NACK CENTER
Building College-University Partnerships for Nanotechnology Workforce Development

Quick Overview of Top Down, and Botton up Manufacturing in Nanofabrication

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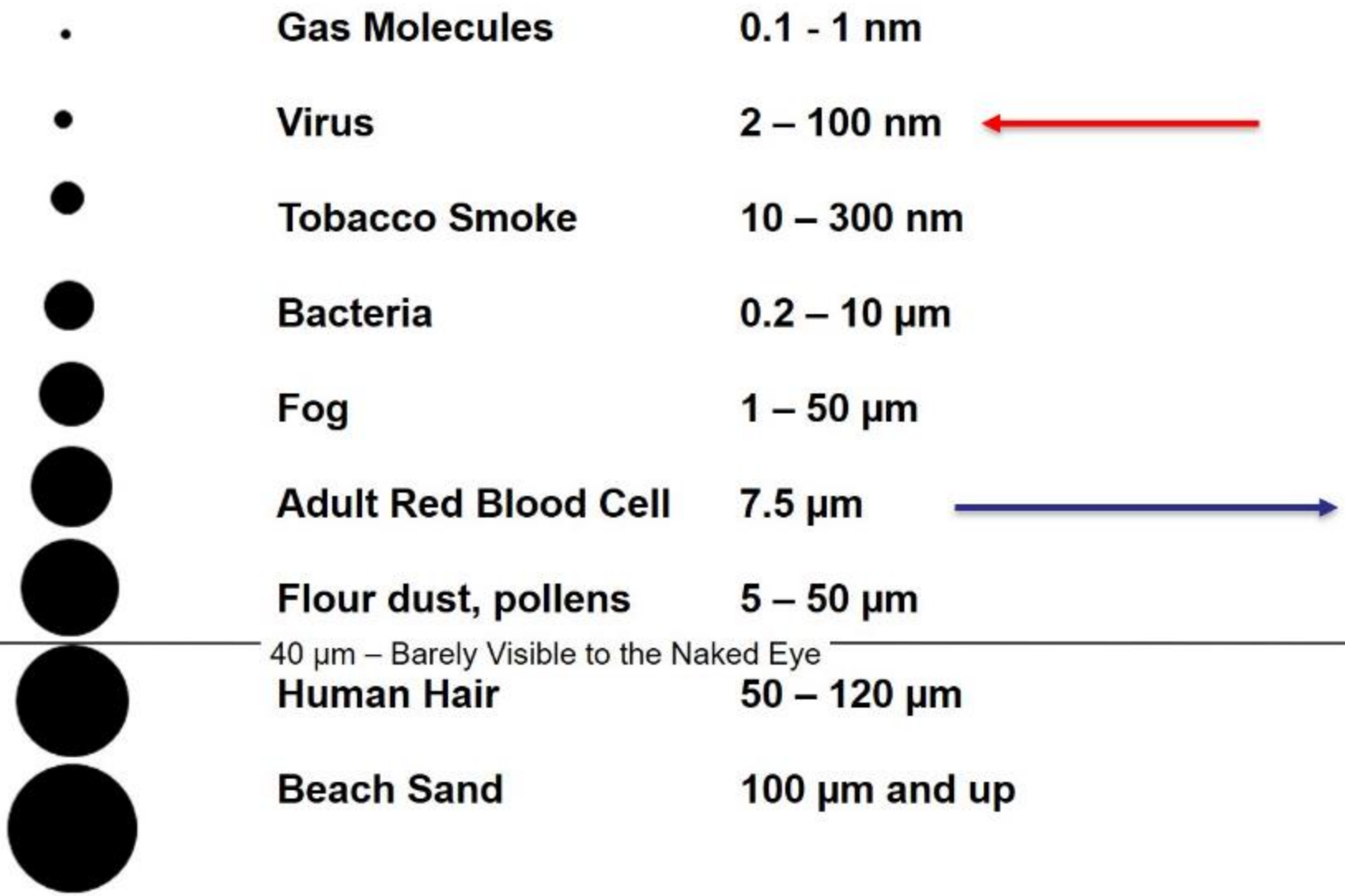
Outline

- Defining both top down and bottom up manufacturing
- An example of top down used in electronics
- An example of bottom up used in biomaterials

Nanofabrication Processing

- Makes “things” that have at least one dimension that is 100 nm or less
- These “things” vary broadly from nanoparticles for drug delivery or chemical processing catalysts to plasmon waveguides for light signal processing or transistors for microelectronics

Relative Particle Sizes



Top-Down Vs. Bottom-Up Nanofabrication

Top-Down Nanofabrication

In “top-down” nanofabrication, one grows or deposits layers of materials and, by some combination of physical and chemical methods, creates the desired nanostructure, as you would make a statue from a block of marble. Top-down nanotechnology is based on the methods that are used to make microelectronics chips; i.e., structures of carefully controlled, limited dimensions are created by laying down layers of material, modifying properties as needed, and etching away those parts of each layer that are unwanted. These steps are guided by lithography.

Bottom-Up Nanofabrication

In “bottom-up” nanofabrication approaches, one starts with small components – for example, individual molecules and nano-particles – and then assembles these components to make the desired structure. Often the assembly is self-guiding; i.e., self-assembling.

Top-down Nanofabrication is like Sculpting

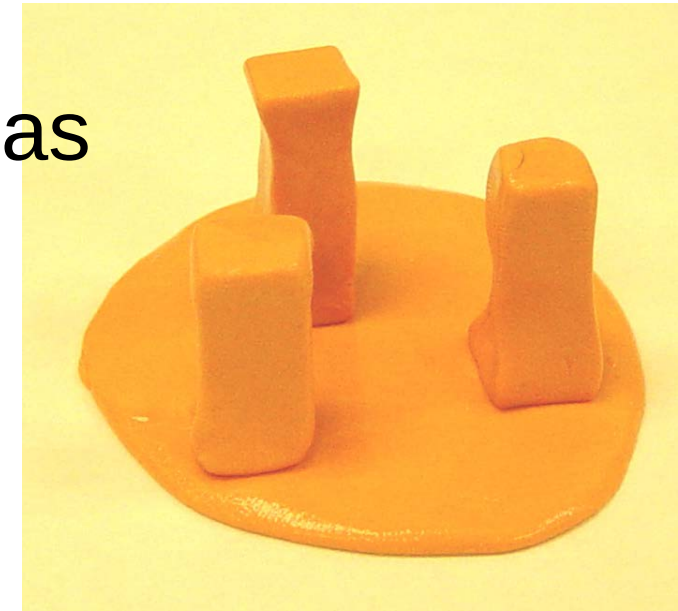
Start with a material supported on a substrate

Add some new material according to a pattern (lithography)

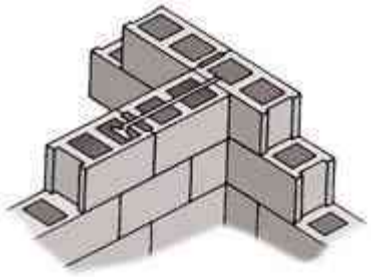
Top-down Nanofabrication is like Sculpting

Subtract some of the material according to a pattern (process order is not important; can subtract before or after adding)

Repeat the adding/subtracting as needed following the pattern



Bottom-up nanofabrication is like putting blocks together



The building blocks can go together in some inherent pattern dictated by shape, bonding, etc (self-assembly) or they can go together randomly

