Central Dogma

Replication

DNA

AIDS virus

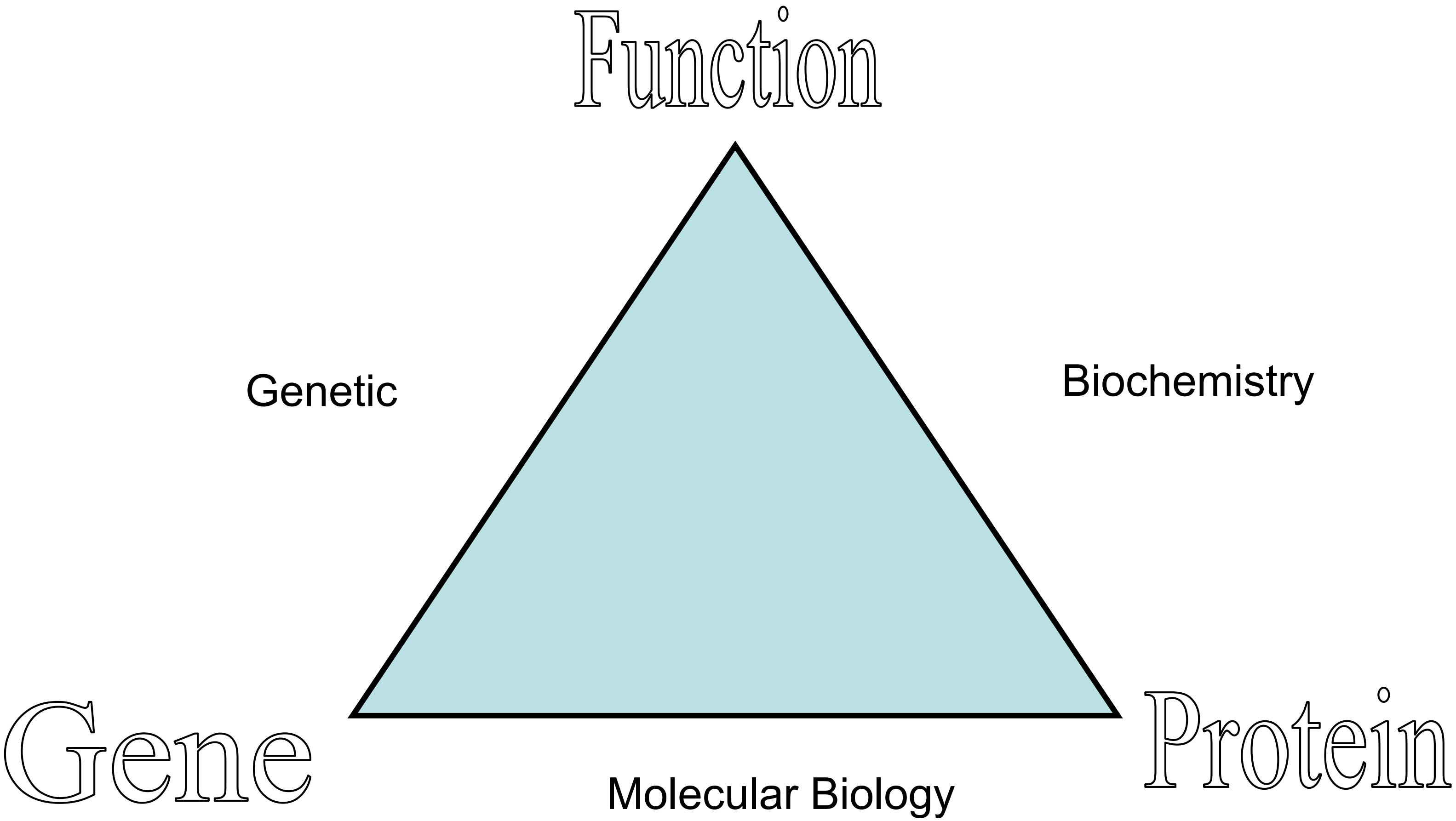
Transcription

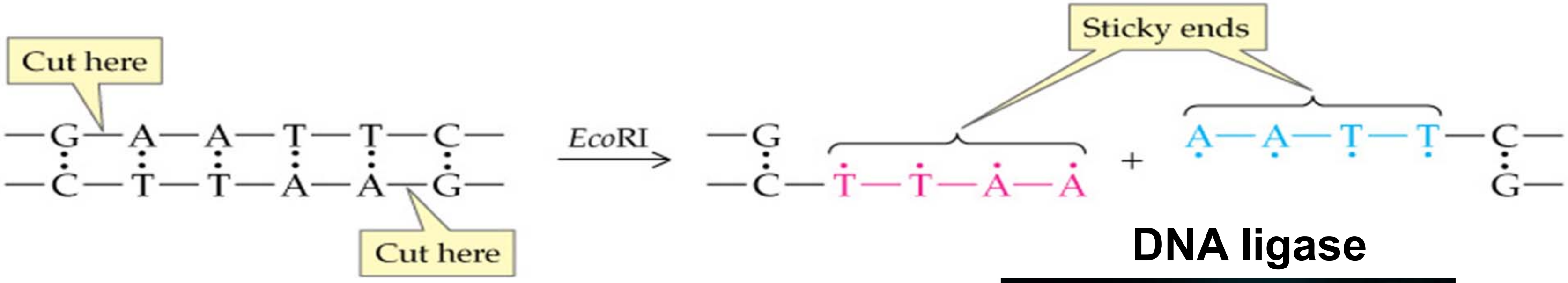
RNA

Translation

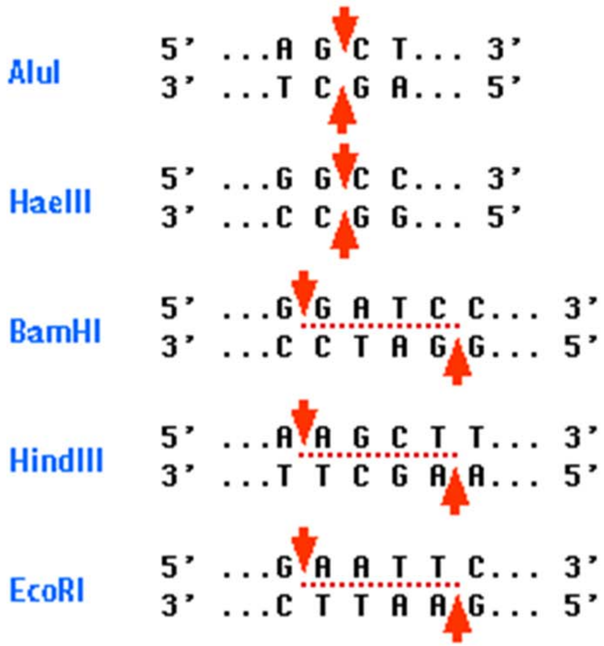
Proteins

Recombinant DNA





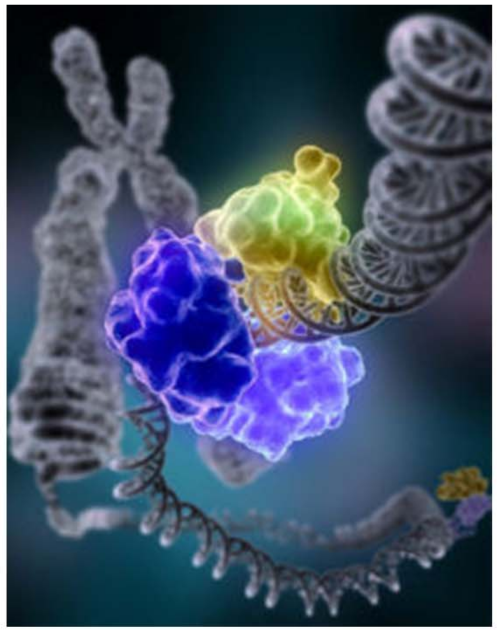
Restriction Enzyme

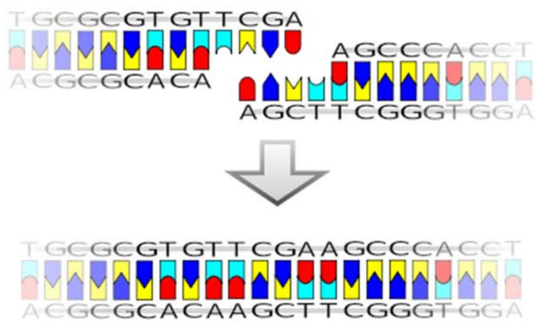


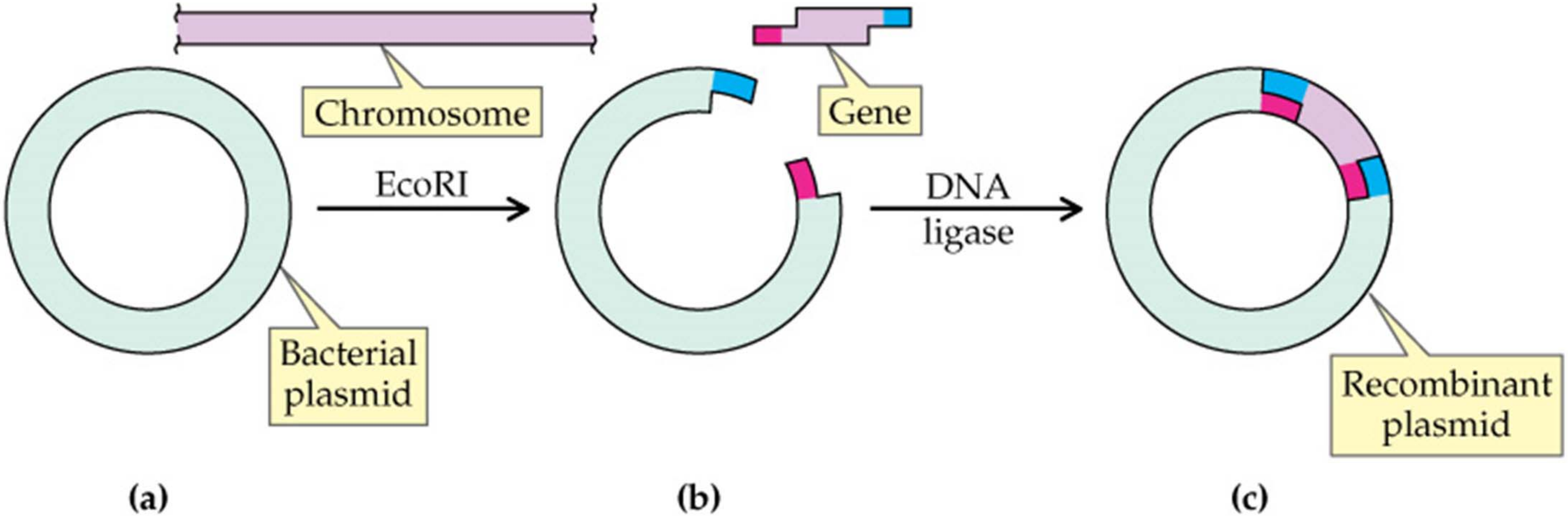
AluI and HaeIII produce blunt ends

BamHI HindIII and EcoRI produce "sticky" ends

DNA ligase

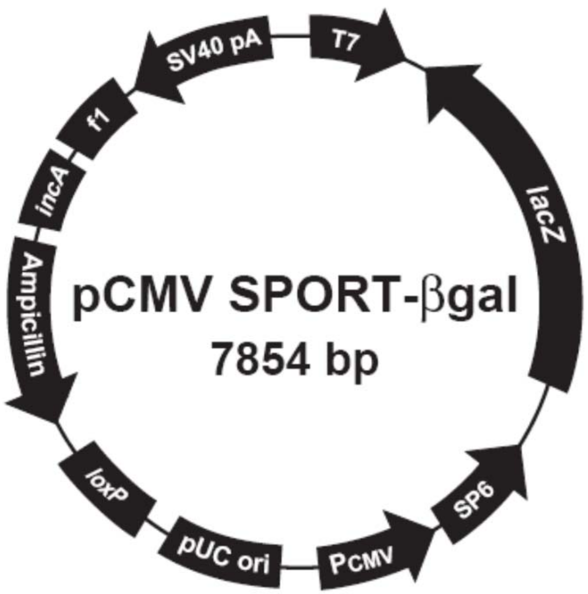


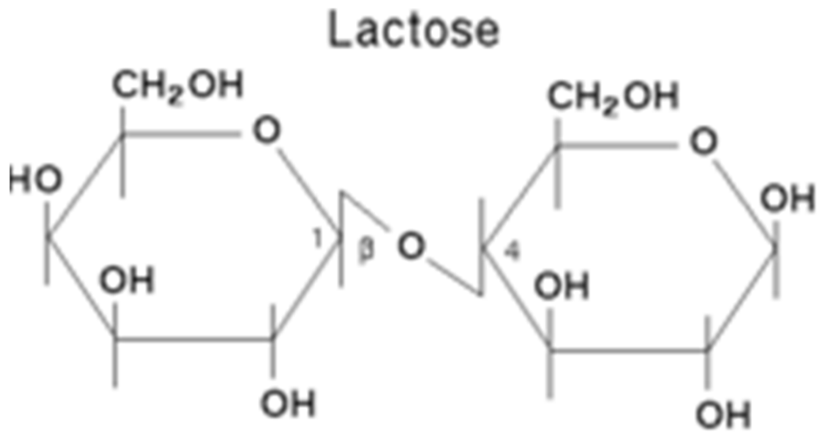



Chromosome
Gene
EcoRI
DNA ligase
Bacterial plasmid
Recombinant plasmid
(a)
(b)
(c)

β-Galactosidase

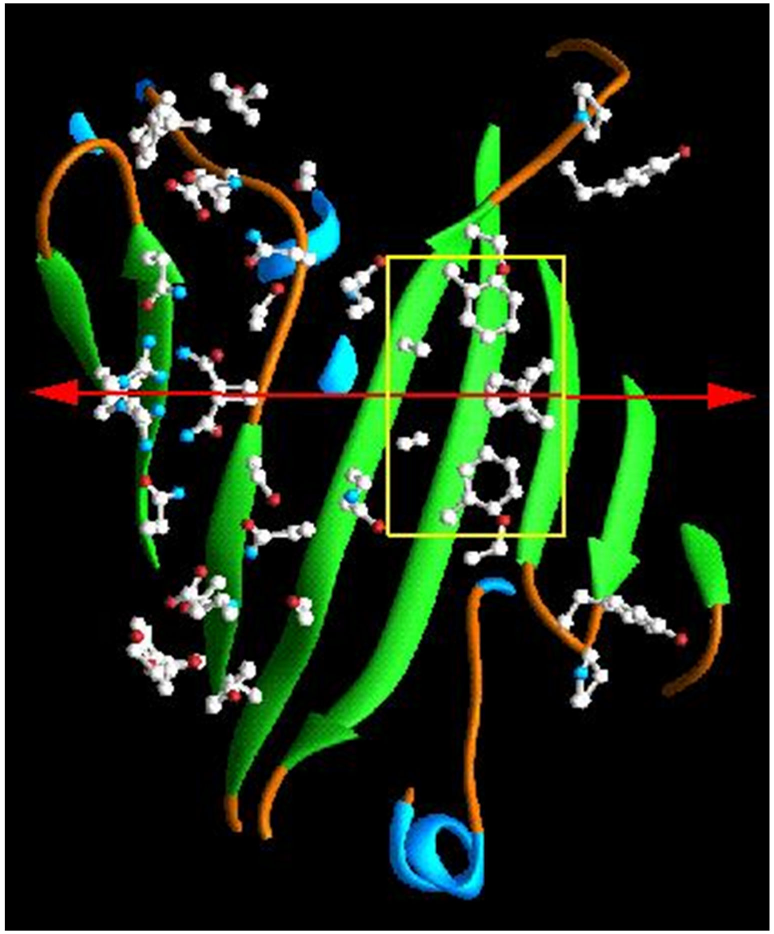
The enzyme that splits lactose into glucose and galactose. Coded by a gene (lacZ) in the lac operon of Escherichia coli.



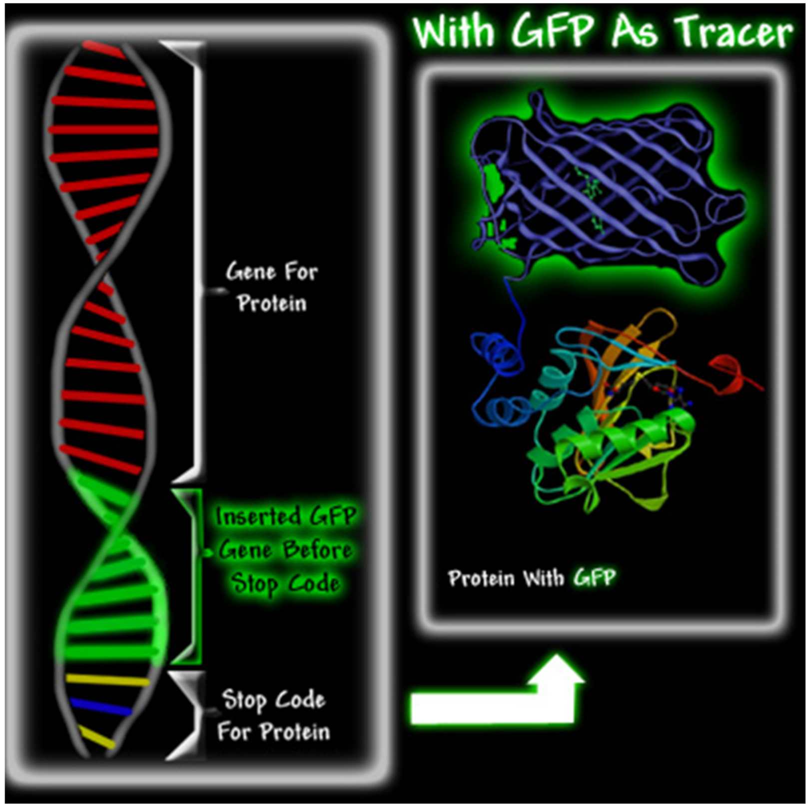


PUC is a family of plasmids that have an ampicillin resistance gene and more importantly a *lacZ* gene. A functional lacZ gene will produce the protein β - galactosidase. Bacterial colonies in which β - galactosidase is produced, will form blue colonies in the presence of the substrate 5 - bromo - 4 - chloro - 3 - indolyl - b - D - galactoside or as it is more commonly referred to, X-gal.

Green Fluorescent Protein (GFP)

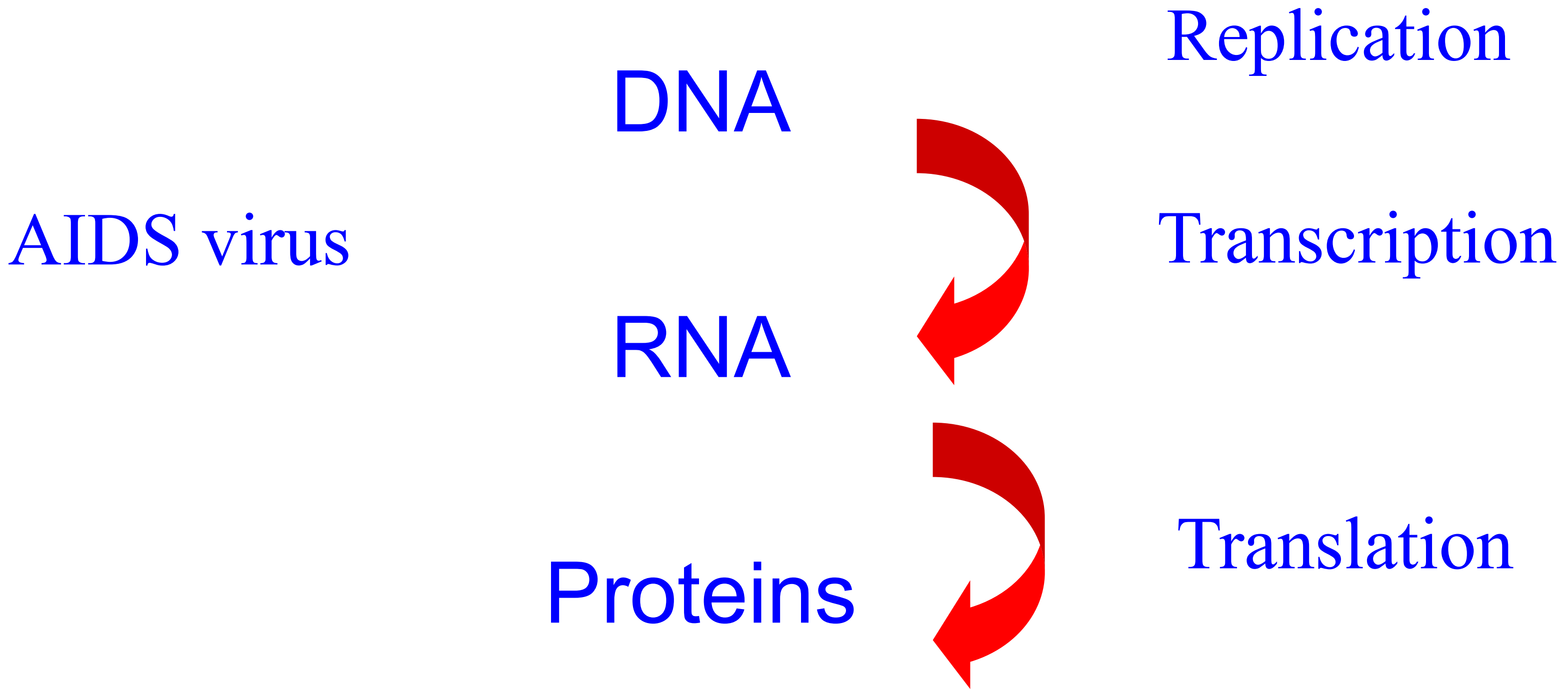


The **green fluorescent protein** (**GFP**) is a protein from the jellyfish *Aequorea victoria* that fluoresces green when exposed to blue light.



GFP Rats

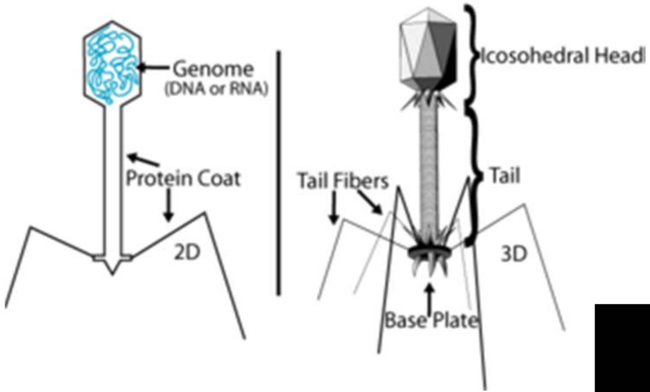
Central Dogma

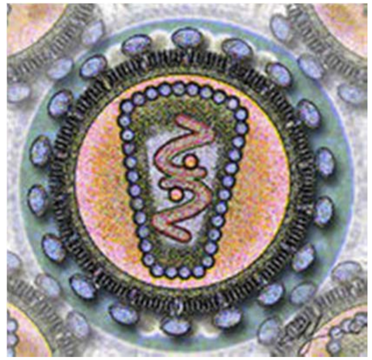


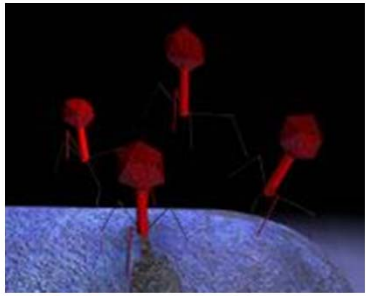
Life

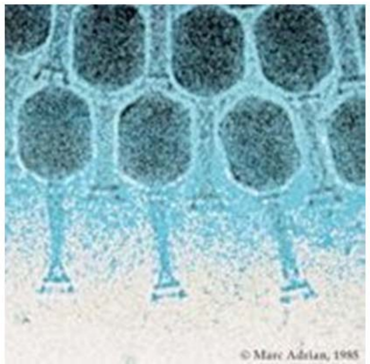
- Replication: reproduction
- Function: catalytic functions
- RNA world:
- Virus is not alive

Virus

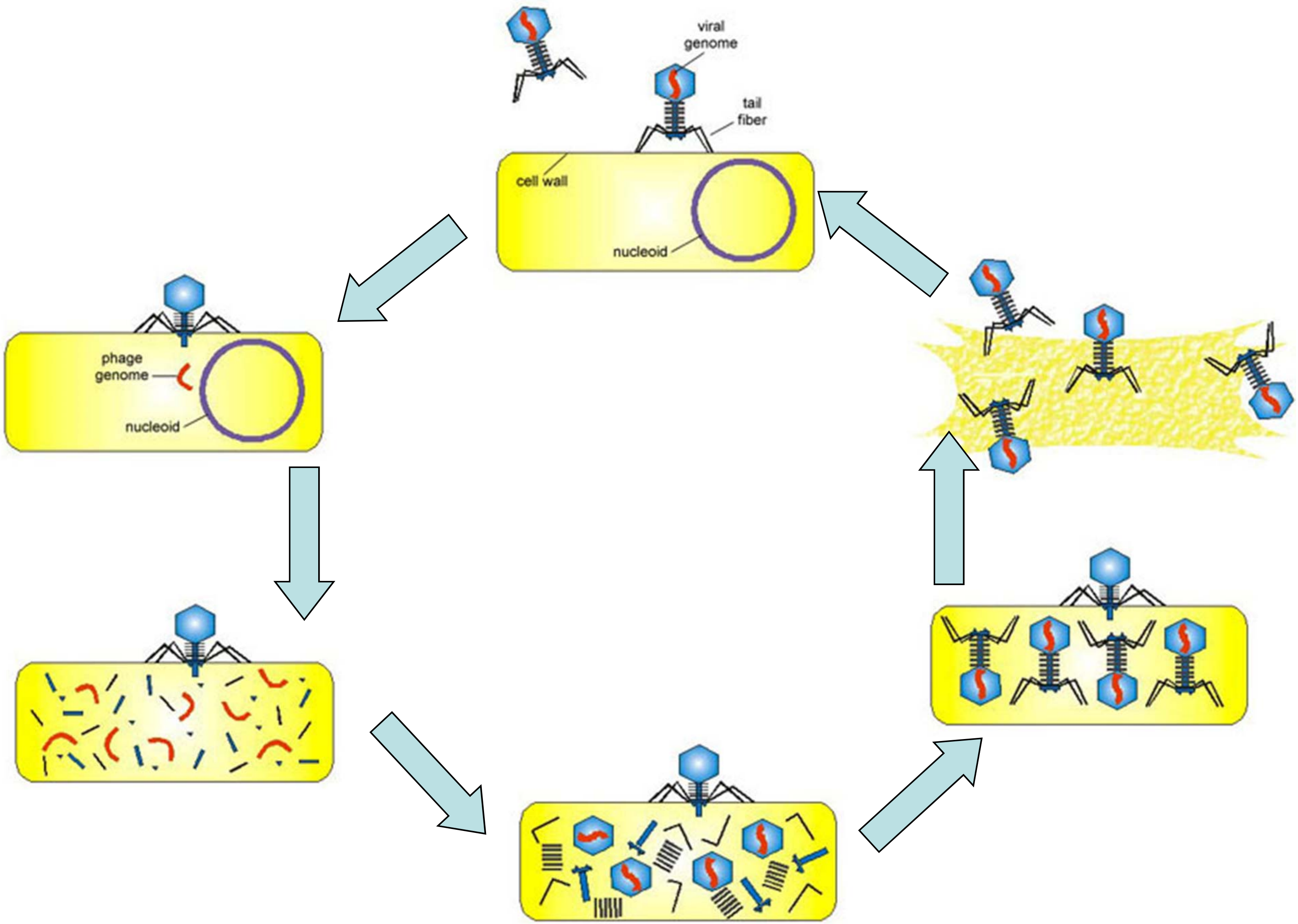

Genome
(DNA or RNA)
Protein Coat
2D
Icosohedral Head
Tail
Tail Fibers
Base Plate
3D






© Marc Adrian, 1985

Virus Reproduction



- Eukaryotic cells are about 1000 times larger than bacteria cells and also have a membrane enclosed nucleus containing their DNA, and several other internal structures known as organelles.

