Lecture 9:

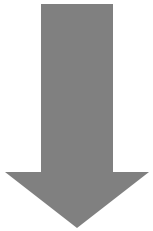
Surface Modification of Biomaterials

Supporting notes

3.051J/20.340J Materials for Biomedical Applications,
Spring 2006

Purpose:

Alter surface properties to enhance performance in biological environment while <u>retaining bulk properties</u> of device



The modified zone at the surface of the device should be **as thin as possible**. Ideally < 1 nm

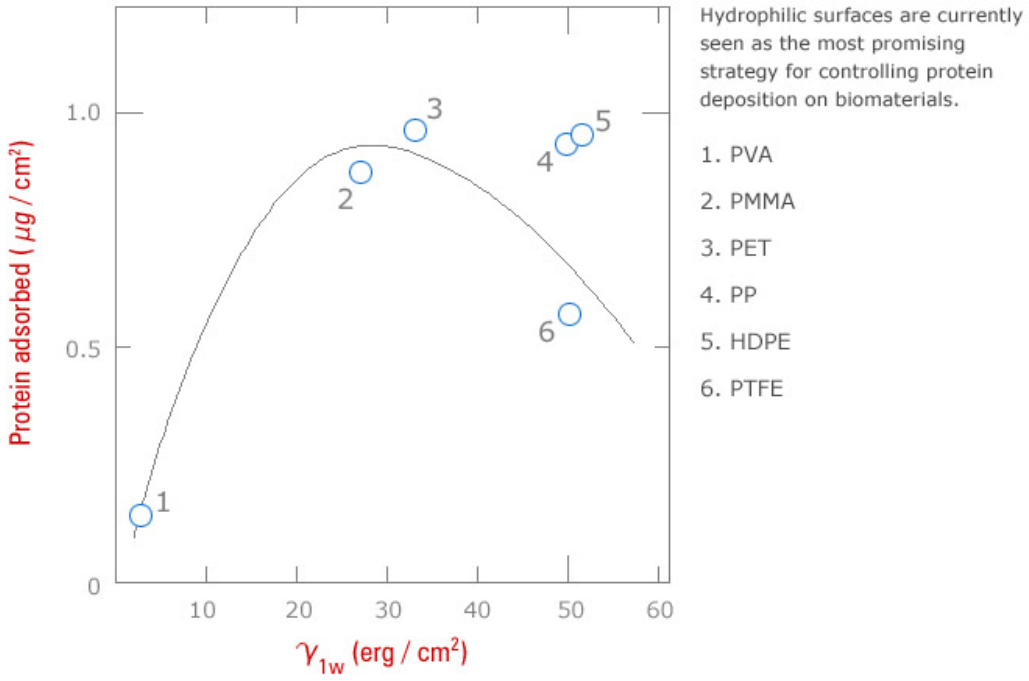
Specific objectives:

1. Clean a surface
2. **Reduce/eliminate protein adsorption**
3. **Reduce/eliminate cell adhesion**
4. **Reduce bacterial adhesion**
5. **Reduce thrombogenicity**
6. **Promote cell attachment/adhesion**
7. Alter transport properties
8. Increase lubricity
9. Increase hardness
10. Enhance corrosion/degradation resistance

Preparation of non-fouling surfaces

to prevent non-specific protein/cell or bacterial adhesion

to reduce thrombogenicity



Hydrophilic surfaces are currently seen as the most promising strategy for controlling protein deposition on biomaterials.

1. PVA
2. PMMA
3. PET
4. PP
5. HDPE
6. PTFE

(after Y. Ikada et al., *Polymers as Biomaterials*,Plenum Press, NY 1984)

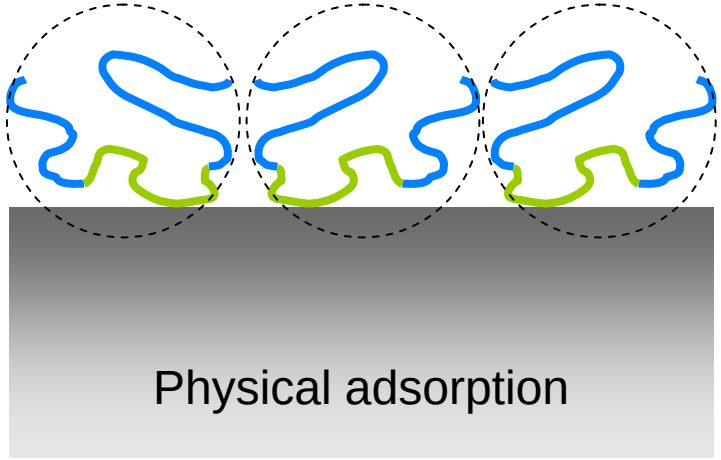
Figure by MIT OCW.