The building blocks can be atoms, molecules, or nanoparticles

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Top-down nanofabrication

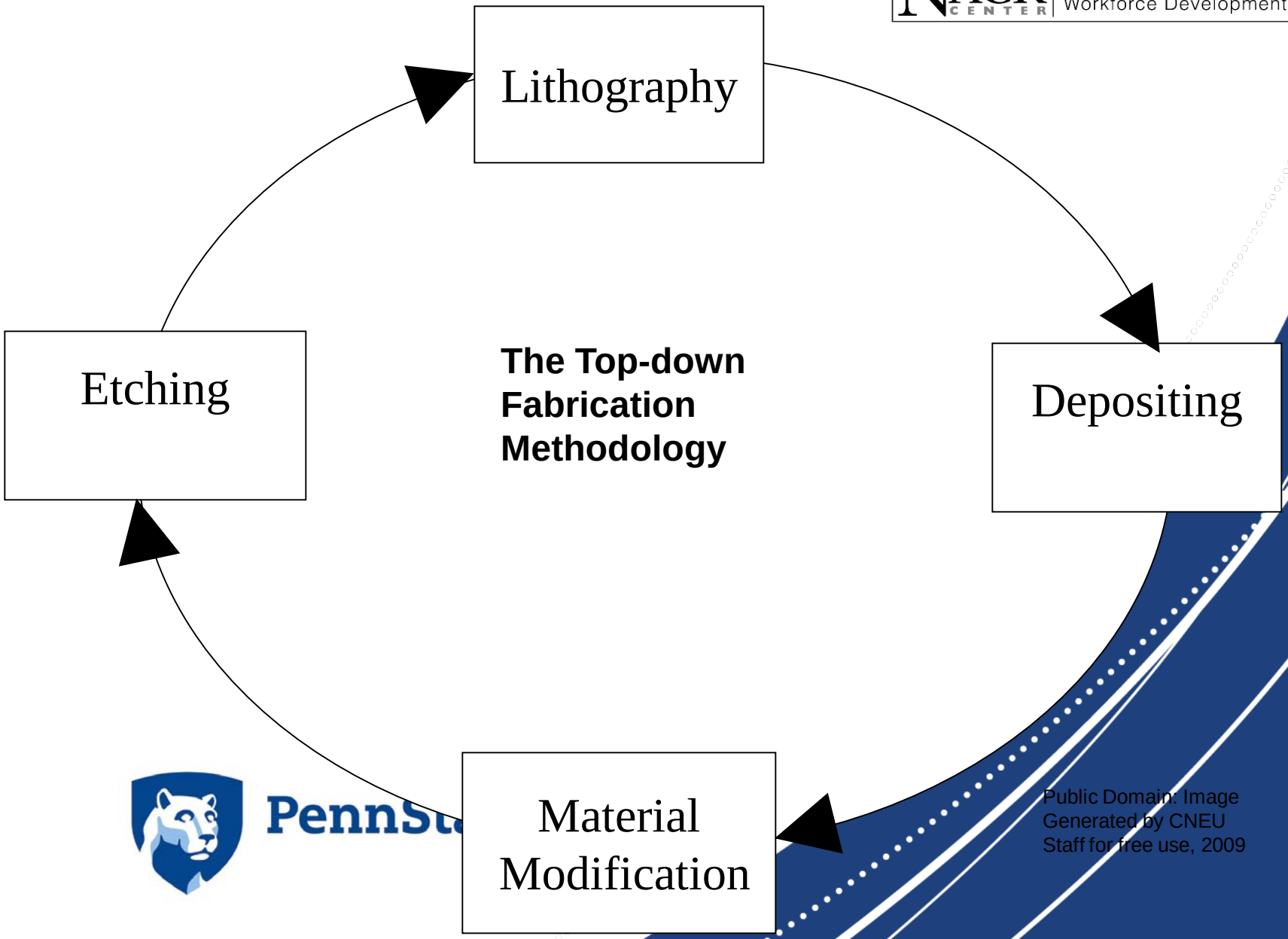
- **Top-down nanofabrication uses some combination of the following basic processes**
- Lithography (Pattern transfer)
- Deposition (Addition process)
- Etching (Subtraction process)
- Materials Modification (Property tailoring)

Top-down nanofabrication always uses some combination of the following processes

- Lithography (Pattern transfer)
- Deposition (Addition process)
- Etching (Subtraction process)
- Materials Modification (Property tailoring)

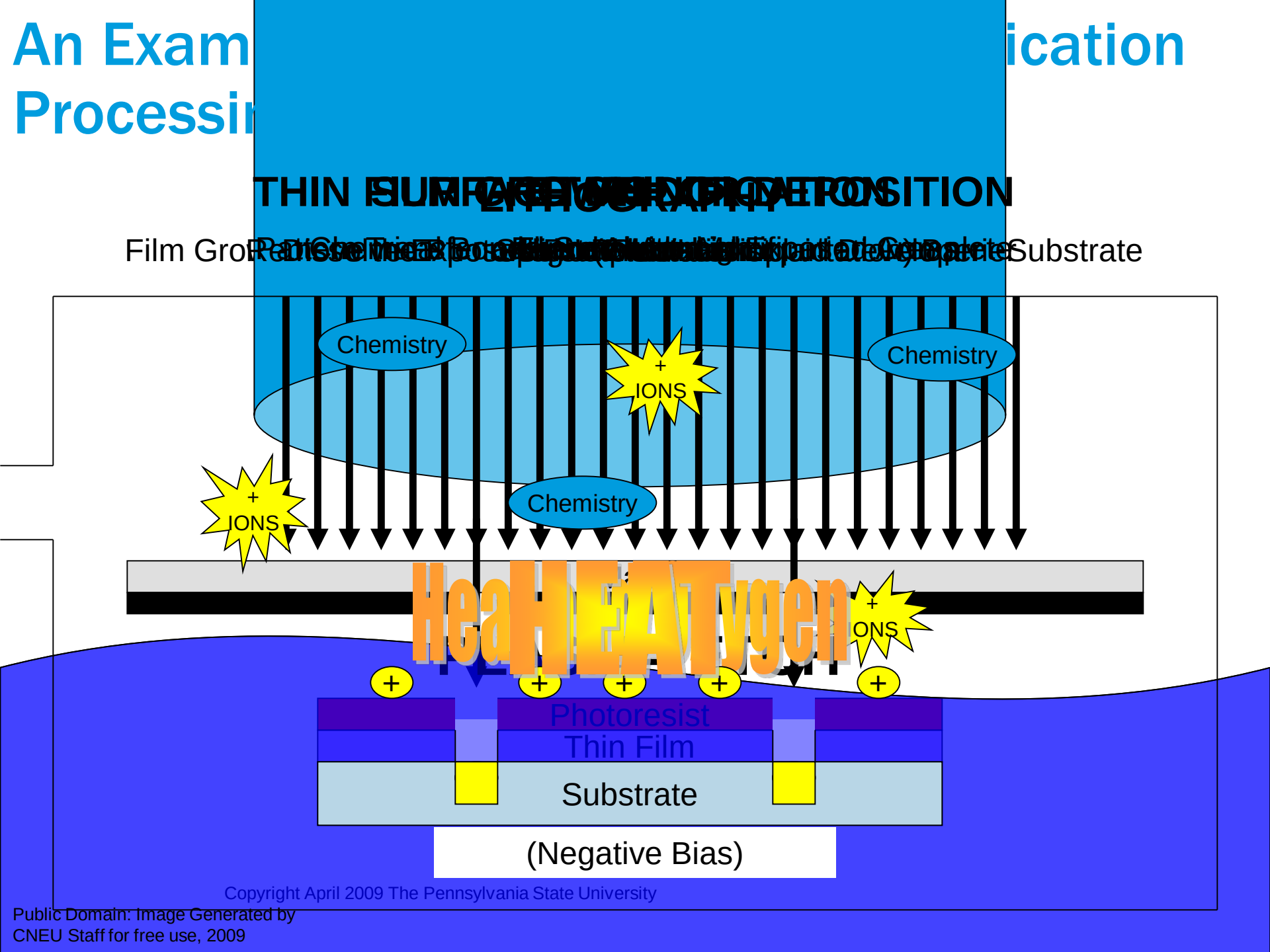
Here's the way top-down nanofabrication is done:

- The four steps (lithography, addition, subtraction, and modification) are used in some sequence.
- Steps may be skipped. You can start with any step.
- The sequence usually starts with deposition of material.
- Lithography is the step which orchestrates all the others. It controls where materials stay and where they are "sculpted" (i.e., etched) away.