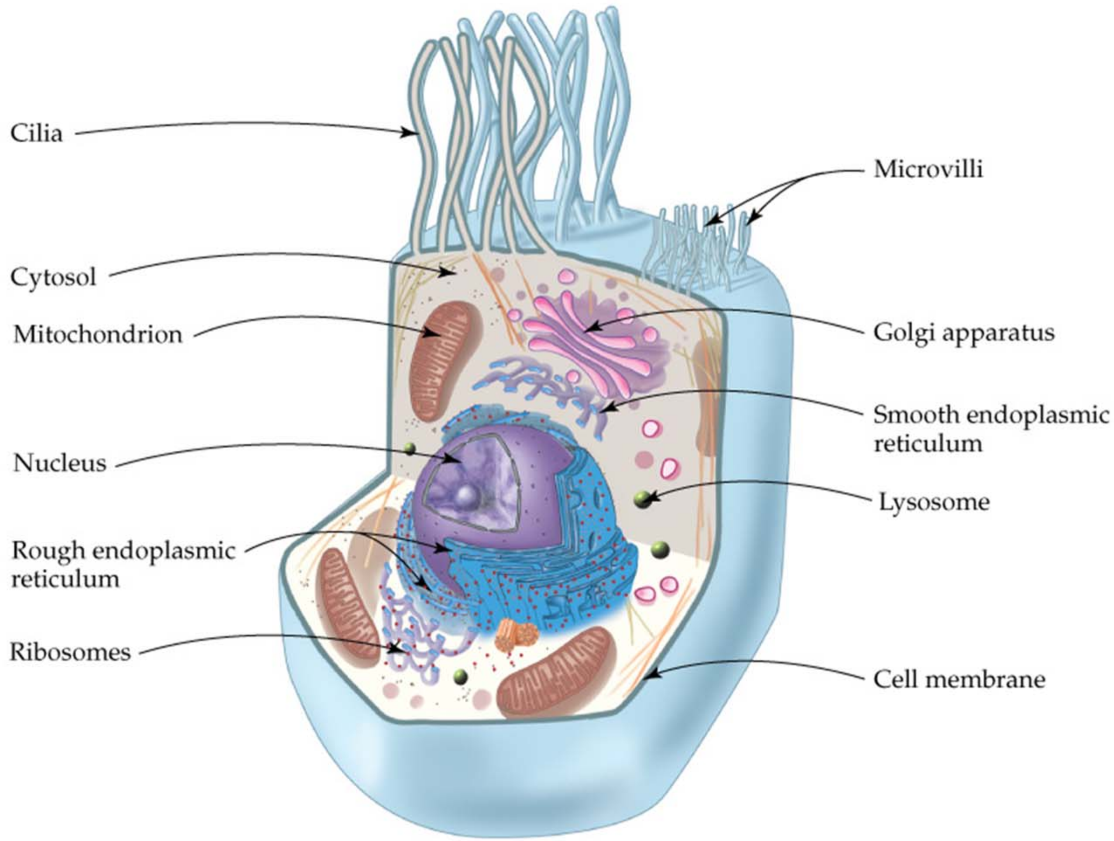
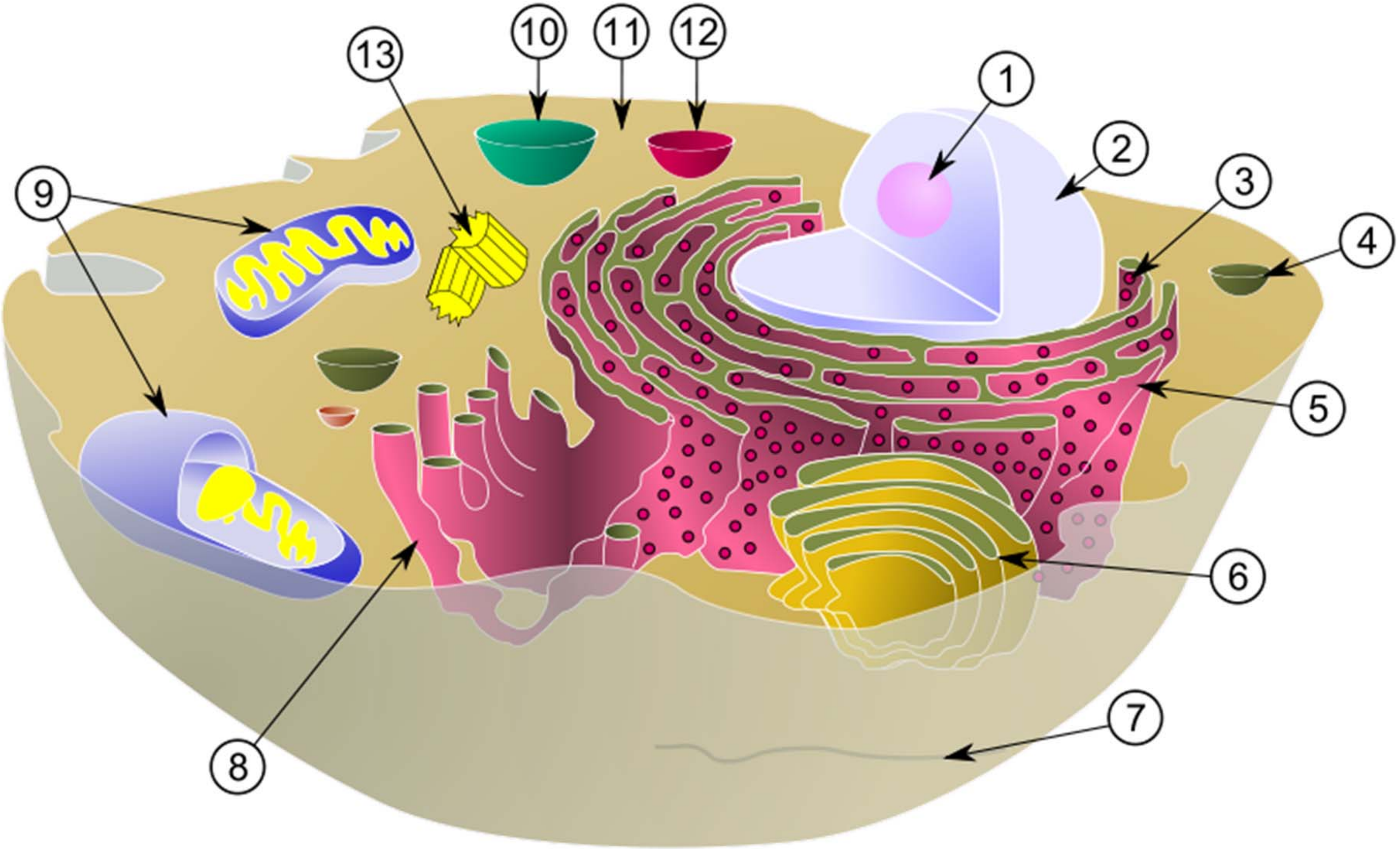
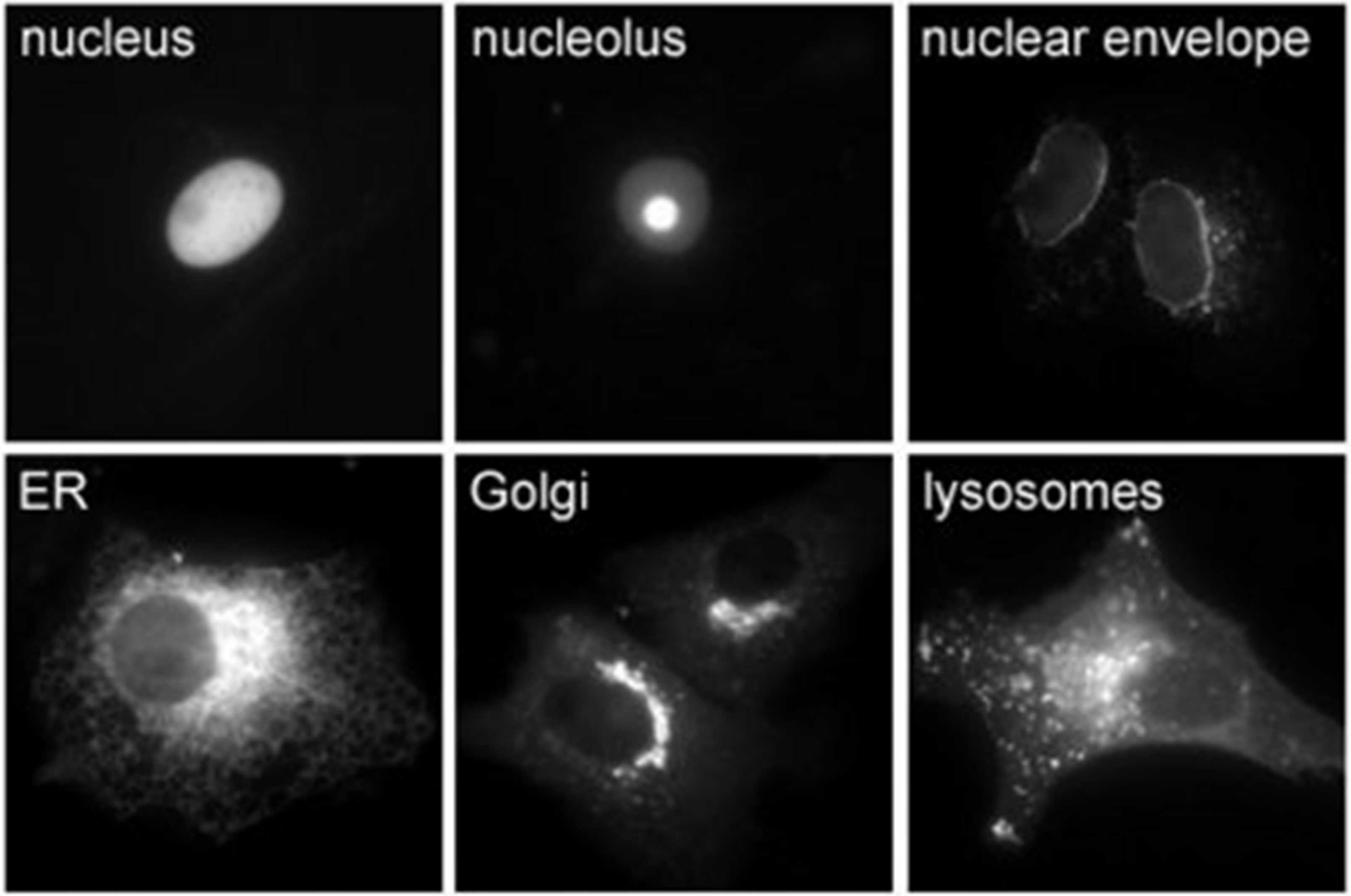
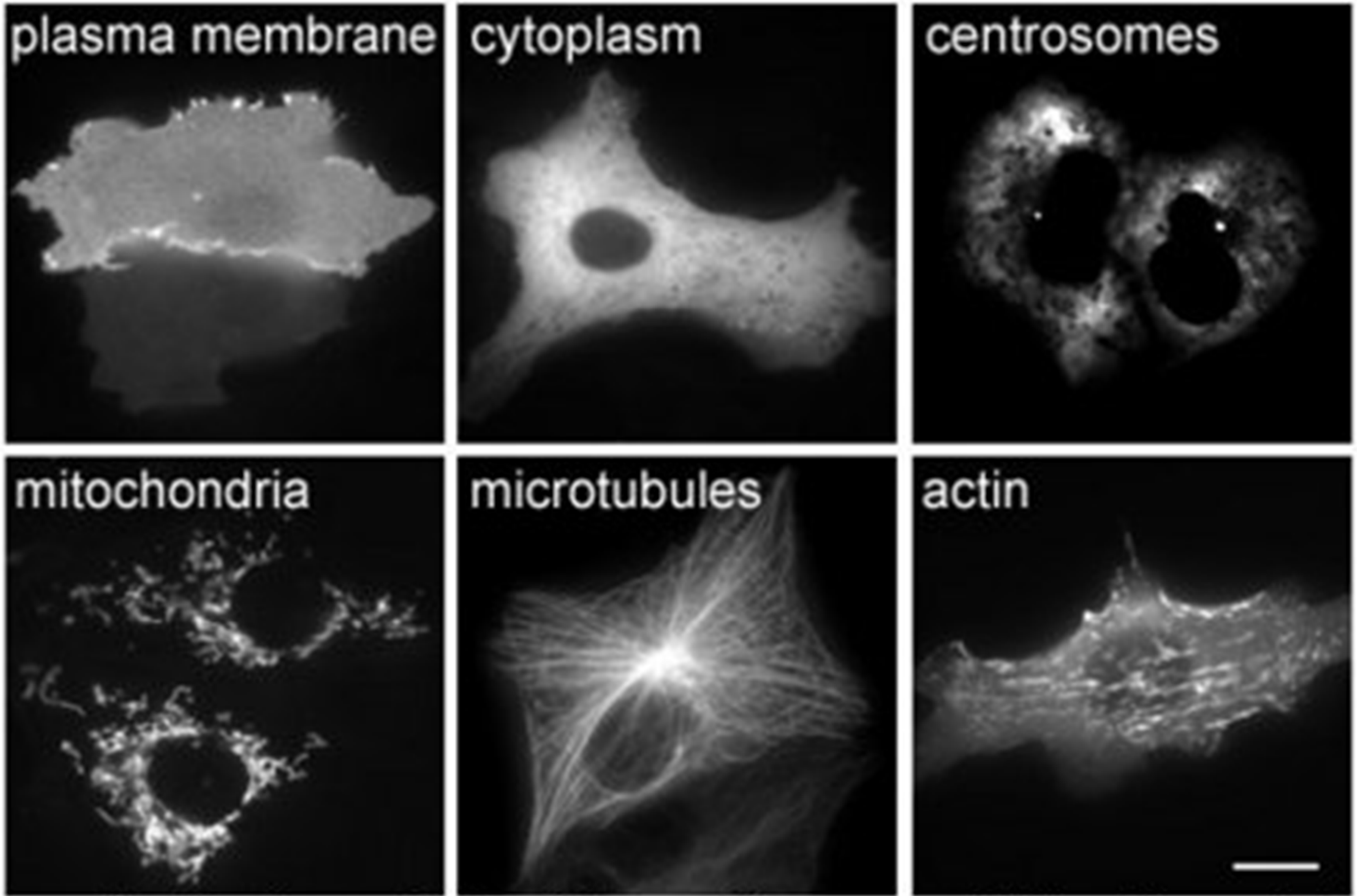


Fig 21.3 A generalized eukaryotic cell.



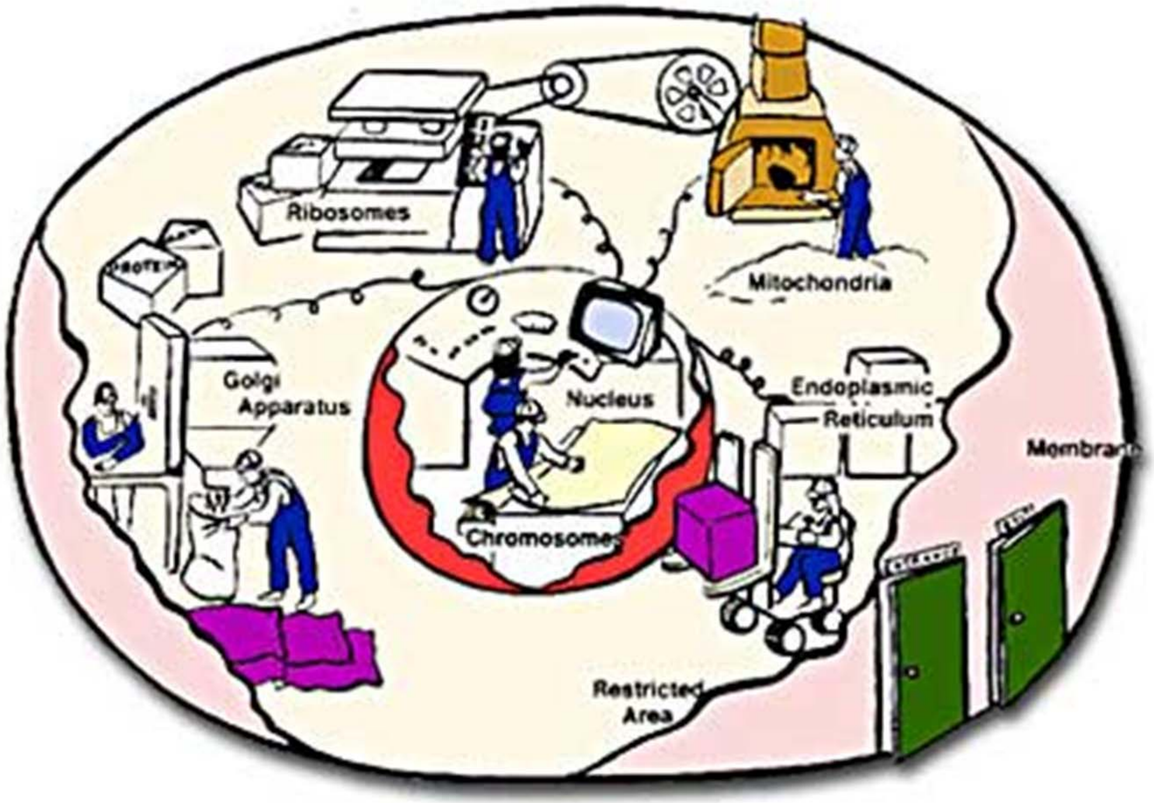
•Schematic showing the cytoplasm, with its components (or *organelles*), of a typical animal cell. Organelles: (1) nucleolus (2) nucleus (3) ribosome (4) vesicle (5) rough endoplasmic reticulum (6) Golgi apparatus (7) cytoskeleton (8) smooth endoplasmic reticulum (9) mitochondria (10) vacuole (11) cytosol (12) lysosome (13) centriole.


nucleus
nucleolus
nuclear envelope
ER
Golgi
lysosomes



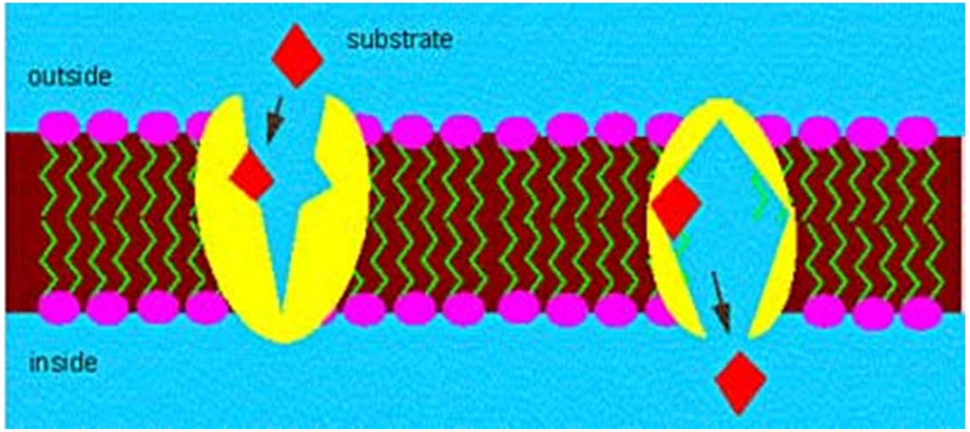
with friendly permission of Jeremy Simpson and Rainer Pepperkok

A Busy Factory

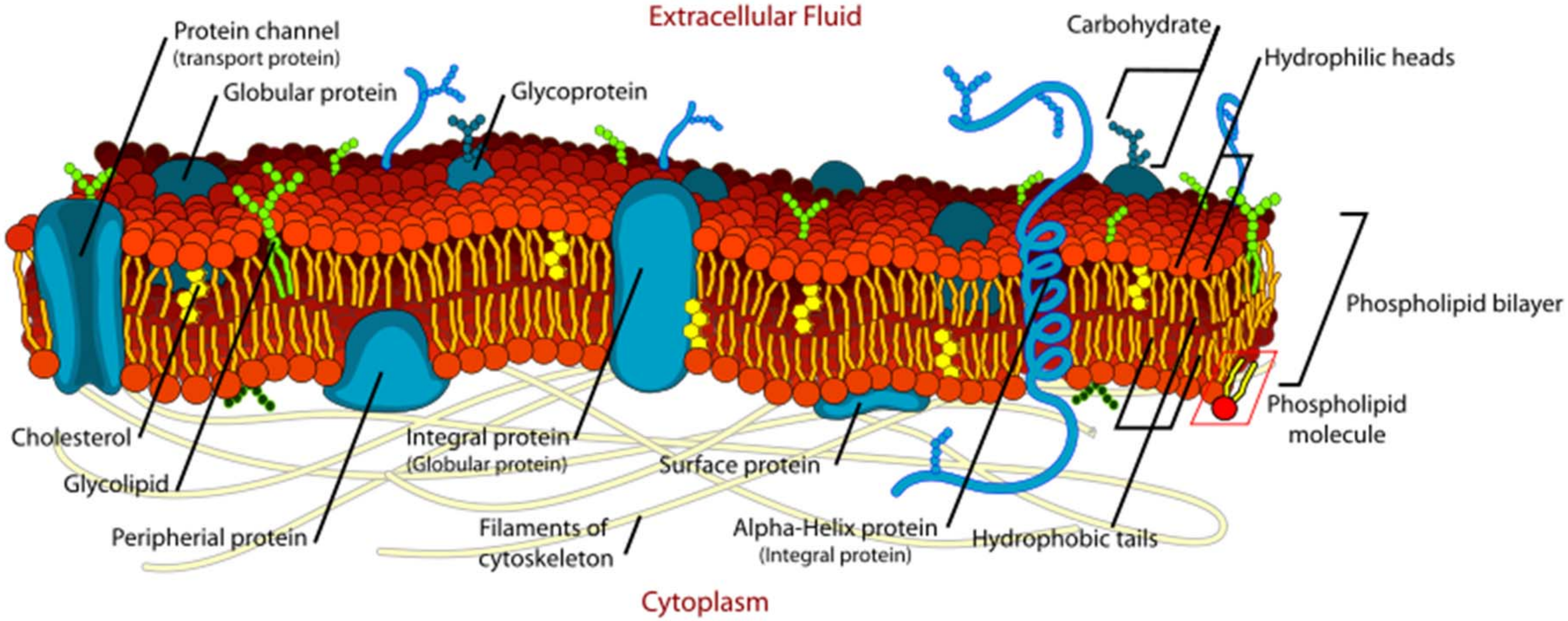


A cell can be thought of as a "factory," with different departments each performing specialized tasks.

The Plasma Membrane

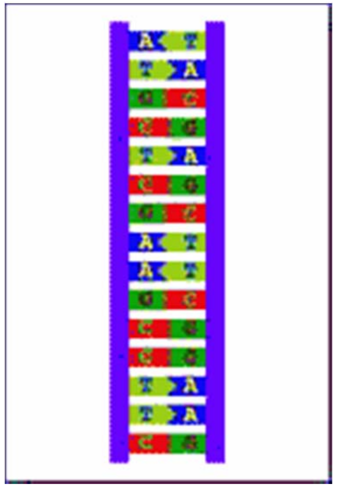


Cell Membrane



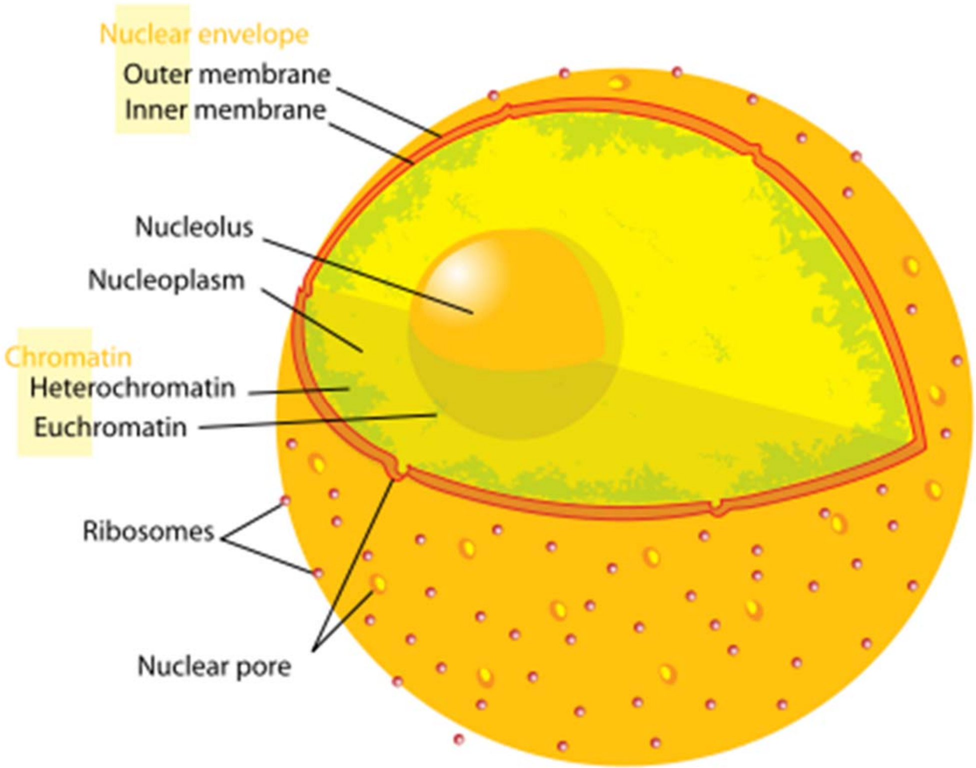
Characteristic diffusivities		
Particle	Typical size	Diffusion constant
Solute ion	10^{-1} nm	$2 \times 10^3\ \mu m^2/s$
Small protein	5 nm	$40\ \mu m^2/s$
Virus	100 nm	$2\ \mu m^2/s$
Bacterium	$1\ \mu m$	$0.2\ \mu m^2/s$
Mammalian/human cell	$10\ \mu m$	$0.02\ \mu m^2/s$

The Nucleus



The cell factory contains a large inventory of blueprints dating all the way to its founding. Some of these blueprints are out of date, and some are for parts and products that are no longer made. Part of your job would entail sorting through everything, finding the correct blueprints, copying them, and sending the copies out to the assembly line at the correct time.

Nucleus

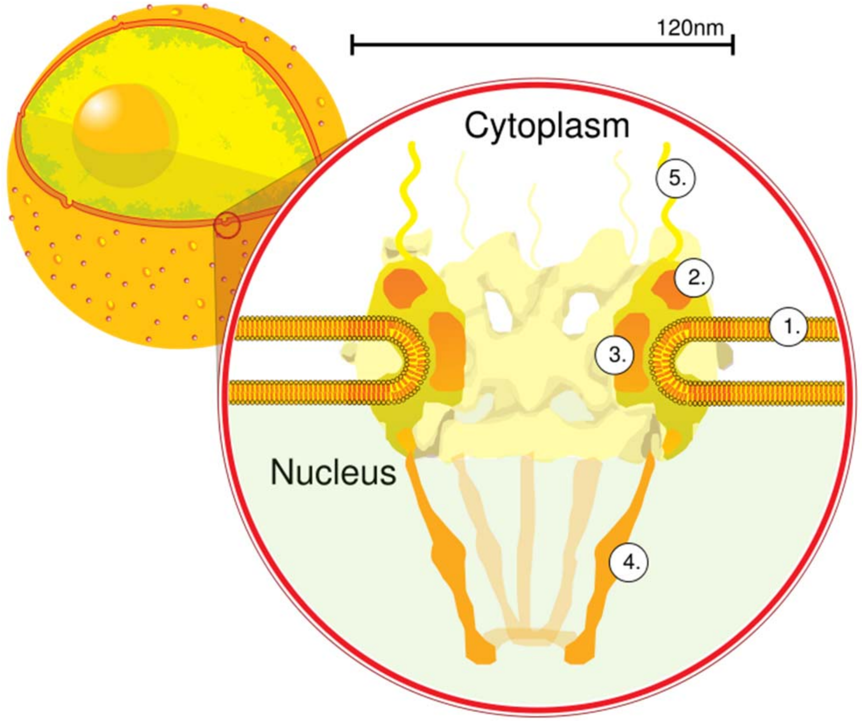


•In cell biology, the **nucleus** is a membrane-enclosed organelle found in most eukaryotic cells. It contains most of the cell's genetic material, organized as multiple long linear DNA molecules in complex with a large variety of proteins such as histones to form chromosomes. The genes within these chromosomes make up the cell's nuclear genome. The function of the nucleus is to maintain the integrity of these genes and to control the activities of the cell by regulating gene expression.

In cell biology, the **nucleolus** (plural *nucleoli*) is a "sub-organelle" of the cell nucleus, which itself is an organelle. A main function of the nucleolus is the production and assembly of ribosome components

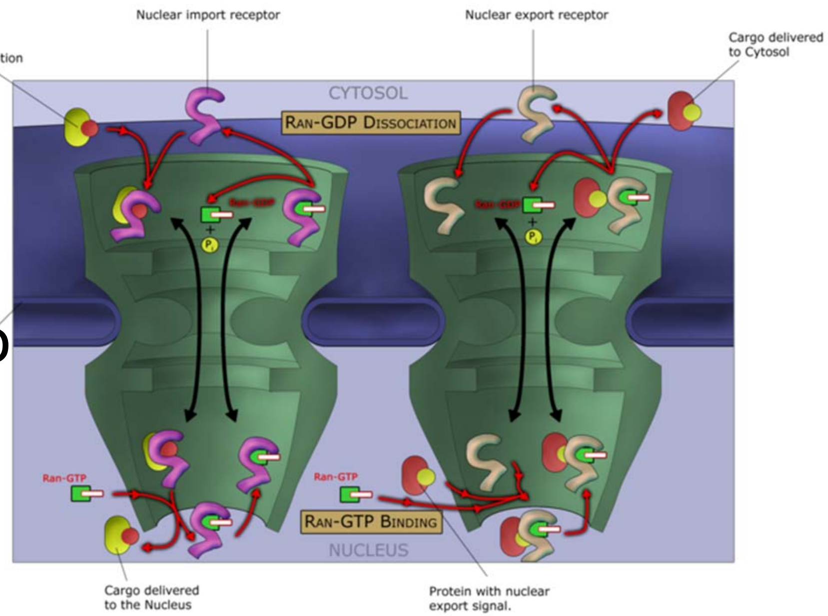
Nuclear pores

Nuclear pores, which provide aqueous channels through the envelope, are composed of multiple proteins, collectively referred to as nucleoporins. The pores are 100 nm in total diameter; however, the gap through which molecules freely diffuse is only about 9 nm wide, due to the presence of regulatory systems within the center of the pore. This size allows the free passage of small water-soluble molecules while preventing larger molecules, such as nucleic acids and proteins, from inappropriately entering or exiting the nucleus. These large molecules must be actively transported into the nucleus instead. The nucleus of a typical mammalian cell will have about 3000 to 4000 pores throughout its envelope

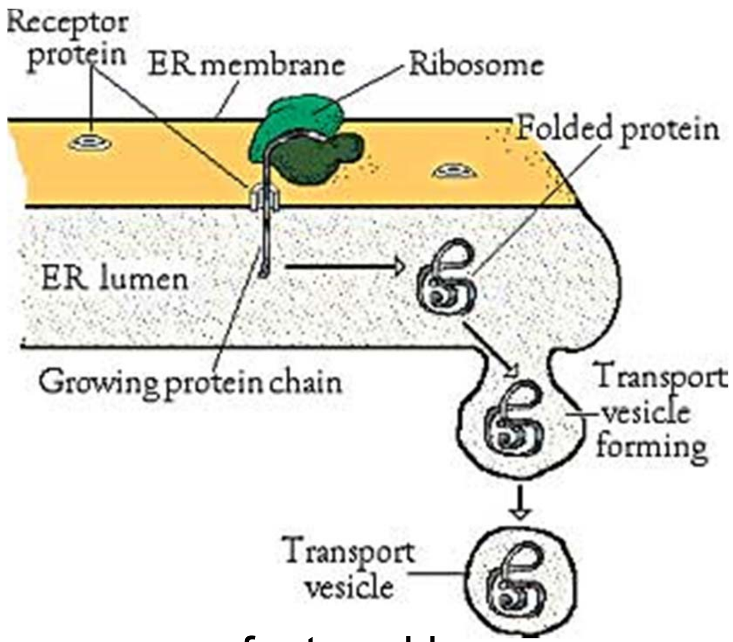


Nuclear localizing sequence (NLS)

- A **nuclear localizing sequence** (**NLS**) is an amino acid sequence which acts like a 'tag' on the exposed surface of a protein. This sequence is used to confine the protein to the cell nucleus through the **Nuclear Pore Complex** and to direct a newly synthesized protein into the nucleus via its recognition by cytosolic nuclear transport receptors. Typically, this signal consists of a few short sequences of positively charged lysines or arginines. Typically the NLS will have a sequence (NH2)-Pro-Pro-Lys-Lys-Lys-Arg-Lys-Val-(COOH).



