3.051J/20.340J

Lecture 9:
Surface Modification of Biomaterials

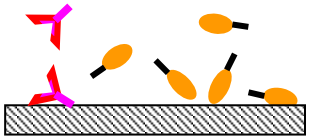
Purpose: alter surface properties to enhance performance in biological environment while retaining bulk properties of device

Specific Objectives:

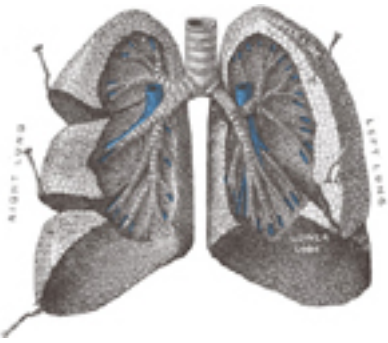
1. clean a surface

2. reduce/eliminate protein adsorption

- reduce undesirable/uncontrolled responses to implants & extracorpeal devices



C3b/IgG adsorption ⇒ activation of WBCs



Source: Wikipedia (Gray's Anatomy)

- reduce nonspecific adsorption on biosensors & bioassays (noise & fouling)

- current strategy: hydrated, hydrophilic surfaces

  PEO is current "gold standard"

3. reduce/eliminate cell adhesion

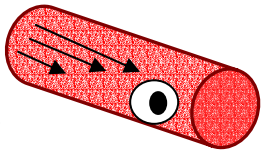
- create surfaces that mimic nature's cell resistant surfaces

ex. Human serum albumin: naturally low affinity to components of body fluids & tissues (*consider its high conc. in blood—60 wt% of proteins!*)

4. reduce thromogenicity

- hydrophilic surfaces
  - eliminate protein adsorption

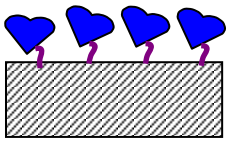
- hydrophobic surfaces



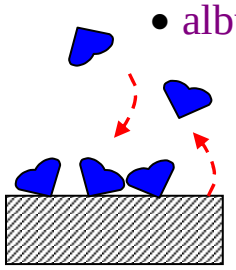
  - inherently weak surface/cell interface
  - exploits shear stress due to blood flow

- surface-bound heparin
  - natural surface of endothelial cells lining blood vessels
  - inactivates factor Xa & thrombin by binding anti-thrombin

- surface-bound albumin
  - no ligands for platelets (can attach if HSA denatures-how?)

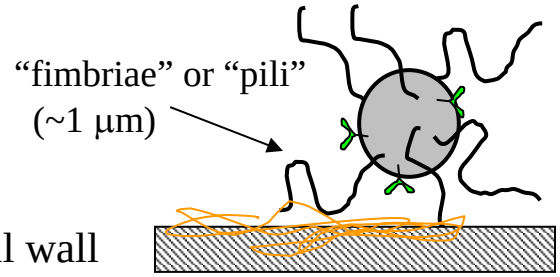


- albumin affinity coatings
  - surfaces that strongly adsorb albumin from blood to make a passive coating; ex. bilirubin $K_d \sim 10^{-8}$ l/mol



- endothelial cell attachment
  - natural blood vessel lining $\Rightarrow$ fibrinolytic activity (hydrolysis of fibrin)

5. reduce bacterial adhesion



Bacterial adhesion

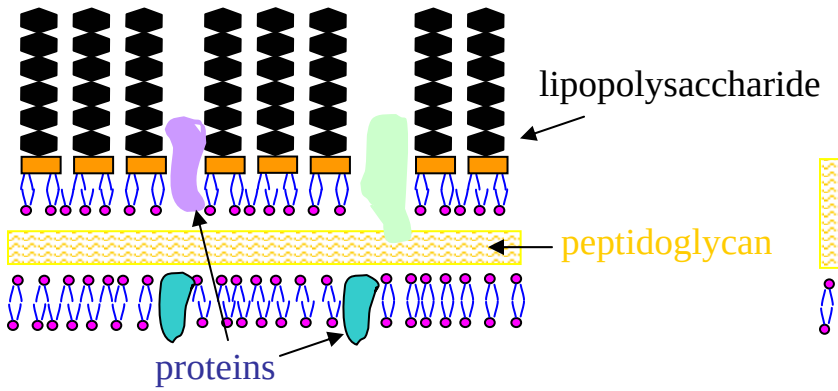
- via proteins & polysaccharides in cell wall
  (nonspecific)
- specific receptors for plasma proteins
  (ex. *S. aureus* binds fibrinogen/fibrin, FN, VN)
- pili facilitate initial surface attachment