Surfaces should be hydrophilic or very hydrophobic.

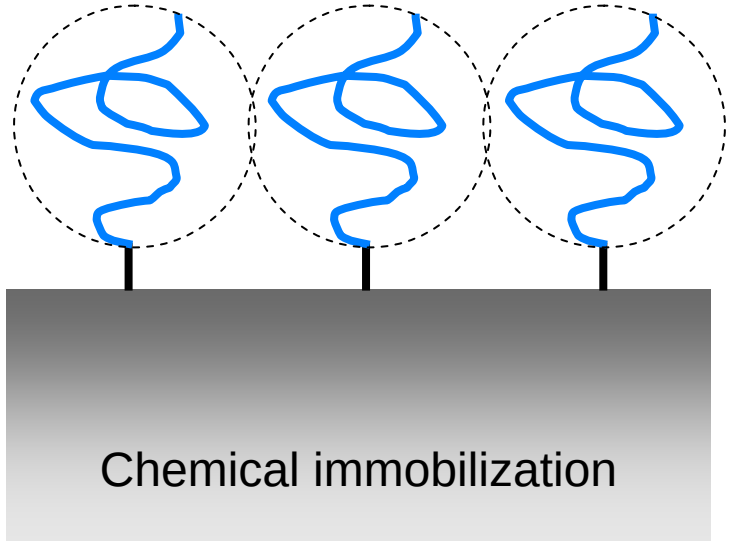
Example of “gold standard”

Surface modification with PEO derivative.

PEO-PPO-PEO, Pluronic



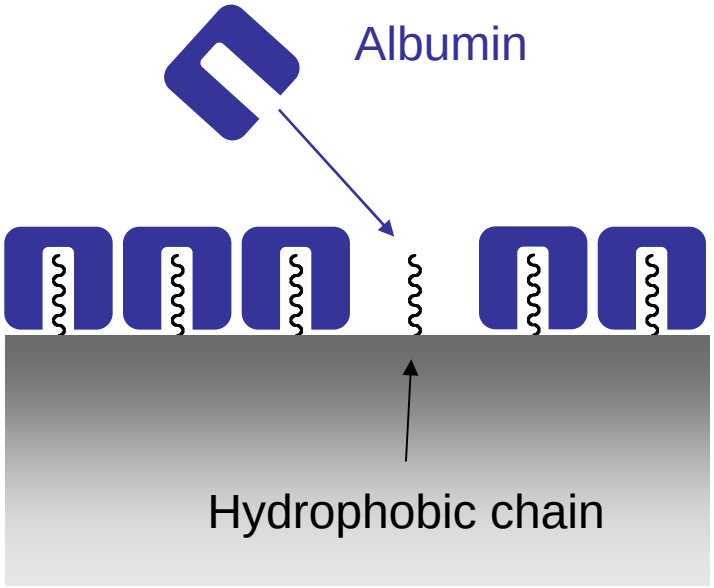
Short-time use
Ex. Drug delivery



Long-time use

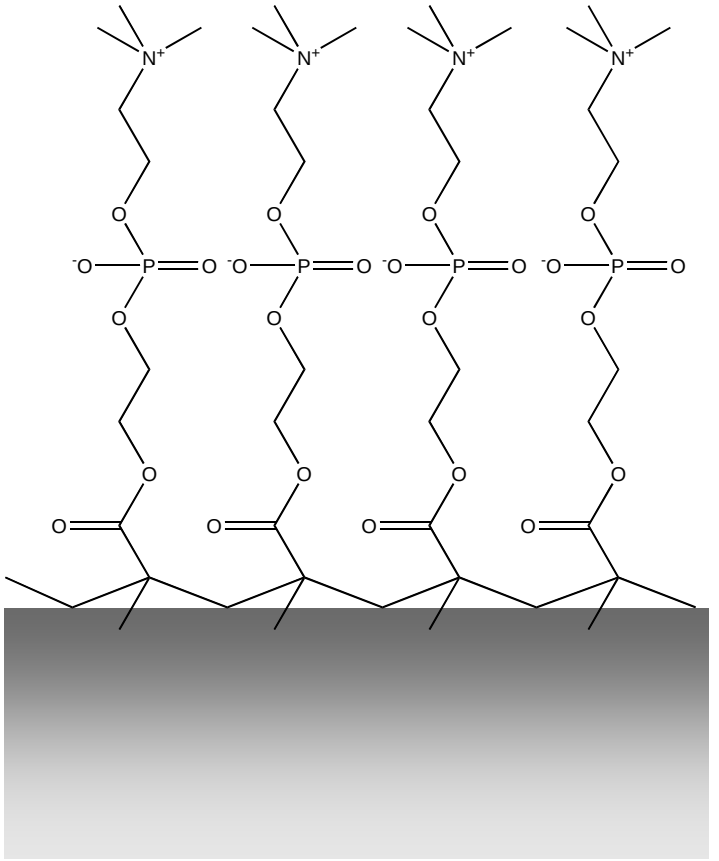
Other strategies for hydrophilic surfaces 1