The Ribosomes and the ER

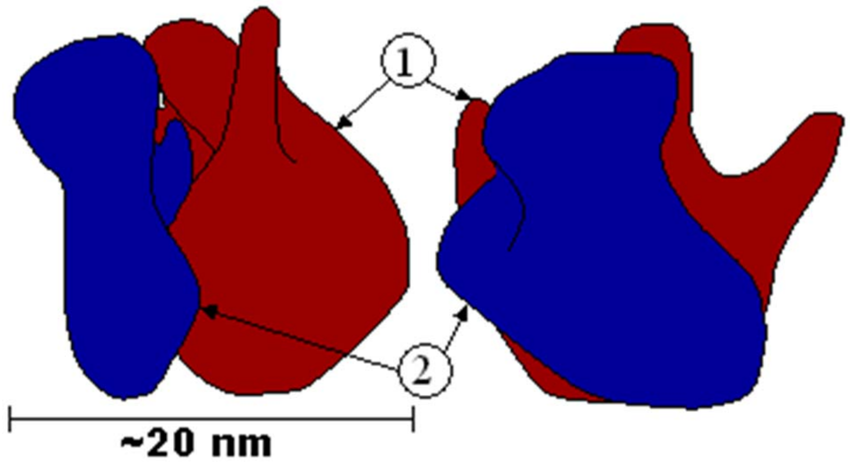


Ribosomes, the workers that build proteins, are manufactured by the nucleolus. They consist of two separate subunits: a large, lower subunit and a small, upper subunit. Ribosomes attach to the rough ER . Now let's take a look at how final processing occurs

The cell has its own assembly line and workers. Within the cytoplasm is a series of large, flattened membranes that fold back and forth on each other and have a very large surface area. This collection of membranes is called the **ENDOPLASMIC RETICULUM**, or**ER**.

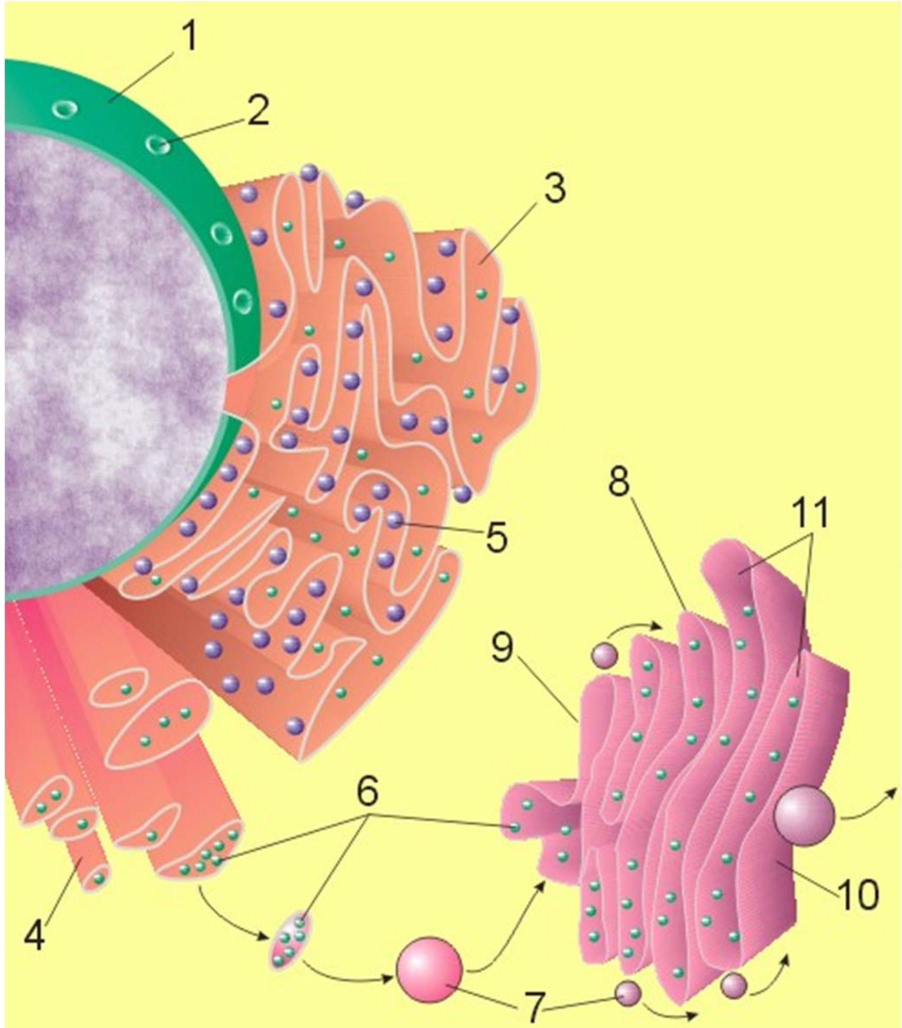
Ribosome

A **ribosome** is a small, dense organelle in cells that assembles proteins. Ribosomes are about 20nm in diameter and are composed of 65% ribosomal RNA and 35% ribosomal proteins (known as a Ribonucleoprotein or RNP). It translates messenger RNA (mRNA) to build a polypeptide chain (e.g., a protein) using amino acids delivered by Transfer RNA (tRNA). It can be thought of as a giant enzyme that builds a protein from a set of genetic instructions. Ribosomes can float freely in the cytoplasm (the internal fluid of the cell) or bound to the endoplasmic reticulum, or to the nuclear envelope.



Endoplasmic Reticulum

The **endoplasmic reticulum** or **ER** is an organelle found in all eukaryotic cells that is an interconnected network of tubules, vesicles and cisternae that is responsible for several specialized functions: Protein translation, folding, and transport of proteins to be used in the cell membrane (e.g., transmembrane receptors and other integral membrane proteins), or to be secreted (exocytosed) from the cell (e.g., digestive enzymes); sequestration of calcium; and production and storage of glycogen, steroids, and other macromolecules.[1] The endoplasmic reticulum is part of the endomembrane system. The basic structure and composition of the ER membrane is similar to the plasma membrane.



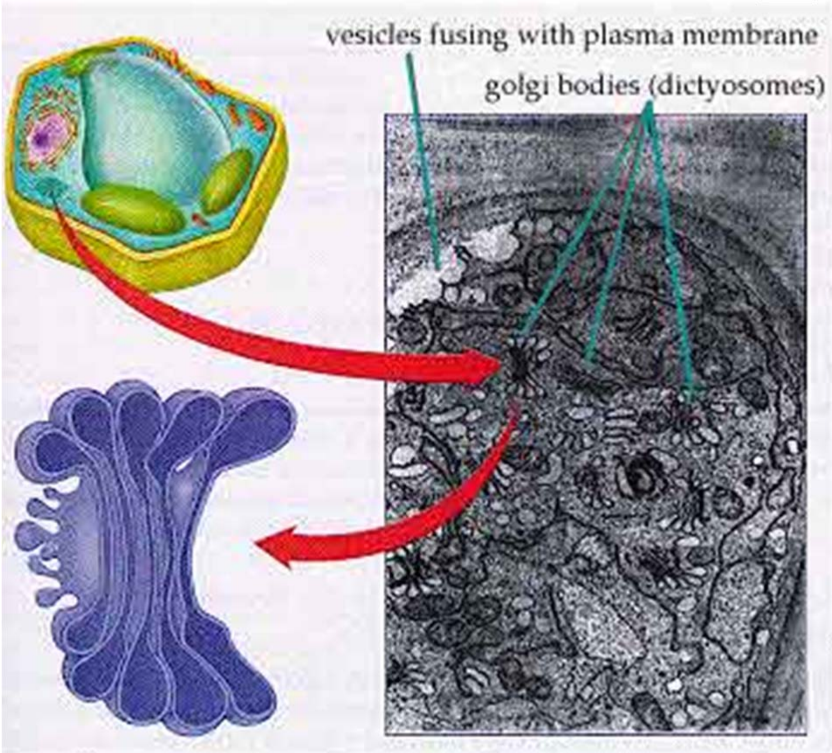
Rough endoplasmic reticulum

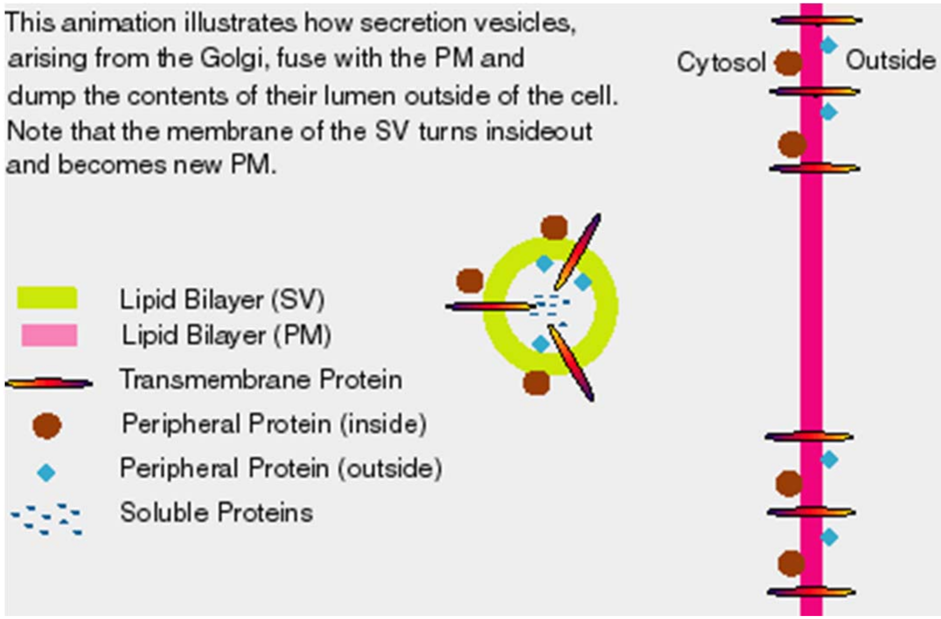
- The surface of the rough endoplasmic reticulum is studded with protein-manufacturing ribosomes giving it a "rough" appearance. But it should be noted that these ribosomes are not resident of the endoplasmic reticulum incessantly. The ribosomes only bind to the ER once it begins to synthesize a protein destined for sorting. The membrane of the rough endoplasmic reticulum is continuous with the outer layer of the nuclear envelope. Although there is no continuous membrane between the rough ER and the Golgi apparatus, membrane bound vesicles shuttle proteins between these two compartments. The rough endoplasmic reticulum works in concert with the Golgi complex to target new proteins to their proper destinations

Smooth endoplasmic reticulum

- The smooth endoplasmic reticulum has functions in several metabolic processes, including synthesis of lipids, metabolism of carbohydrates and calcium concentration, and attachment of receptors on cell membrane proteins. It is connected to the nuclear envelope. Smooth endoplasmic reticulum is found in a variety of cell types (both animal and plant) and it serves different functions in each. It consists of tubules and vesicles that branch forming a network. In some cells there are dilated areas like the sacs of rough endoplasmic reticulum. The network of smooth endoplasmic reticulum allows increased surface area for the action or storage of key enzymes and the products of these enzymes. The smooth endoplasmic reticulum is known for its storage of calcium ions in muscle cells.

The Golgi Apparatus



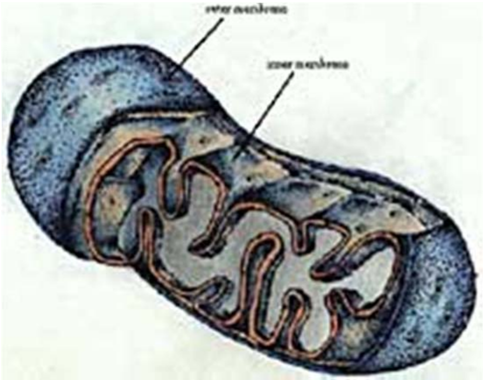


The Golgi apparatus is analogous to the finishing and packing room in a factory. Once the ribosome finishes manufacturing a protein in the rough ER, the protein needs to be prepared for use or export. Special enzymes will trim off any extra amino acids, and then the unfinished protein moves through channels in the smooth ER.

Golgi apparatus

The **Golgi apparatus** (also called the **Golgi body**, **Golgi complex**, or **dictyosome**) is an organelle found in typical eukaryotic cells. It was identified in 1898 by the Italian physician Camillo Golgi and was named after him. The primary function of the Golgi apparatus is to process and package macromolecules synthesised by the cell, primarily proteins and lipids. The Golgi apparatus forms a part of the endomembrane system present in eukaryotic cells.

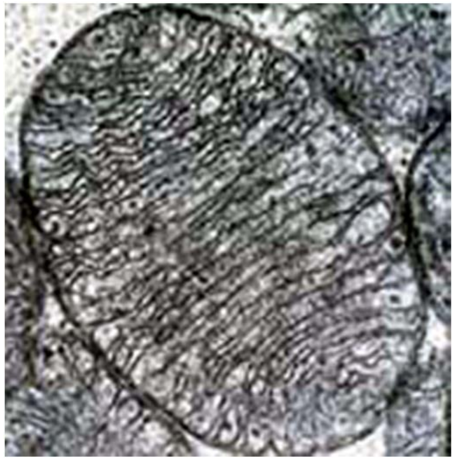
Mitochondria



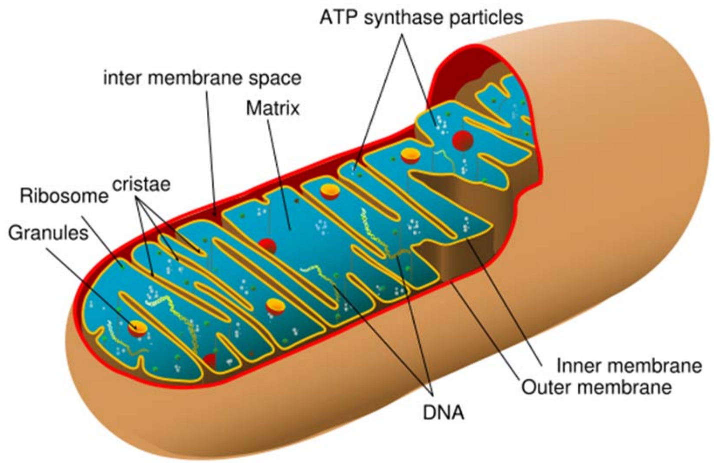
- ATP -
a Source of
ENERGY

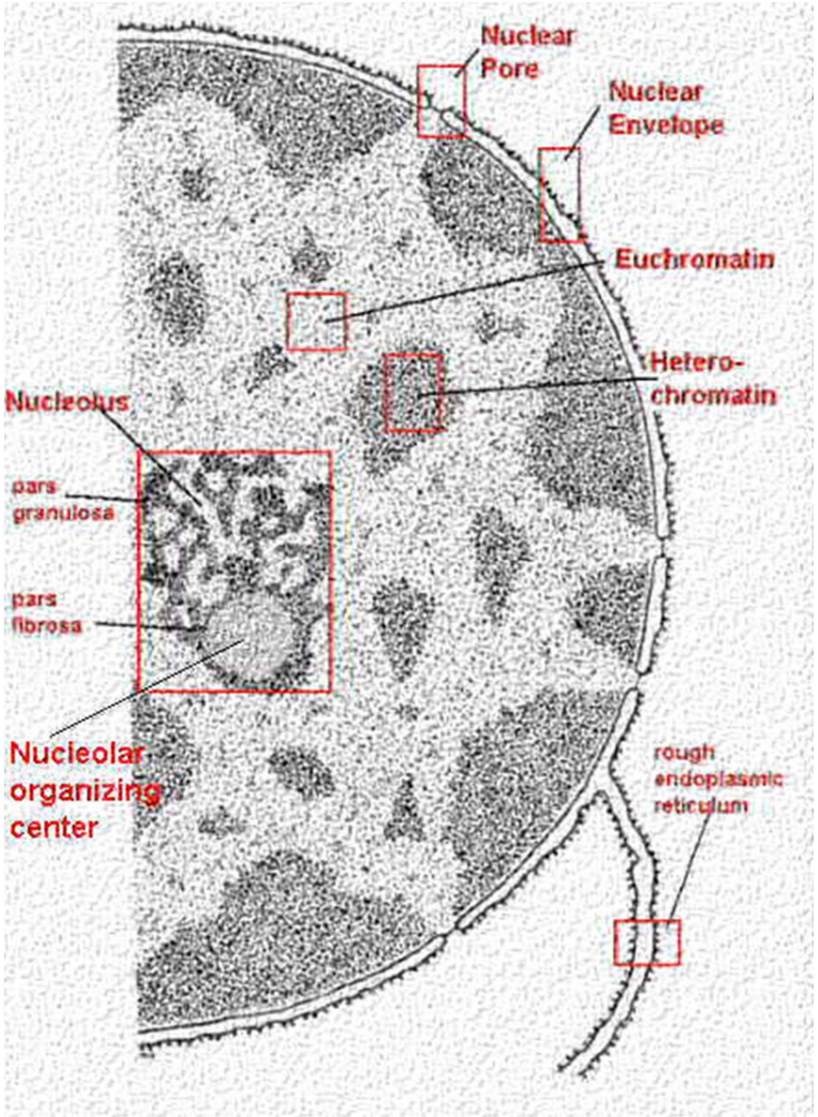
Like our factory's power plant, mitochondria and chloroplasts transform one form of energy to another. Remember that nearly all the energy used by living things on Earth comes from the Sun. This section discusses how energy is made available for cell processes.

Mitochondrion



- In cell biology, a **mitochondrion** is a membrane-enclosed organelle, found in most eukaryotic cells.Mitochondria are sometimes described as "cellular power plants," because they convert NADH and NADPH into energy in the form of ATP via the process of oxidative phosphorylation. A typical eukaryotic cell contains about 2,000 mitochondria, which occupy roughly one fifth of its total volume. Mitochondria contain DNA that is independent of the DNA located in the cell nucleus. According to the endosymbiotic theory, mitochondria are descended from free-living prokaryotes.





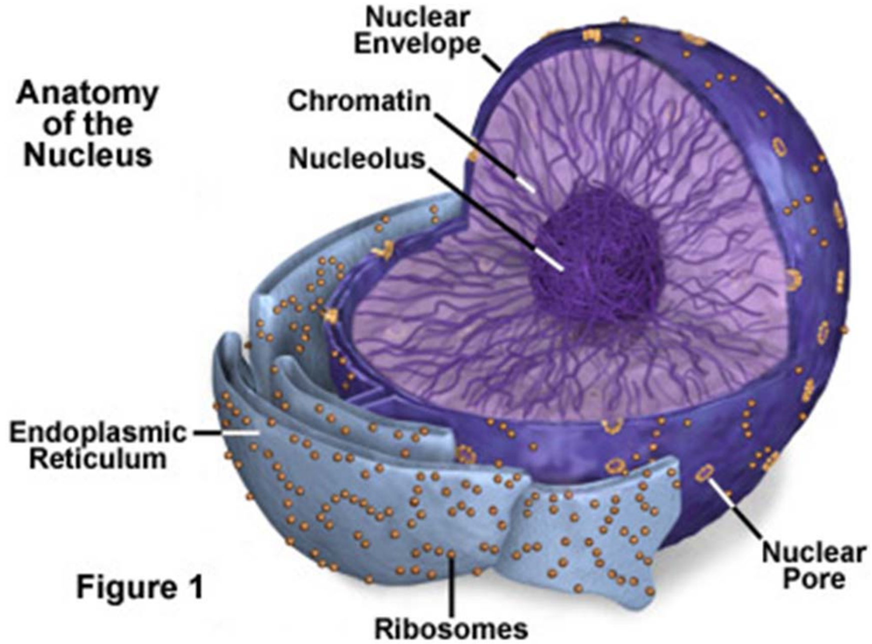


Figure 1

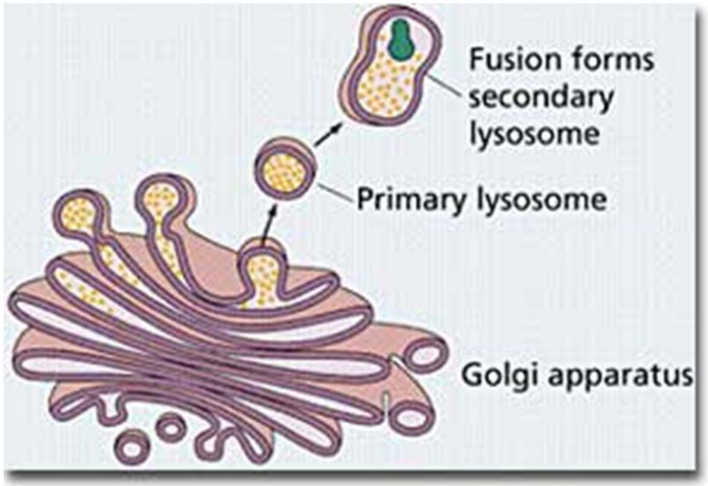
The main roles of the nucleolus are to synthesize rRNA and assemble ribosomes

The main function of the cell nucleus is to control gene expression and mediate the replication of DNA during the cell cycle

Lysosomes

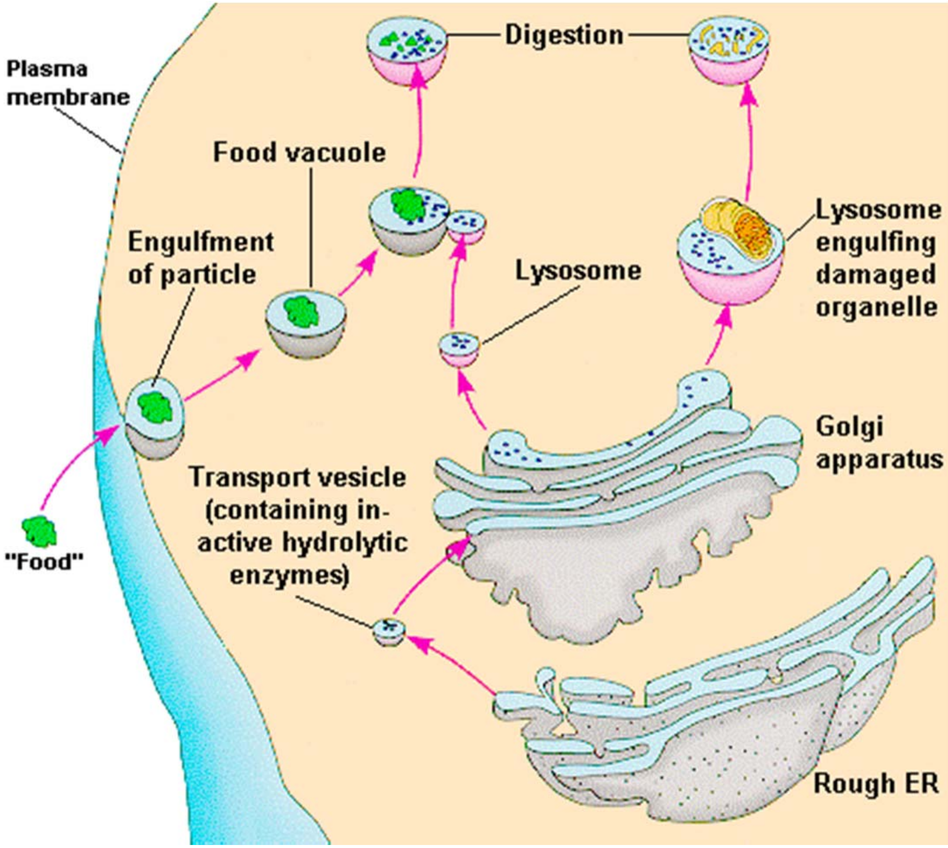
- **Lysosomes** are organelles that contain digestive enzymes (acid hydrolases). They digest excess or worn out organelles, food particles, and engulfed viruses or bacteria. The membrane surrounding a lysosome prevents the digestive enzymes inside from destroying the cell. Lysosomes fuse with vacuoles and dispense their enzymes into the vacuoles, digesting their contents. They are built in the Golgi apparatus. The name *lysosome* derives from the Greek words *lysis*, which means dissolution or destruction, and *soma*, which means body. They are frequently nicknamed "suicide-bags" or "suicide-sacs" by cell biologists due to their role in autolysis.

Lysosomes



Lysosomes are responsible for the breakdown and absorption of materials taken in by the cell. Often, a cell engulfs a foreign substance through **ENDOCYTOSIS**, another form of active transport. During endocytosis, the cell membrane puckers up, forms a pouch around materials outside the cell, and pinches off to become a vesicle. If the contents need to be destroyed, lysosomes combine with the vesicle and release their enzymes.

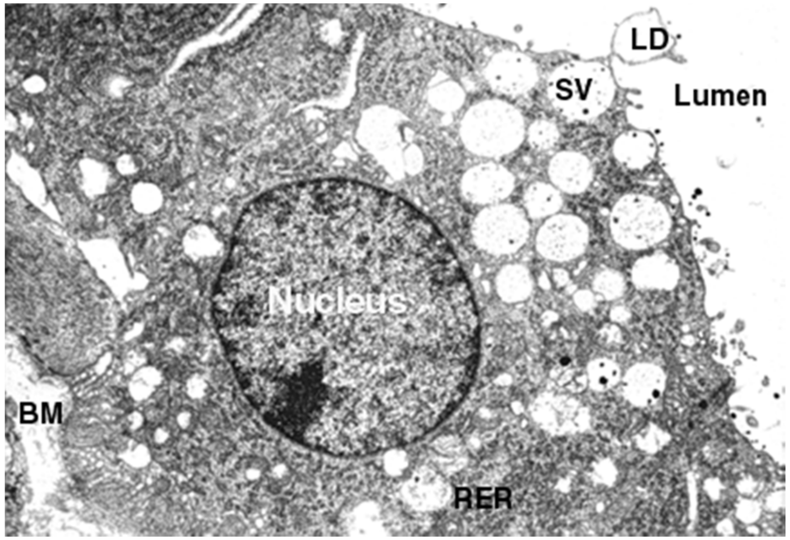
Lysosome

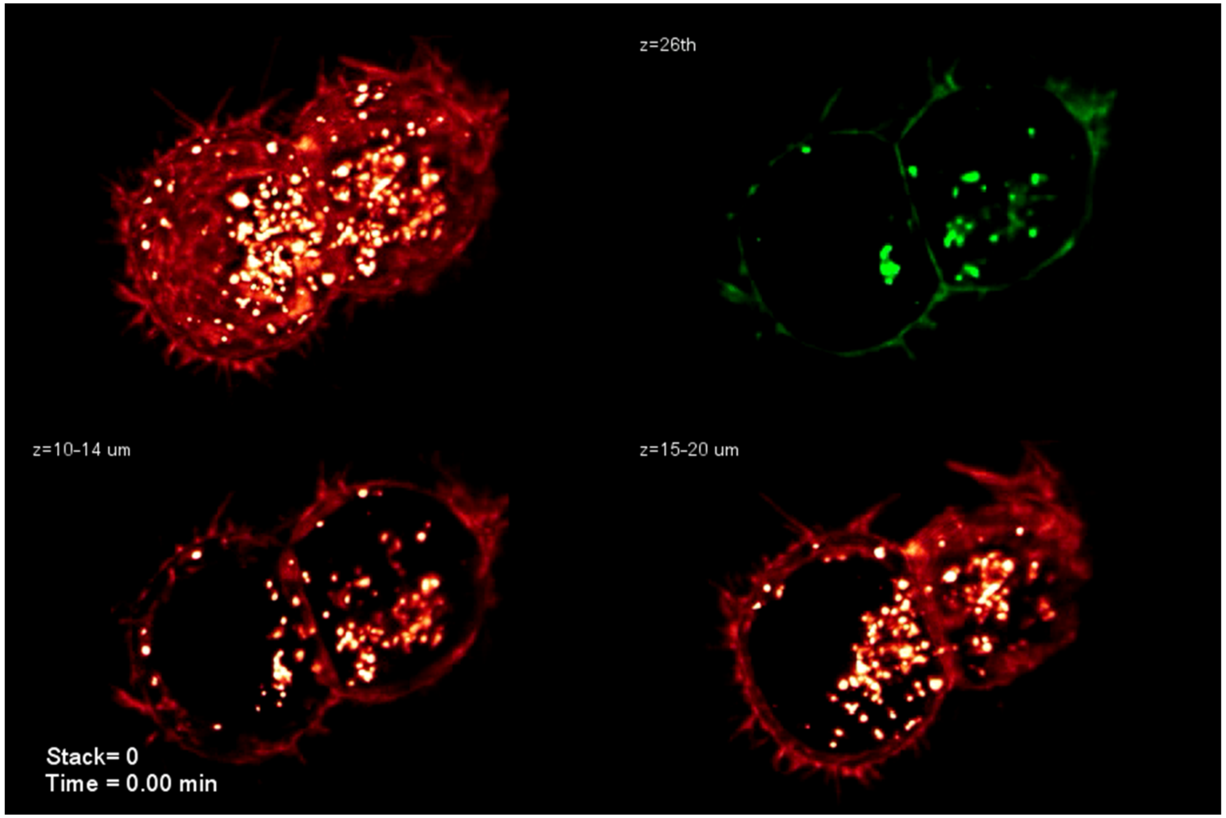

Plasma membrane
Digestion
Food vacuole
Engulfment of particle
Lysosome
Lysosome engulfing damaged organelle
Golgi apparatus
Transport vesicle (containing in-active hydrolytic enzymes)
"Food"
Rough ER

Vesicle

In cell biology, a **vesicle** is a relatively small and enclosed compartment, separated from the cytosol by at least one lipid bilayer. If there is only one lipid bilayer, they are called *unilamellar* vesicles; otherwise they are called *multilamellar*. Vesicles store, transport, or digest cellular products and waste.

