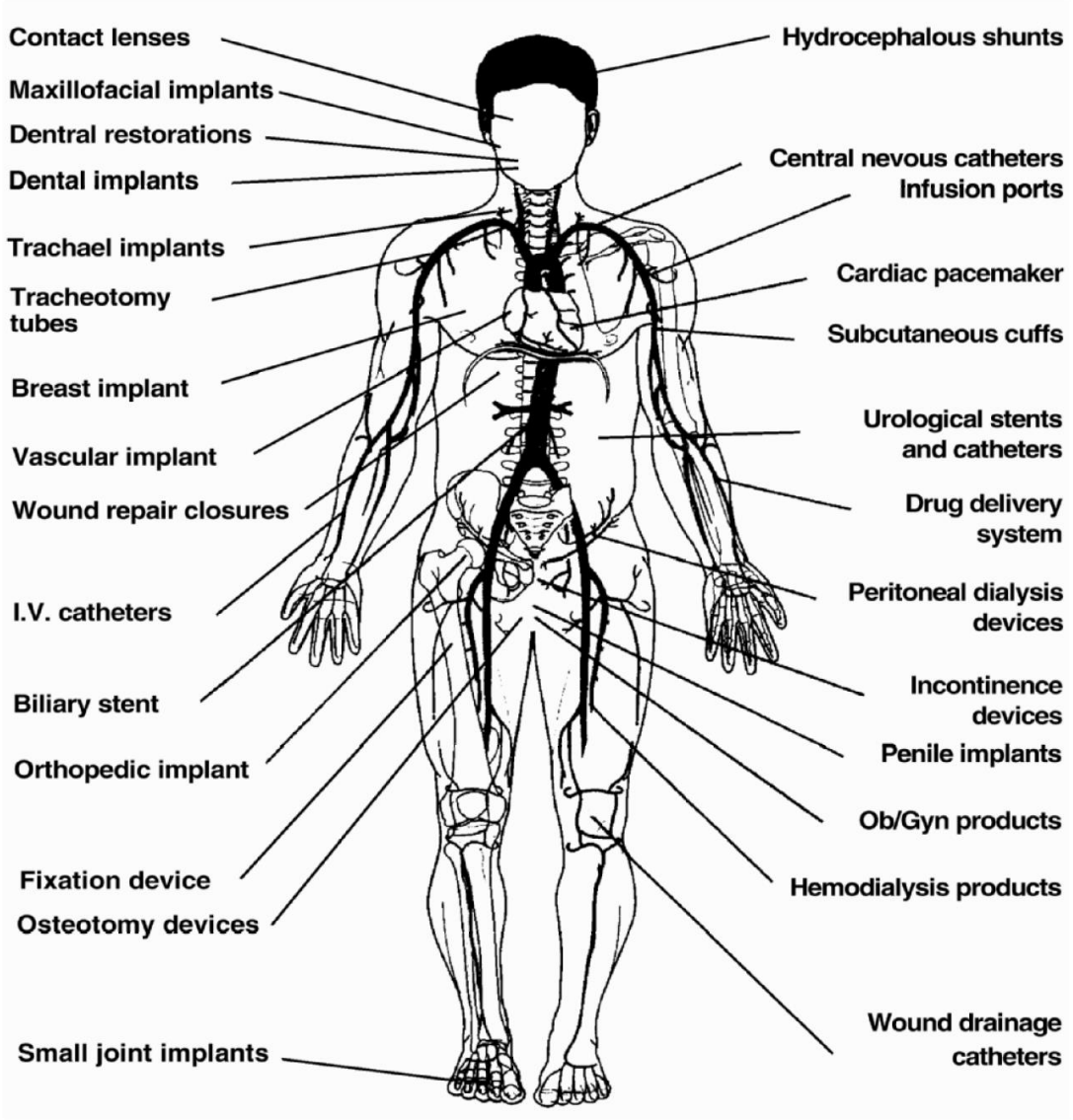
> "*any substance (other than a drug) or combination of substances synthetic or natural in origin, which can be used for any period of time, as a whole or part of a system which treats, augments, or replaces tissue, organ, or function of the body*."
>
> (National Institutes of Health (NIH))

a biomaterial is

> *any substance that simulates the extracellular matrix by functionally interacting with isolated cells to support fabrication and maturation of 3D artificial tissue*

Contoh-contoh penggunaan Biomaterials

Organ/Tissue	Examples
heart	pacemaker, artificial valve, artificial heart
eye	contact lens, intraocular lens
ear	artificial stapes, cochlea implant
bone	bone plate, intramedullary rod, joint prosthesis, bone cement, bone defect repair
kidney	dialysis machine
bladder	catheter and stent
muscle	sutures, muscle stimulator
circulation	artificial blood vessels
skin	burn dressings, artificial skin
endocrine	encapsulated pancreatic islet cells



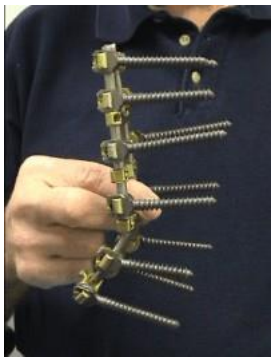
Penggunaan Biomaterial

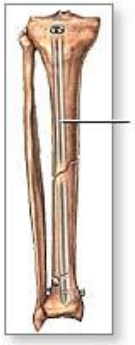
Application	Number Used / Year
Intraocular lenses	1 500 000
Contact lenses	4 500 000
Vascular grafts	350 000
Heart valves	58 000
Blood bags	30 000 000
Catheters	200 000 000
Renal dialyzers	16 000 000
Sutures	20 000 000
Hips and knees	1 400 000

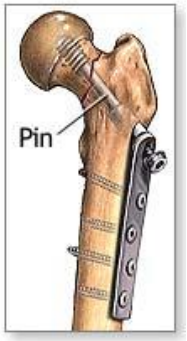
Biomaterial

- *Non viable materials* yang digunakan untuk peralatan kedokteran yang berinteraksi dengan system biologis
  - **Biomaterial polimer**
    - silicones, poly(ethylene), poly(vinyl chloride), polyurethanes, polylactides
    - collagen, gelatin, elastin, silk, polysaccharides
  - **Biokeramik** :
    - aluminum oxide, zirconia, calcium phosphates
  - **Biomaterial metal**
    - stainless steel, cobalt alloys, titanium alloys
  - **Biokomposit**
  - **Biologically based (derived) biomaterials**

