

Review of Cell Biology

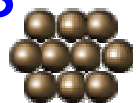


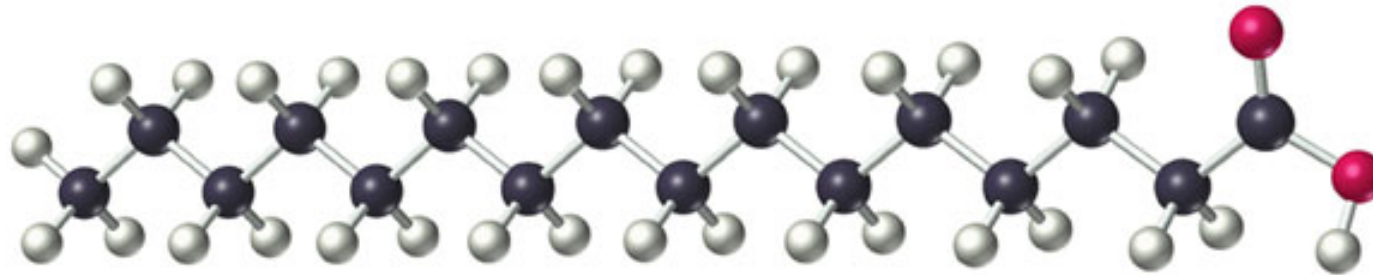
Lipid

- ***Lipids*** are naturally occurring molecules from plants or animals that are soluble in nonpolar organic solvents.
- Lipid molecules contain large hydrocarbon portion and not many polar functional group, which accounts for their solubility behavior.

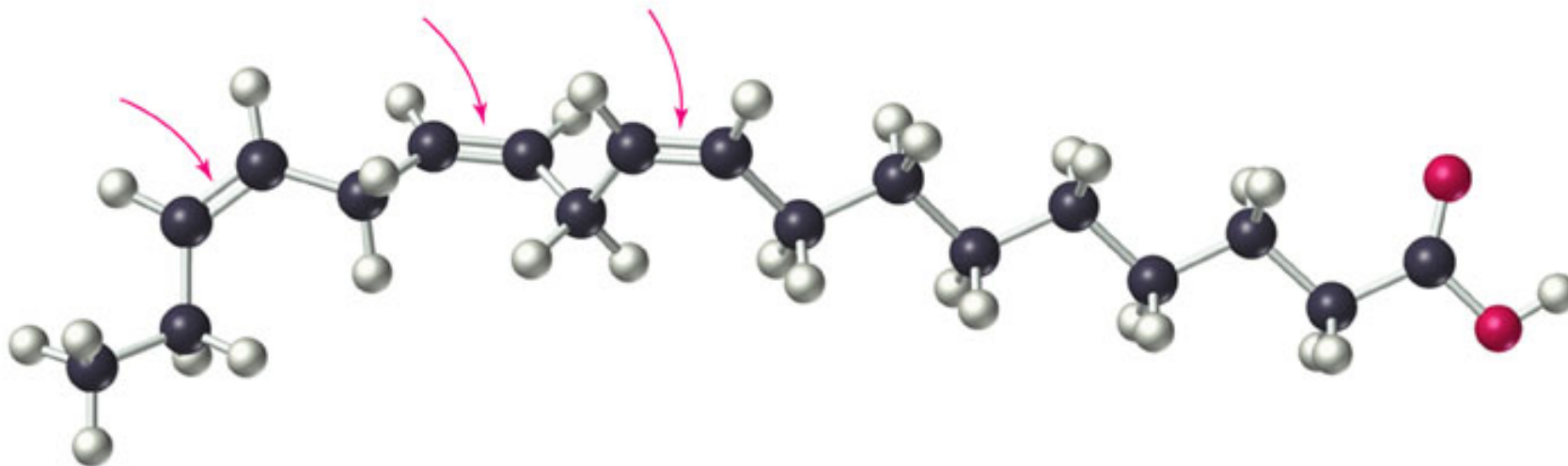
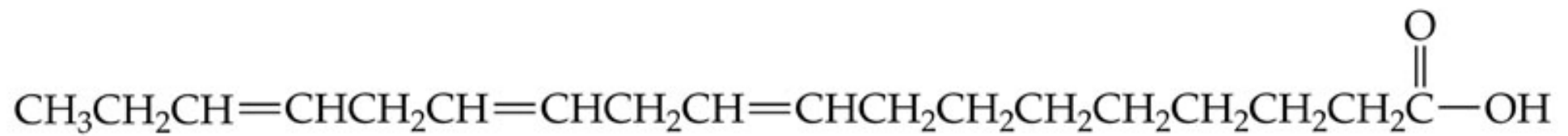