Albumin coating surface



Serum albumin:
High water solubility and stability
No affinity to proteins and platelets

Phospholipid-mimicking surface

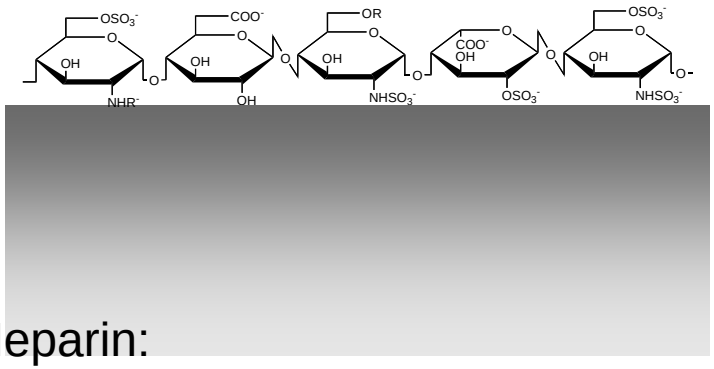


Hydrophilic phosphocholine head

Hydrophobic acylchain

Other strategies for hydrophilic surfaces 2

Heparinized surface

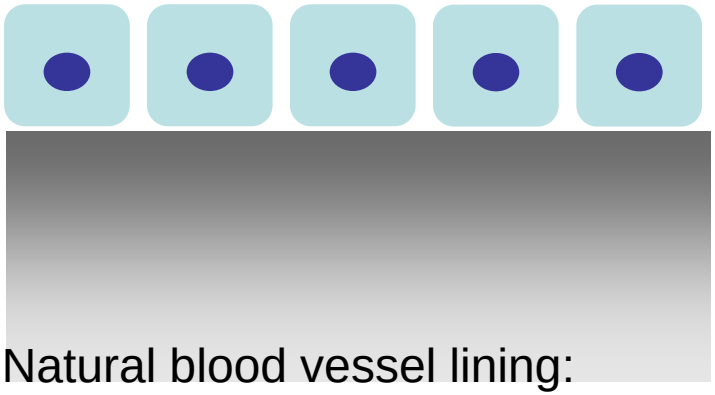


Heparin:

Immobilized covalently and ionically

Inhibitor for thrombin or platelet adhesion

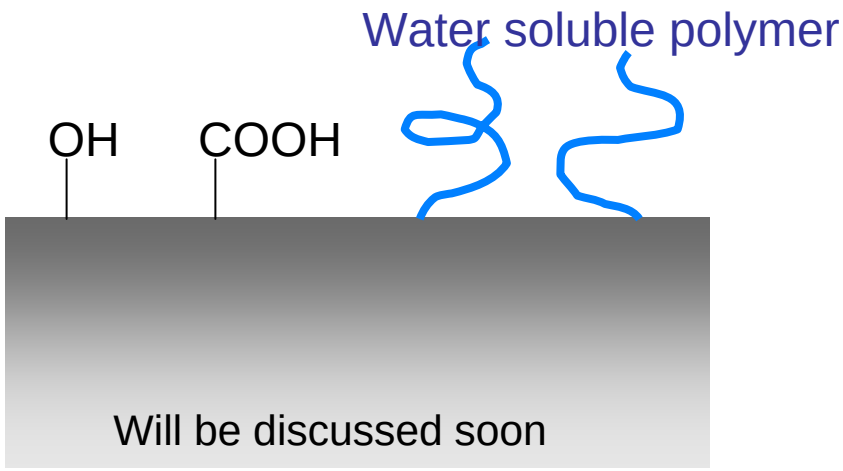
Endothelial cell attachment



Natural blood vessel lining:

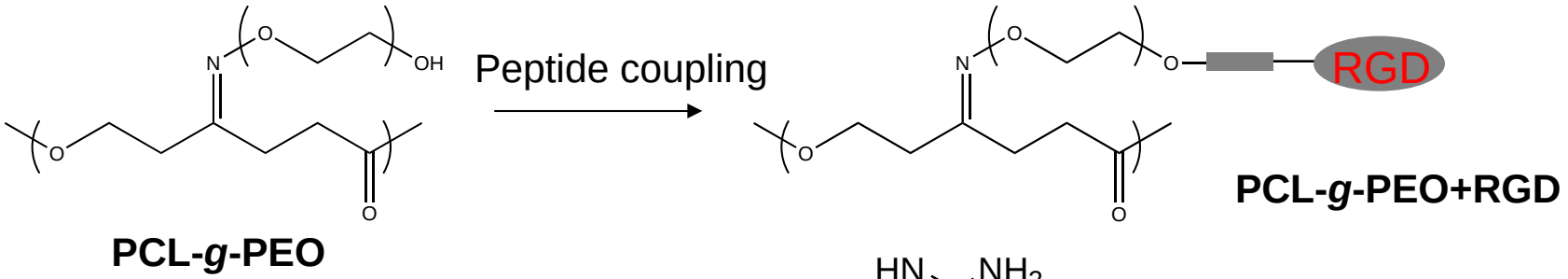
Fibrinolytic activity (hydrolysis of fibrin)

Plasma treatment



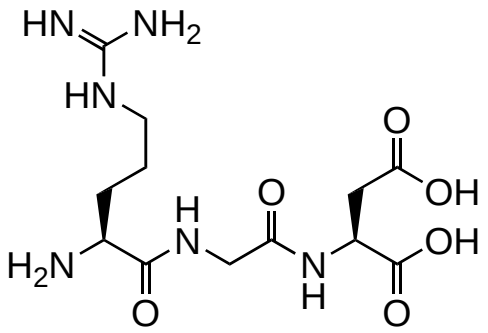
NR6 WT fibroblast adhesion triggered by RGD recognition

Photos removed for copyright reasons.



PCL-*g*-PEO

PCL-*g*-PEO+RGD



Arginine Glycine Aspartate

R **G** **D**

NR6 WT:
mice fibroblast bearing human integrin

Taniguchi, *Polym Int*. submitted

Biomolecule immobilization method for specific surfaces

Physical adsorption	van der Waals
	Electrostatic
	Affinity
	Adsorbed and cross-linked
Physical “entrapment”	Barrier system
	Hydrogel
	Dispersed system
Covalent attachment	Soluble polymer conjugate
	Solid surface
	Hydrogel

Biomolecules: proteins/peptides, saccharides, lipids, drugs, ligands, nucleic acids/nucleotides, (cells,) etc.