Biomaterials – Metals





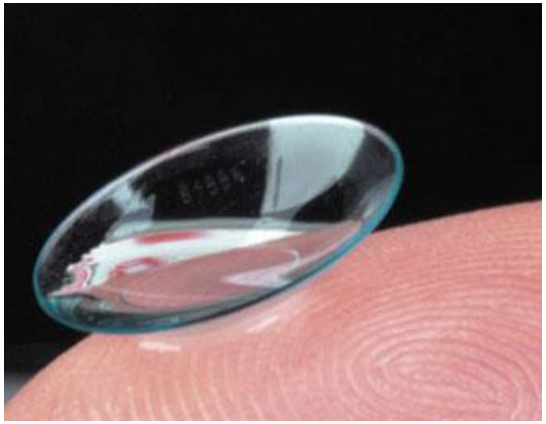


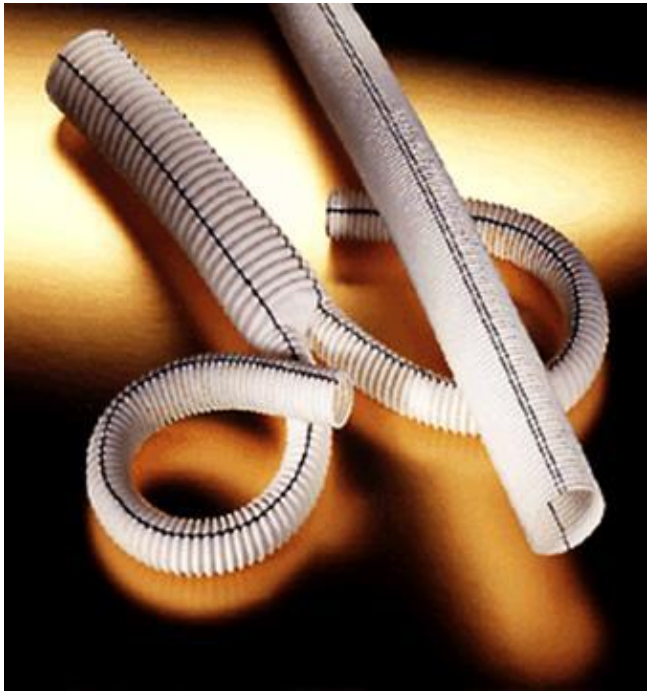
A.D.A.M.

Biomaterials – Metals

Material	Applications
316, 316L Stainless Steel	Fracture fixation Joint Replacement Spinal Instruments Surgical Instruments
Pure Titanium Ti-6Al-4V Ti-13Nb-13Zr	Bone and Joint Replacements Dental Implants
CoCr Alloys	Bone and Joint Replacements Dental Implants Heart Valves
Gold Alloys	Heart Valves

Biomaterials – Polymers



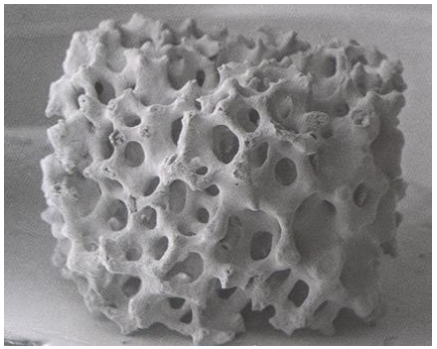


Biomaterials – Polymers

Material	Applications
Polyethylene (UHMWPE)	Joint Replacement Bearings
Polypropylene	Sutures, MCP Joints
Polytetrafluoroethylene (Teflon)	Vascular Prosthetics
Polyesters	Vascular Prosthetics, Drug Delivery, Sutures, Ligament Grafts
Polyurethanes	Vascular Prosthetics, Heart Valves, Catheters
Polyvinylchloride (PVC)	Catheters
Polymethylmethacrylate (PMMA)	Implant Fixation
Silicones	Ophthalmology
Hydrogels	Ophthalmology
Polylactic and Polyglycolic Acid	Resorbable Devices, Drug Delivery

Biomaterials – Ceramics

Material	Applications
Alumina	Joint Replacements
Zirconia	Joint Replacements
Calcium Phosphates	Bone Grafting, Surface Coatings for Fixation
Bioactive Glasses	Bone Grafting, Surface Coatings for Fixation
Porcelain	Dental Implants



Hal merugikan dari biomaterial yang sudah ada

- Terdapat sedikit material yang dirancang sebagai biomaterial
- Tidak terdapat interaksi biologis
- Tidak dirancang secara khusus untuk bersifat biokompatibel, tetapi dioptimisasi dengan *trial and error*

Tantangan biomaterial dalam rekayasa jaringan

- Mengembangkan jaringan pengganti yang mendukung :
  - Secara mekanik
  - Secara fisik
  - Fungsi

- Berinteraksi dengan lingkungan di sekitarnya pada saat sudah diimplantasikan

- Menjadi terintegrasi dengan lingkungan sekitarnya
- Hubungan bersimbiosis
- Biomaterial yang tepat:
  - Harus merupakan biomaterial yang sesuai untuk aplikasi jaringannya
  - Harus memiliki porositas yang tinggi dan interkonektifitas , tetapi secara mekanis cukup kuat untuk sel
  - Harus mendukung pelekatan dan diferensiasi sel
  - Scaffold yang digunakan untuk melepas obat dan sitokin harus punya peranan fungsional untuk jaringan

Biokompatibilitas

- **Definisi awal**

- *"Lack of interaction between material and tissue"*

  - inert, non-toxic, non-carcinogenic, non-allergenic, non-inflammatory, non-degradable
  - Jadi material mempunyai zero influence