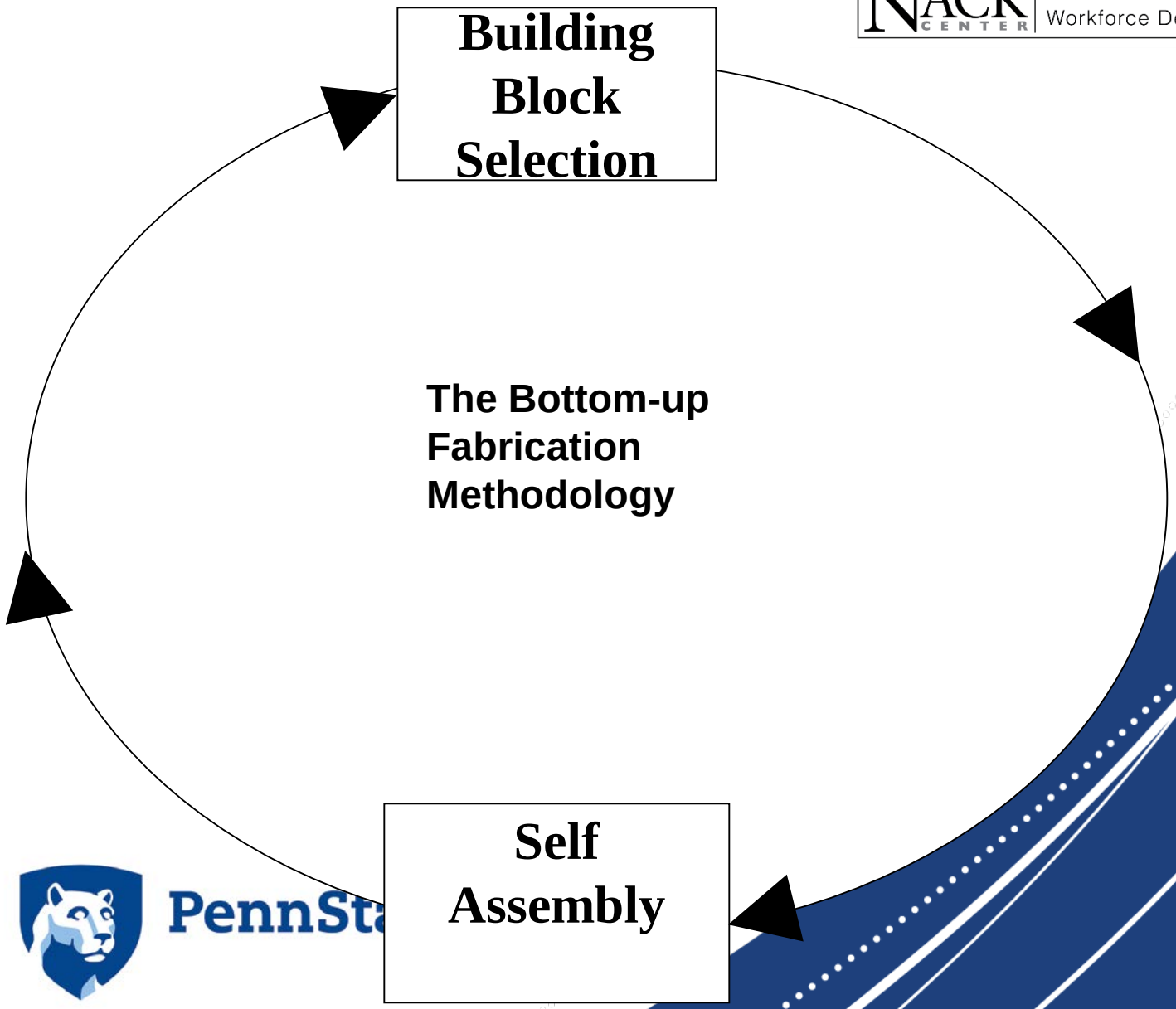
Let's see an example of how top-down nanofabrication is used to make nano-scale structures.

An Exam ication
Processi



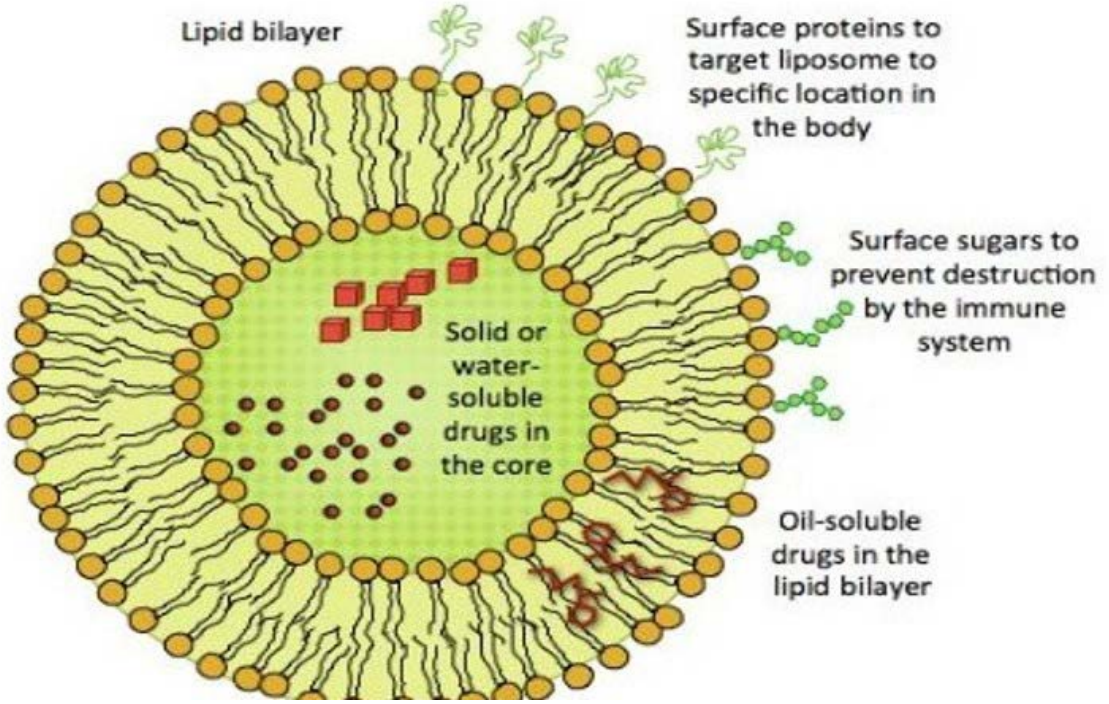
Here's the way bottom-up nanofabrication is done

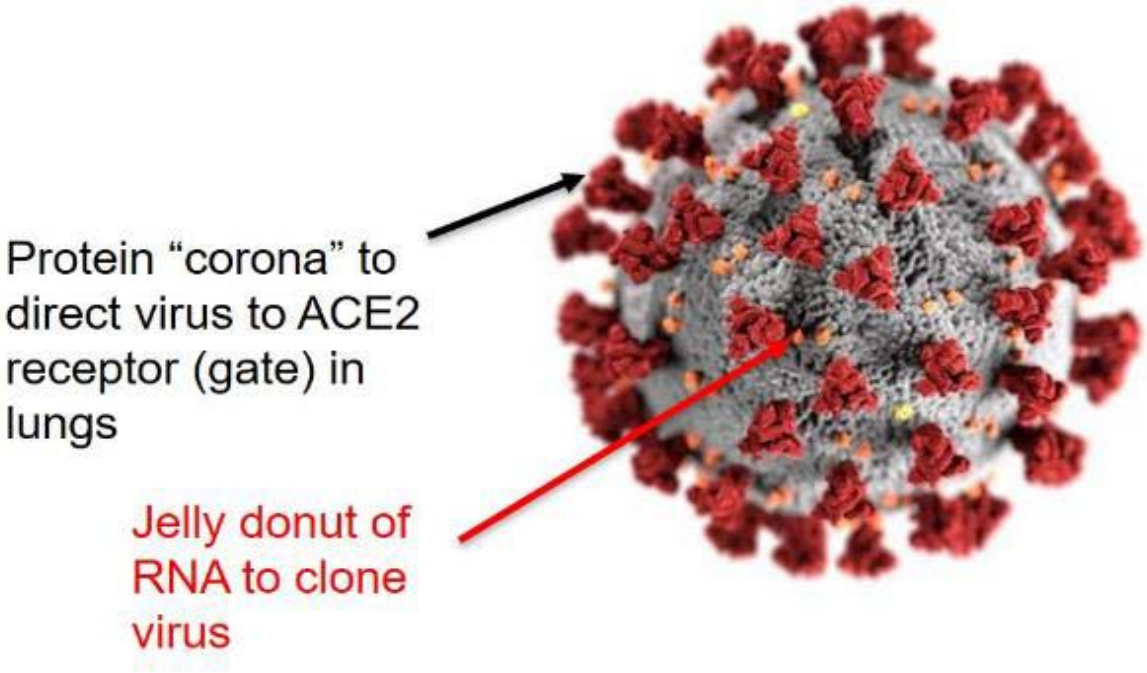
- The two steps (building block selection and self-assembly) are used in some sequence.
- Steps may be skipped.
- The sequence usually starts with building block selection.
- The pattern develops due to the size and/or shape of the building blocks.