Chemical modification of materials

ref. Ratner, *Biomaterials Science*, p. 229

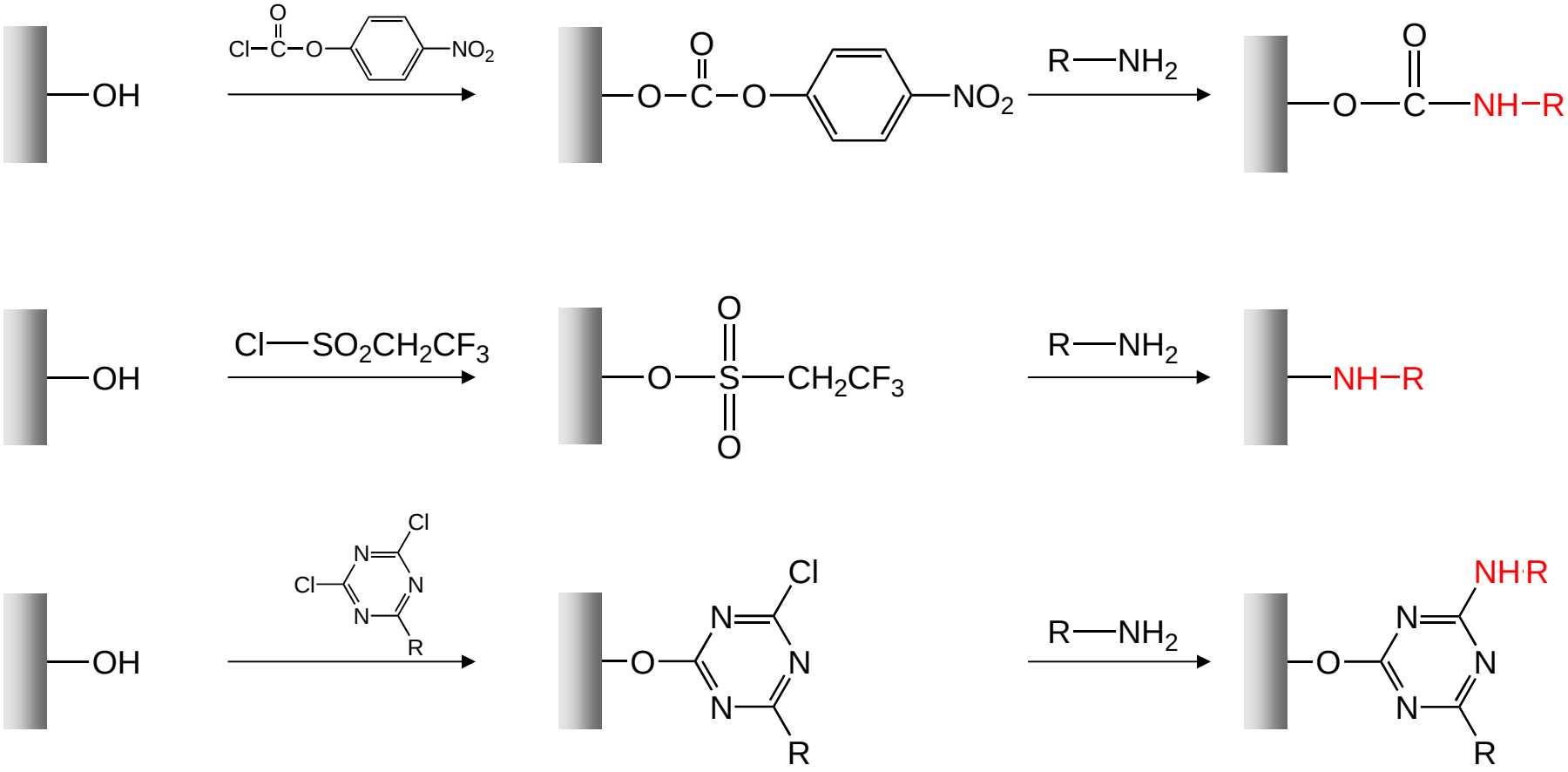
For covalent binding to an inert solid polymer surface, the surface **must first be chemically modified** to provide reactive groups for the subsequent immobilization step.

-OH	-SH
$-NH_2$	$-CH=CH_2$
-COOH	etc.

Protein/peptide immobilization strategies 1

Major reacting groups: **-NH_2**

Activation of -OH

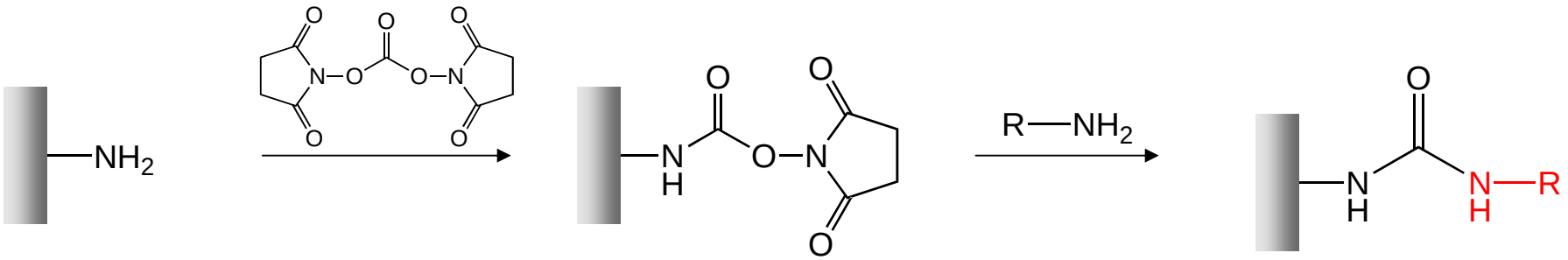


All the procedures must be carried out under anhydrous condition

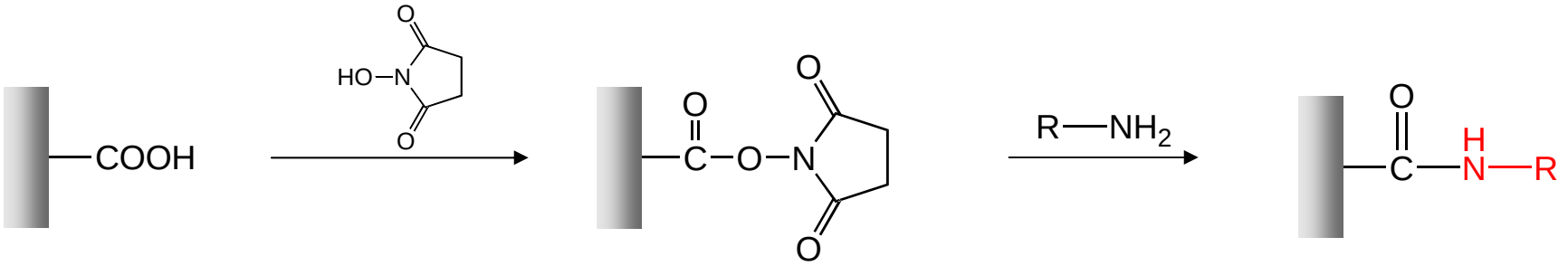
Protein/peptide immobilization strategies 2