Biokompatibilitas

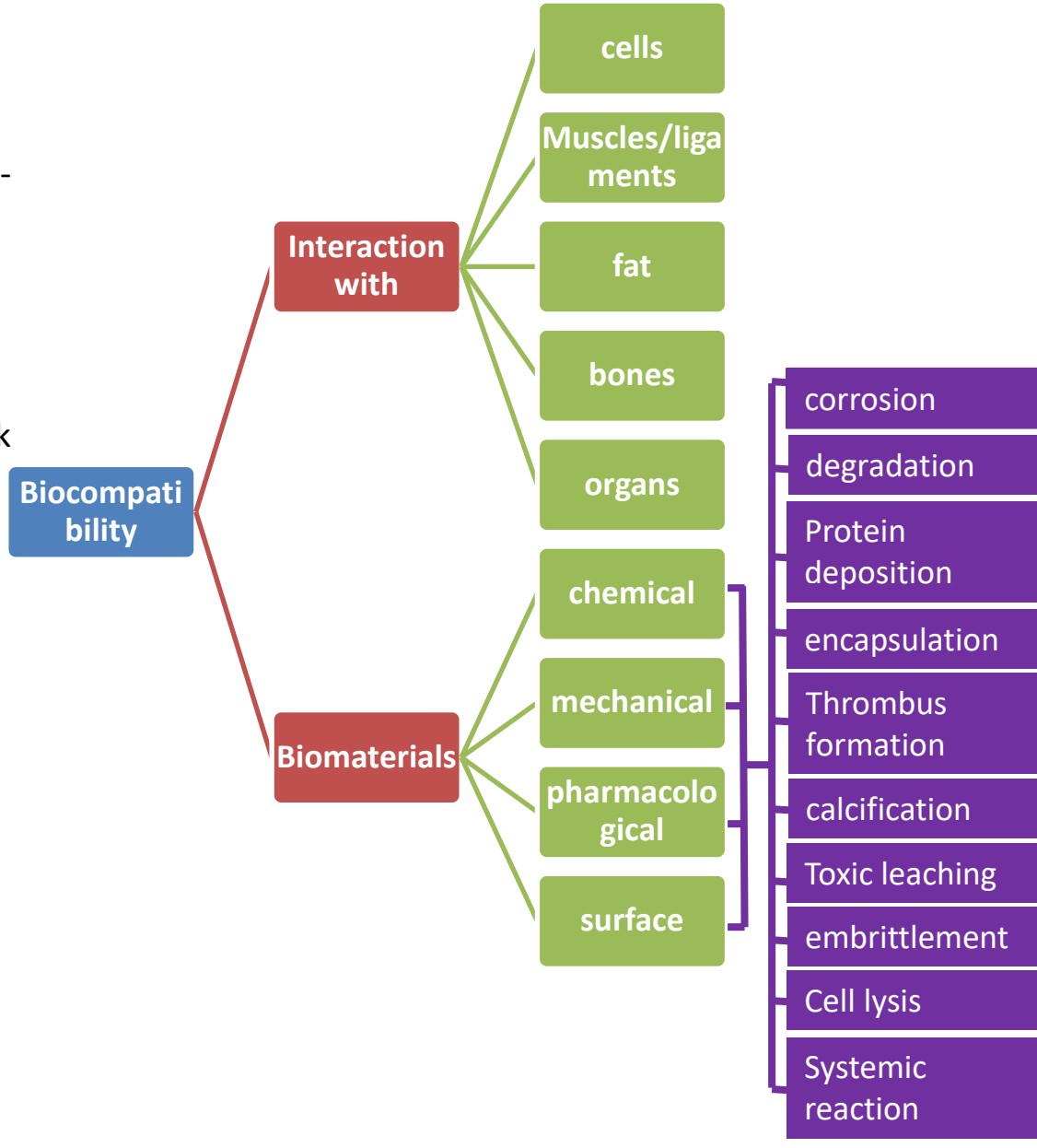
- **Definisi saat ini**

- *"Ability of a material to perform with an appropriate host response, in a specific application"*

  - Terlibat dalam sejumlah proses dan mekanisme interaksi antara material dan jaringan
  - "*Ability of material to perform*" dan tidak terus ada di dalam tubuh
  - "*Appropriate host response*" dapat diterima oleh tubuh
  - "*Specific application*"

Karakteristik untuk biomaterial untuk aplikasi medis

- Biocompatibilitas
  - Non-carcinogenic, non-pyrogenic, non-toxic, non-allergenic, blood compatible, non-inflammatory
- Dapat disterilkan
  - Tidak rusak atau berubah akibat Teknik sterilisasi (autoklaf, sterilisasi panas, radiasi, etilen oksida
- Karakteristik fisik
  - Kuat, toughness, elastis, tidak korosif, wear-resistance, stabilitas long-term
- Dapat dibuat dalam pabrik
  - Machinable, moldable, extrudable



Biokompatibilitas

– Waktu kontak dengan biomaterial harus diperhatikan

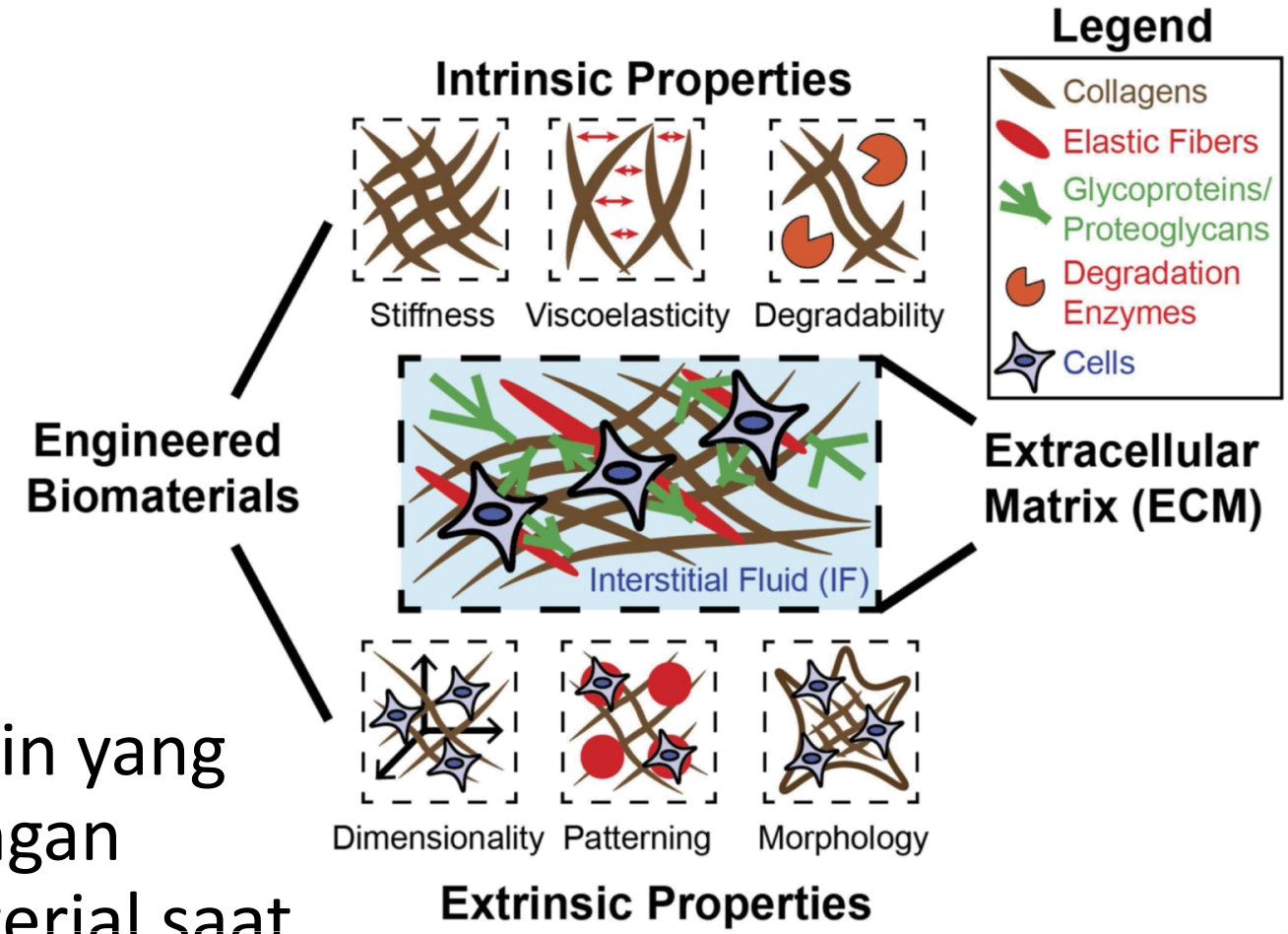
material	contact time
syringe needle	**1-2 s**
tongue depressor	**10 s**
contact lens	**12 hr - 30 days**
bone screw / plate	**3-12 months**
total hip replacement	**10-15 yrs**
intraocular lens	**30 + yrs**