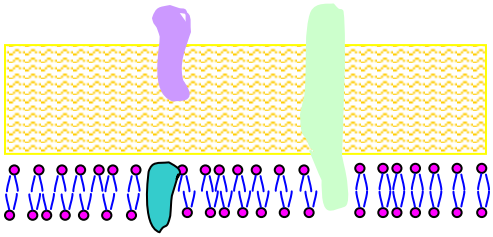
bacteria cell wall
(gram negative)

ex. *E. coli*

bacteria cell wall
(gram positive)

ex. *Staphylococcus aureus*, *S. epidermis*



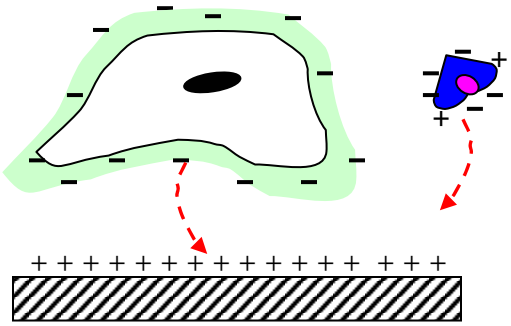


- passive coatings
  hydrophilic polymers, HSA,
- bactericidal agents
  - Ag-containing films
  - antibiotics (ex., gentamicin eluting film)
  - cell wall-disrupting agents (cationic)
    i) non-mammal anti-microbial peptides:
    amphiphilic helix structures (ex. LKLLKKL)
    ii) cationic polymers (ex. lipid-like side chains)

6. promote cell attachment/adhesion

- modify γ_1 (vary chemistry $\Rightarrow \uparrow$ protein adsorption)
- create positive surface charge

  - many proteins have net negative surface charge $\Rightarrow \uparrow$ protein adsorption
  - cell glycocalyx has neg. charge $\Rightarrow$ nonspecific attraction



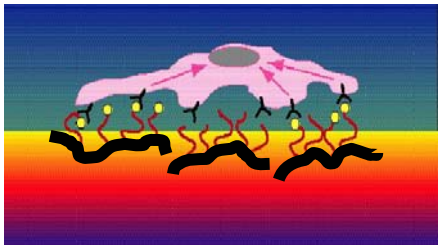
NOTE: a strongly ++ surface can inhibit cell growth

- increase surface roughness/porosity

  - promotes cell attachment ($\uparrow$ surface area for binding)
  - can inhibit cell growth

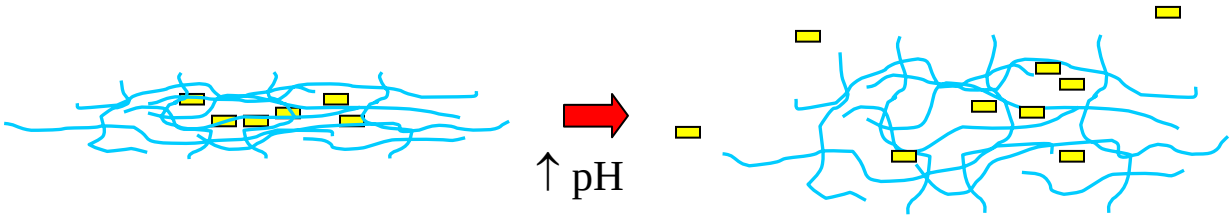
- bind cell adhesion ligands to surface

  - adhesion proteins (fibronectin)
  - adhesion protein epitopes: RGD (fibronectin, collagen…); YIGSR(tyr-isoleuc-gly-ser-arg) (laminin B1)



7. alter transport properties

- regulate the passage of H_2O, theraputic agents, etc.
  ex. crosslinking (passive) or pH "valves" (active)

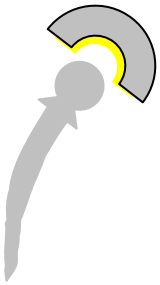


8. increase lubricity (↓ friction/wear)

in vivo: hydrophilic surfaces

9. increase hardness

enhance wear resistance



10. enhance corrosion/degradation resistance