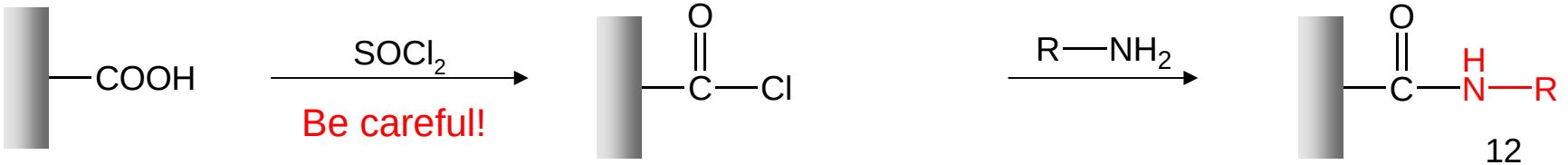
Major reacting groups: **-NH_2**

Activation of -NH_2



Activation of -COOH

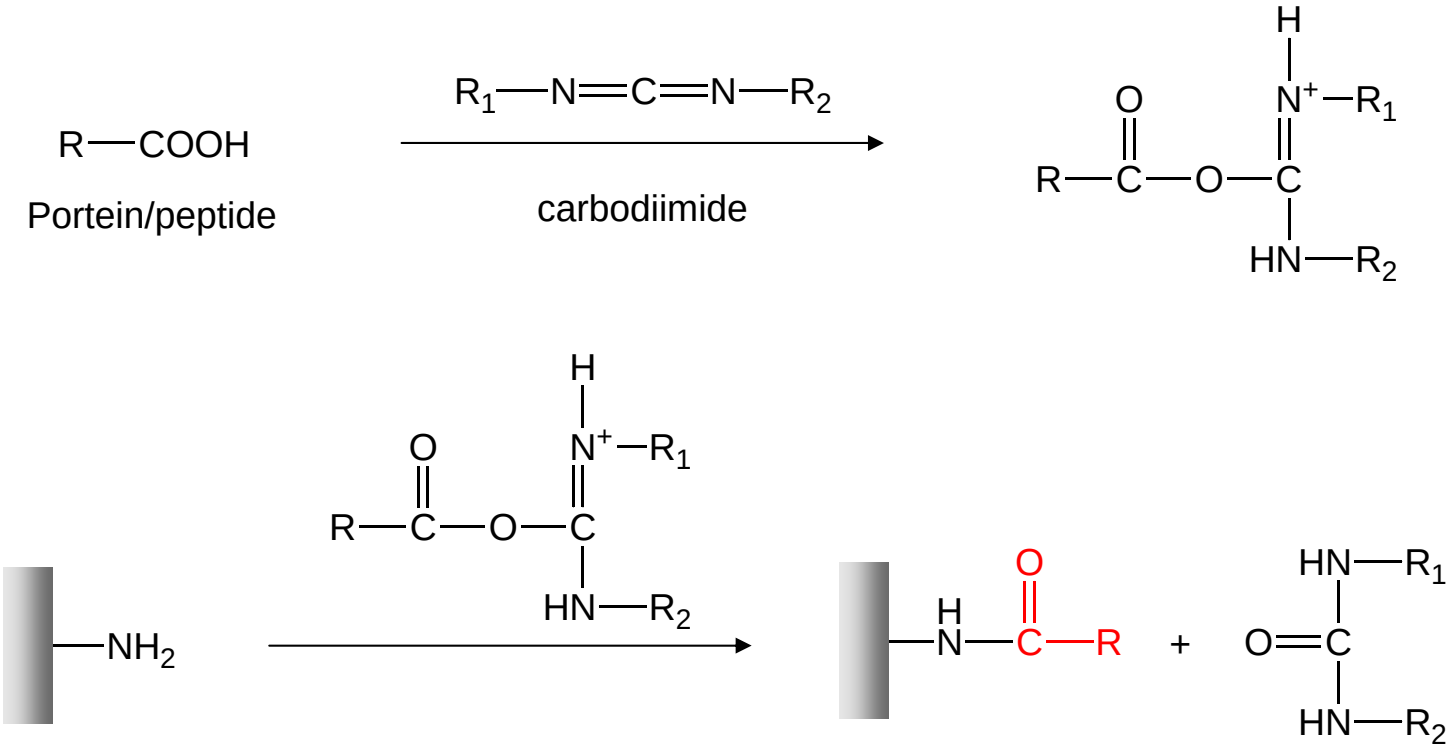




Protein/peptide immobilization strategies 3

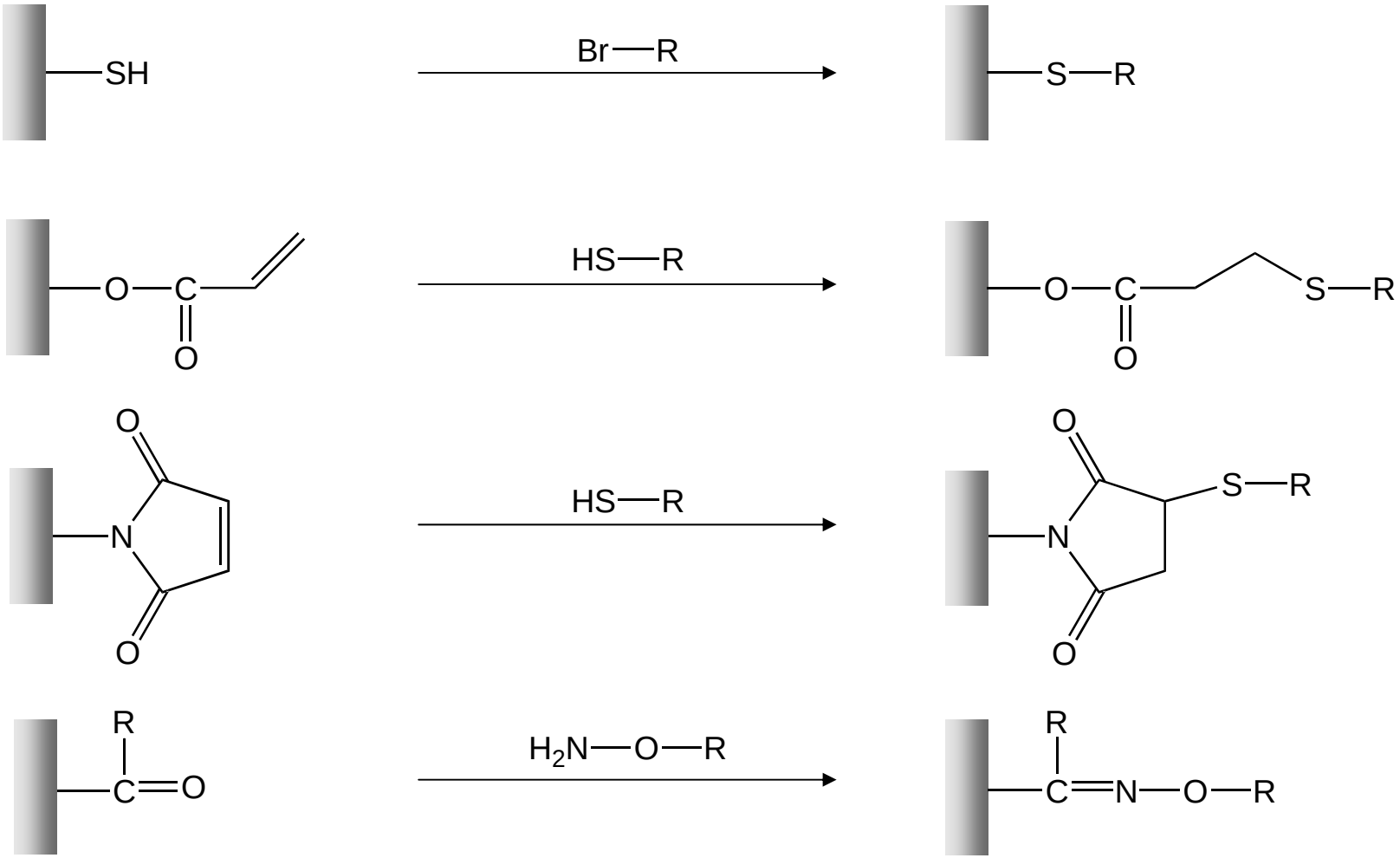
Major reacting groups: **-COOH**

Activation of -NH_2