Biomaterial Properties

	Tensile Modulus (GPa)	**Yield Strength** (MPa)	**UTS** (MPa)	**Elongation at Break** (%)	**Endurance Limit** (MPa)
Co-Cr-Mo (cast)	200	440 – 570	650 – 750	8	235 – 275
Co-Cr-Mo (forged)	210	650 – 1000	896	35 – 55	400 – 600
Titanium	100	480 – 510	550 – 620	15 – 20	250 – 280
Ti-6Al-4V	100	825	930	10 – 15	400 – 440
316 SS	200	250 – 330	520 – 620	35 – 75	245 – 300
Cortical Bone	18	80	80 – 150	1 – 3	30
Cancellous Bone	0.2 – 0.5	5 – 30	10 – 20	5 – 7	–
UHMWPE	1	20	30	390	16
PMMA	3	–	35	0.25	6
Alumina	350	–	270	0	–
Zirconia	200	–	500 – 650	0	–

Karakterisasi Biomaterial

- Mekanik
- Thermal
- Kimiawi
- Optikal
- Elektrikal
- Karateristik lain yang berkaitan dengan fungsi biomaterial saat ditransplantasikan

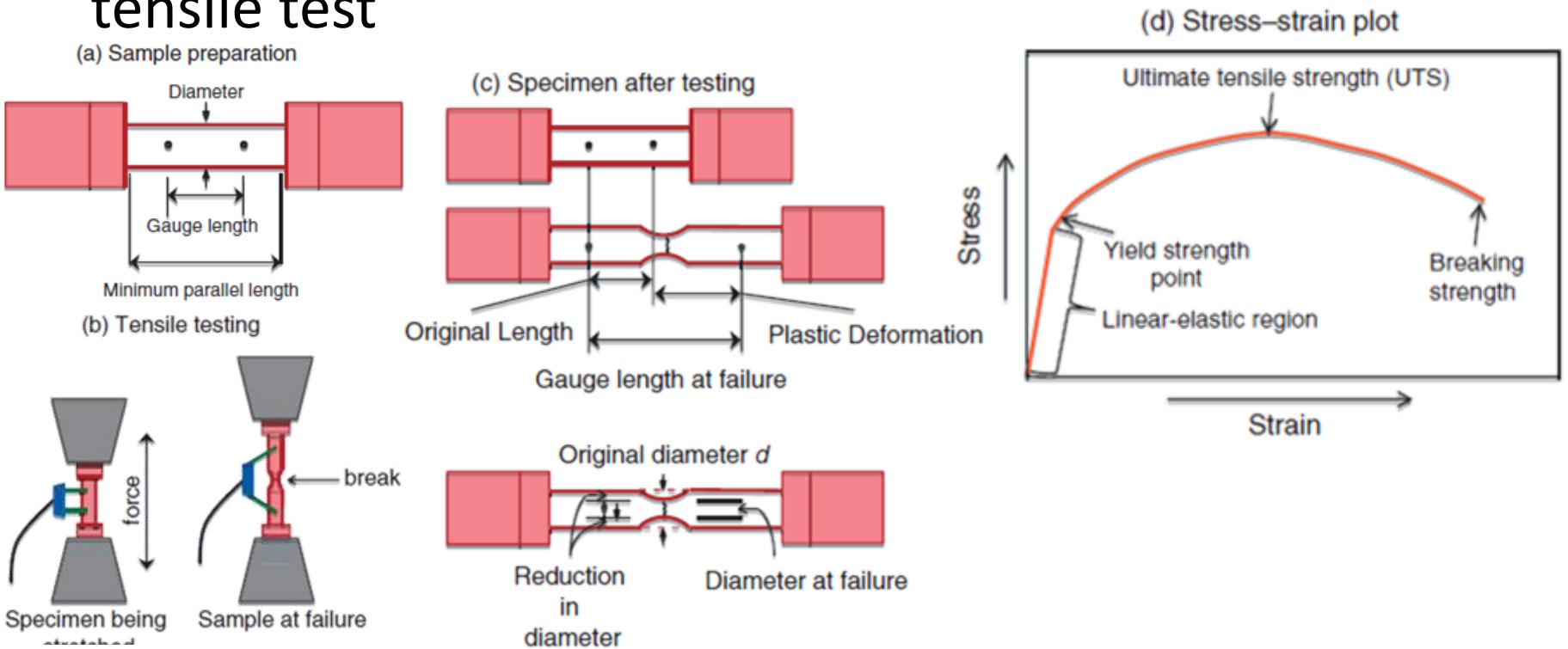


pH dalam tubuh manusia

- Gastric content 1.0
- Urine 4.5-6.0
- Intracellular 6.8
- Interstitial 7.0
- Blood 7.17-7.35

Karakteristik Stress–Strain Behavior suatu material

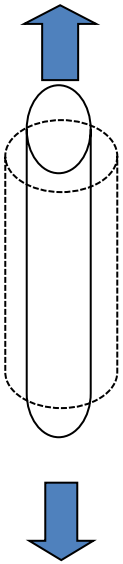
- Kriteria penting:
  - Kekuatan material
  - Kemampuan menahan beban tertentu
  - Elastisitas
- Pengujian: load-deflection test/stress-strain test/ tensile test