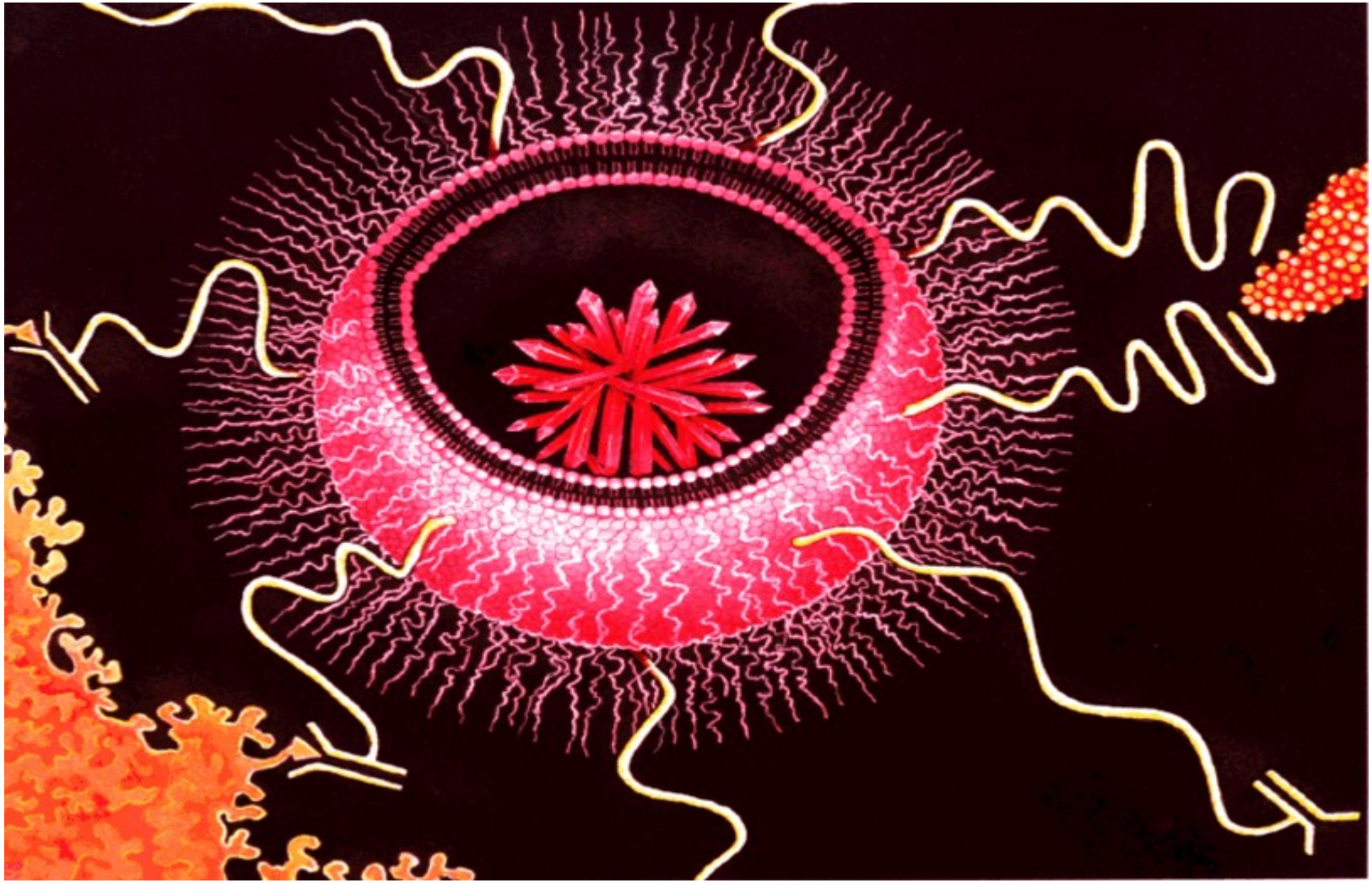
Bottom-up Nanofabrication

- People copy nature, such as the virus to make pharmaceuticals like Covid 19 vaccines or cancer treatments.
- Often a self assembled nanoparticle with and additional "smart" coating





Nanoparticles-Liposomes



www.imcr.uzh.ch

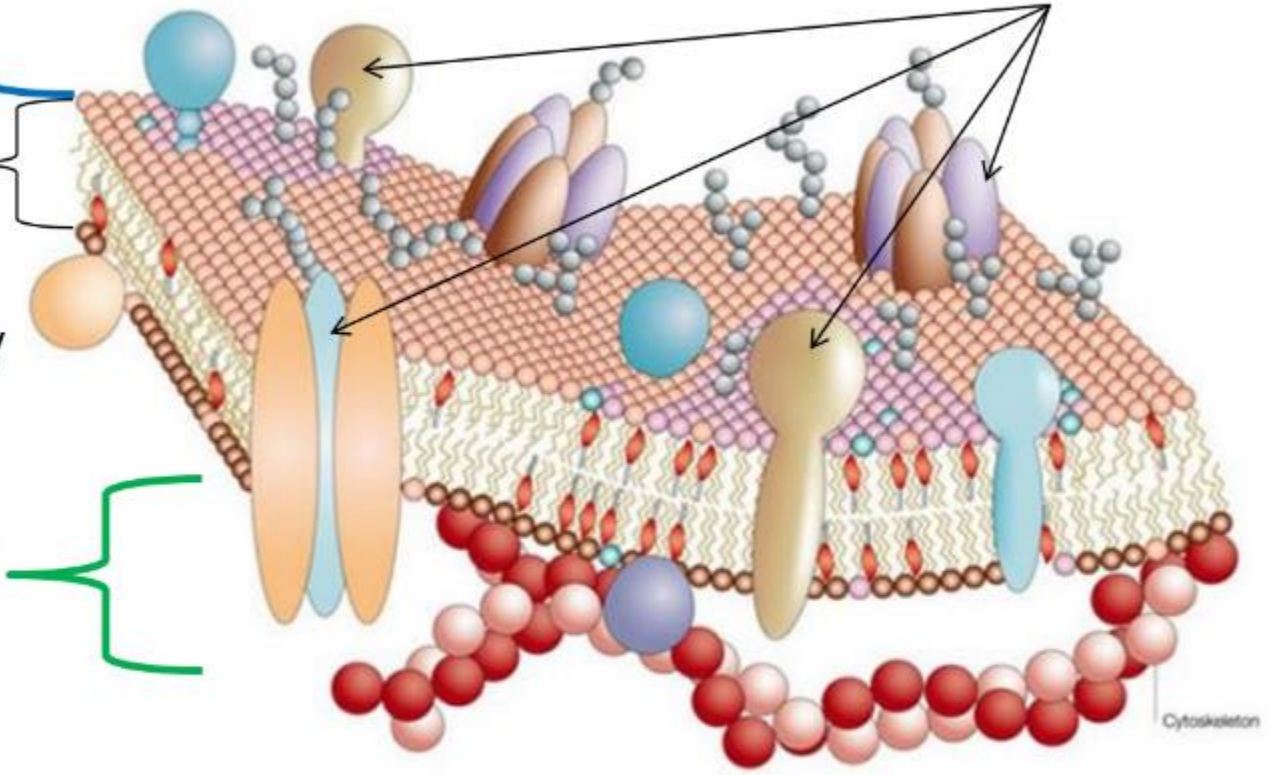
Membrane Structure/Protein Keys

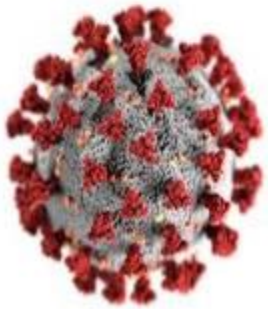
Extracellular environment

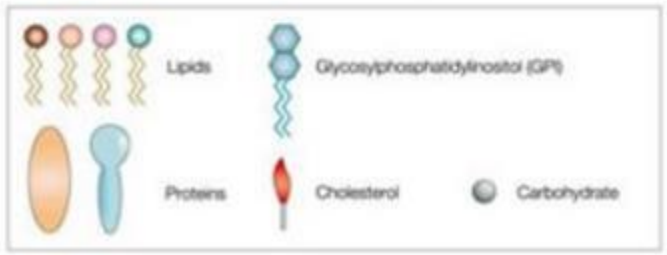
Lipid Bilayer: Excellent example of how "nature" does self assembly