Protein/peptide immobilization strategies 4

Chemoselective ligation

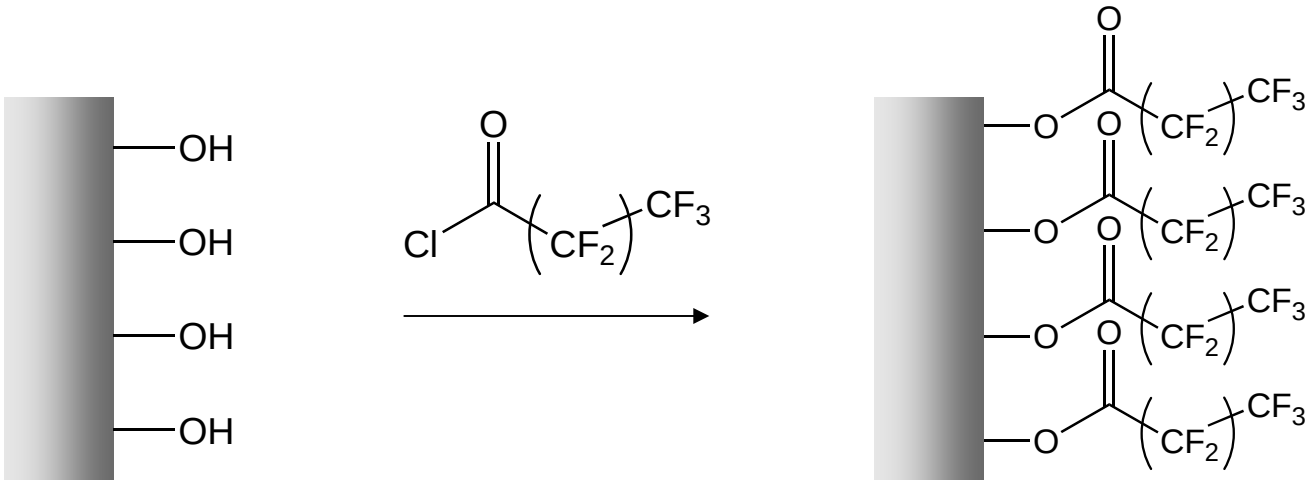


Reactions take place between selected pairs of functional groups

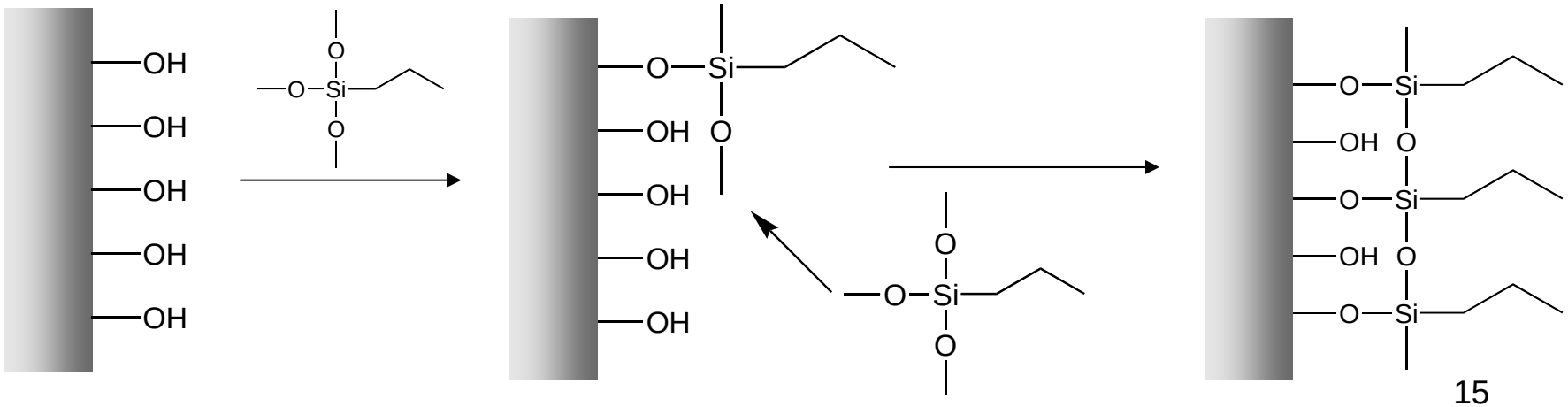
Other chemical surface modifications

Preparation of hydrophobic and inert surfaces

Fluorination



Silanization



Summary:

- Clean a surface
- Reduce/eliminate protein/cell/bacteria adsorption, reduce thrombogenicity

Non-fouling and bioinert surfaces

- Promote biological response

Immobilization of biomolecules

Short time - Physical adsorption

Long time - Covalent bonding