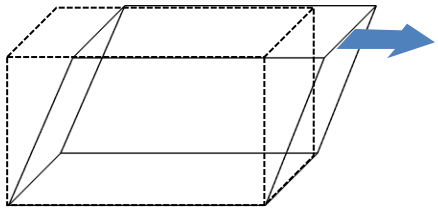
Karakteristik Mekanis

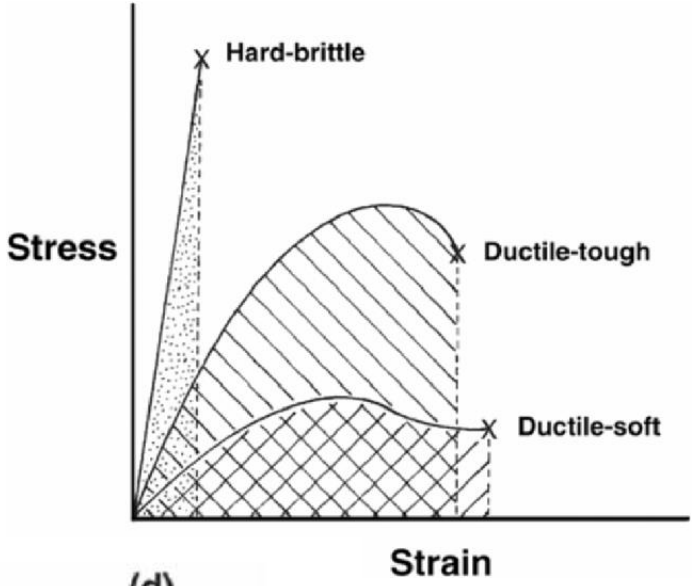
- perlu diperhatikan beban mekanis apa yang harus dihadapi

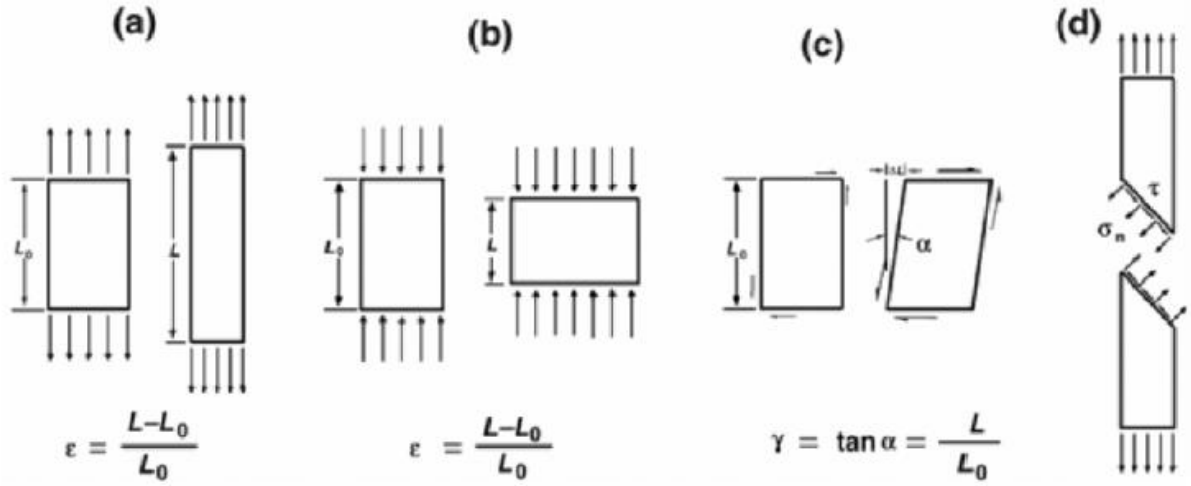
tension



shear



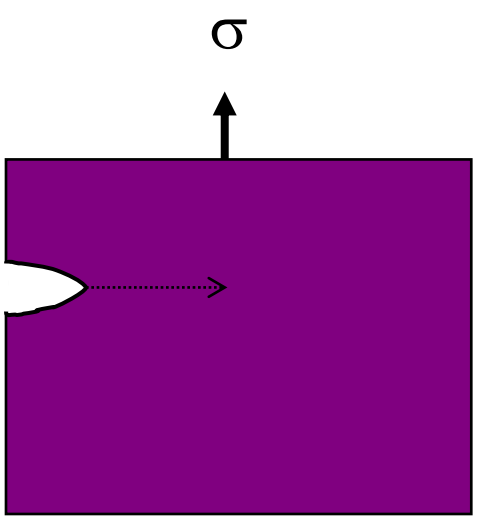




(a) tension, (b) compression, (c) shear, and (d) shear in tension

Brittle Fracture

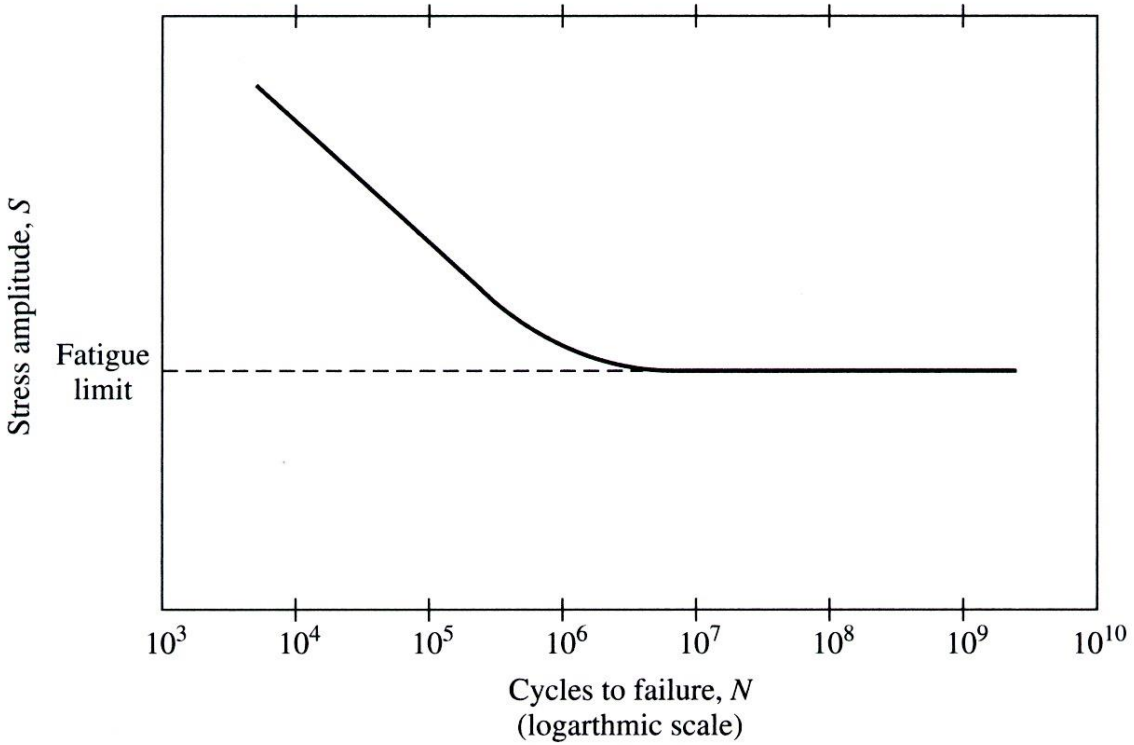
- Kekuatan tekanan tertinggi secara teoritis memiliki nilai yang besar dibandingkan dengan Kekuatan tekanan tertinggi yang terukur ➔ disebabkan karena adanya *microcracks* permukaan.