This biomembrane enclosing the vesicle is similar to that of the plasma membrane. Because it is separated from the cytosol, the intravesicular environment can be made to be different from the cytosolic environment. Vesicles are a basic tool of the cell for organizing metabolism, transport, enzyme storage, as well as being chemical reaction chambers. Many vesicles are made in the Golgi apparatus, but also in the endoplasmic reticulum, or are made from parts of the plasma membrane.

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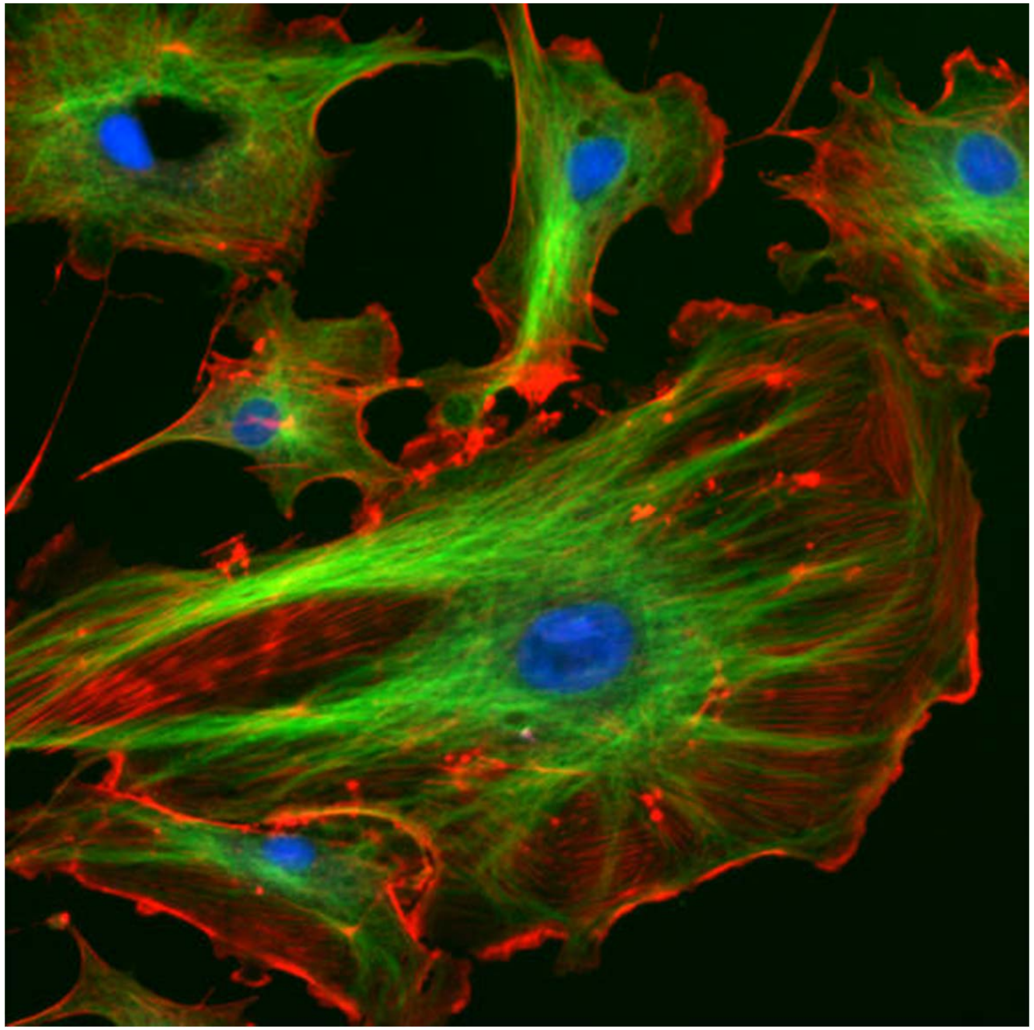
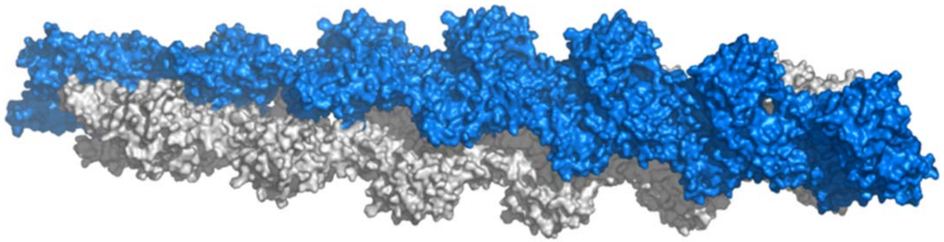
Cytoskeleton



The eukaryotic cytoskeleton. Actin filaments are shown in red, microtubules in green, and the nuclei are in blue.

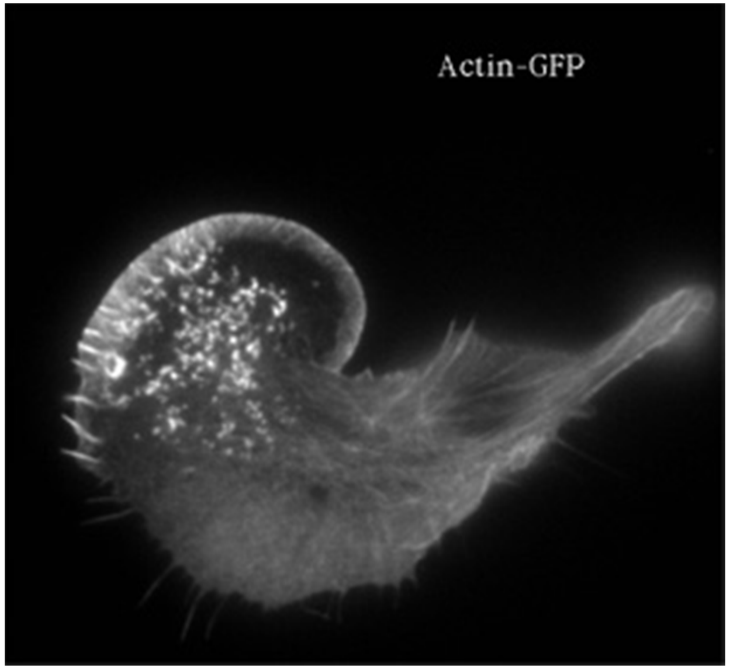
Actin

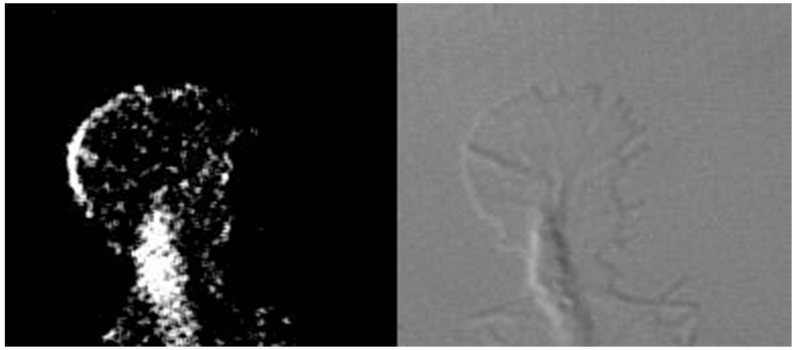


- **Actin** is a globular structural, 42 kDa, protein that polymerizes in a helical fashion to form **actin filaments** (or **microfilaments**). These form the cytoskeleton, a three-dimensional network inside the eukaryotic cell. Actin filaments provide mechanical support for the cell, determine its shape, and enable movement of the cell through lamellipodia, filopodia, or pseudopodia. Actin filaments, along with myosin, have an essential role in muscular contraction. In the cytosol, actin is predominantly bound to ATP, but can also bind to ADP. An ATP-actin complex polymerizes faster and dissociates slower than an ADP-actin complex.

Lamellipodia

- The **lamellipodium** is a cytoskeletal actin projection on the mobile edge of the cell. It contains a two-dimensional actin mesh; the whole structure pulls the cell across a substrate. Within the lamellipodia are ribs of actin called microspikes, which, when they spread beyond the lamellipodium frontier, are called filopodia (Small, et all, 2002). The lamellipodium is born of actin nucleation in the plasma membrane of the cell (Alberts, et al, 2002) and is the primary area of actin incorporation or microfilament formation of the cell. Lamellipodia range from 1μm to 5μm in breadth and are approximately 0.2μm thick.Lamellipodia are found primarily in very mobile cells, crawling at a speeds of 10-20μm/minute over epithelial surfaces..
- The tip of the lamellipodium is the site where exocytosis occurs in migrating mammalian cells as part of their clathrin-mediated endocytic cycle.

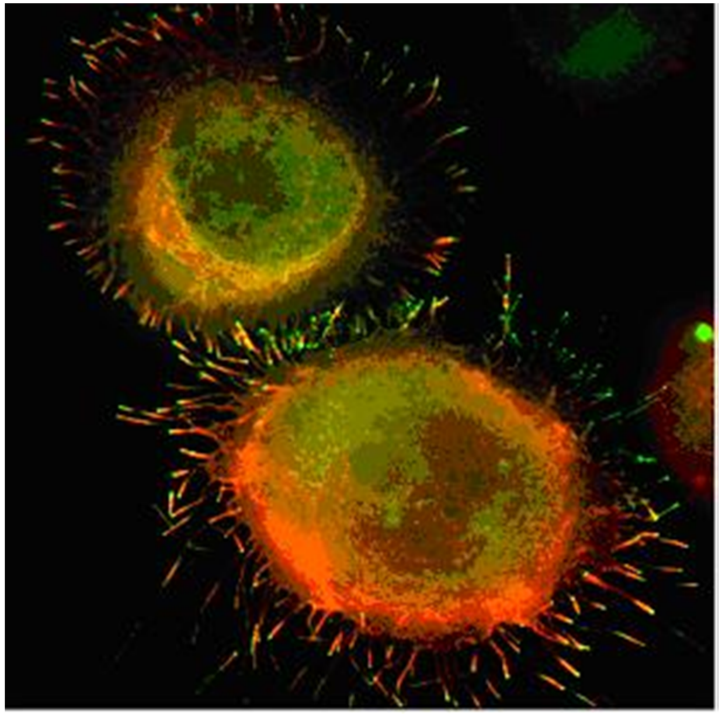




http://www.microscopyu.com/moviegallery/livecellimaging/3t3/t1/3t3-dslwmp1.html

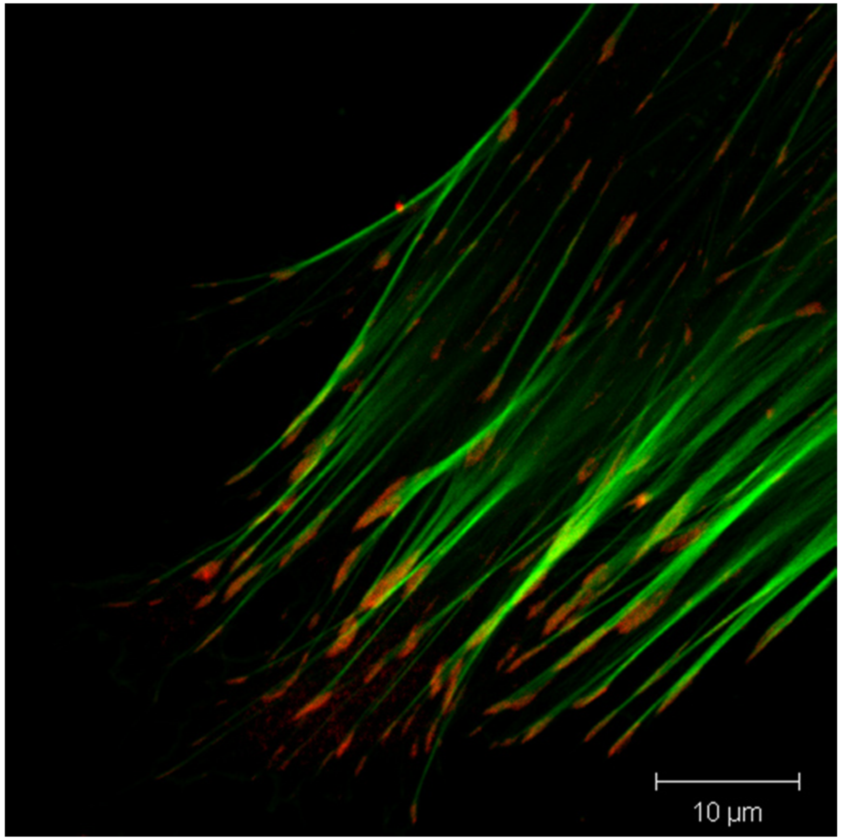
Filopodia

The **filopodia** are slender cytoplasmic projections, similar to lamellipodia, which extend from the leading edge of migrating cells. They contain actin filaments cross-linked into bundles by actin-binding proteins, e.g. fimbrin. Filopodia form focal adhesions with the substratum, linking it to the cell surface. A cell migrates along a surface by extending filopodia at the leading edge. The filopodia attach to the substratum further down the migratory pathway, then contraction of stress fibres retracts the rear of the cell to move the cell forwards.



Focal adhesion

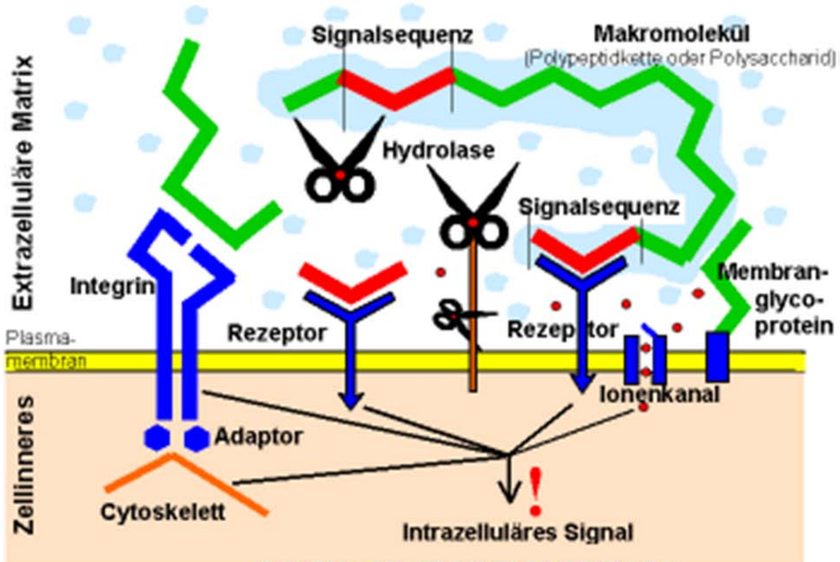
- In cell biology, **'Focal Adhesions'** are specific types of large macromolecular assemblies through which both mechanical force and regulatory signals are transmitted. More precisely, **FAs** can be considered as sub-cellular macromolecules that mediate the regulatory effects (e.g. cell anchorage) of extracellular matrix (ECM) adhesion on cell behavior.



Extra Cellular Matrix

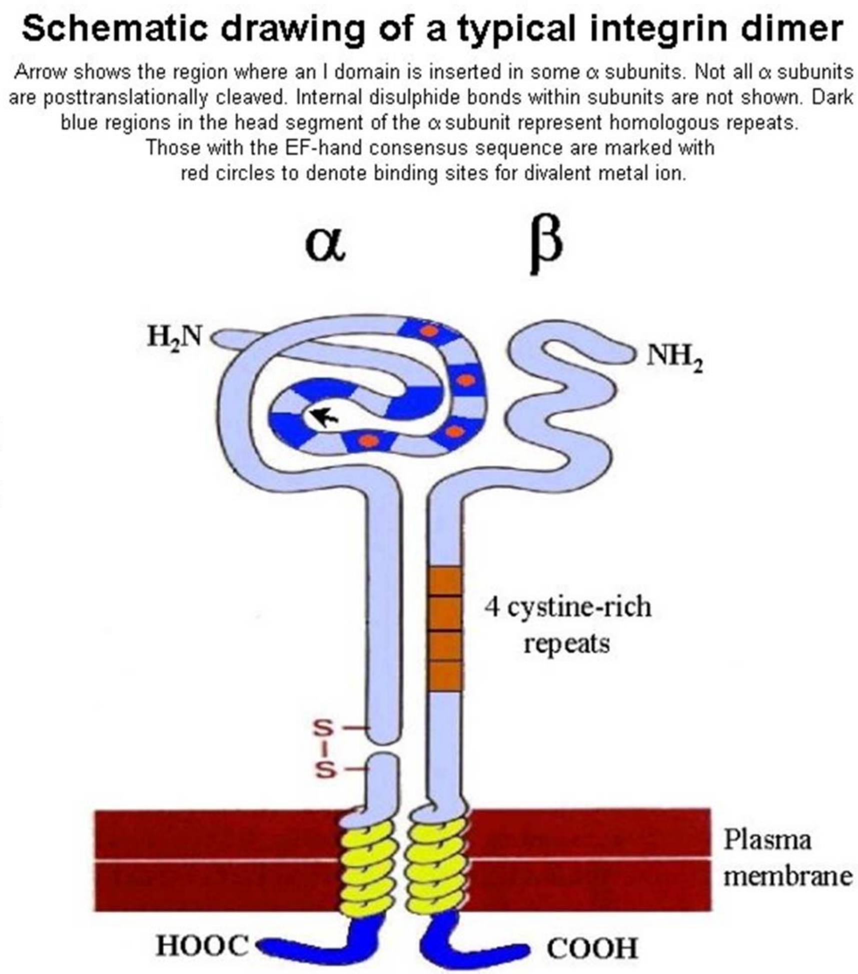
The ECM's main components are various glycoproteins, proteoglycans and hyaluronic acid. In most animals, the most abundant glycoproteins in the ECM are collagens.

ECM also contains many other components: proteins such as fibrin, elastin, fibronectins, laminins, and nidogens, and minerals such as hydroxylapatite, or fluids such as blood plasma or serum with secreted free flowing antigens.

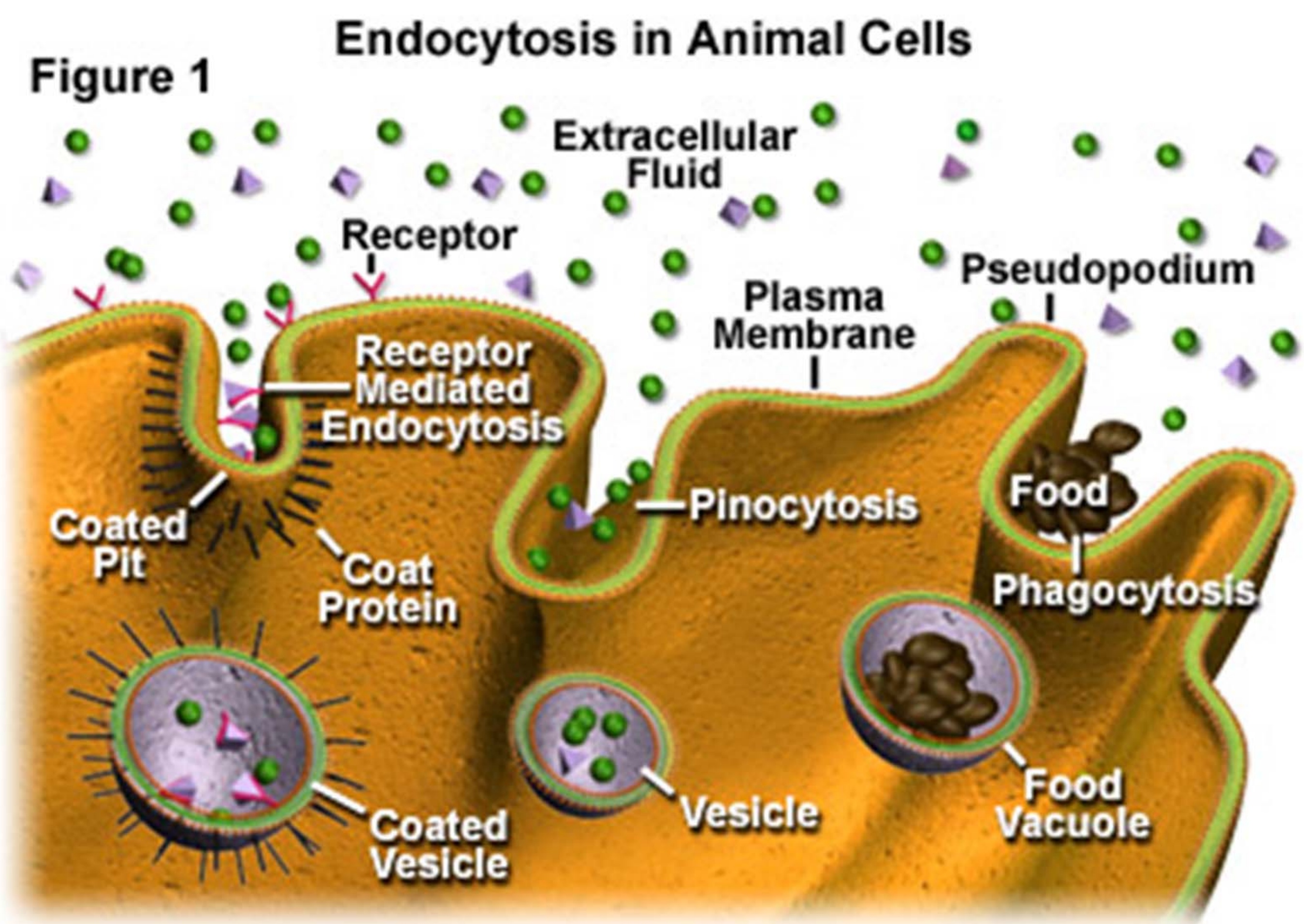


Integrin

An **integrin**, or **integrin receptor**, is an integral membrane protein in the plasma membrane of cells. It plays a role in the attachment of a cell to the extracellular matrix (ECM) and to other cells, and in signal transduction from the ECM to the cell. There are many types of integrin, and many cells have multiple types on their surface. Integrins are of vital importance to all metazoans, from humans to sponges.



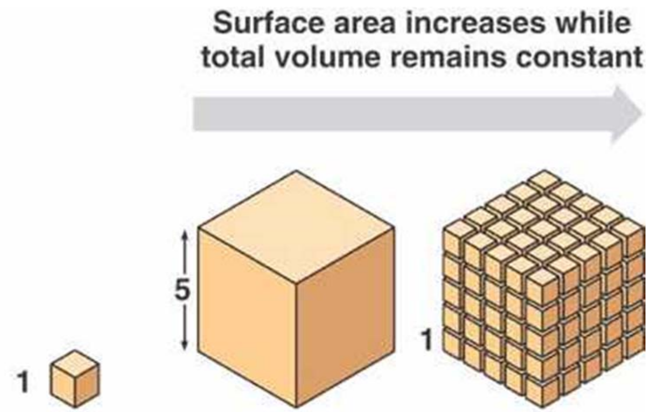
Endocytosis



Nanomaterials

- Metals and Alloys
  - Fe, Al, Au
- Semiconductors
  - Band gap, CdS, TiO_2, ZnO
- Ceramic
  - Al_2O_3, Si_3N_4, MgO, , SiO_2, ZrO_2
- Carbon based
  - Diamond, graphite, nanotube, C60, graphene
- Polymers
  - Soft mater, block co-polymer
- Biological
  - Photonic, hydrophobic, adhesive,
- Composites

Surface to Volume Ratio



Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (surface area / volume)	6	1.2	6

Surface Energy

One face surface energy: γ

27 cube: 27 x 6 γ

3 x 9 cube line: 114 γ

3 x (3x3) square: 90 γ

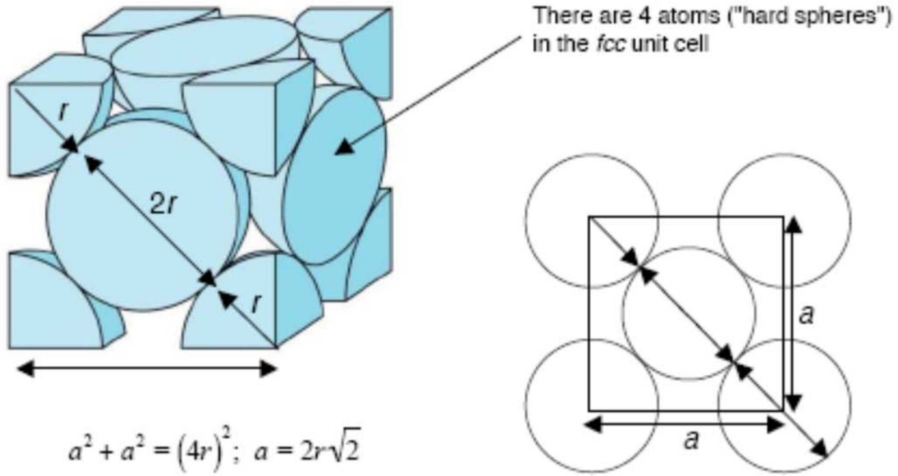
3 x 3 x 3 cube: 54 γ

Surface to Volume Ratio

Au: AAA
Atomic mass: 196.967
Density 19.31
Radii =0.144 nm

Number of Au atoms in 1 m	$3.4\ 10^{9}$
Volume of Au atom	$4.19\ 10^{28}$
Surface area Au atom	$7.22\ 10^{19}$
Surface/volume ratio	$1.72\ 10^{-9}$

fcc



$$a^2 + a^2 = (4r)^2;\ a = 2r\sqrt{2}$$

$$V_{unit\ cell} = a^3 = \left(2r\sqrt{2}\right)^3 = 16(r)^3\sqrt{2}$$

$$V_{unit\ cell} = a^3 = \left(2r\sqrt{2}\right)^3 = 16(0.5\text{nm})^3\sqrt{2} = \mathbf{2.828\ nm^3}$$

$$\frac{10^{27}\ \text{nm}^3}{2.828\ \text{nm}^3} = \mathbf{3.536x10^{26}\ nano\ \ unit\ cells}$$

$$\text{Collective Area} = 3.536x10^{26}\ \text{nano unit cells}\left(\frac{4\ \text{spheres}}{\text{unit cell}}\right)\left(\frac{4\pi r^2}{\text{sphere}}\right) = \mathbf{4.44x10^{27}\ nm^2}$$

$$\frac{S_{spheres}}{S_{unit\ cell}} = \frac{4.44x10^9\ \text{m}^2}{6.0x10^9\ \text{m}^2} = \mathbf{0.74}$$

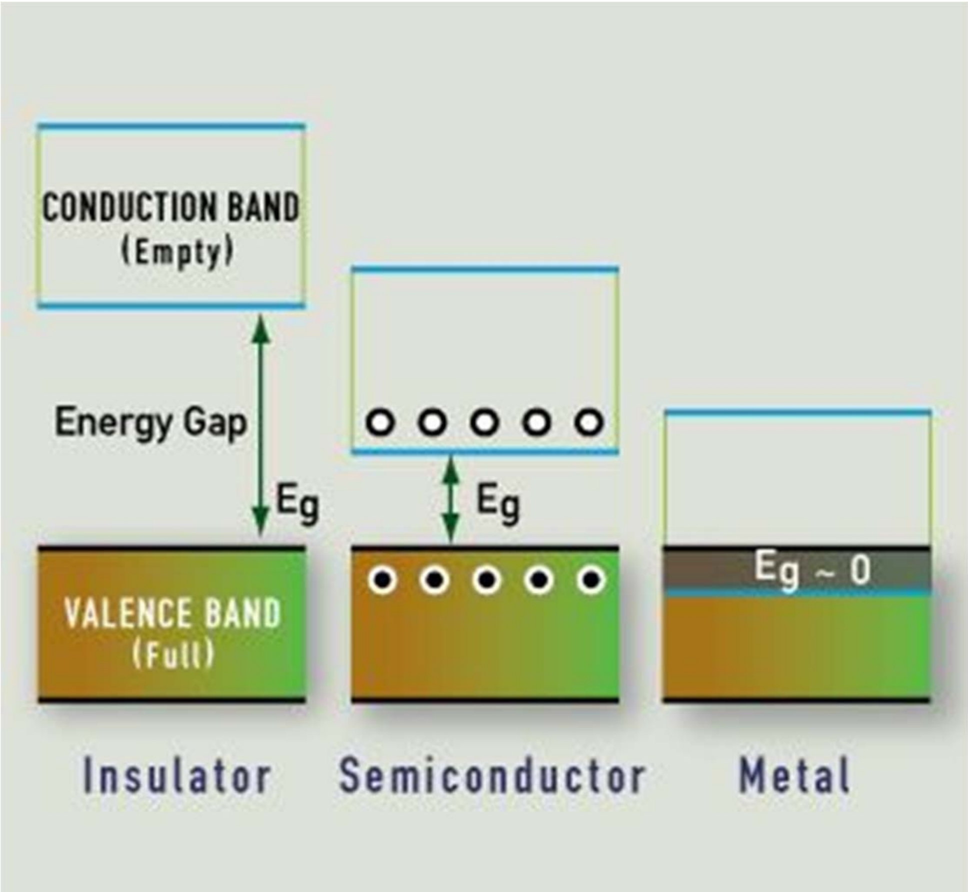
Packing Fraction

$$\mathrm{APF} = \frac{N_{\mathrm{atoms}} V_{\mathrm{atom}}}{V_{\mathrm{crystal}}}$$