- Classification of Lipids
- *Lipids that are ester or amides of fatty acids:*
- *Waxes* – are carboxylic acid esters where both R groups are long straight hydrocarbon chain. Performs external protective functions.
- *Triacylglycerol* – are carboxylic acid triesters of glycerols. They are a major source of biochemical energy.
- *Glycerophospholipids* - triesters of glycerols that contain charged phosphate diesters. They help to control the flow of molecules into and out of cells.

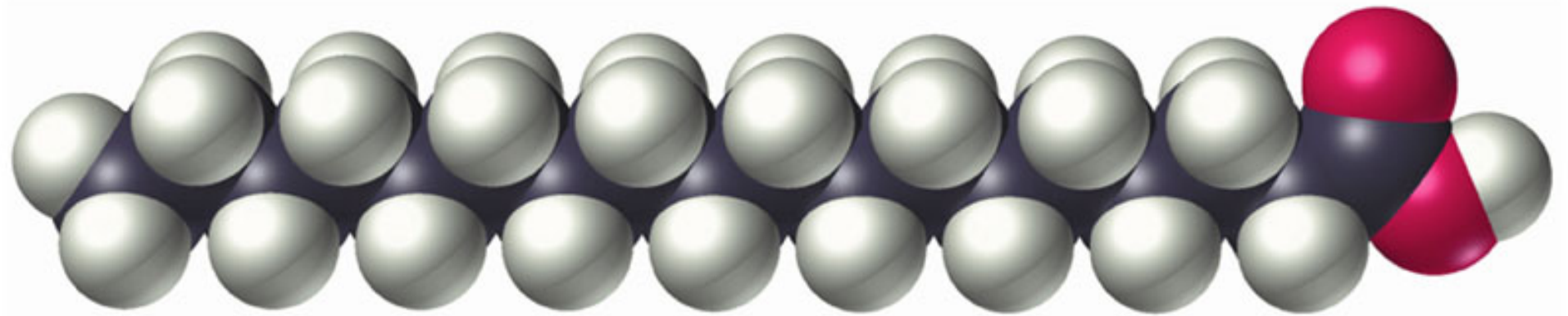




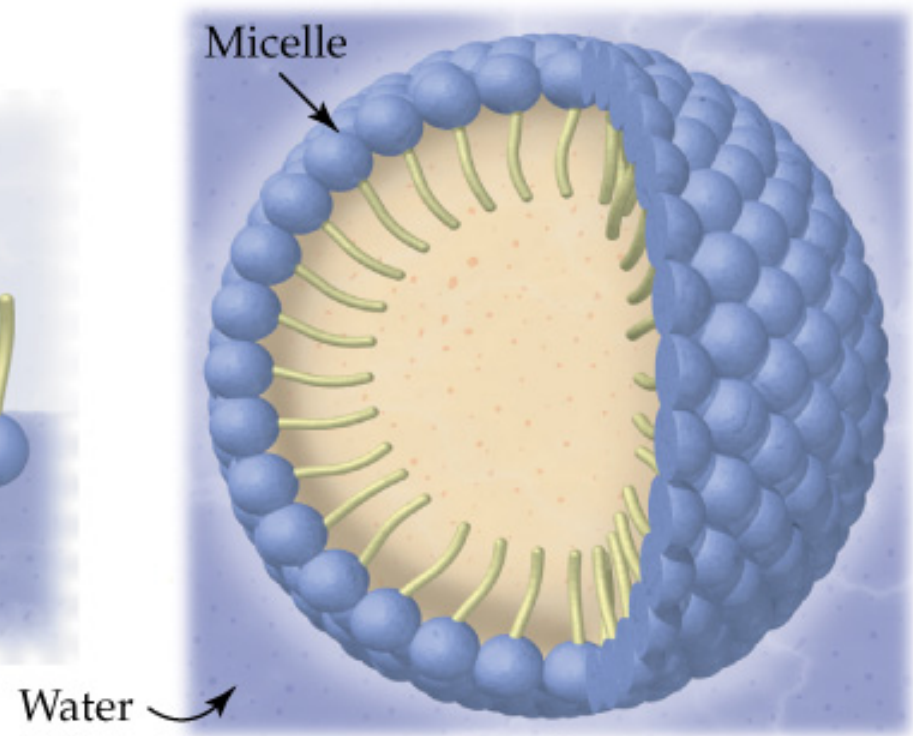
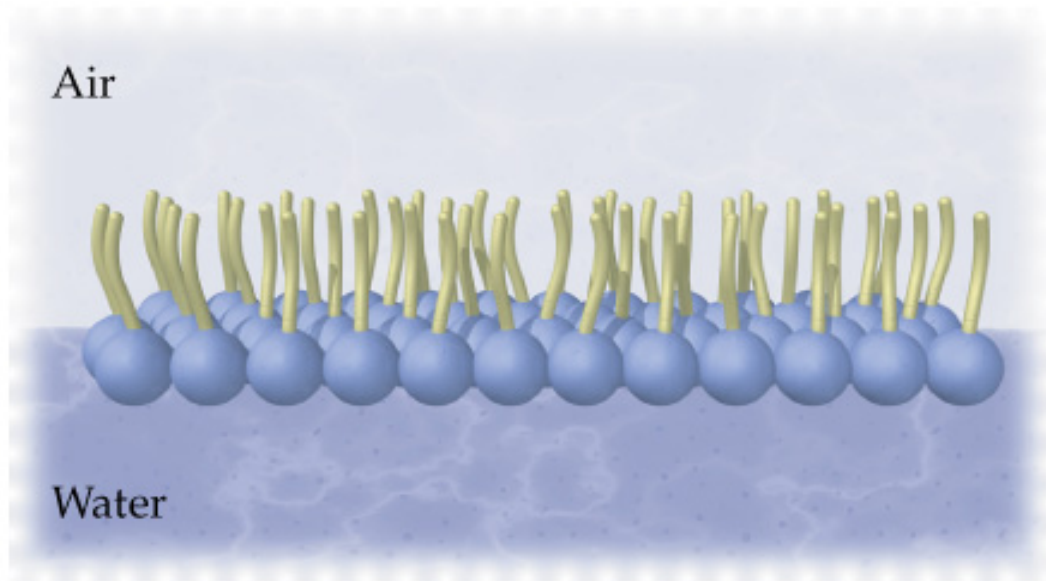
A saturated fatty acid
(palmitic acid)

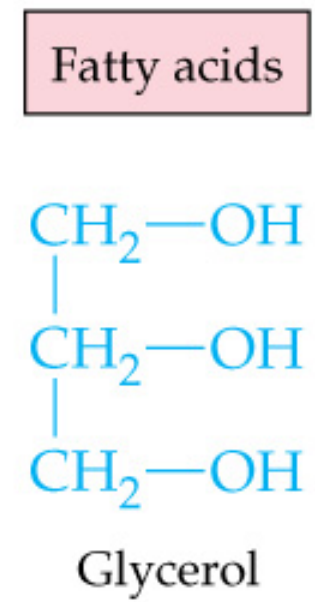
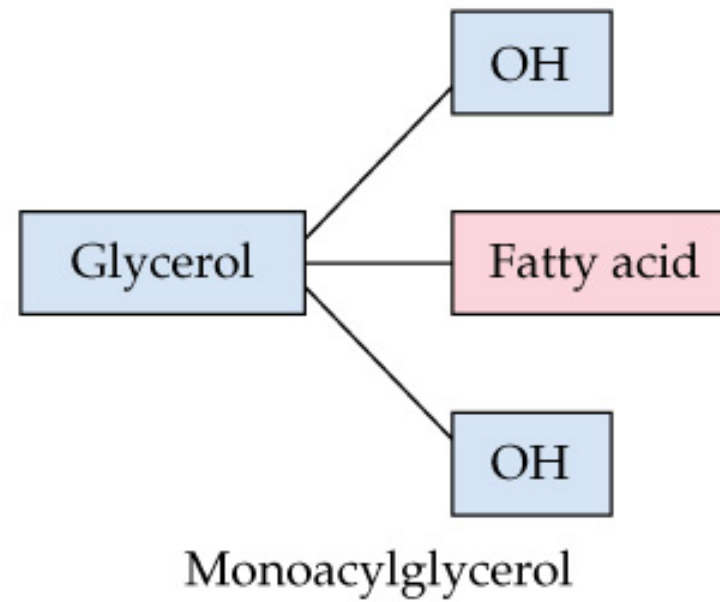
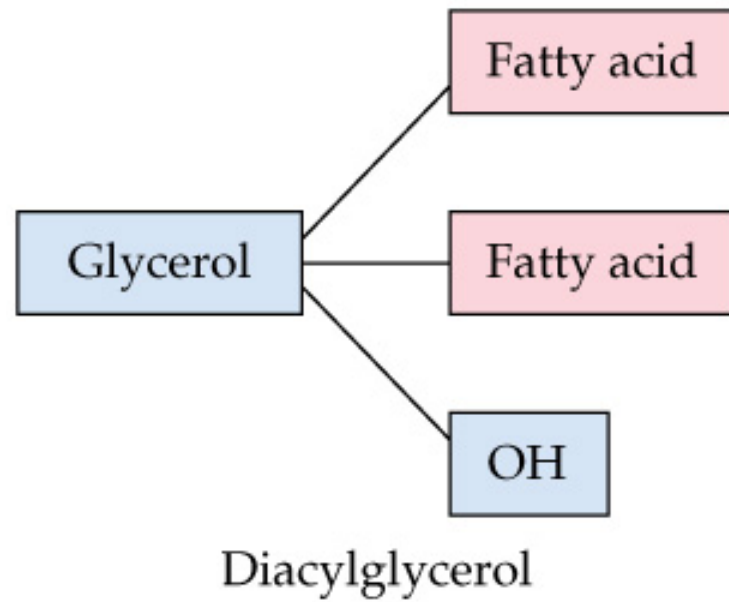