$$s_f = \frac{K_{1c}}{\sqrt{pc}}$$

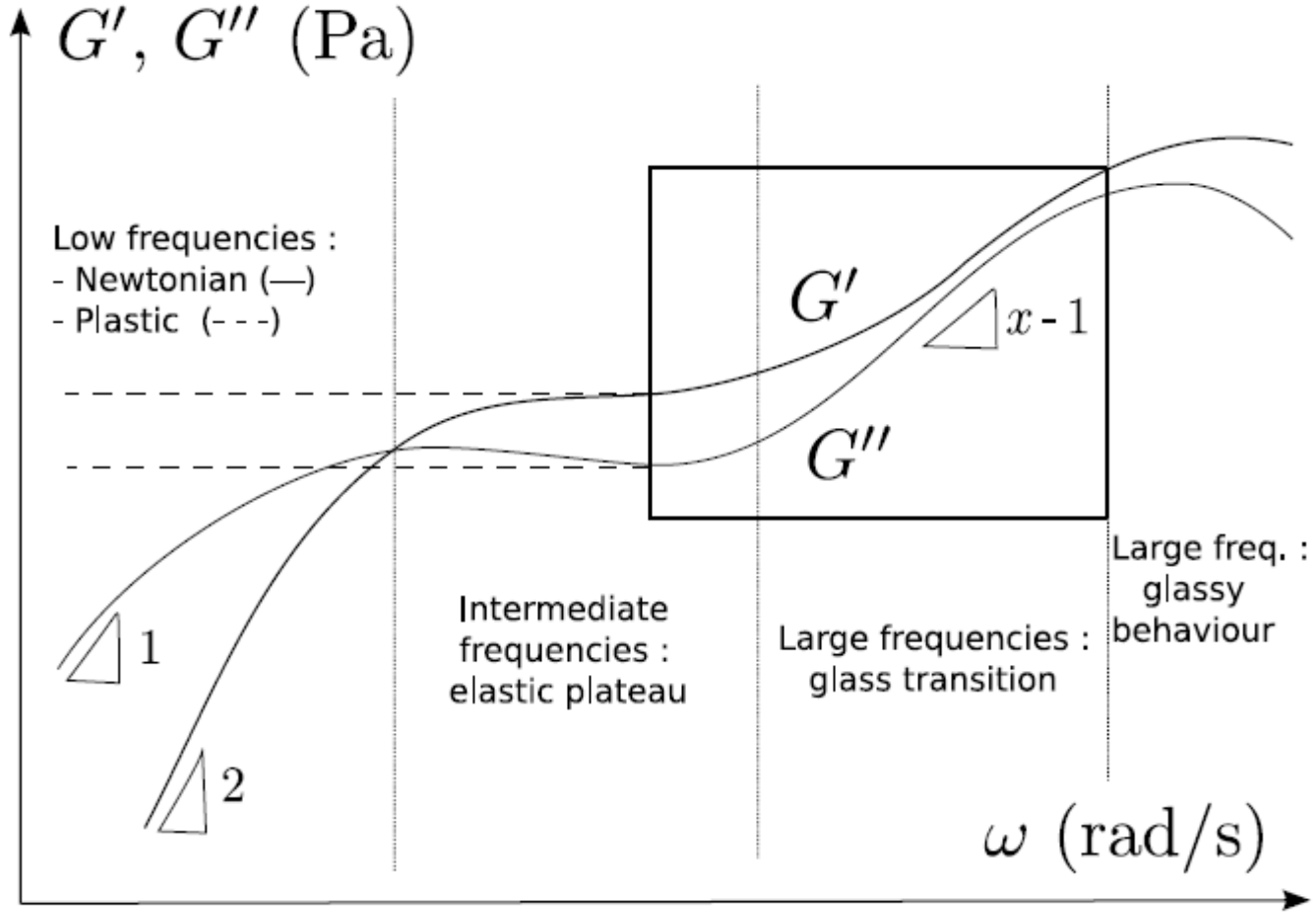
Fatigue

- Perusakan progresif material yang terjadi pada suatu material.
- *Cyclic Fatigue*:



Viskoelastisitas

- Karakteristik *viscous* dan *elastic* biomaterial



Karakteristik termal

Table 3-2. Thermal Properties of Materials

Substance	Melting temp. (°C)	Specific heat (J/g)	Heat of fusion (J/g)	Thermal conductivity (W/mK)	Linear thermal expansion coeff. ($\times 10^{-6}$/°C)
Mercury	–38.87	0.138	12.7	68	60.6
Gold	1,063	0.13	67	297	14.4
Silver	960.5	0.2345	108.9	421	19.2
Copper	1,083	0.385	205.2	384	16.8
Platinum	1,773	0.134	113	70	–
Enamel	–	0.75	–	0.82	11.4
Dentine	–	1.17	–	0.59	8.3
Acrylic	70*	1.465	–	0.2	81.0
Water	0	4.187	334.9 (ice)	–	–
Paraffin	52	2.889	146.5	–	–
Beeswax	62	–	175.8	0.4	350
Alcohol	–117	2.29	104.7	–	–
Glycerin	18	2.428	75.4	–	–
Amalgam	480	–	–	23	22.1–28
Porcelain	–	1.09	–	1	4.1

*Softening temperature (T_g).