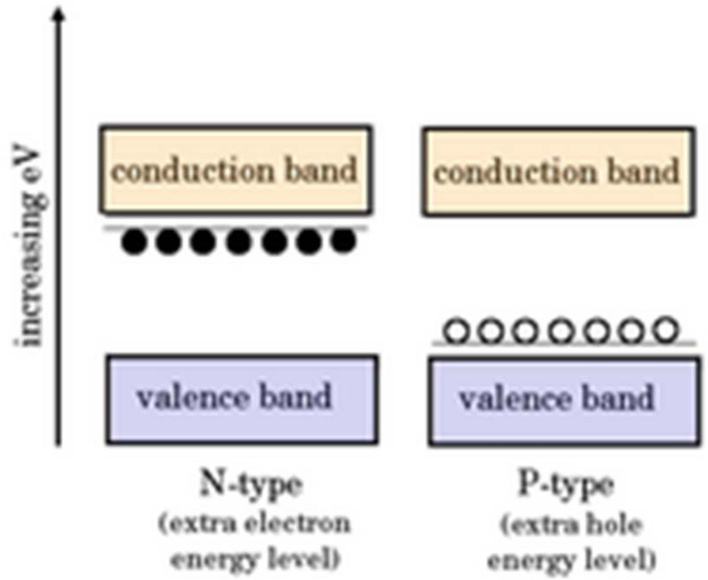
Surfaces

- Collective surface area of nanocube 1 nm
- Porous materials
  - Micropore (<2 nm)
  - Mesopore (2 nm ~ 50 nm)
  - Marcopore (> 50nm)
- Void volume
  - $V_{pore}/V_{material}$

Bandgap

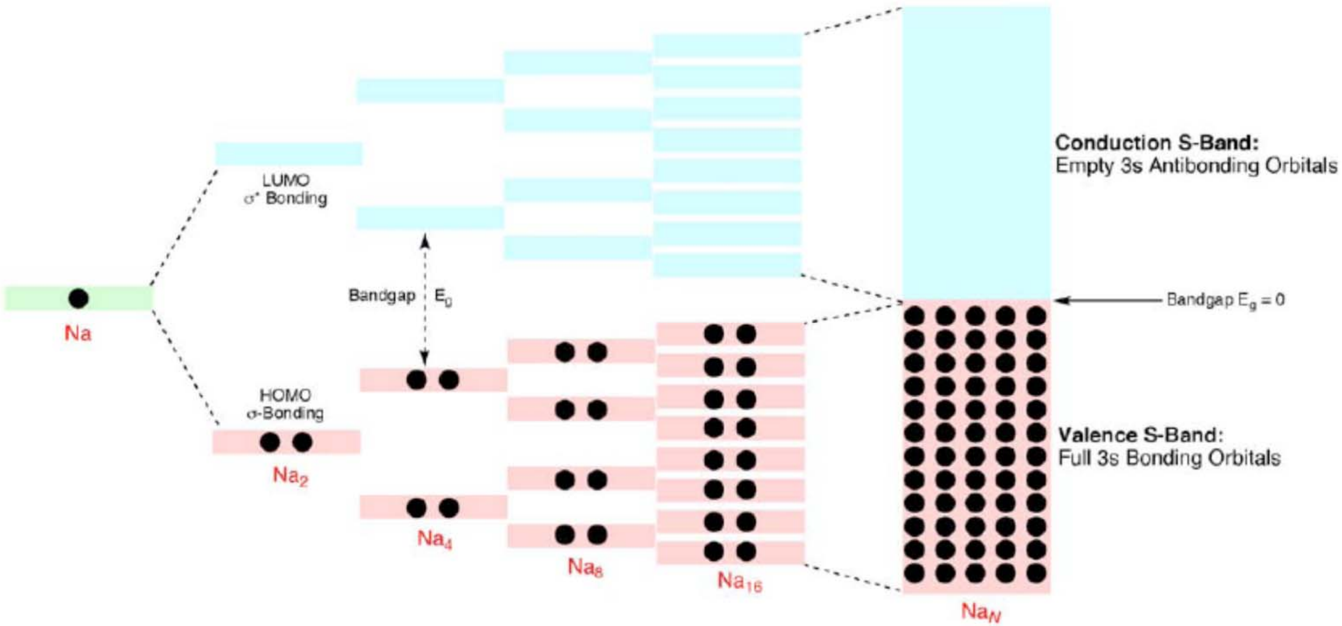


CONDUCTION BAND
(Empty)
Energy Gap
Eg
Eg
Eg ~ 0
VALENCE BAND
(Full)
Insulator
Semiconductor
Metal



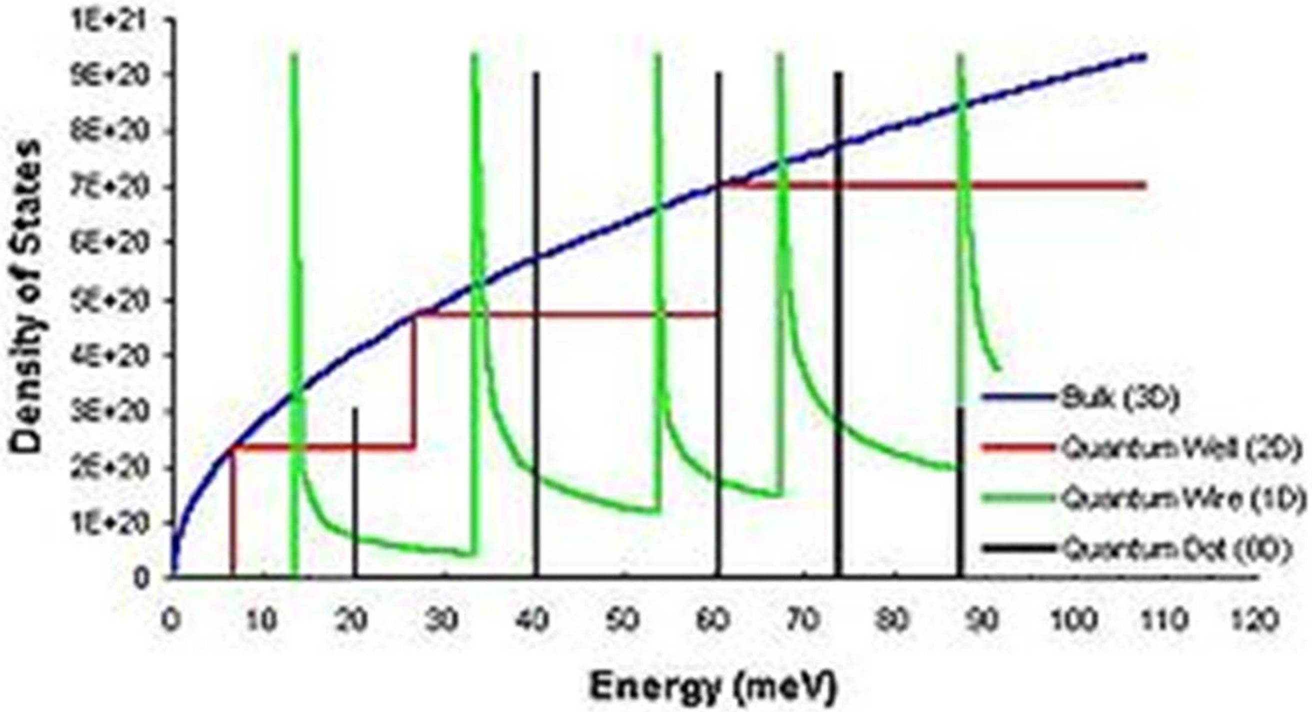
increasing eV
conduction band
conduction band
valence band
valence band
N-type
(extra electron
energy level)
P-type
(extra hole
energy level)

Bandgap



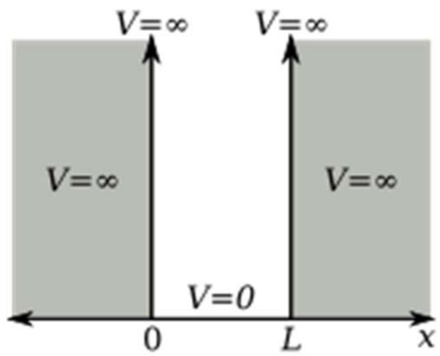
LUMO
σ* Bonding
Bandgap E0
HOMO
σ-Bonding
Na
Na2
Na4
Na8
Na16
NaN
Conduction S-Band:
Empty 3s Antibonding Orbitals
Bandgap Eg = 0
Valence S-Band:
Full 3s Bonding Orbitals

Density of State



Particle in a Box

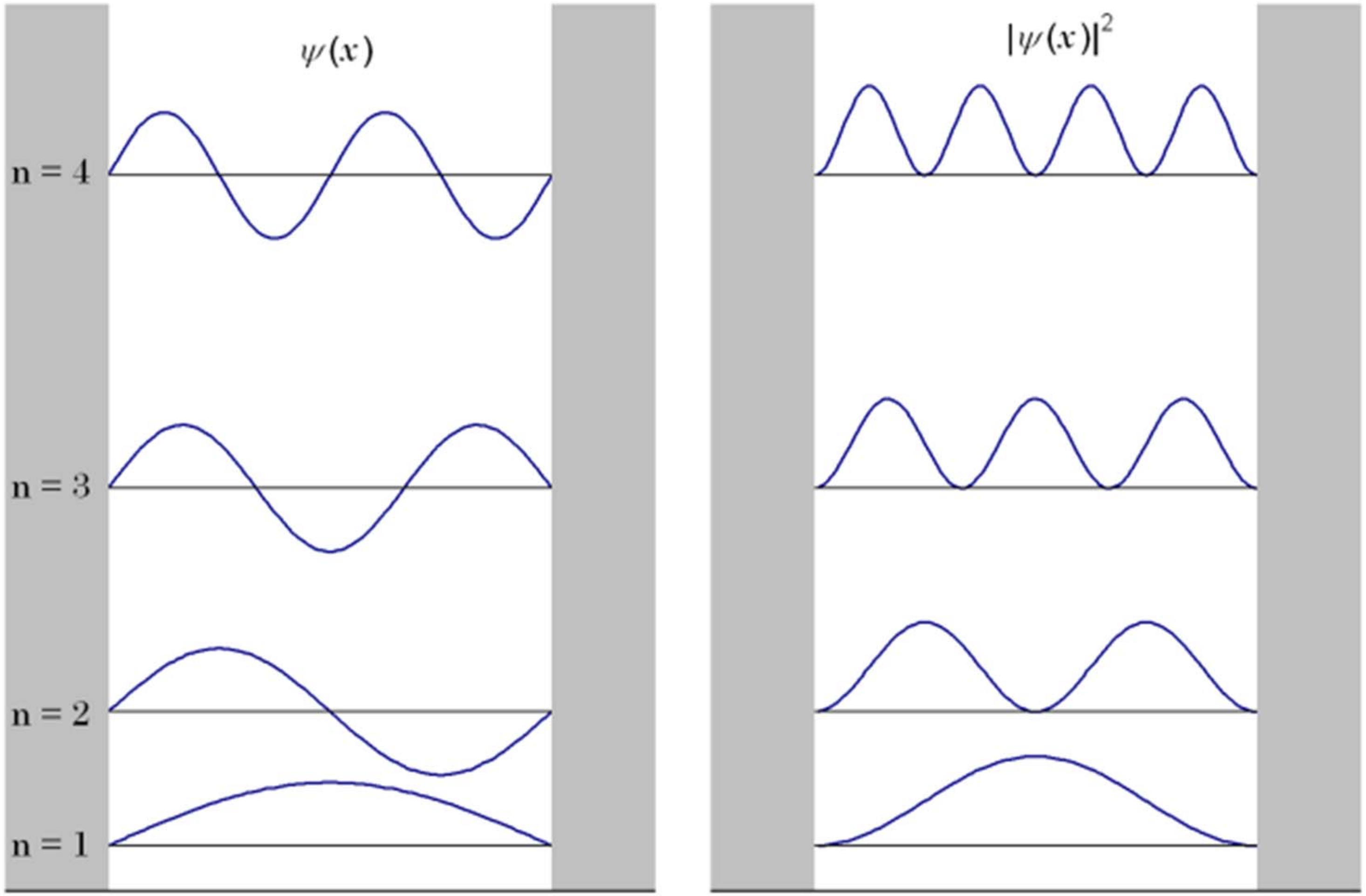
$$-\frac{\hbar^2}{2m}\frac{\mathrm{d}^2\psi(x)}{\mathrm{d}x^2}+V(x)\psi(x)=E\psi(x) \quad (1)$$



$$\psi_n=\sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right)$$

$$E_n=\frac{\hbar^2\pi^2}{2mL^2}n^2$$

Particle in a Box



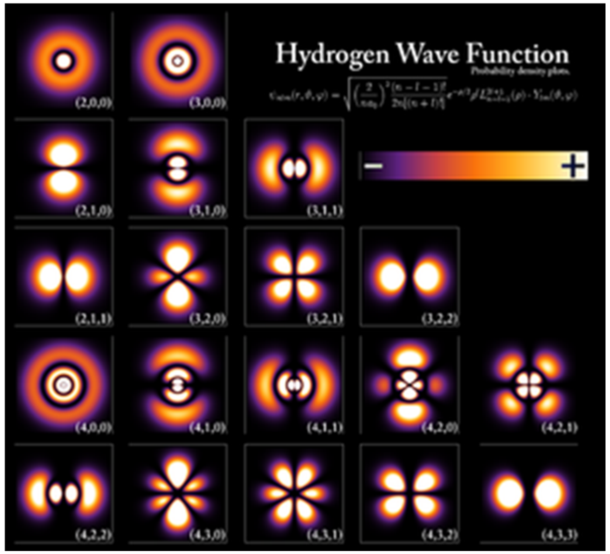
$$\psi_{n_x,n_y} = \sqrt{\frac{4}{L_x L_y}} \sin\left(\frac{n_x \pi x}{L_x}\right) \sin\left(\frac{n_y \pi y}{L_y}\right)$$

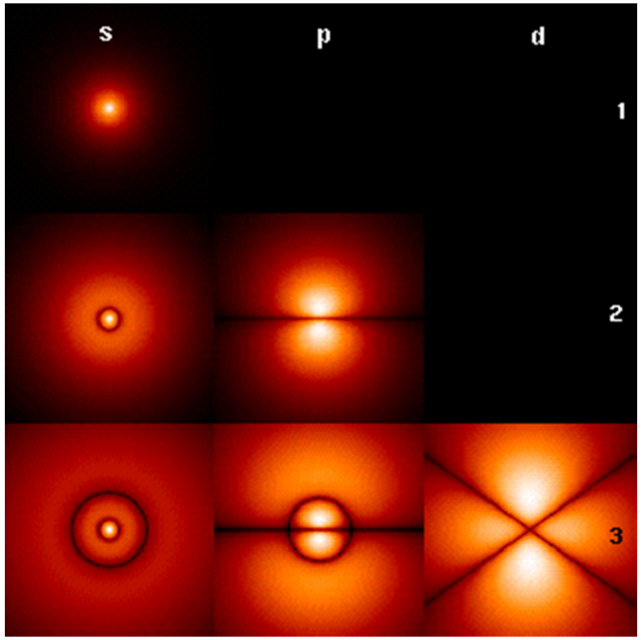
$$E_{n_x,n_y} = \frac{\hbar^2 \pi^2}{2m}\left[\left(\frac{n_x}{L_x}\right)^2 + \left(\frac{n_y}{L_y}\right)^2\right]$$

$$\psi_{n_x,n_y,n_z} = \sqrt{\frac{8}{L_x L_y L_z}} \sin\left(\frac{n_x \pi x}{L_x}\right) \sin\left(\frac{n_y \pi y}{L_y}\right) \sin\left(\frac{n_z \pi z}{L_z}\right) \quad (22)$$

$$E_{n_x,n_y,n_z} = \frac{\hbar^2 \pi^2}{2m}\left[\left(\frac{n_x}{L_x}\right)^2 + \left(\frac{n_y}{L_y}\right)^2 + \left(\frac{n_z}{L_z}\right)^2\right] \quad (23)$$

Wave Functions





$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},\,t) = \hat{H}\Psi = \left(-\frac{\hbar^2}{2m}\nabla^2 + V(\mathbf{r})\right)\Psi(\mathbf{r},\,t) = -\frac{\hbar^2}{2m}\nabla^2\Psi(\mathbf{r},\,t) + V(\mathbf{r})\Psi(\mathbf{r},\,t)$$

$$V(r) = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r}$$

$$\psi_{n\ell m}(r,\vartheta,\varphi) = \sqrt{\left(\frac{2}{na_0}\right)^3\frac{(n-\ell-1)!}{2n(n+\ell)!}}e^{-\rho/2}\rho^\ell L_{n-\ell-1}^{2\ell+1}(\rho)\cdot Y_\ell^m(\vartheta,\varphi)$$

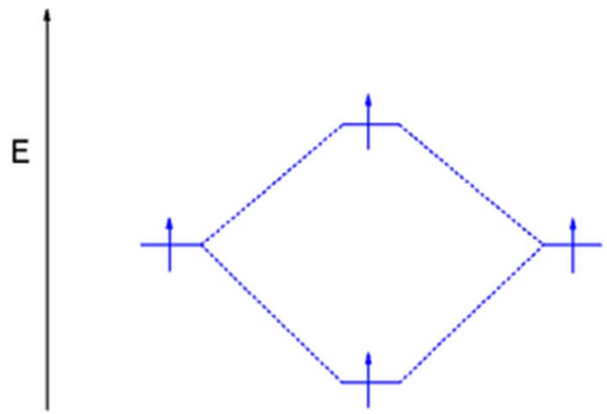
Linear combination of atomic orbitals molecular orbital method

$$\phi_i = c_{1i}\chi_1 + c_{2i}\chi_2 + c_{3i}\chi_3 + \cdots + c_{ni}\chi_n$$

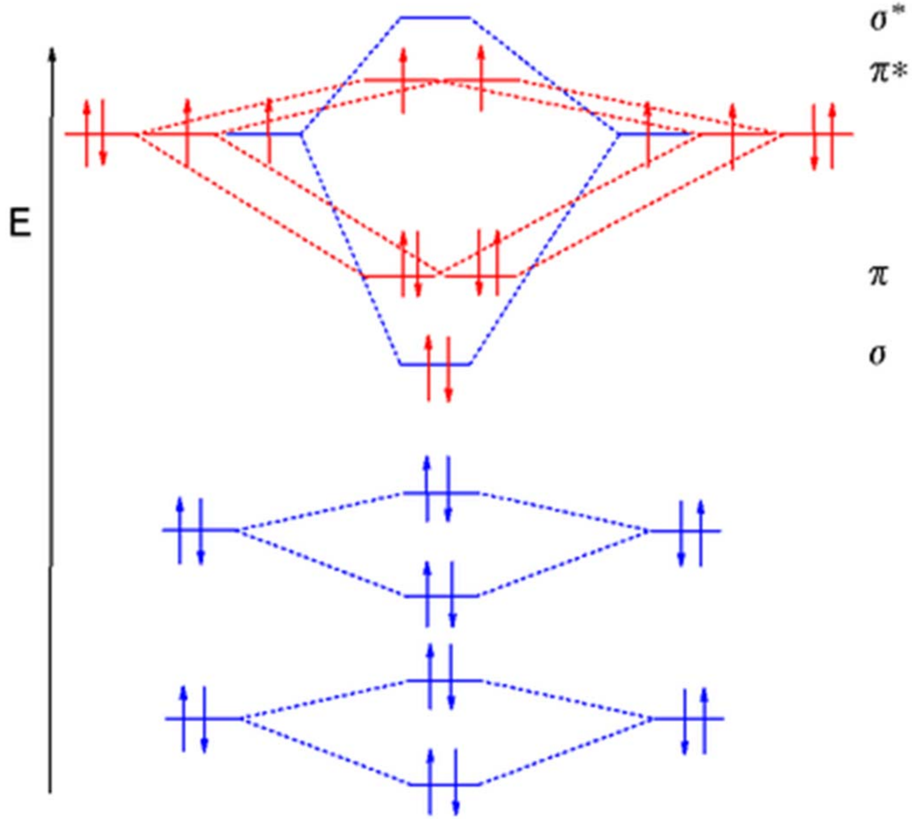
coefficient of AO_μ in MO_i

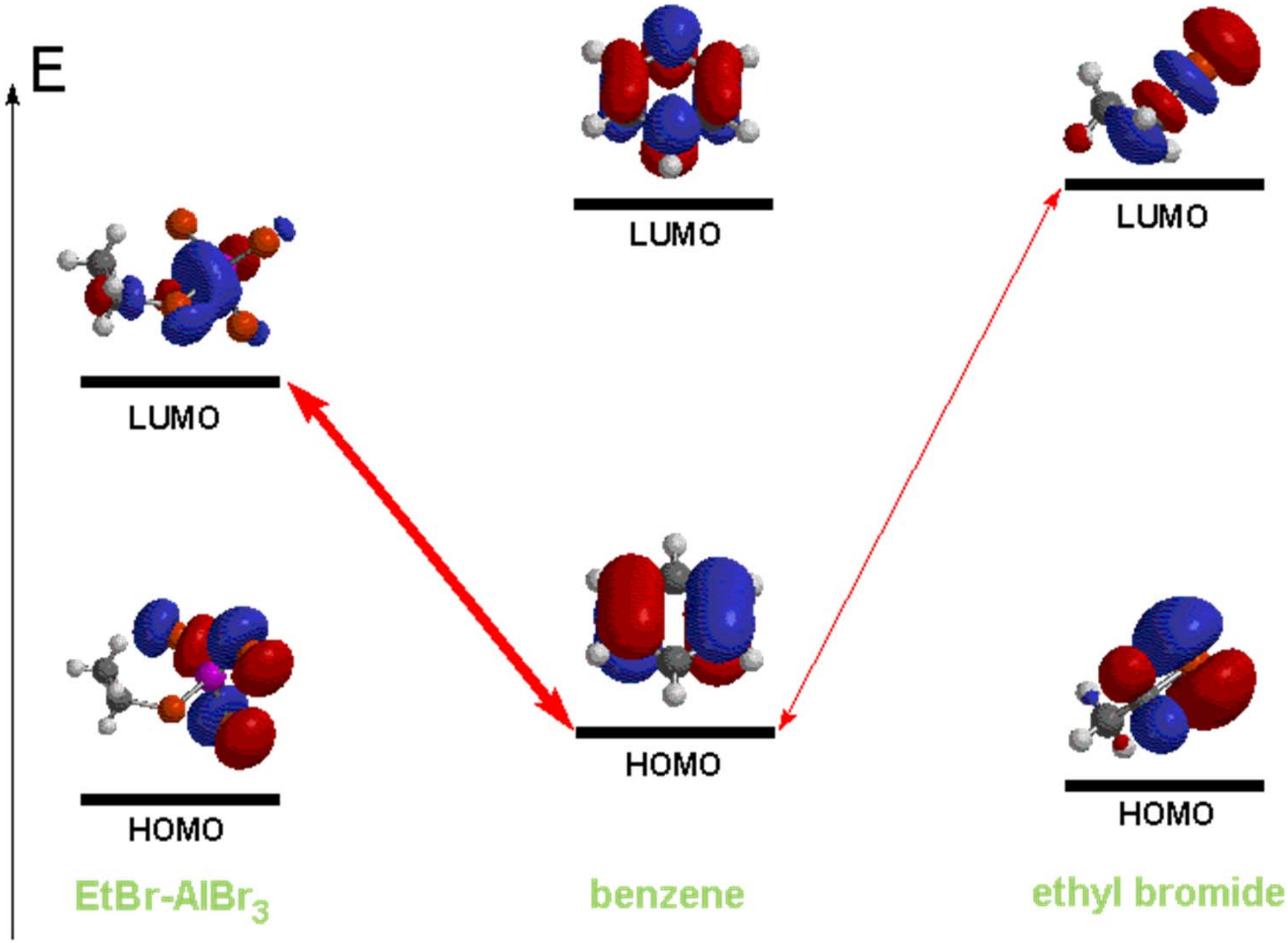
$$\psi_i = \sum_\mu c_{\mu i}\phi_\mu$$

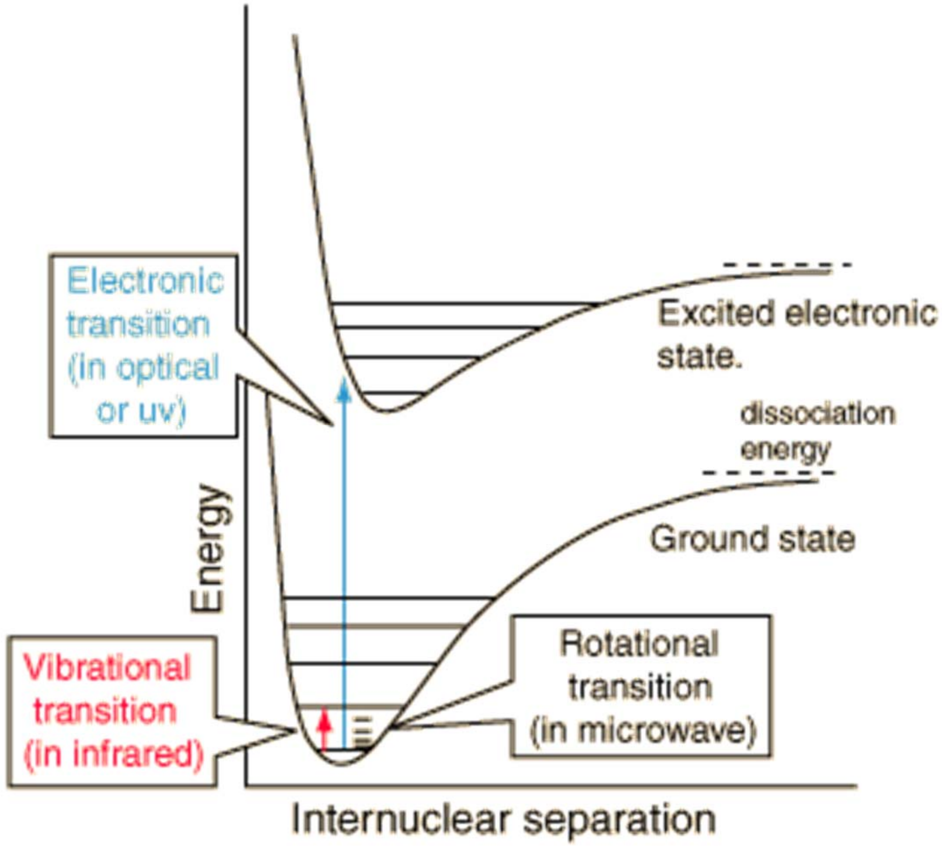
MO AO



Oxygen




E
LUMO
LUMO
LUMO
HOMO
HOMO
HOMO
EtBr-AlBr3
benzene
ethyl bromide


Electronic transition (in optical or uv)
Excited electronic state.
dissociation energy
Energy
Ground state
Rotational transition (in microwave)
Vibrational transition (in infrared)
Internuclear separation

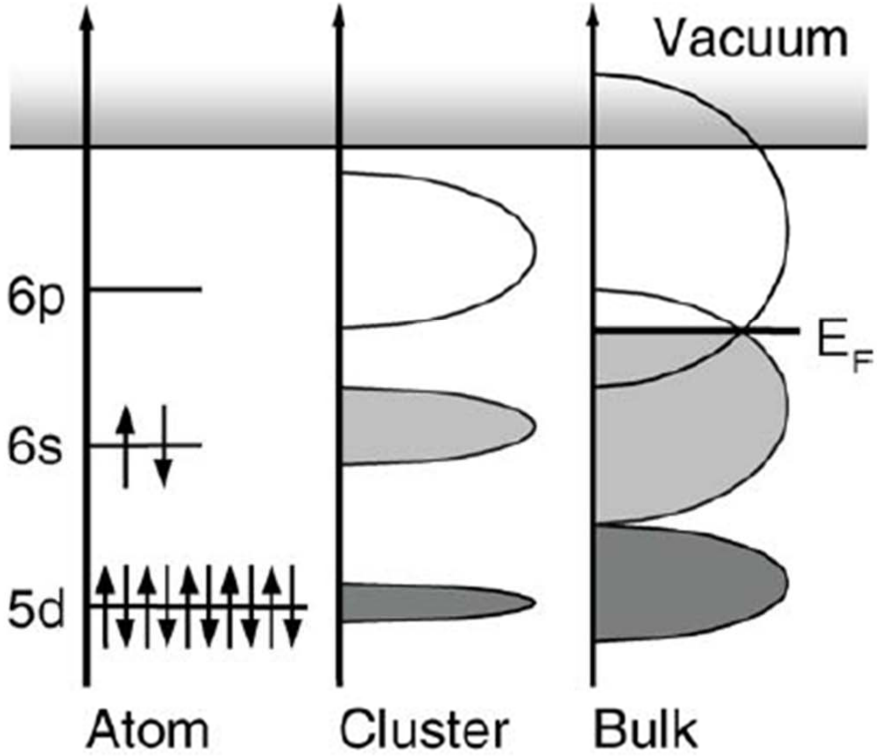


Figure 5 Energy diagram describing a generic Bloch-Wilson MIT in clusters (with specific reference to the energy levels of mercury). For sufficiently large clusters, the *s-p* band gap closes with increasing cluster size (shaded areas represent energy range with occupied electron levels). Overlap leads to a "continuous" DOS at E_F and to an Insulator to Metal transition.