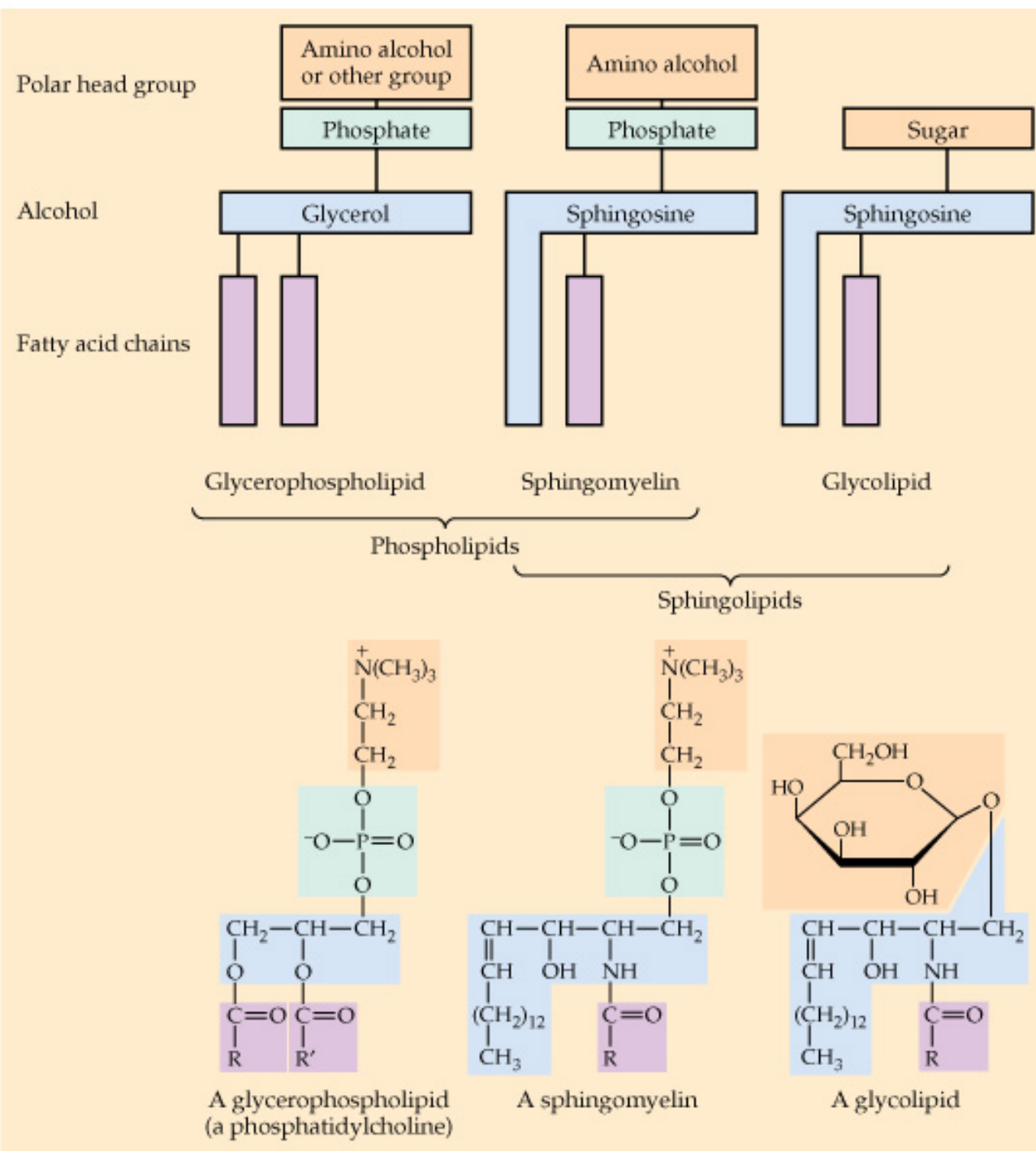
A *cis* unsaturated fatty acid
(linolenic acid)