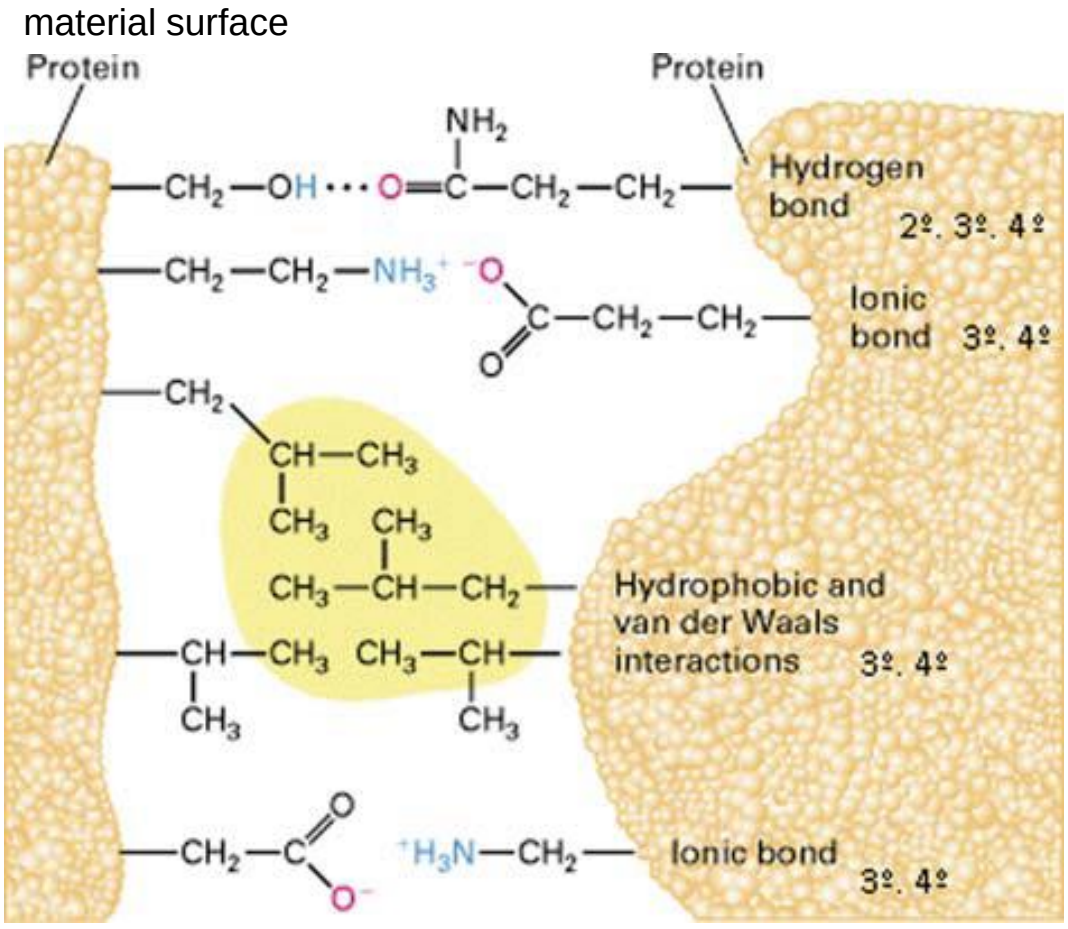
Surface Energy

- Interface
  - Perbatasan antara 2 permukaan

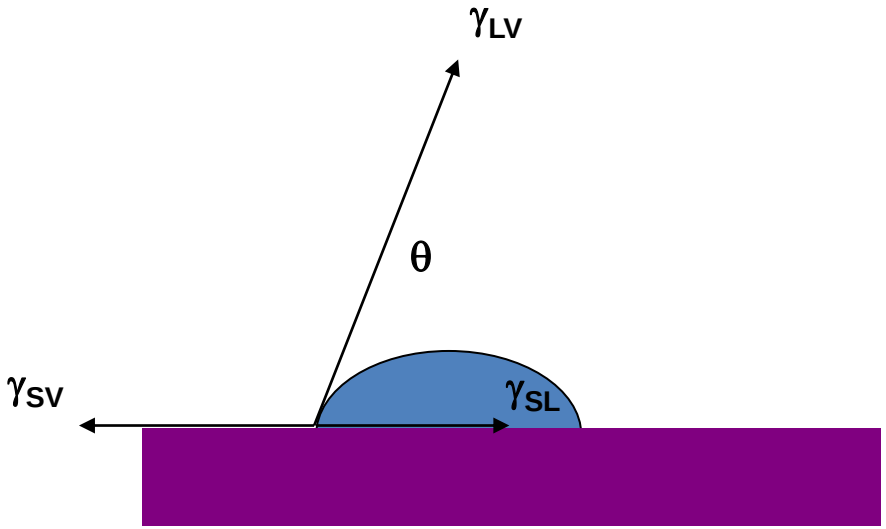
- Menentukan
  - Adsorpsi protein pada material
  - Koagulasi darah / thrombosis akibat kontak terhadap material
  - Respon sel terhadap material

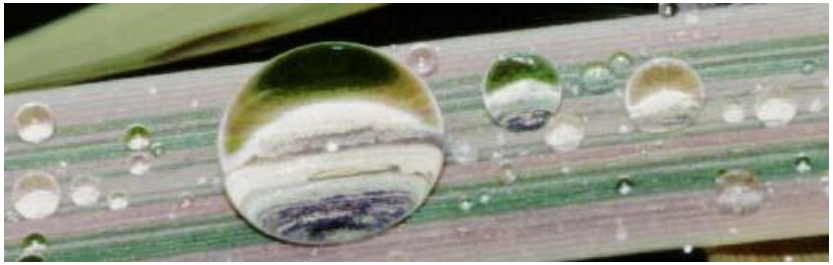
Surface Chemistry

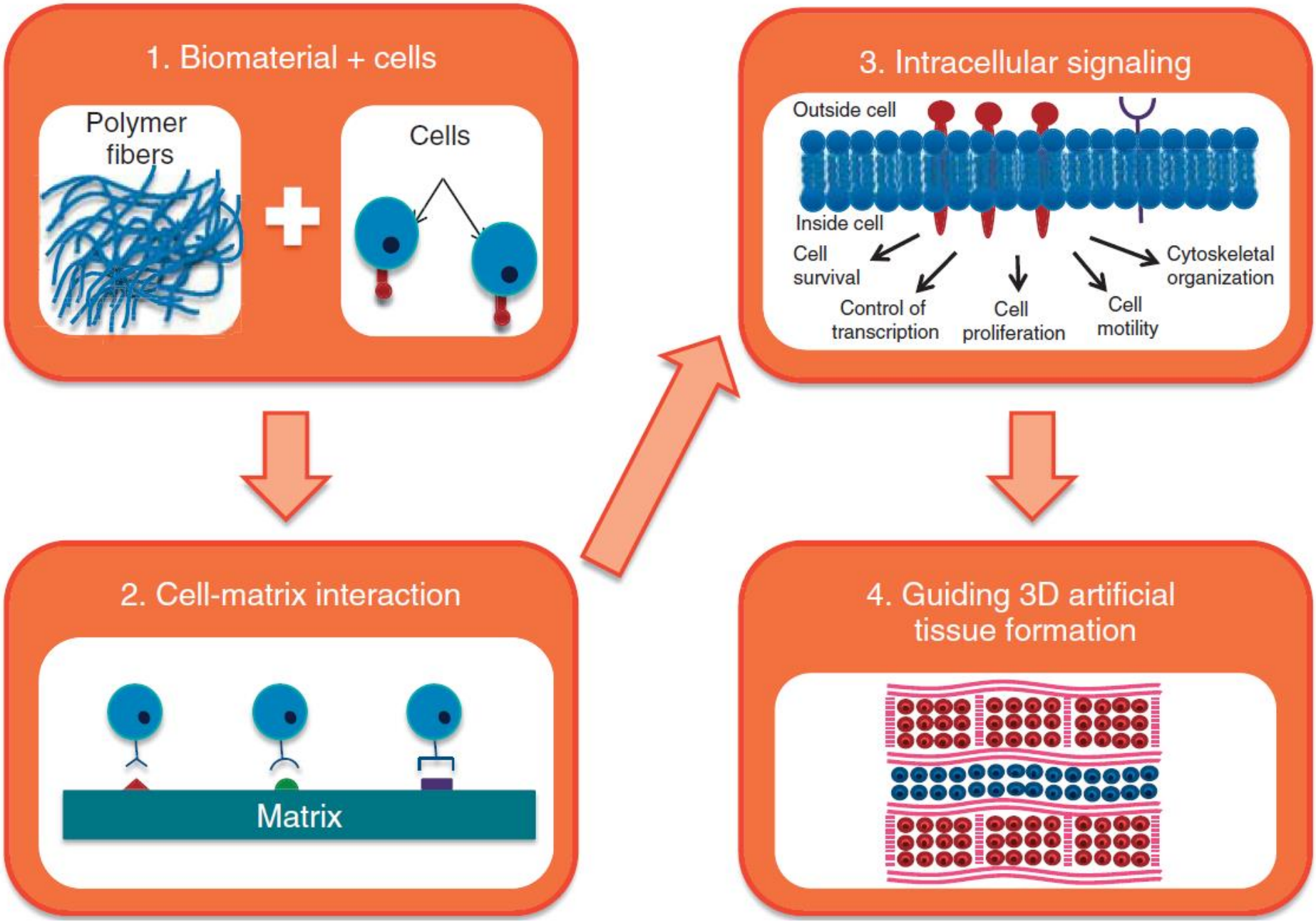
- Interaksi molekul pada permukaan material
- van der Waals forces :
- Hydrogen Bonds :
- Coulombic :