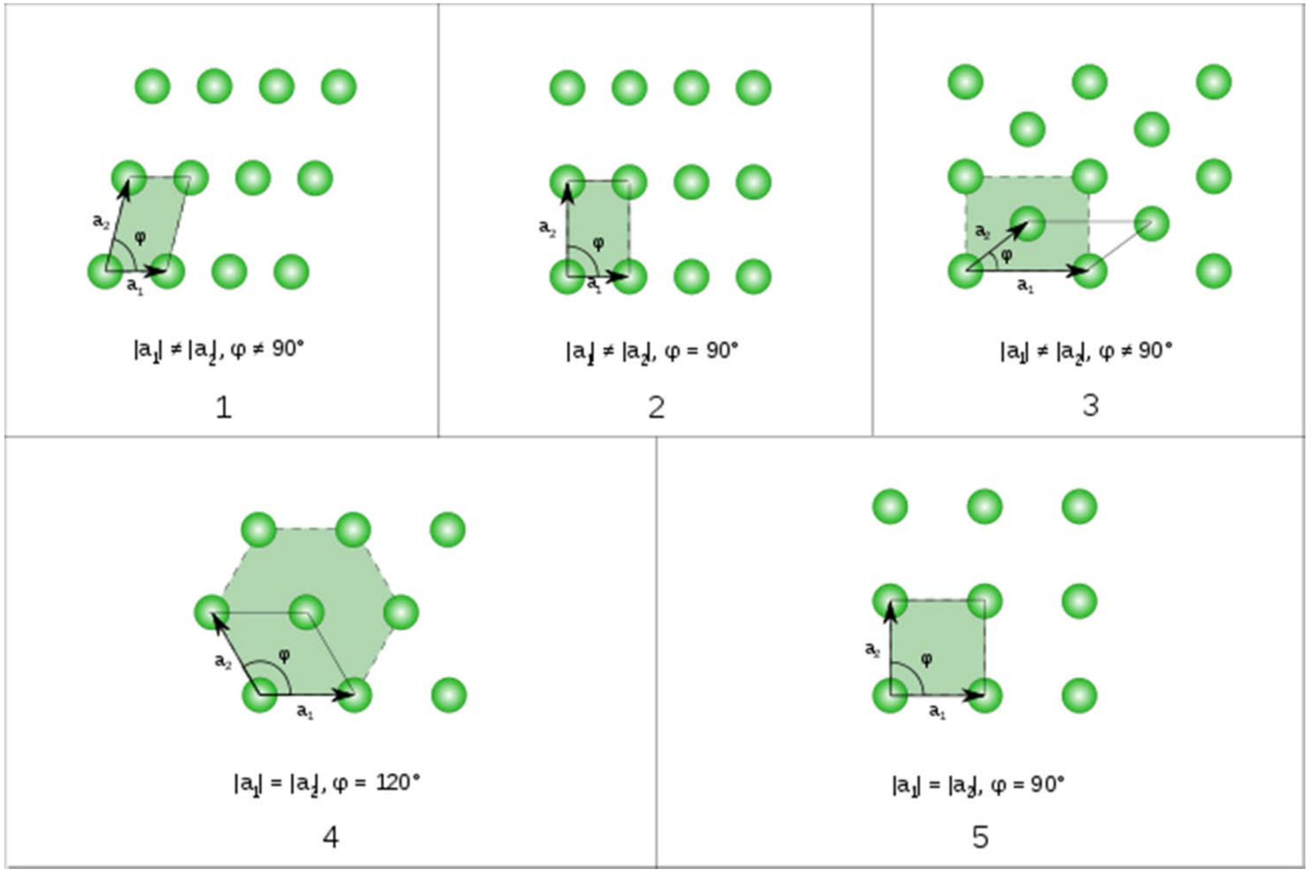
Bloch wave

$$\psi_{n\mathbf{k}}(\mathbf{r}) = e^{i\mathbf{k}\cdot\mathbf{r}} u_{n\mathbf{k}}(\mathbf{r})$$

A **Bloch wave** or **Bloch state**, named after Felix Bloch, is the wavefunction of a particle (usually, an electron) placed in a periodic potential.

$\epsilon n(\mathbf{k}) = \epsilon n(\mathbf{k} + \mathbf{K})$,

The five fundamental two-dimensional Bravais lattices



Unit Cell

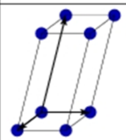
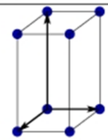
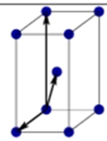
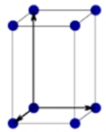
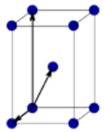
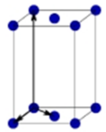
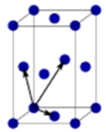
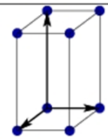
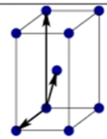
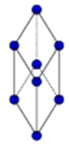
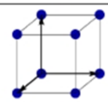
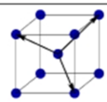
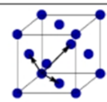
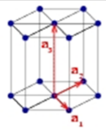
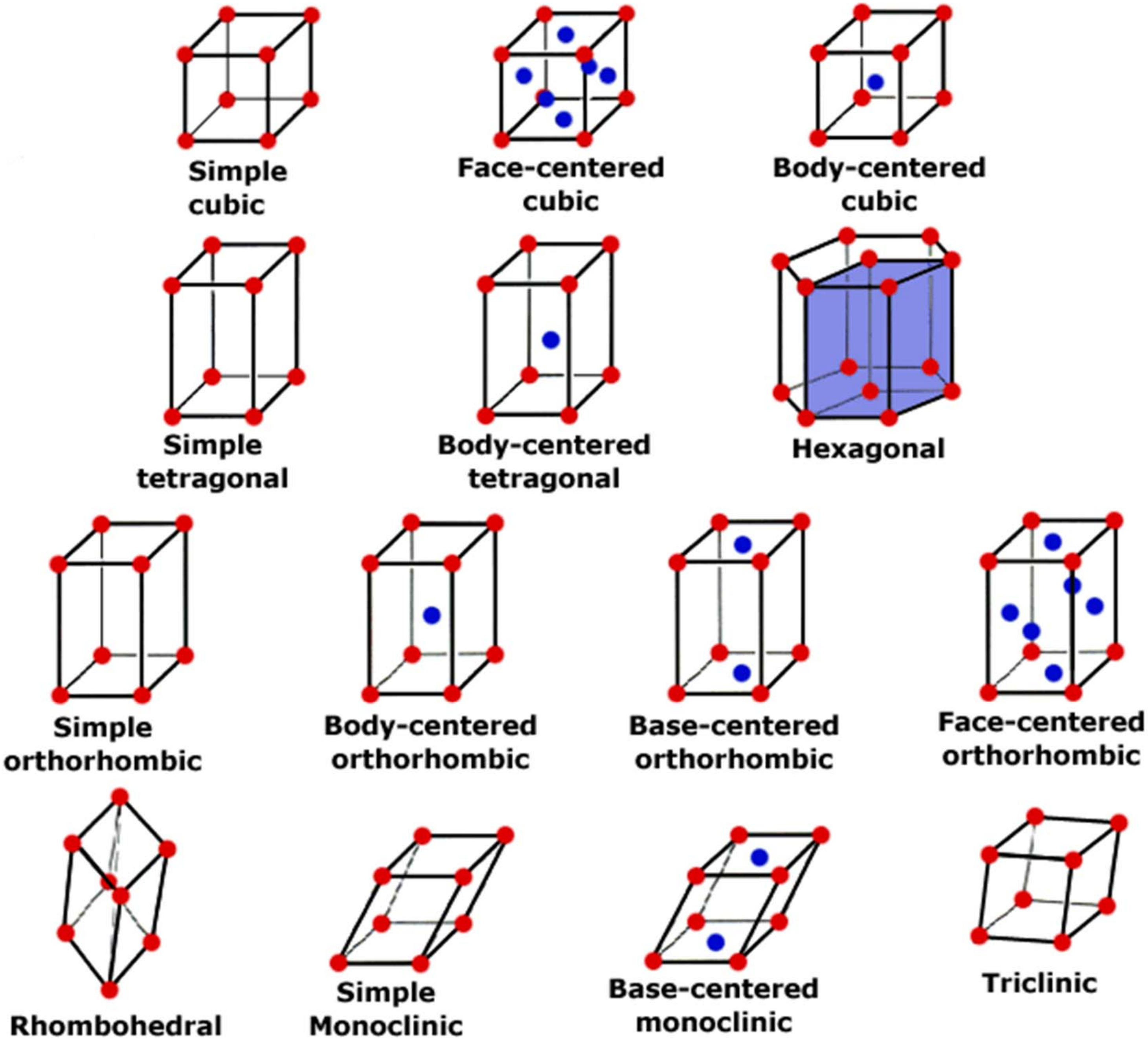
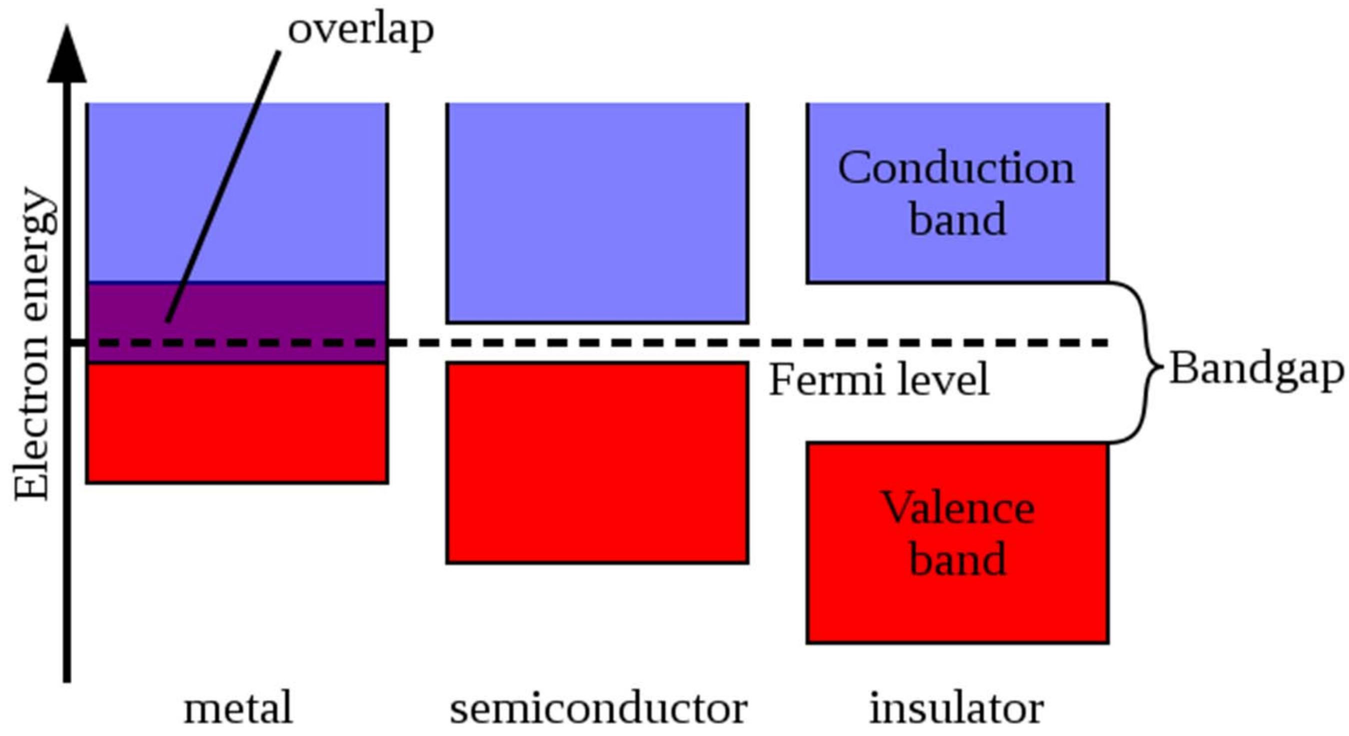
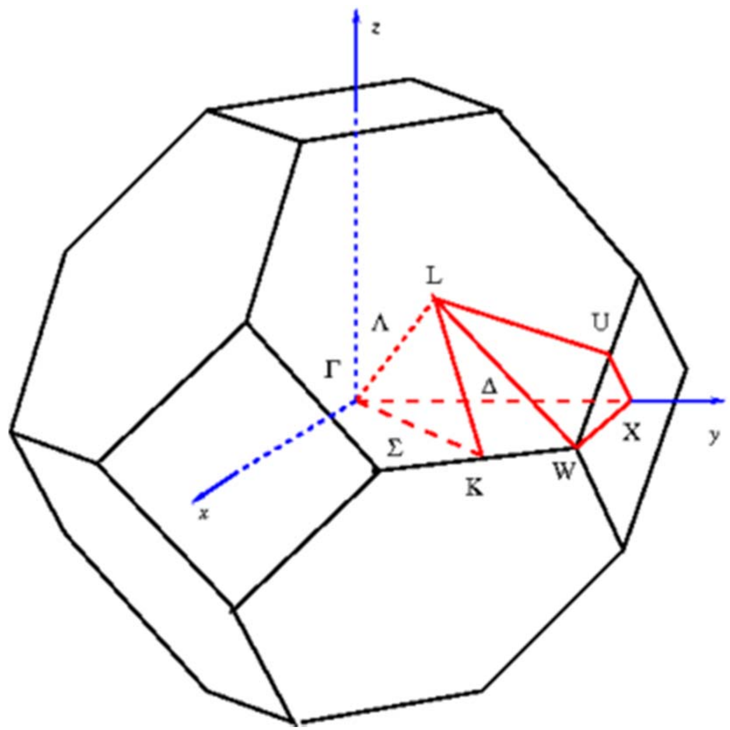
Bravais	Parameters	Simple (P)	Volume	Base	Face
lattice			centered (I)	centered (C)	centered (F)
Triclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} \neq \alpha_{23} \neq \alpha_{31}$				
Monoclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{23} = \alpha_{31} = 90°$ $\alpha_{12} \neq 90°$				
Orthorhombic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90°$				
Tetragonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90°$				
Trigonal	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} < 120°$				
Cubic	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90°$				
Hexagonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = 120°$ $\alpha_{23} = \alpha_{31} = 90°$				

Table 1.1: Bravais lattices in three-dimensions.

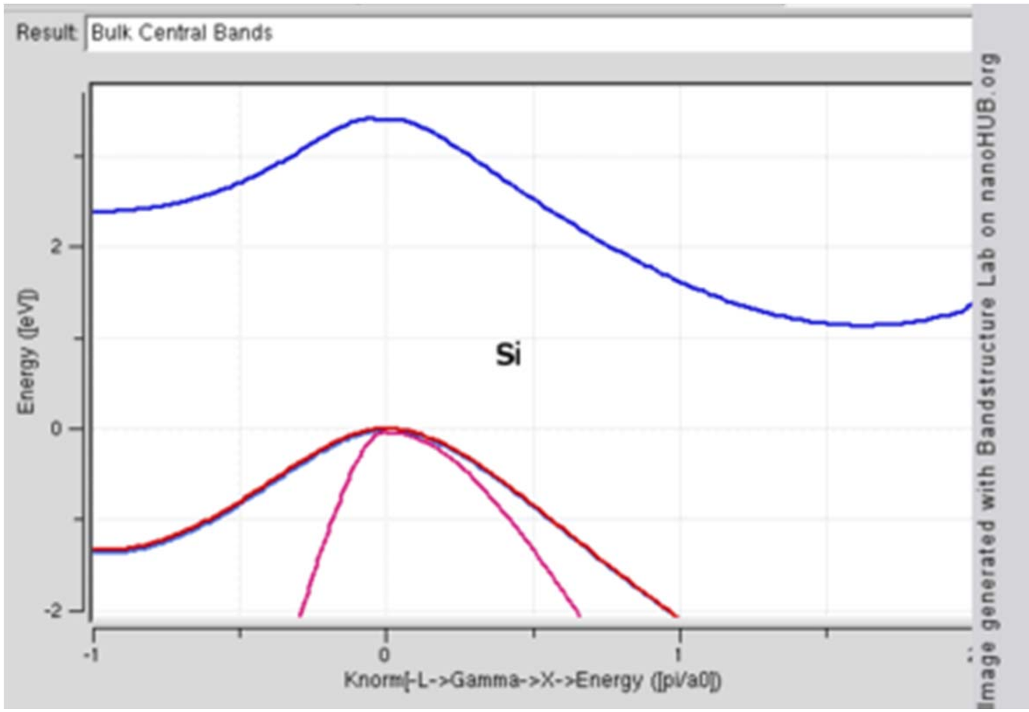

Simple cubic
Face-centered cubic
Body-centered cubic
Simple tetragonal
Body-centered tetragonal
Hexagonal
Simple orthorhombic
Body-centered orthorhombic
Base-centered orthorhombic
Face-centered orthorhombic
Rhombohedral
Simple Monoclinic
Base-centered monoclinic
Triclinic


overlap
Electron energy
Conduction band
Fermi level
Bandgap
Valence band
metal
semiconductor
insulator

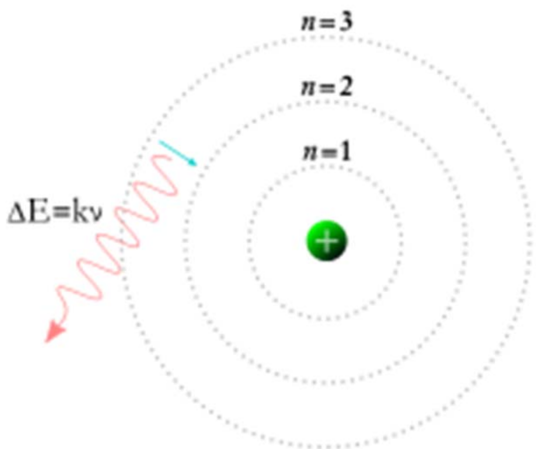
First Brillouin zone of FCC lattice showing symmetry labels

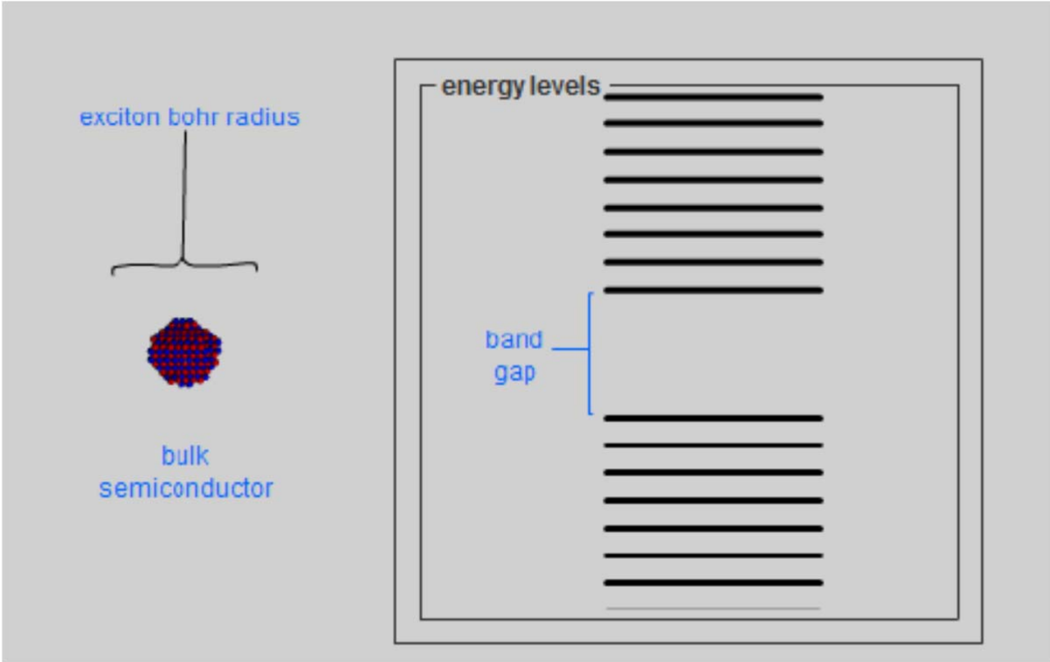


Band Structures

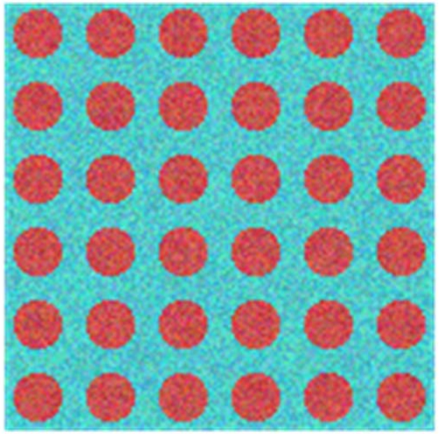


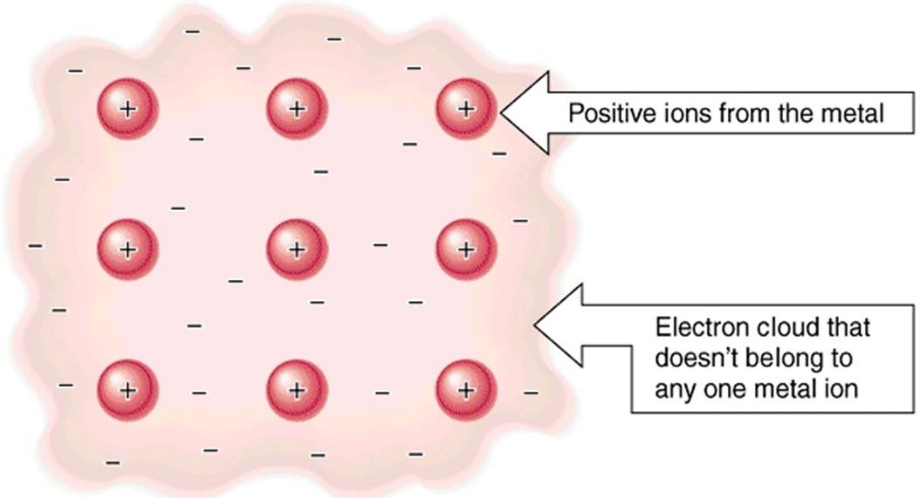
Bohr Exciton Radius





Electron Sea

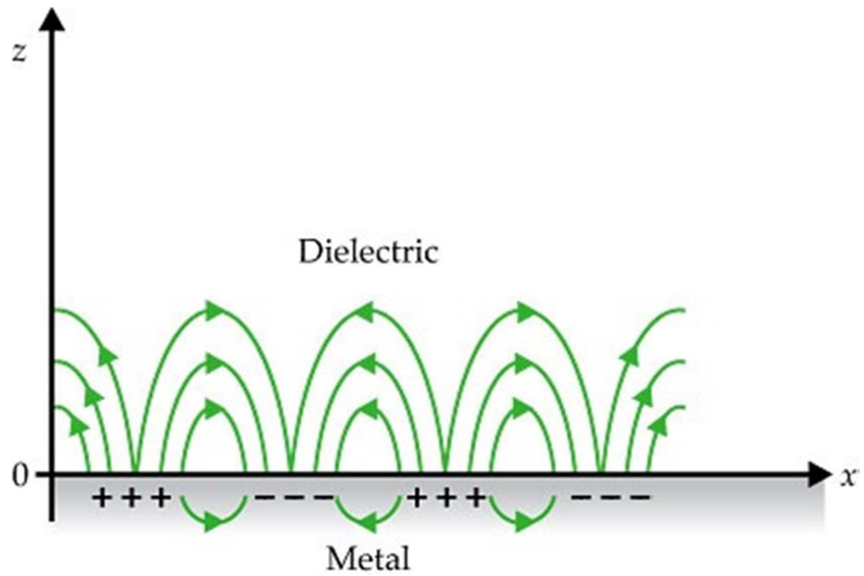




$$m \frac{d^2 \delta x}{dt^2} = e\, E_x = -m {\omega_p}^2\, \delta x,$$

$$ {\omega_p}^2 = \frac{n\, e^2}{\epsilon_0\, m},$$

Surface Plasmonon



$$\varepsilon_m = 1 - \frac{\omega_p^2}{\omega^2}$$

TiO_2

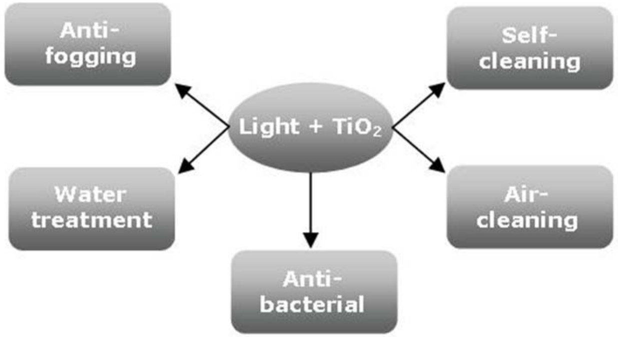
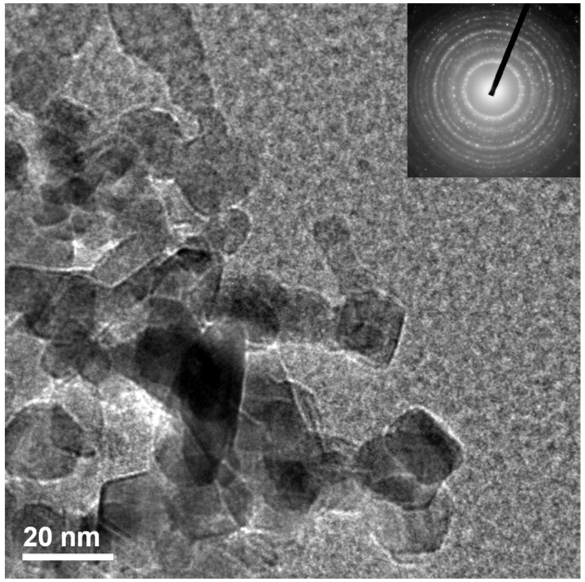
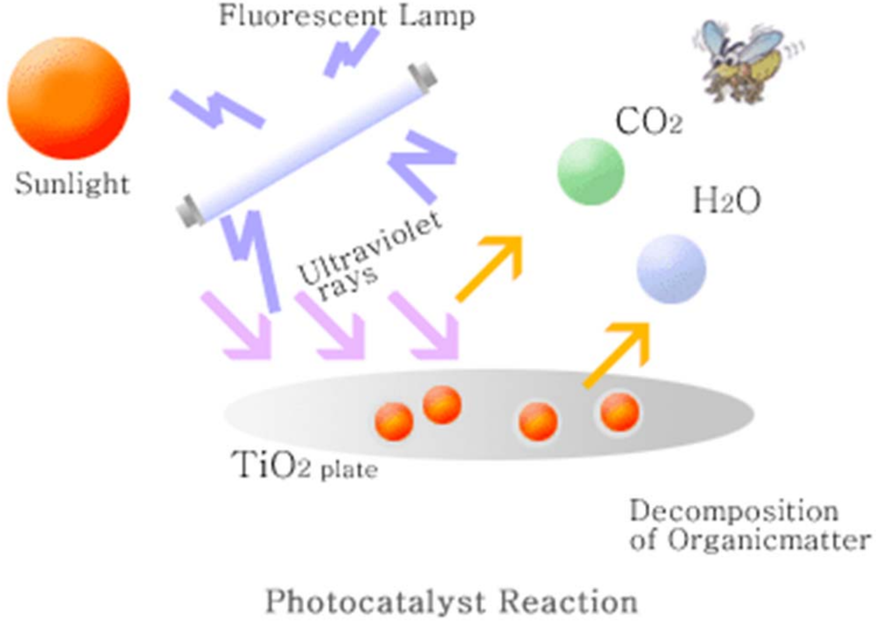
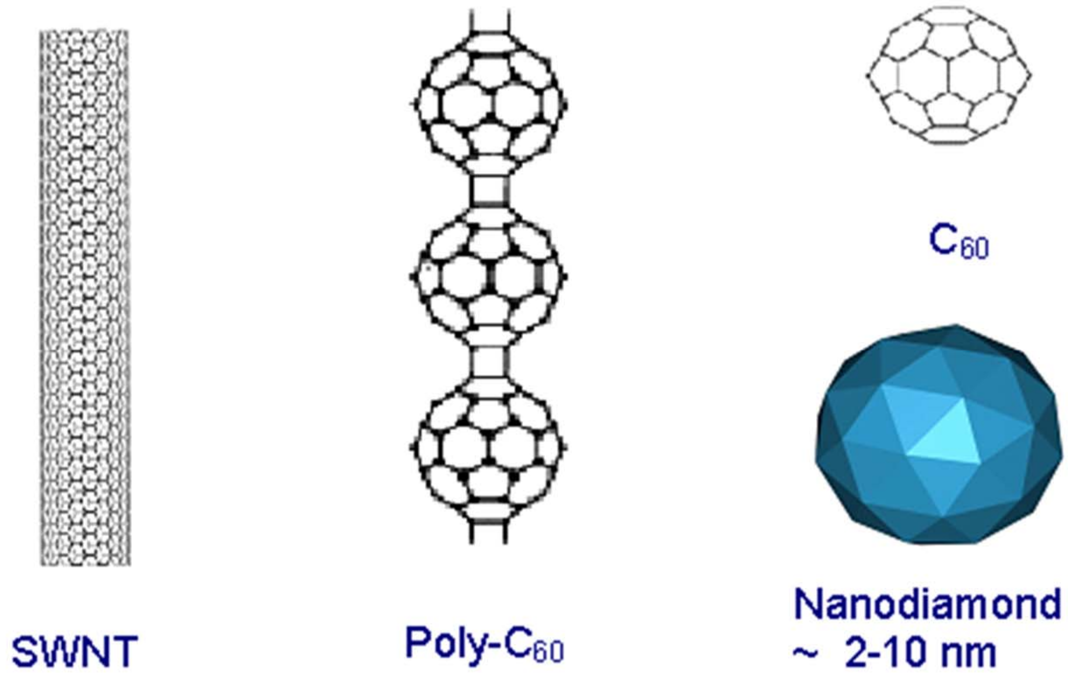