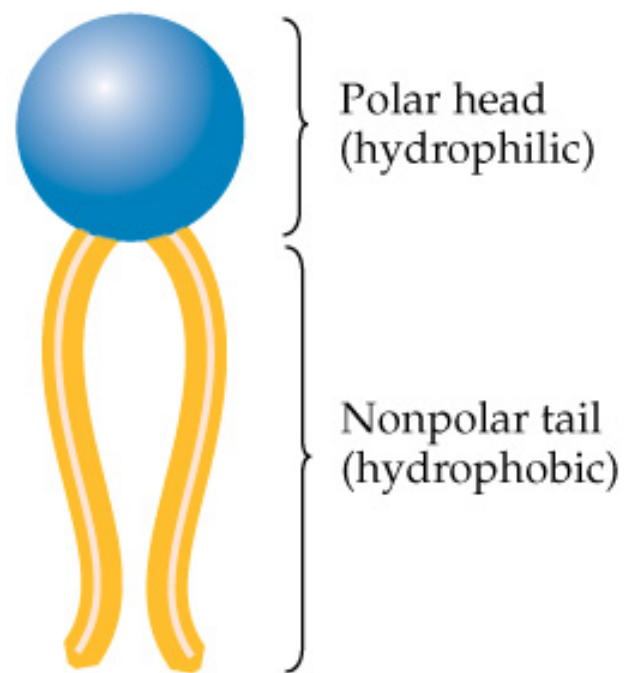
Stearic acid, an 18-carbon saturated fatty acid