Intercellular region (cytoplasm)

Protein receptors for cell communication

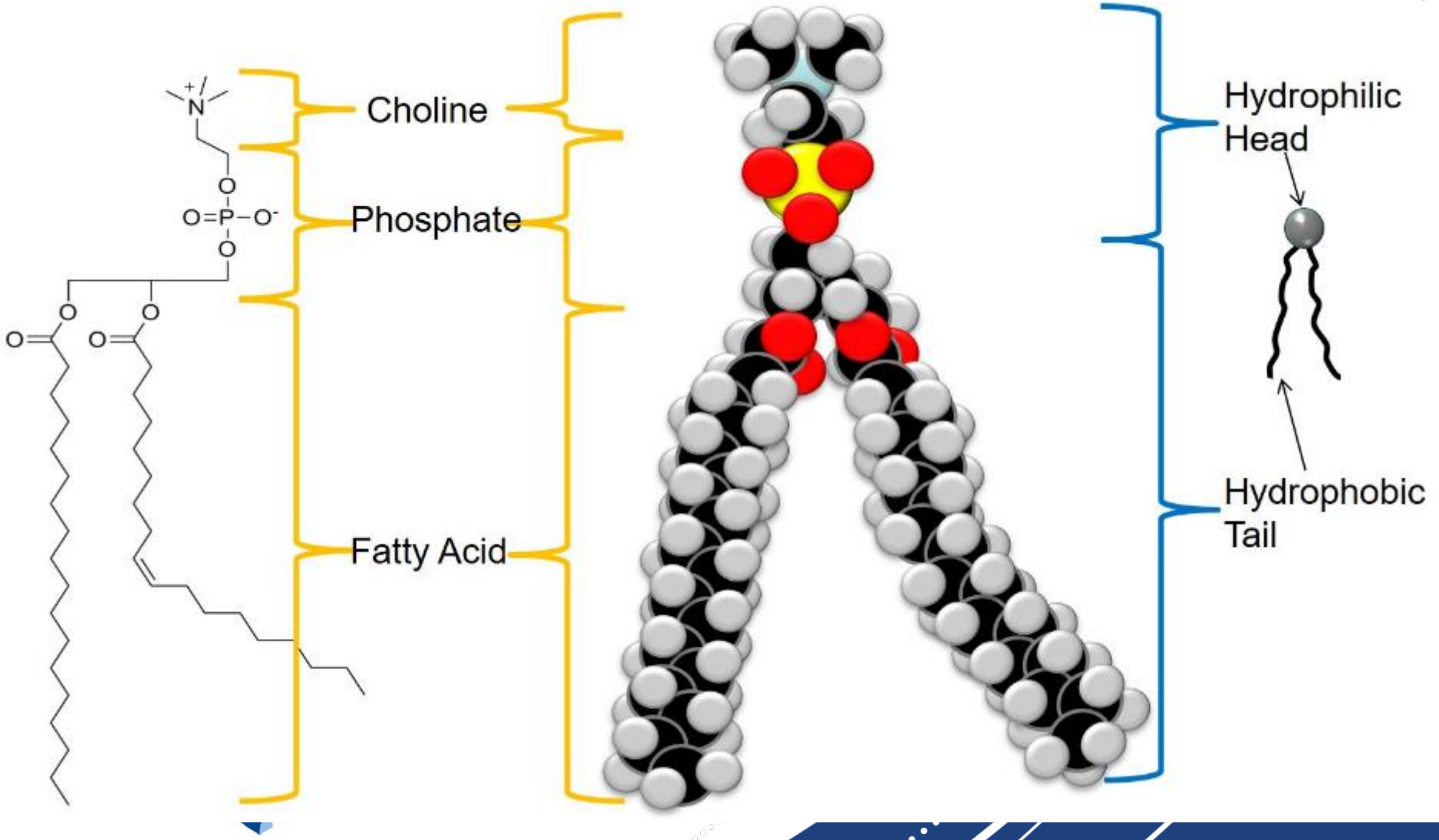






http://neutrons.ornl.gov/conf/dsm2008/registration.shtml

Phospholipid Structure



Nanoparticles-Liposomes

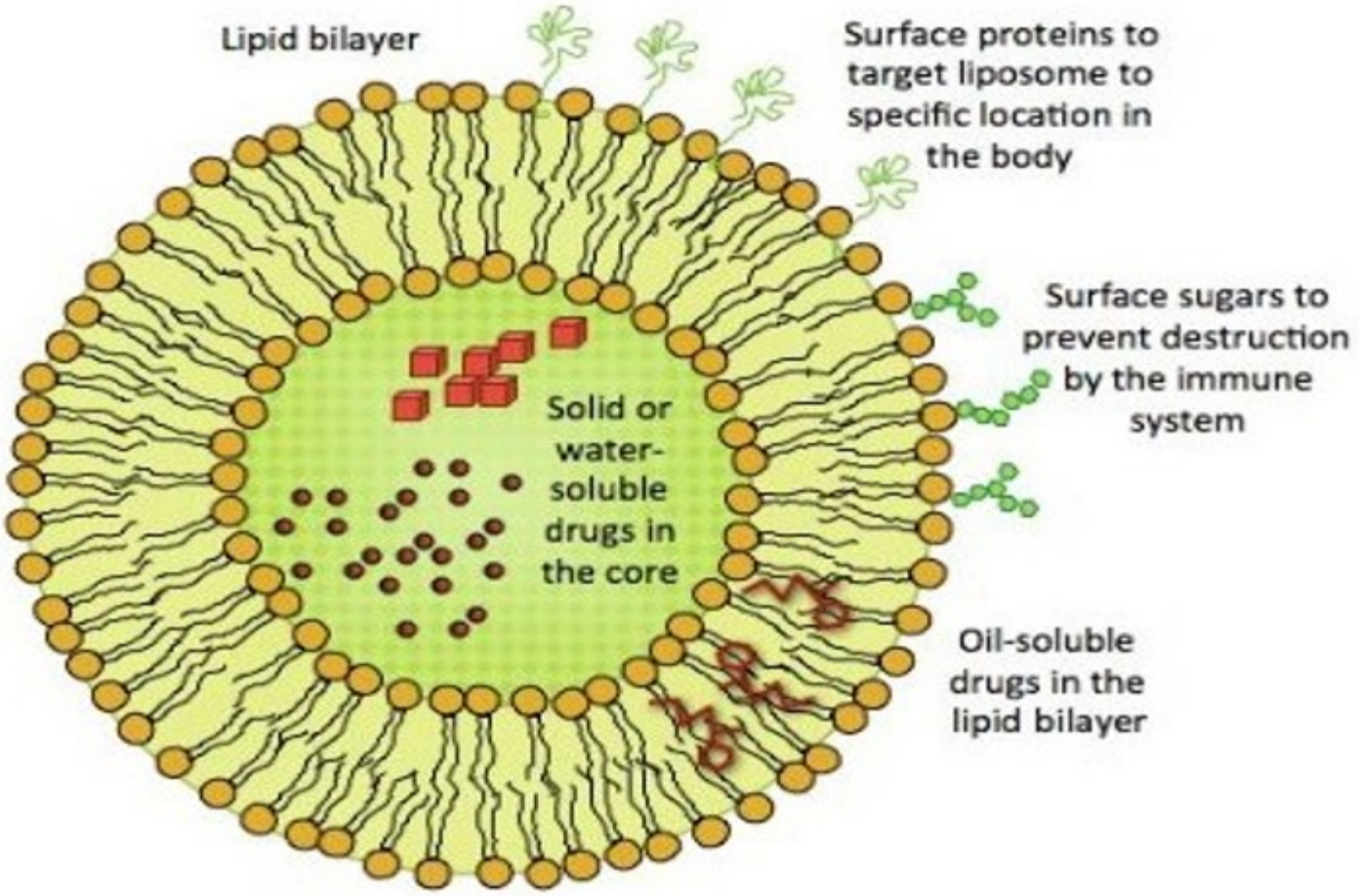
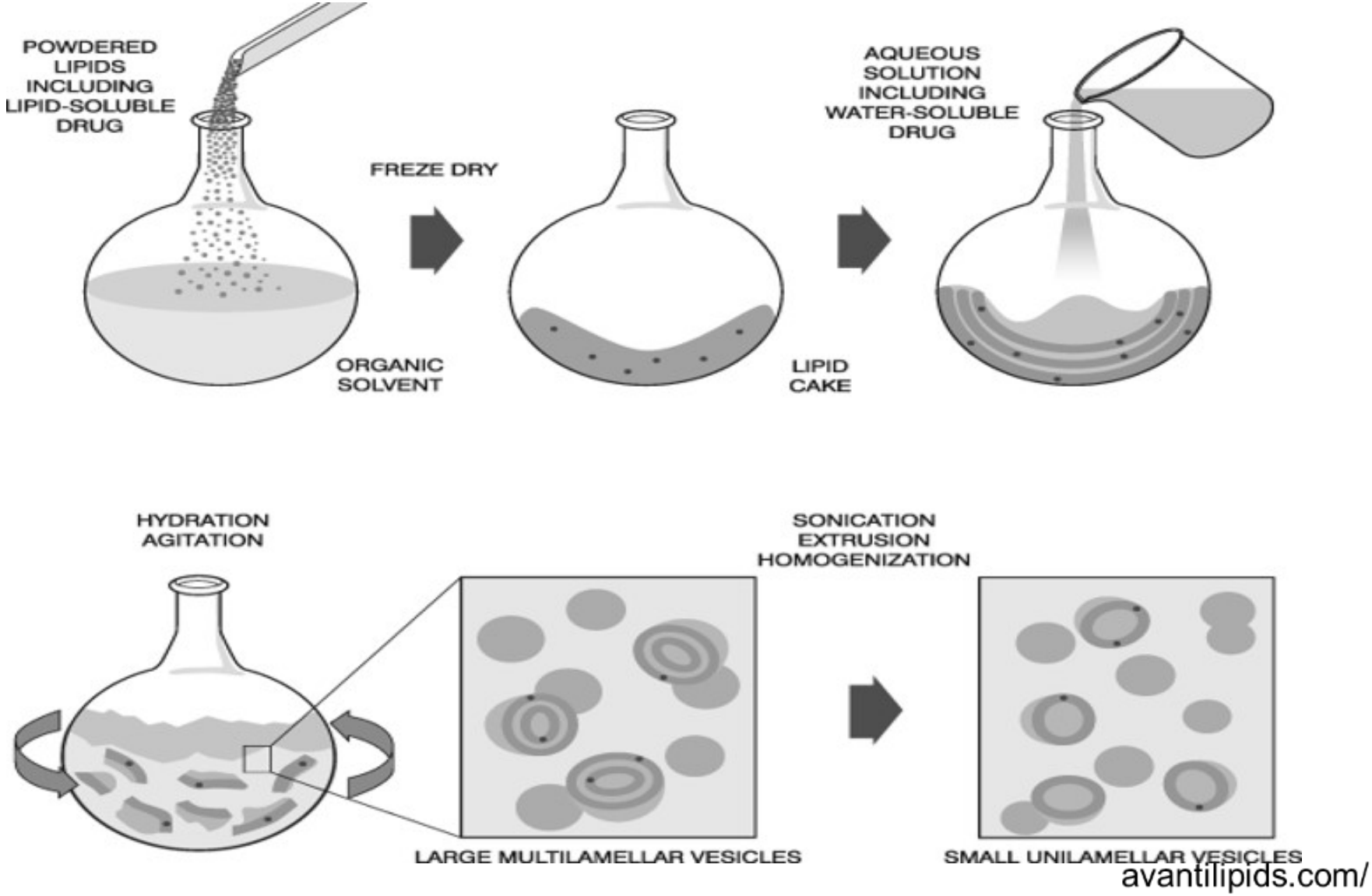


Illustration by Shannon McArdel

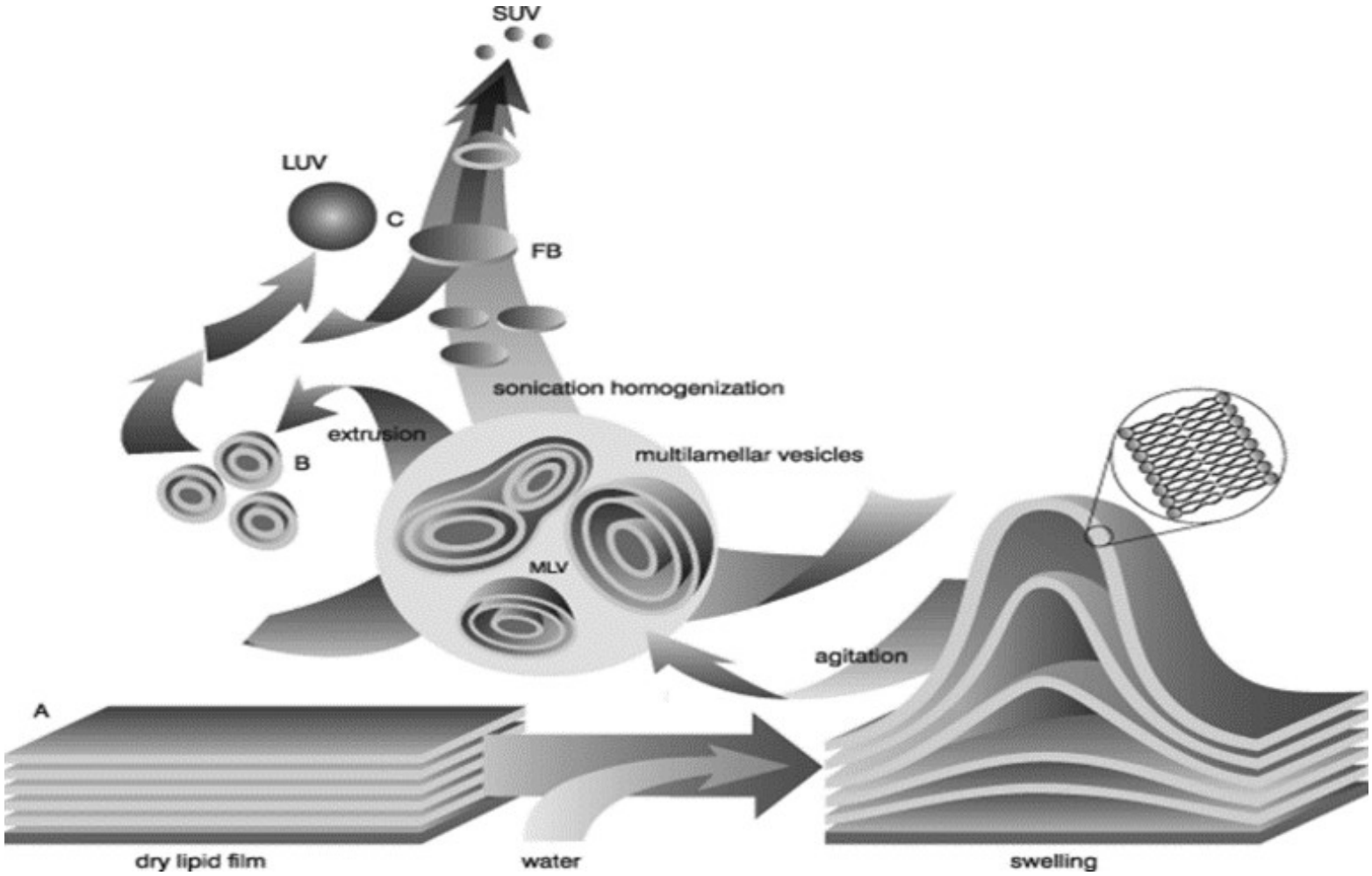
Nanoparticles-Liposomes

- Sigma-Aldrich Liposome Kit: SKU L4395-1VL, Lipid mixtures for the preparation of liposomes Lyophilized powder. 85.00 USD
- Composition: Cholesterol, 9 µmol/package, L-α-Phosphatidylcholine (egg yolk), 63 µmol/package Stearylamine, 18 µmol/package
- http://www.sigmaaldrich.com/catalog/product/sigma/l4395?lang=en&region=US
- http://www.sigmaaldrich.com/catalog/product/sigma/l4395?lang=en&region=US