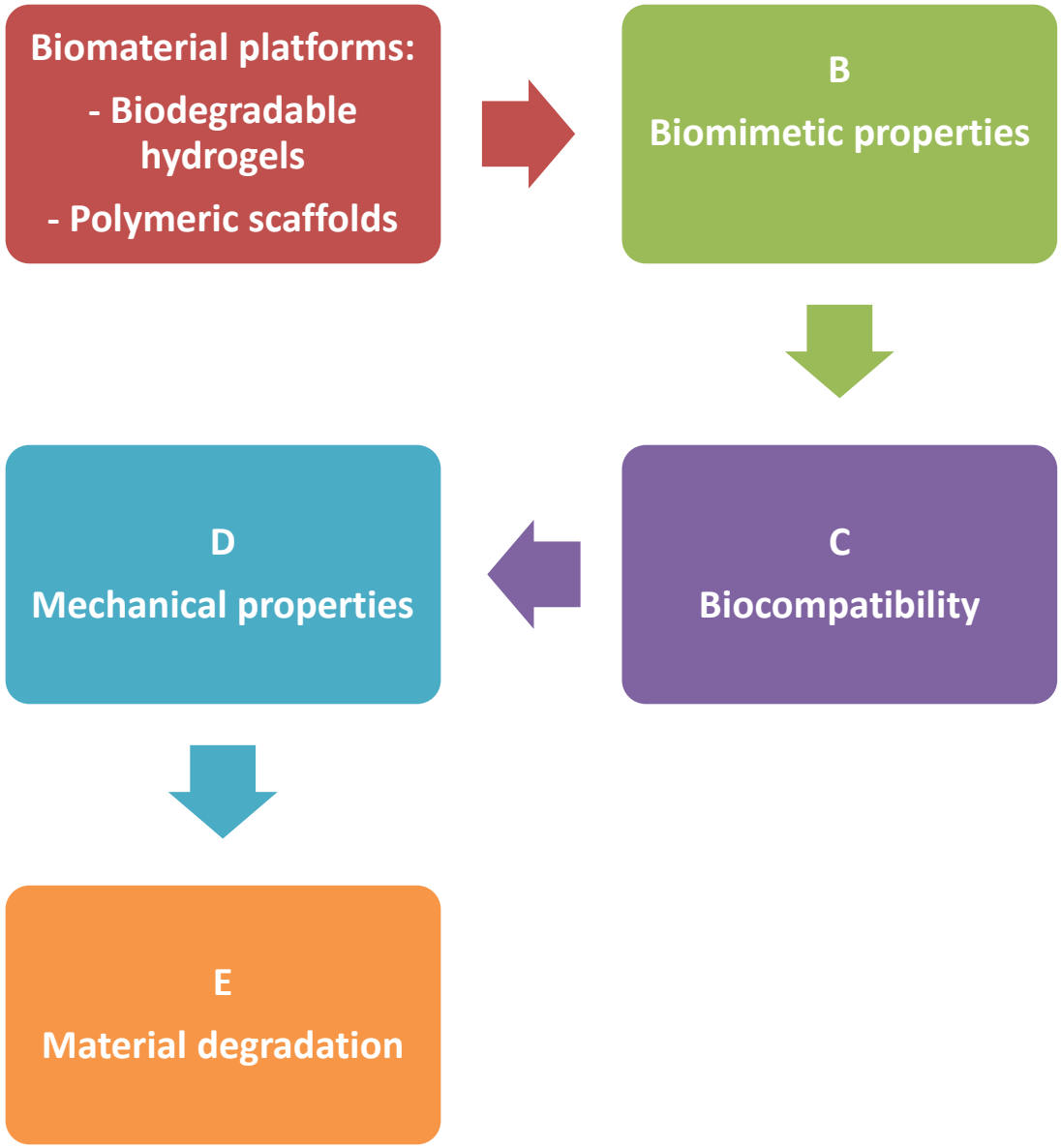
Surface Energy dan *Contact Angle*






1. Biomaterial + cells
Polymer fibers
Cells
2. Cell-matrix interaction
Matrix
3. Intracellular signaling
Outside cell
Inside cell
Cell survival
Control of transcription
Cell proliferation
Cell motility
Cytoskeletal organization
4. Guiding 3D artificial tissue formation

Perkembangan Biomaterial untuk Rekayasa Jaringan



TUGAS INDIVIDU

- BUATLAH PPT MAKS 5 SLIDES UNTUK: APLIKASI BIOMATERIAL DALAM REKAYASA JARINGAN
- BIOMATERIAL (4 TOPIK):
  - BIOKERAMIK
  - BIOMATERIAL PROTEIN
  - BIOMATERTIAL KARBOHIDRAT
  - BIOKOMPOSIT
- ISI PPT:
  - CONTOH APLIKASI BIOMATERIAL DALAM REKJAR
  - PERAN BIOMATERIAL