Figure 1. Major areas of activity in titanium dioxide photocatalysis

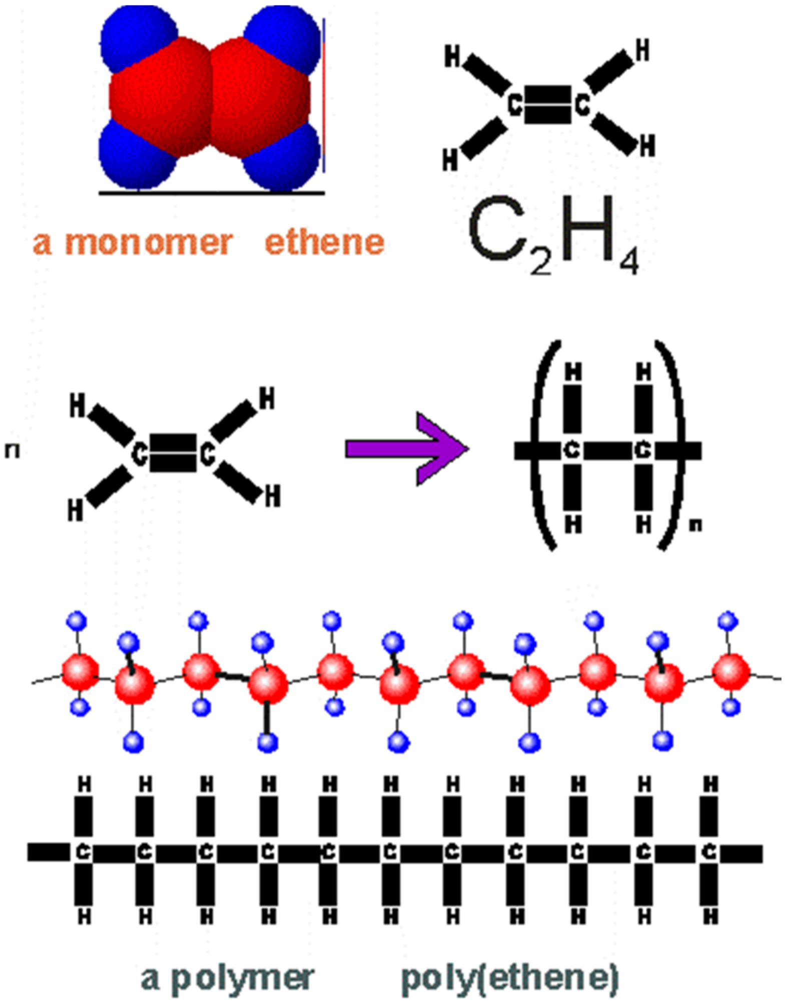


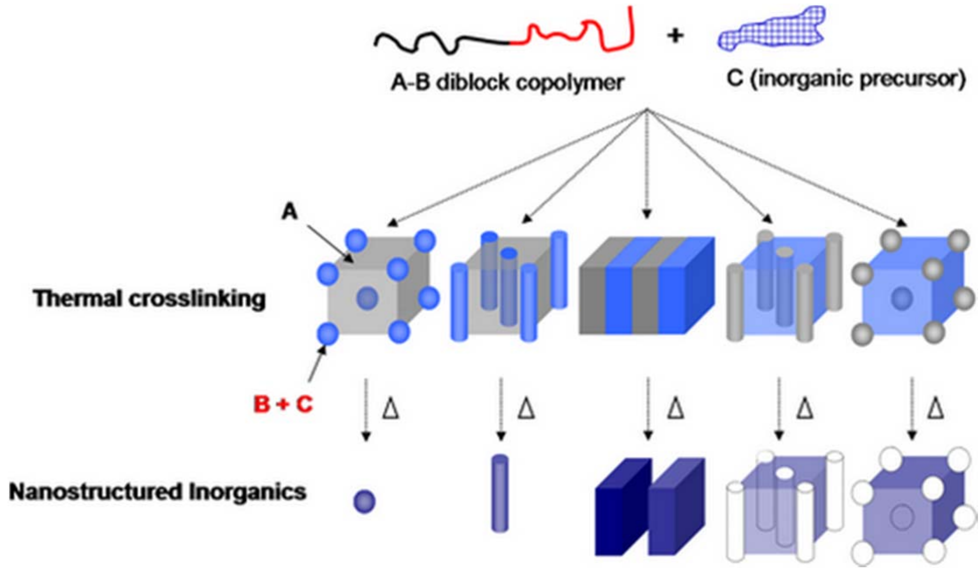


Carbon

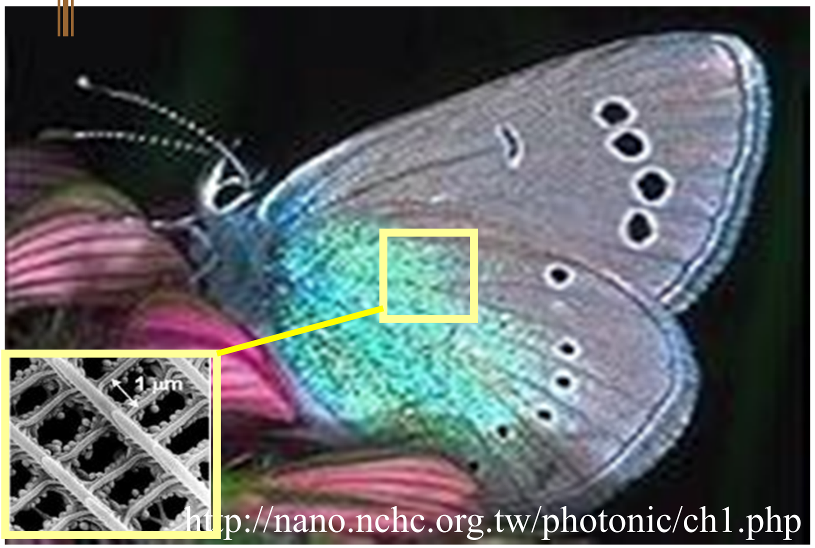


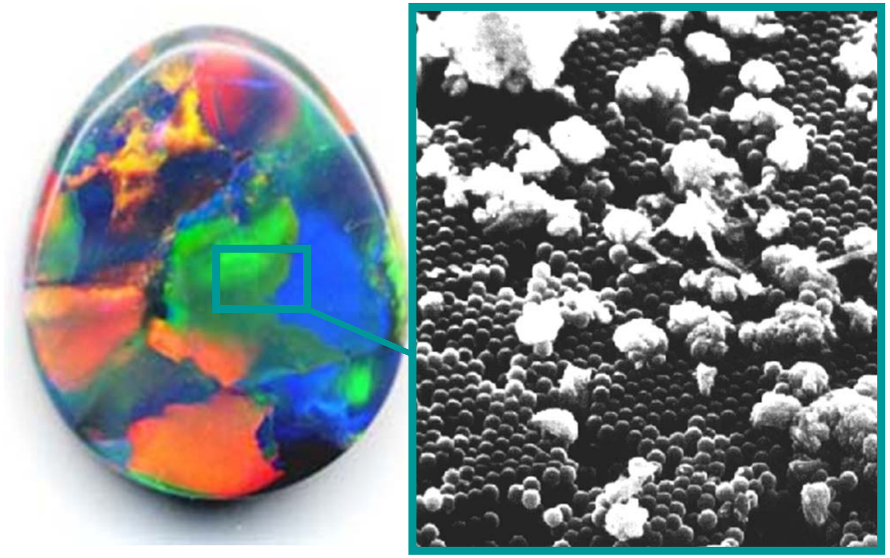
Polymer

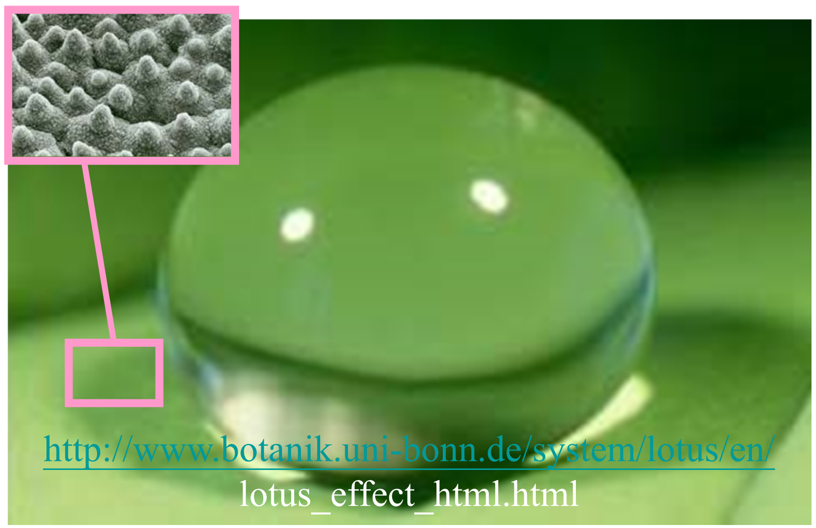

a monomer
ethene
C_2H_4
a polymer
poly(ethene)

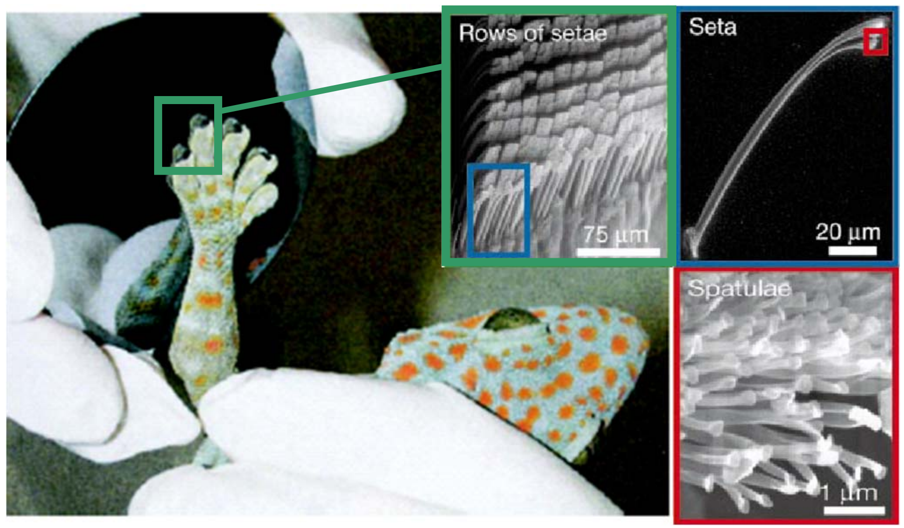

A-B diblock copolymer
+
C (inorganic precursor)
A
Thermal crosslinking
B + C
Δ
Nanostructured Inorganics

Nature Materials

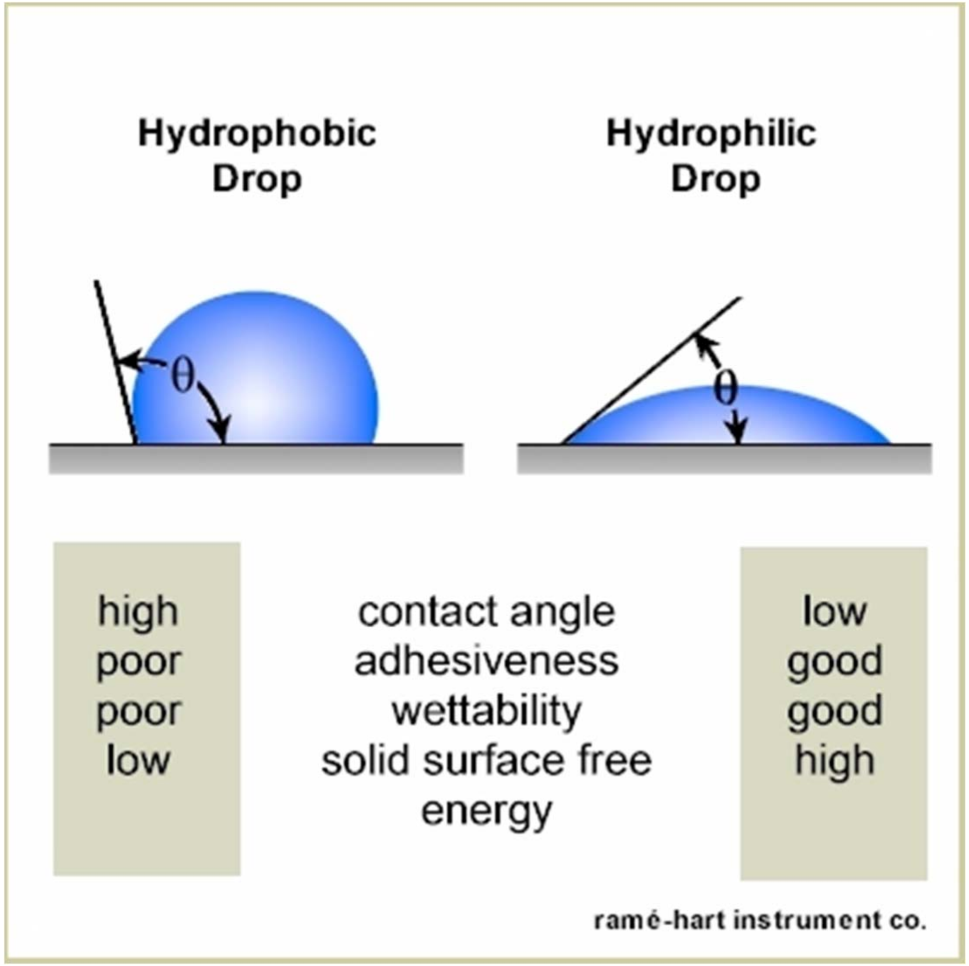






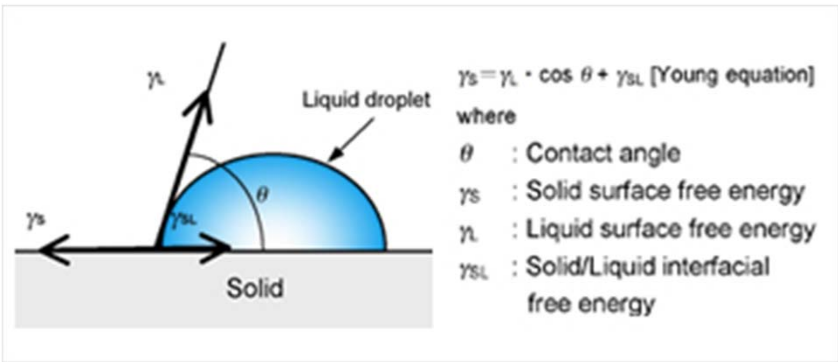


Contact Angle



Young's Equation

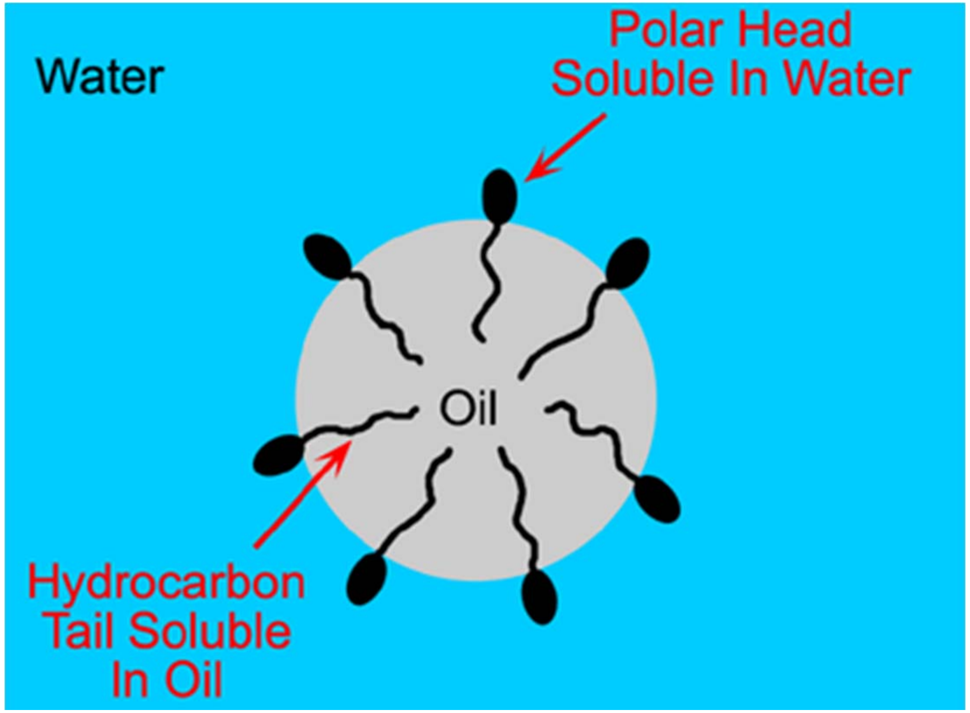
$$\gamma_{SL} + \gamma_{LV}\cos\theta_c = \gamma_{SV}$$



Surface Energy Minimization

- Surfactants
- DLVO
- Polymeric
- Nucleation
- Ostwald Ripening
- Sintering
- Restructure

Surfactant


Water
Polar Head
Soluble In Water
Oil
Hydrocarbon
Tail Soluble
In Oil

DLVO Theory

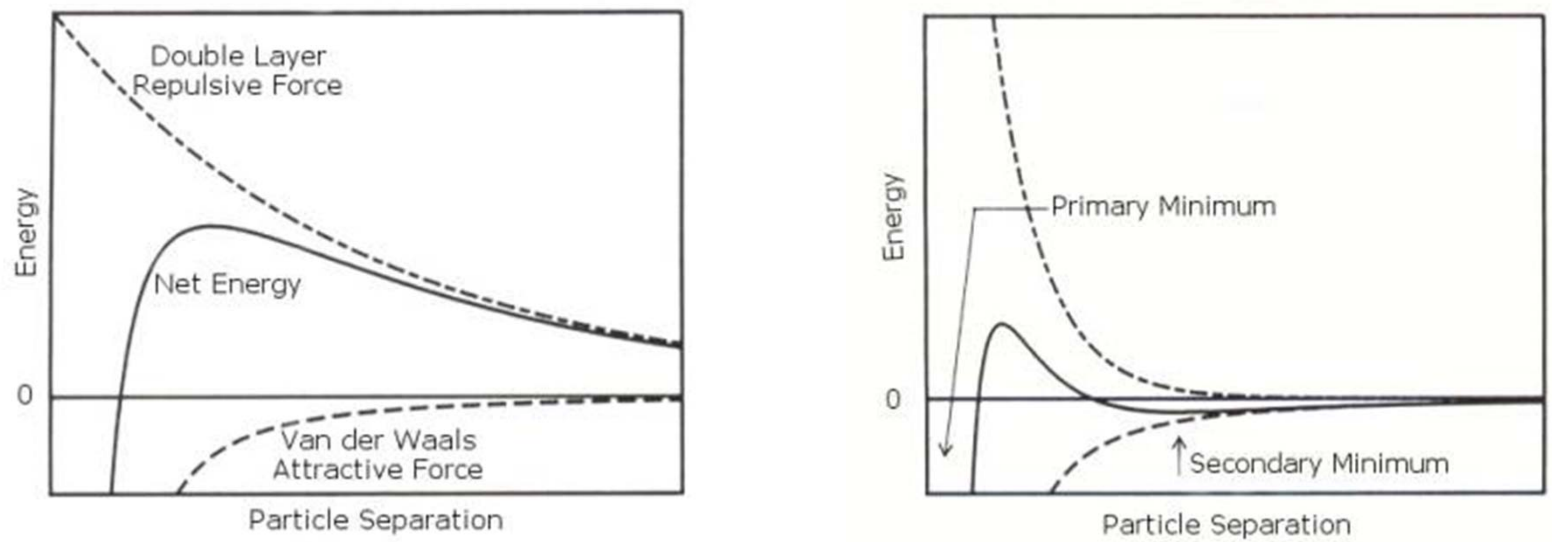
$$V_T = V_A + V_R + V_S$$

$$V_A = -A/(12 \pi D^2)$$

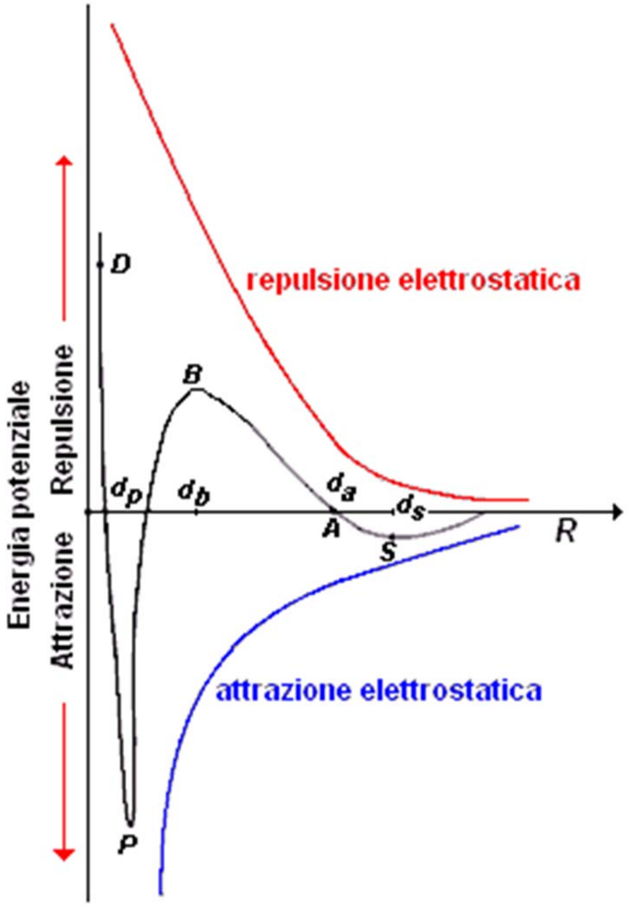
A is the Hamaker constant and D is the particle separation

$$V_R = 2 \pi \varepsilon a \xi^2 \exp(- \kappa D)$$

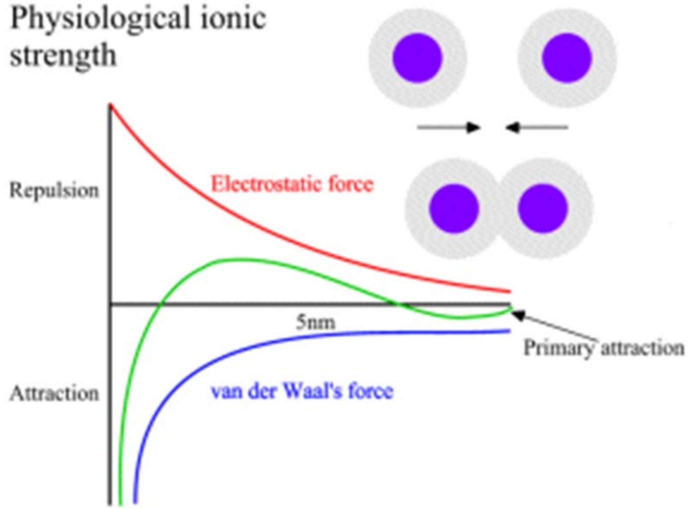
a is the particle radius, π is the solvent permeability,
κ is a function of the ionic composition and ξ is the zeta potential


Double Layer
Repulsive Force
Energy
Net Energy
0
Van der Waals
Attractive Force
Particle Separation
Energy
Primary Minimum
0
Secondary Minimum
Particle Separation

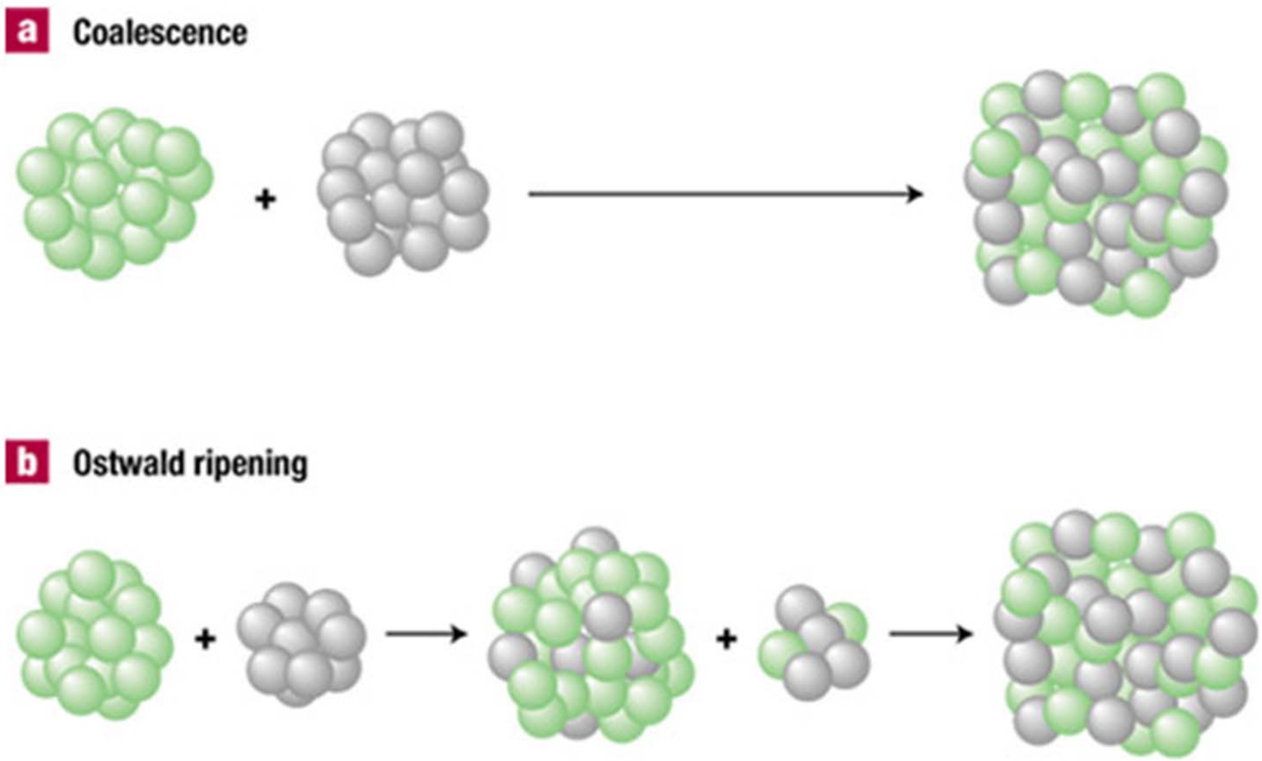
DLVO Theory



Energia potenziale
Repulsione
Attrazione
D
B
d_p
d_b
d_a
d_s
A
S
P
R
repulsione elettrostatica
attrazione elettrostatica



Physiological ionic strength
Repulsion
Attraction
Electrostatic force
van der Waal's force
5nm
Primary attraction



Two main mechanisms are shown here: **a**, coalescence sintering, and **b**, Ostwald ripening sintering. Coalescence sintering occurs when two clusters touch or collide and merge to form one bigger cluster. In contrast, Ostwald ripening sintering occurs by evaporation of atoms from one cluster, which then transfer to another. This is a dynamic process — both clusters exchange atoms, but the rate of loss from the smaller cluster is higher, because of the lower average coordination of atoms at the surface and their relative ease of removal. Thus big clusters get bigger at the expense of smaller clusters, which shrink and eventually disappear. The latter process is the usual form of sintering for metal clusters on a supported surface that are well spaced apart, although coalescence can occur for a high density of clusters. In general, the presence of the surface results in SMORS (surface-mediated Ostwald ripening sintering) in which material is transferred from one cluster to another by diffusion across the surface, and not through the gas phase.