Nanoparticles-Liposomes



Nanoparticles-Liposomes



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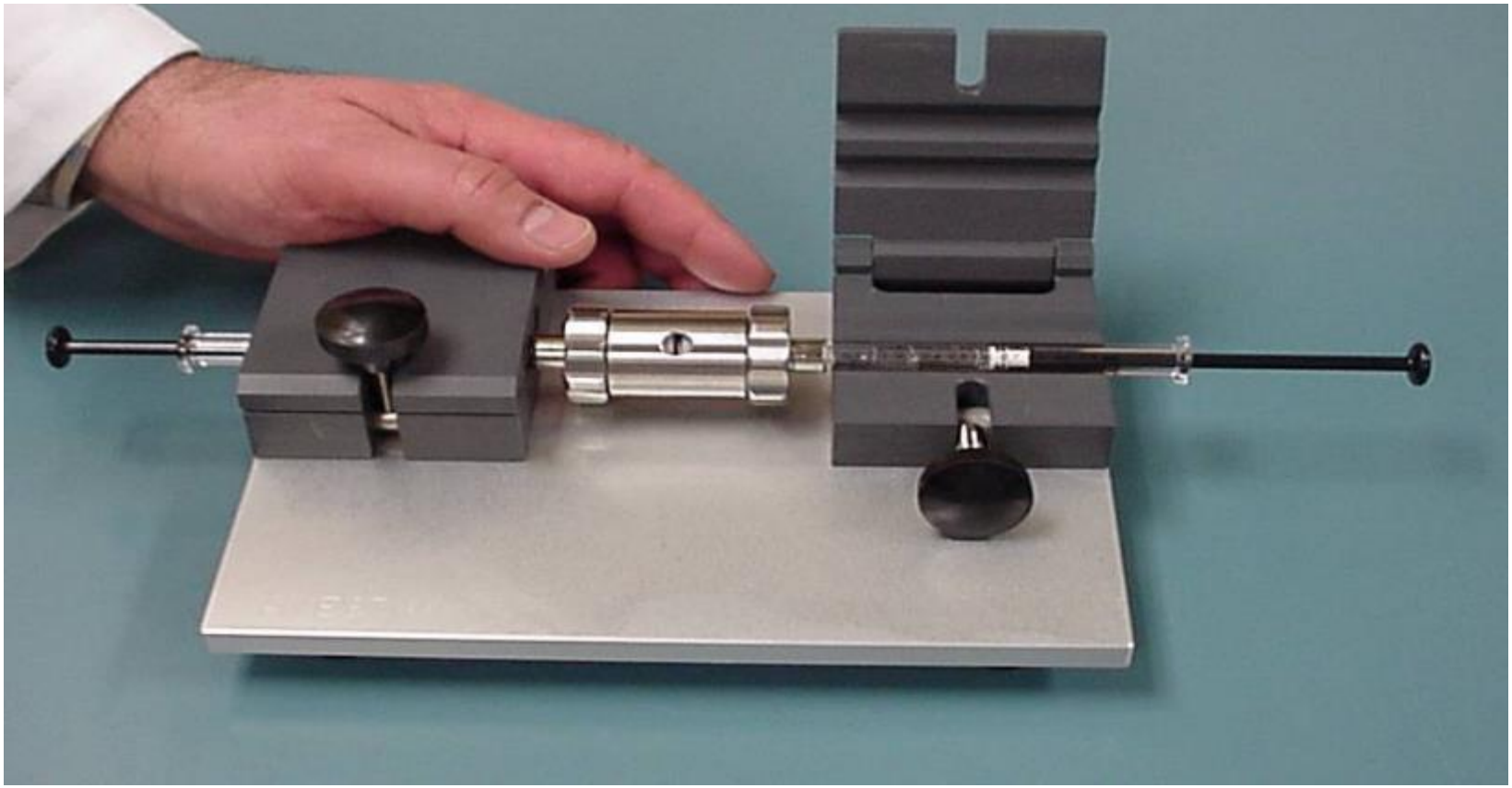
Nanoparticles-Liposomes



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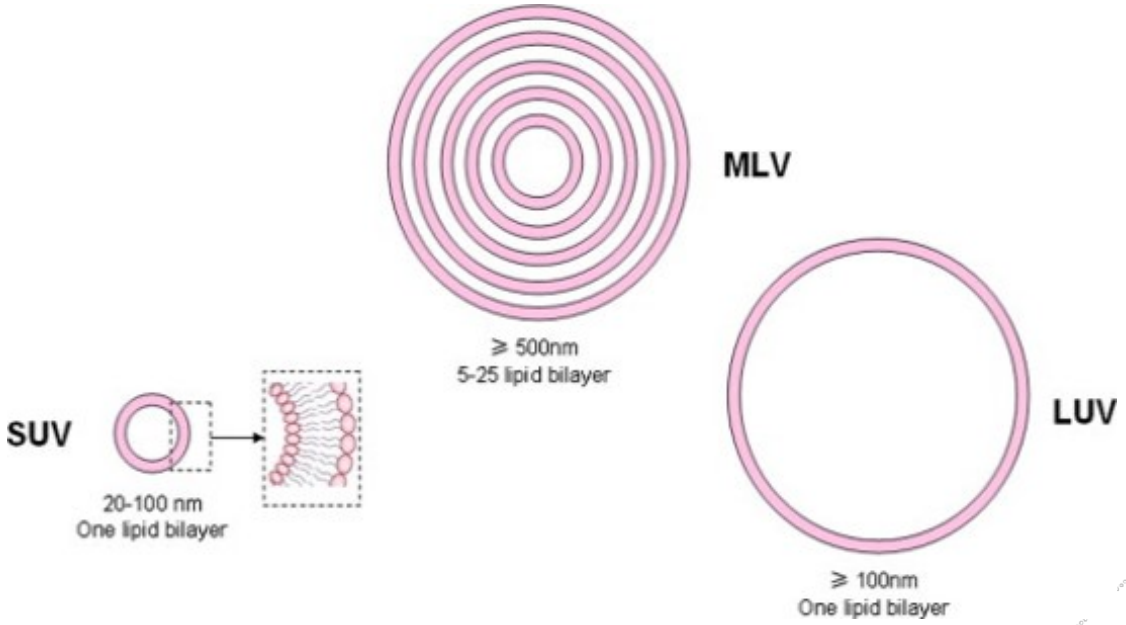
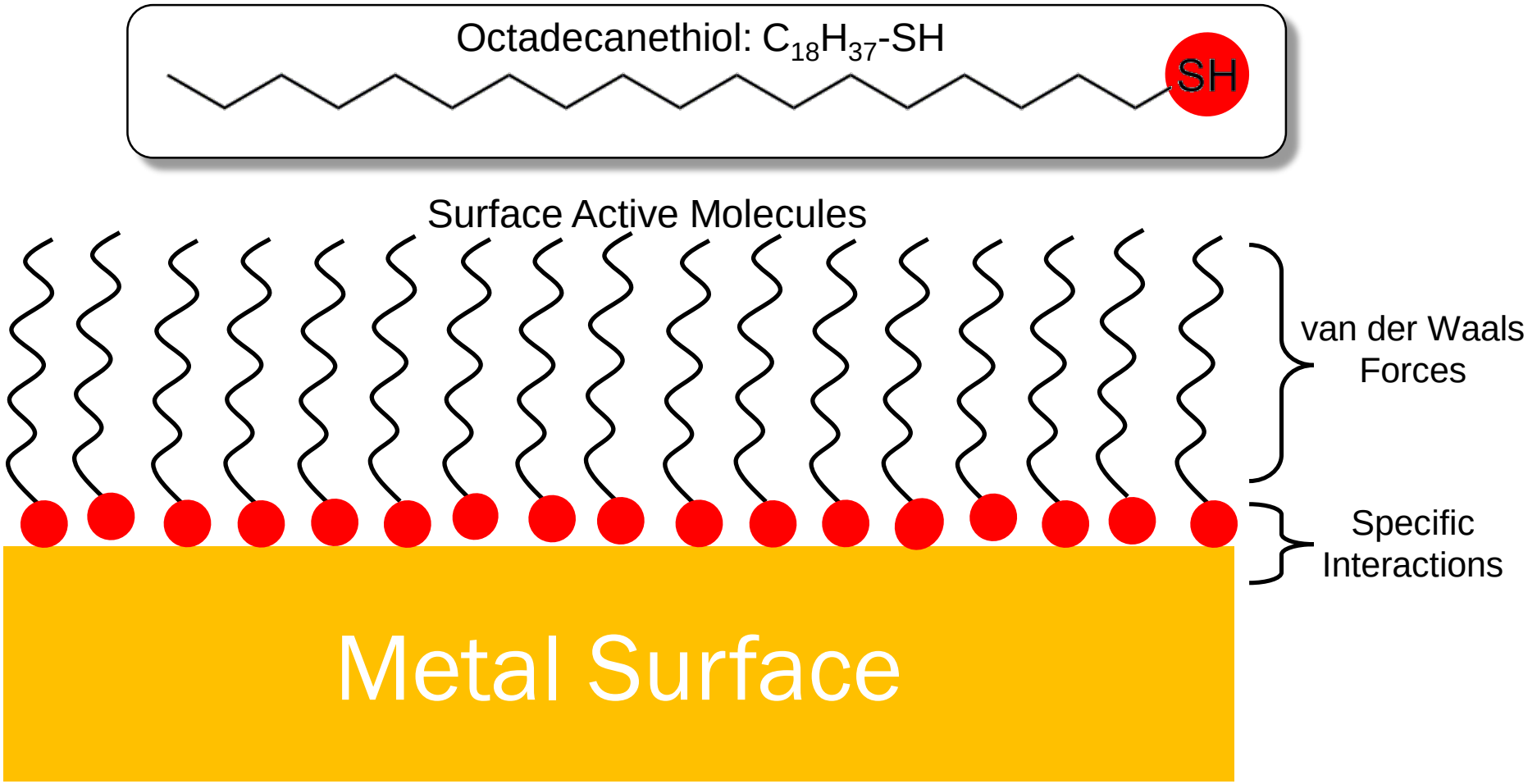
Nanoparticles-Liposomes

