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 & extracorporeal devices
   - 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

- **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. LKLLKKKL)
    - ii) cationic polymers (ex. lipid-like side chains)
6. promote cell attachment/adhesion

- modify $\gamma_1$ (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 H₂O, therapeutic 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