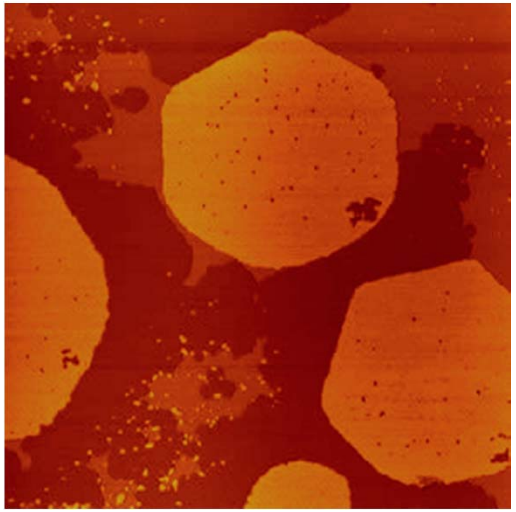
Synthesis of Nanoparticles and Surface Modifications

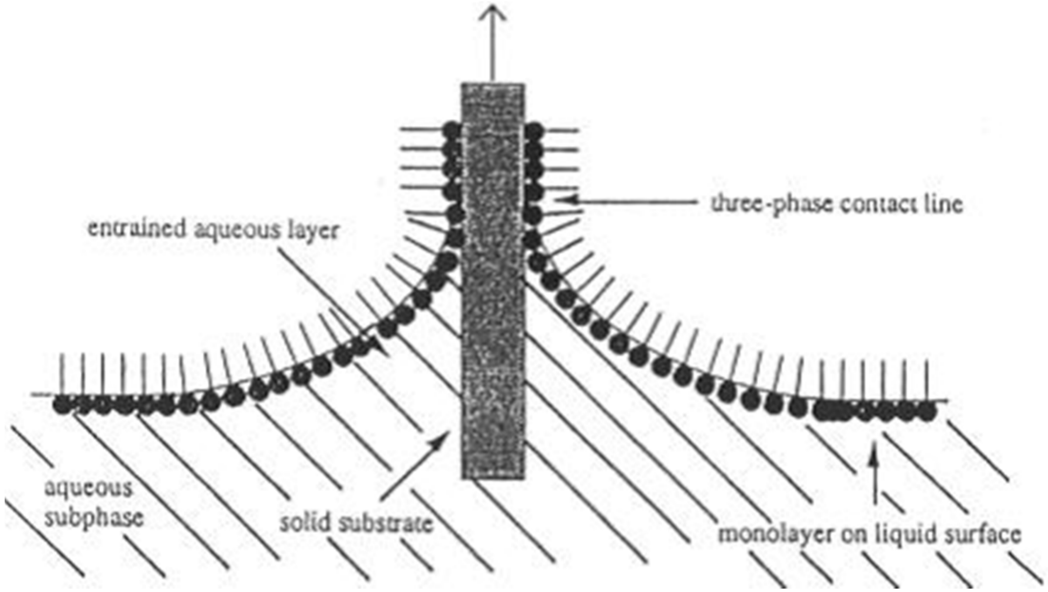
Self-Assembly

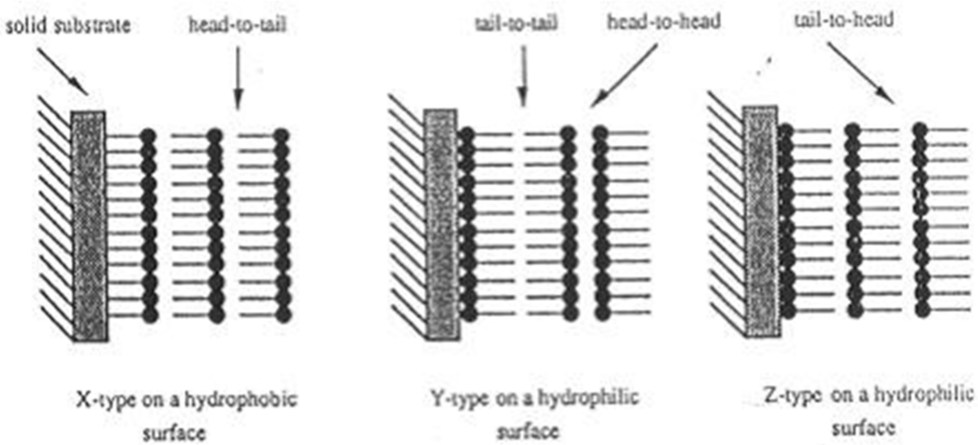
- Static assembly
- Dynamic assembly

  – RT = 8.314 J/mol x 300 = 2.4 kJ/mol
- Driving forces
  – Chemisorption
  – Surface effect
  – Hydrophobic-hydrophilic
  – Intermolecular forces
  – Capillary force

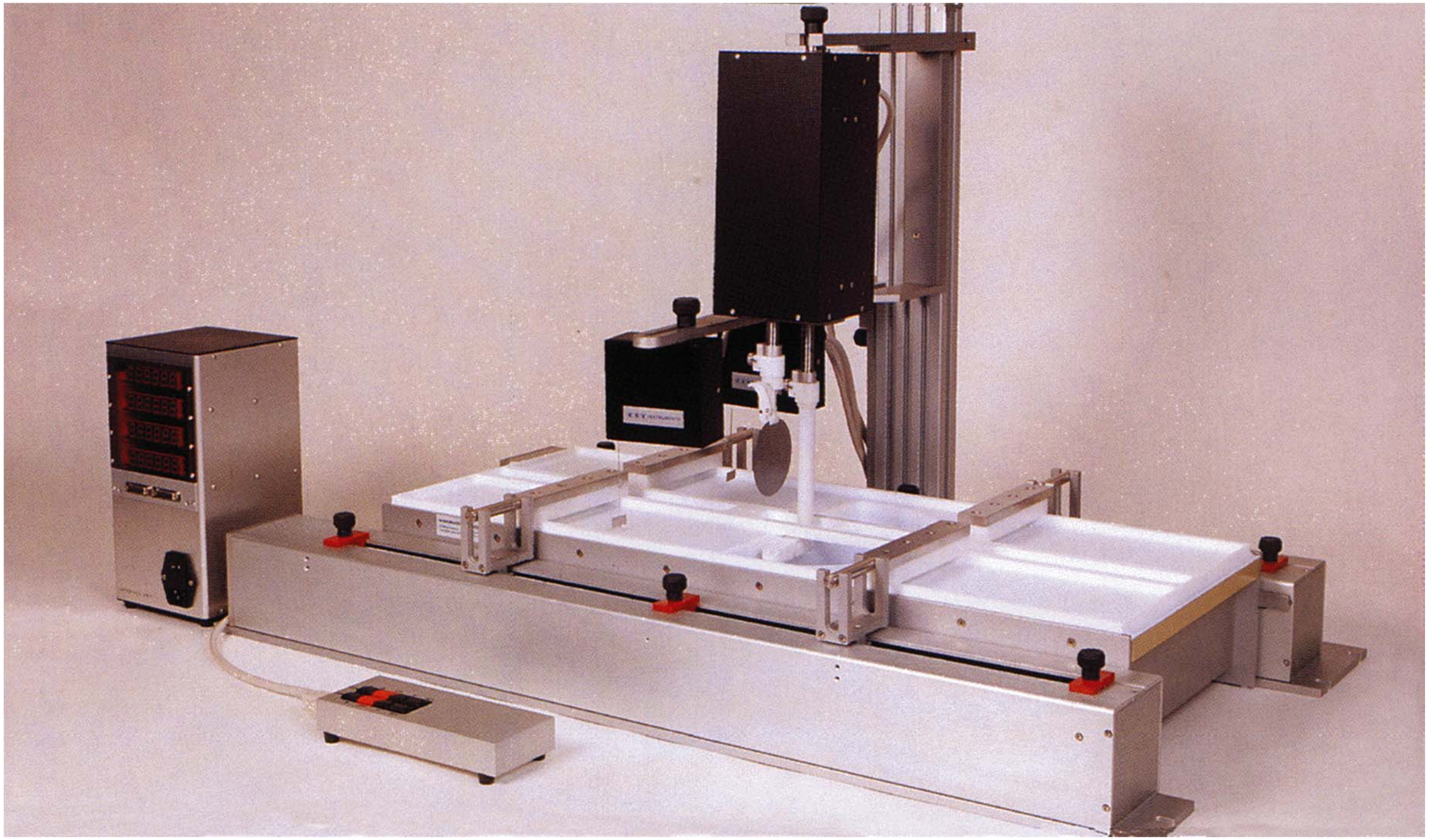
Langmuir-Blodgett Films



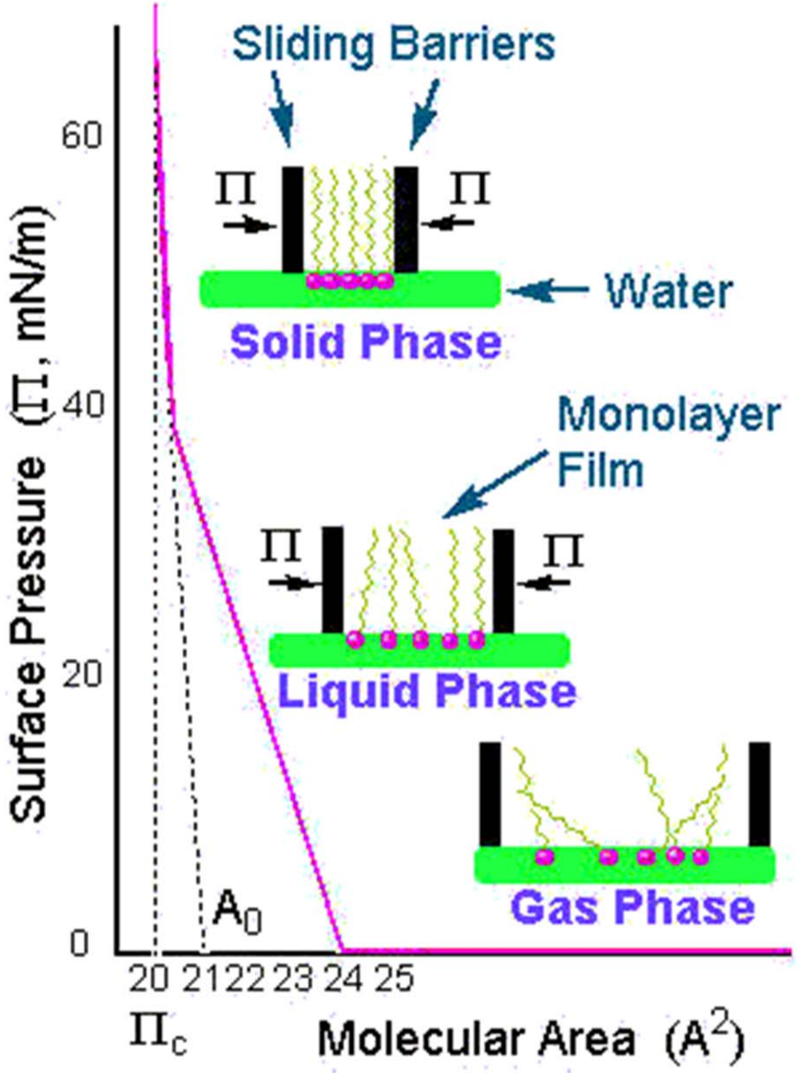




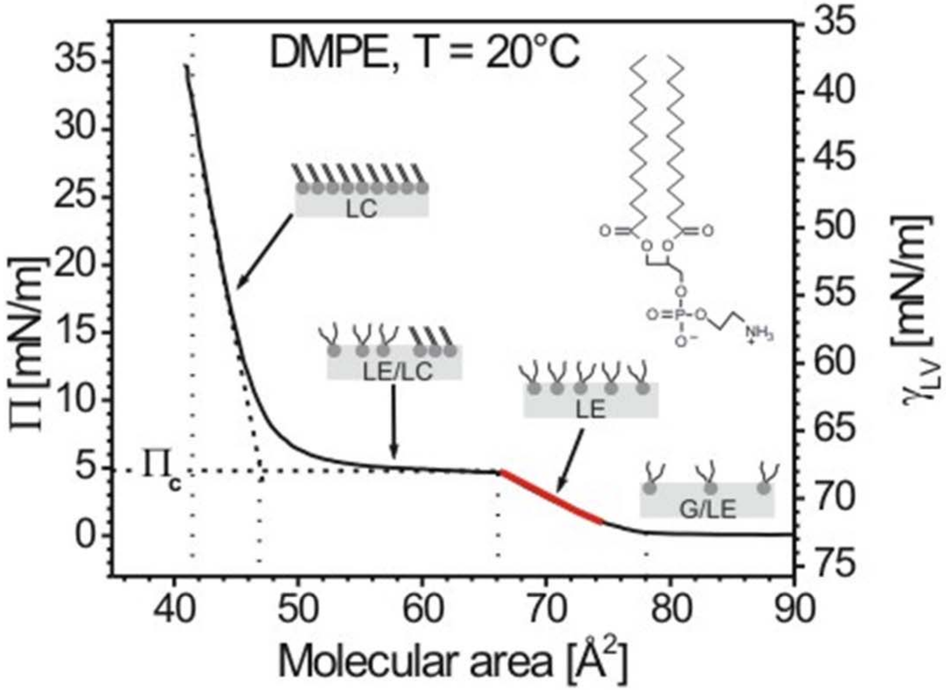
Langmuir-Blodgett Films



Isotherm



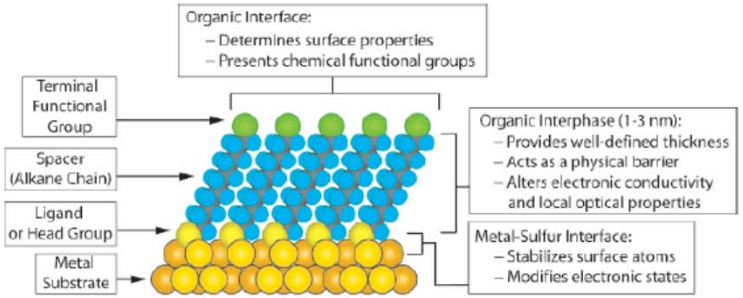
Sliding Barriers
Π
Π
Water
Solid Phase
Monolayer Film
Π
Π
Liquid Phase
Gas Phase
Surface Pressure (Π, mN/m)
60
40
20
0
A0
20 21 22 23 24 25
Πc
Molecular Area (A2)

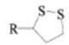


DMPE, T = 20°C
LC
LE/LC
LE
G/LE
Πc
Π [mN/m]
35
30
25
20
15
10
5
0
40
50
60
70
80
90
Molecular area [Å2]
γLV [mN/m]
35
40
45
50
55
60
65
70
75

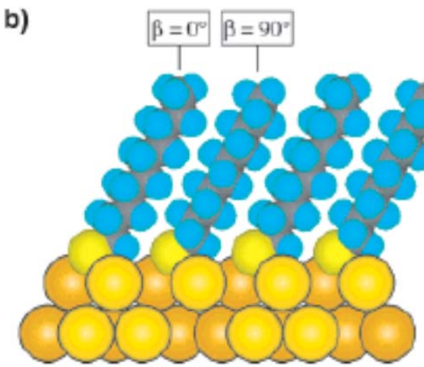
Self-Assemble Monolayer (SAM)

Chem. Rev. **2005,** *105,* 1103–1169



Ligand	Substrates	Morphology of Substrate: Thin Films or Bulk Material	Morphology of Substrate: Nanoparticles or Other Nanostructures
ROH	Fe_xO_y		35
	Si-H	36	
	Si	37	
RCOO-/RCOOH	α-Al_2O_3	38,39	
	Fe_xO_y		40
	Ni		41,42
	Ti/TiO_2	43	
RCOO–OOCR	Si(111):H	44	
	Si(100):H		
Ene-diol	Fe_2O_3		45
RNH_2	FeS_2	46	
	Mica	47	
	Stainless Steel 316L	48	
	$YBa_2Cu_3O_7$-δ	49	
	CdSe		50
RC≡N	Ag	51	
	Au		
R-N≡$N^+(BF_4^-)$	GaAs(100)	52	
	Pd	52	
	Si(111):H	52	
RSH	Ag	26	53,54
	$Ag_{90}Ni_{10}$	55	
	AgS		56
	Au	26	57
	AuAg		58
	AuCu		58
	Au_xPd_{1-x}		58
	CdTe		59
	CdSe		60
	CdS		61,62
	Cu	26	58
	FePt		63-66
	GaAs	67	
	Ge	68	
	Hg	69-71	
	HgTe		72
	InP	73	
	Ir		74
	Ni	75	
	PbS		76-78
	Pd	30	74,79
	PdAg		58
	Pt	32	80
	Ru		81
	Stainless Steel 316L	48	
	$YBa_2Cu_3O_7$-δ	82	
	Zn	83	
	ZnSe	84	
	ZnS		85
RSAc	Au	86	
	Au		87
RSR'	Au	88	
RSSR'	Ag	89	90
	Au	20	90-92
	CdS		61
	Pd	30	
	Au	93	
RCSSH	Au	94	
	CdSe		95
$RS_2O_3^-Na^+$	Au	96	98
	Cu	97	
RSeH	Ag	99	
	Au	100,101	
	CdS		60
	CdSe		102
RSeSeR'	Au	101	
R_3P	Au		103
	FeS_2	46	
	CdS		104
	CdSe		104
	CdTe		104
R_3P=O	Co		105,106
	CdS		104
	CdSe		104
	CdTe		104
RPO_3^{2-}/$RP(O)(OH)_2$	Al	107	
	Al-OH	108	
	$Ca_{10}(PO_4,CO_3)_6(OH)_2$	109	
	GaAs	110	
	GaN	110	
	Indium tin oxide (ITO)	111	
	Mica	112	
	TiO_2	113,114	
	ZrO_2	114,115	
	CdSe		116-118
	CdTe		118,119
RPO_4^{2-}	Al_2O_3	120	
	Nb_2O_5	120	
	Ta_2O_3	121	
	TiO_2	120,122	
RN≡C	Pt	123	124
RHC=CH_2	Si	37	
RC≡CH	Si(111):H	125	
$RSiX_3$ X = H, Cl, OCH_2CH_3	HfO_2	126	
	ITO	127	
	PtO	128	
	TiO_2	113,126,129	
	ZrO_2	126,129	

S-Au 25-30 Kcal/mole
Si-O 190 kcal/mole



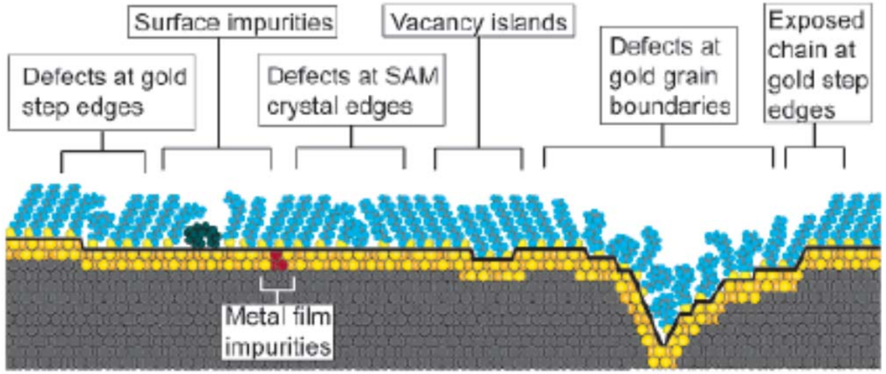
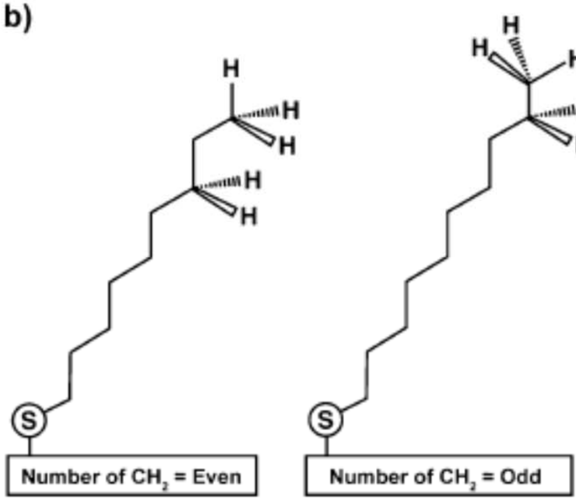
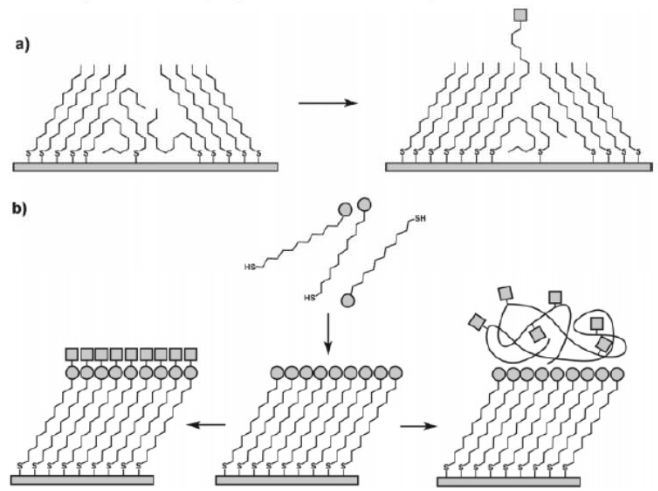


Figure 7. Schematic illustration of some of the intrinsic and extrinsic defects found in SAMs formed on polycrystalline substrates. The dark line at the metal−sulfur interface is a visual guide for the reader and indicates the changing topography of the substrate itself.





[a] (a) Insertion of a functional adsorbate at a defect site in a preformed SAM. (b) Transformation of a SAM with exposed functional groups (circles) by either chemical reaction or adsorption of another material.

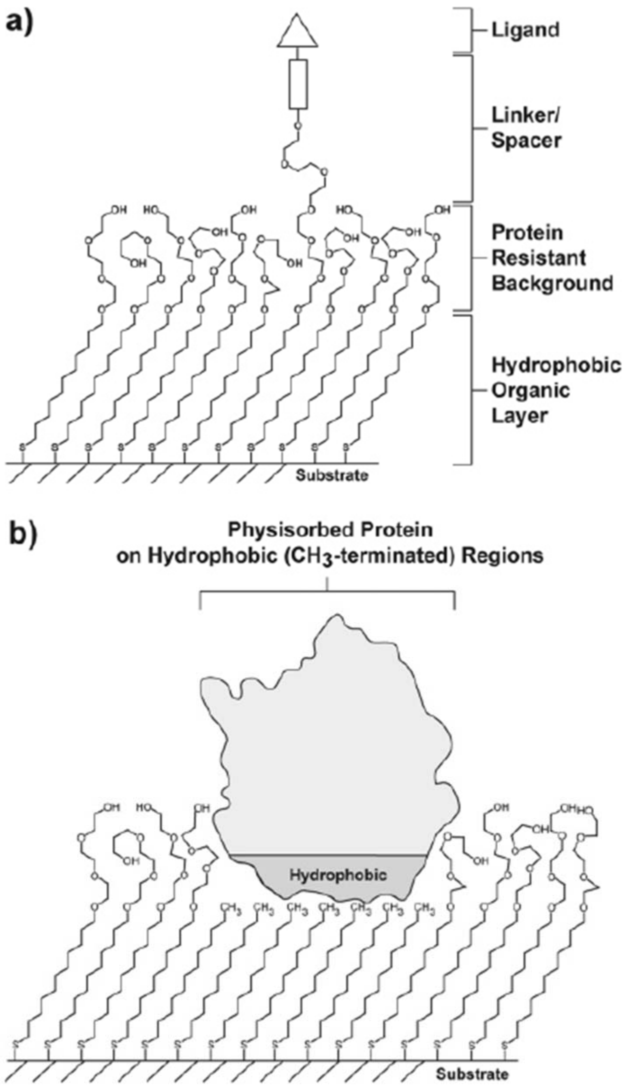


Figure 21. Schematic illustrations of (a) a mixed SAM and (b) a patterned SAM. Both types are used for applications in biology and biochemistry.

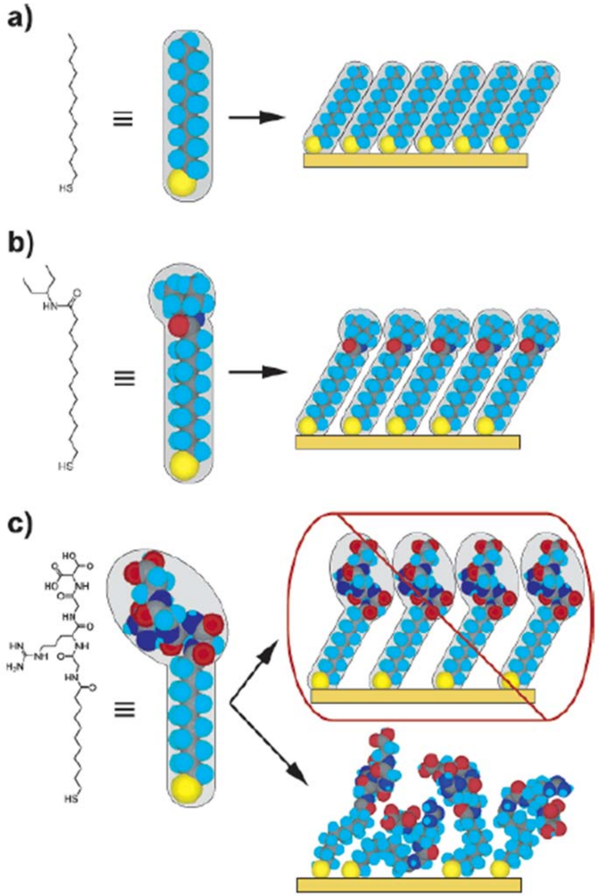


Figure 22. Schematic diagram illustrating the effects that large terminal groups have on the packing density and organization of SAMs. (a) Small terminal groups such as $-CH_3$, $-CN$, etc., do not distort the secondary organization of the organic layer and have no effect on the sulfur arrangement. (b) Slightly larger groups (like the branched amide shown here) begin to distort the organization of the organic layer, but the strongly favorable energetics of metal−sulfur binding drive a highly dense arrangement of adsorbates. (c) Large terminal groups (peptides, proteins, antibodies) sterically are unable to adopt a secondary organization similar to that for alkanethiols with small terminal groups. The resulting structures probably are more disordered and less dense than those formed with the types of molecules in a and b.

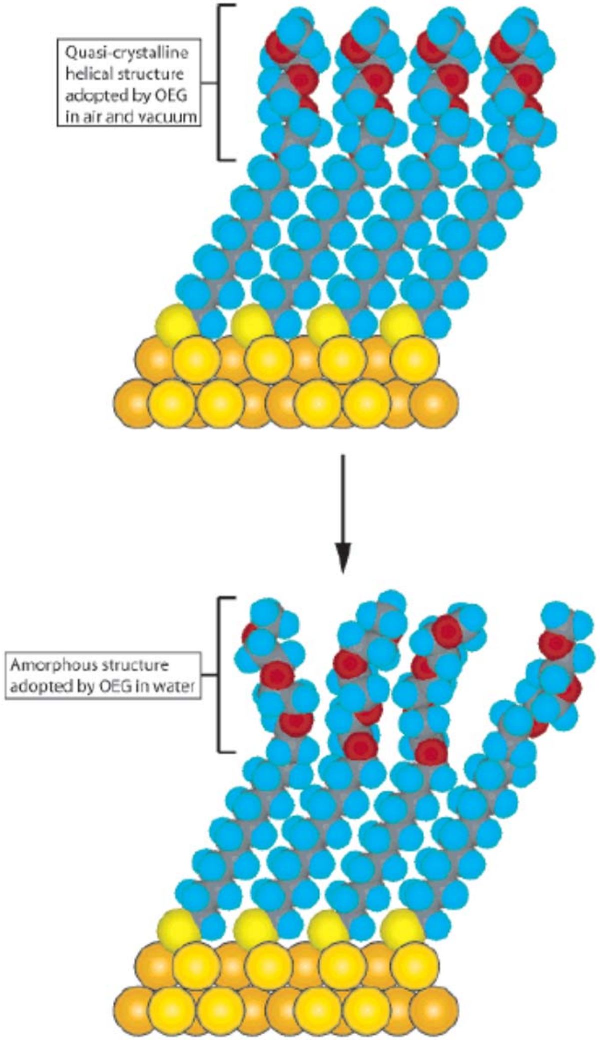
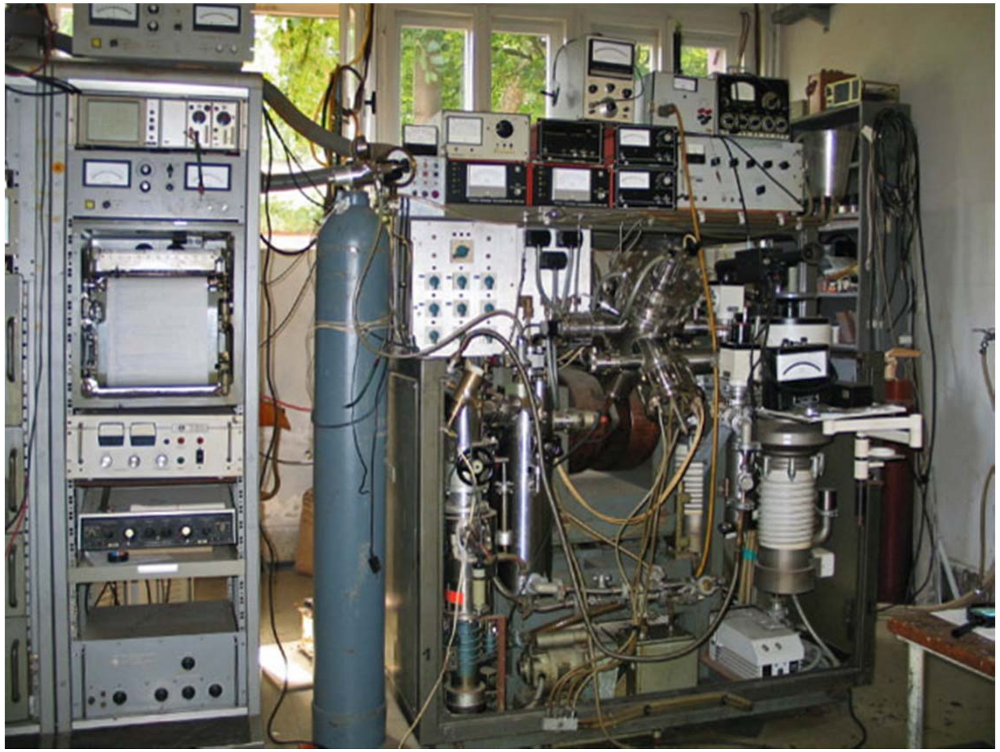
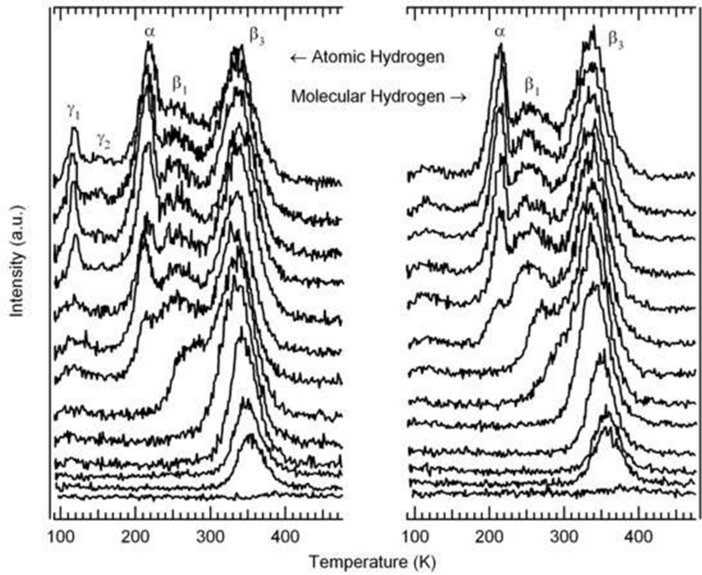


Figure 23. Schematic illustration of the order−disorder transition evidenced by SAMs of alkanethiolates terminated with triethylene glycol. The EG_3 group loses conformational ordering upon solvation in water.

Temperature Programmed Desorption





Self-Assembly

- Substrates
- Interstitial adhesion layer
- Noble metal layer
- Organo-sulfur