- Liposomes can to deliver active molecules to the site of action, less waste and potential damage to other cells
- The major types of liposomes are the multilamellar vesicle (MLV), the small unilamellar vesicle (SUV), the large unilamellar vesicle (LUV).

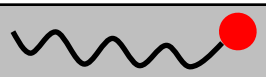


Example: Self-Assembled Monolayer (SAM)



Specific example: alkane thiols on gold. These molecules have a long greasy tail and an –SH head group. The –SH is attracted to the gold while the hydrocarbon tail is exposed to the solvent or air

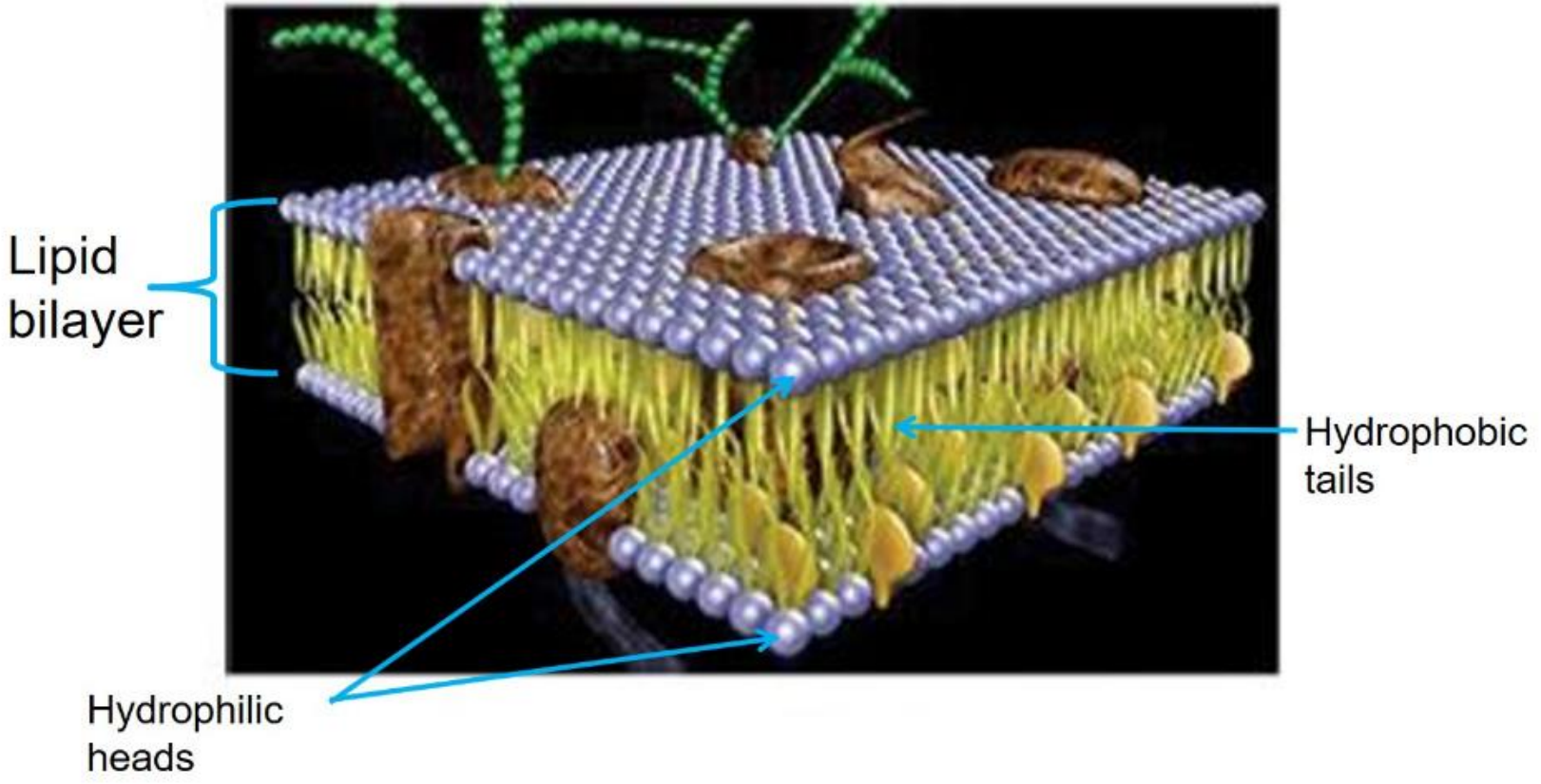
Example Ligands for Various Surfaces

✓ = Yes SAM ✗ = No SAM Surface	Alkylated Ligand 					
	Thiol R-SH	Sulfide R-S-R	Phosphine R_3P	Isonitrile R-NC	Carboxylic Acid R-COOH Phosphonic Acid $R-PO(OH)_2$	Alcohol R-OH Amine $R-NH_2$ Amide $R-CONH_2$
Cr, Ni, Fe, Al	✗	✗	✓	✓	✓	✓
Pt	✓	✗	✓	✓	✓	✓
Cu, Ag	✓	✗	✓		✓	
Au	✓	✓	✓	✓	✗	✗
Zn	✓	✗	✓	✓	✓	✓
Other Surfaces						
Metal & Silicon Oxides	✓ Silanes $R-SiCl_3$					

Adsorption generally follows "Hard-Soft-Acid-Base" rules: Carboxylic and phosphonic acids adsorb onto any metal oxide surface. Thiols and isonitriles adsorb onto soft metals (Cu, Ag, Au, Pt). However, phosphines (which are considered soft) form monolayers on many surfaces (soft or hard). This could be due to their oxidation to phosphine oxides

Pure and Applied Chemistry **1991**, *63(6),* 821-828.

Liposome/Virus can open up cellular gates



- Source: https://www.llnl.gov/str/JanFeb06/Schwegler.html

Questions?

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