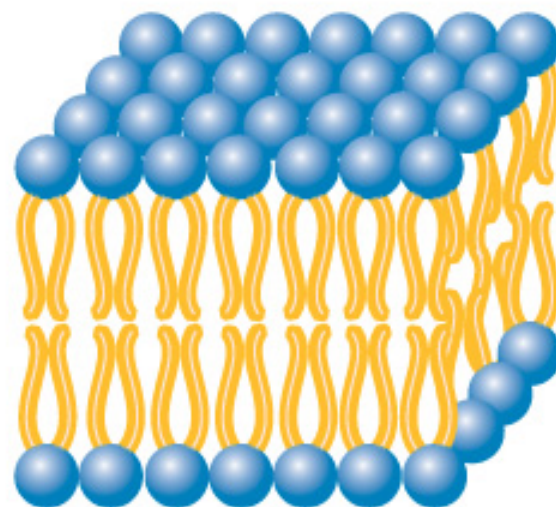




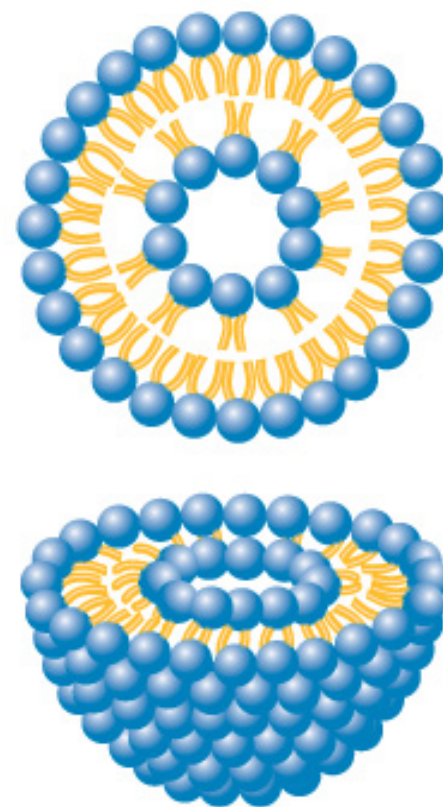




Membrane lipid



Lipid bilayer



Liposome

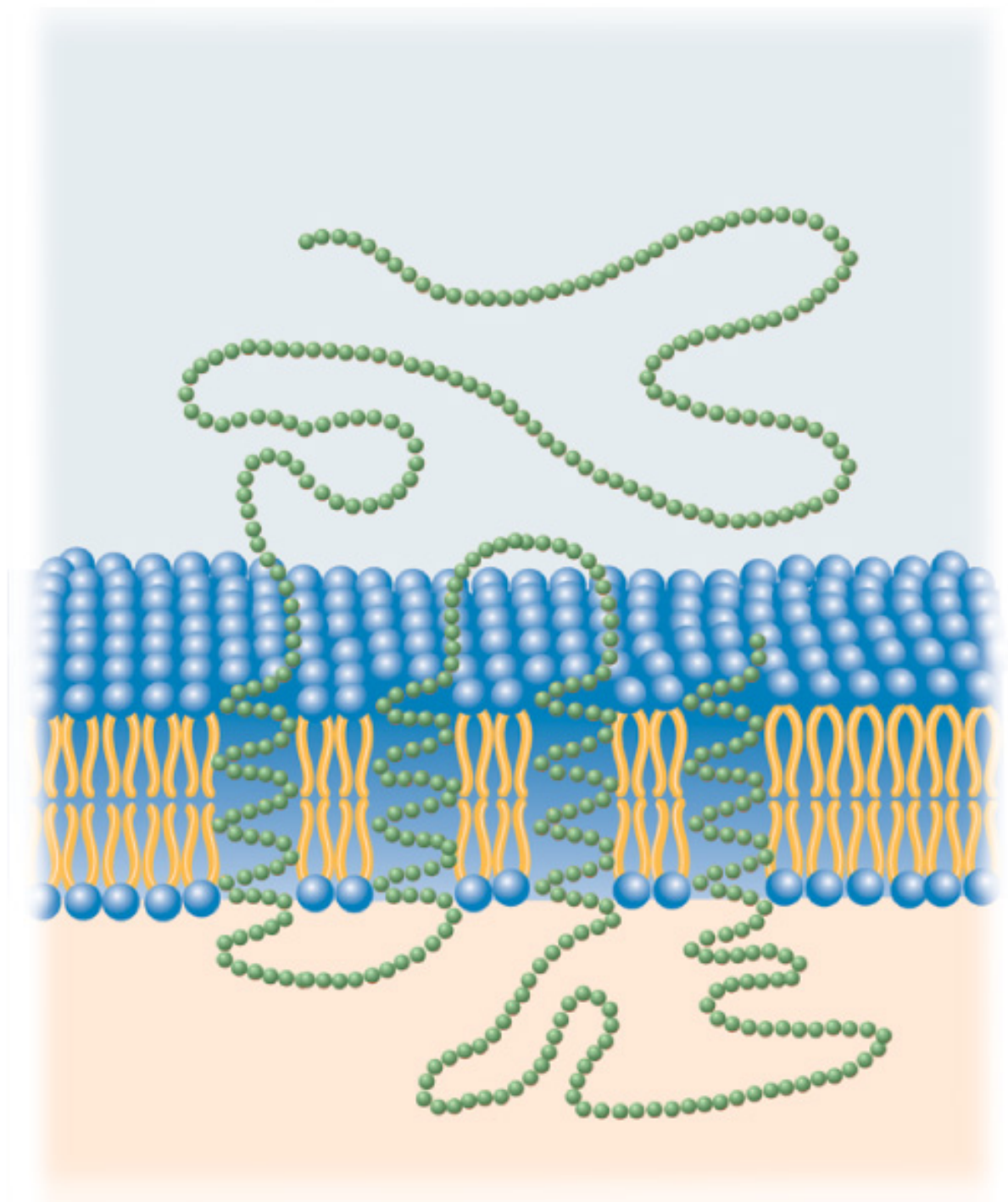
Properties of cell membranes:

- Cell membranes are composed of a fluid like phospholipid bilayer.
- The bilayer incorporates cholesterol, proteins, and glycolipids.
- Small nonpolar molecules cross by diffusion through the lipid bilayer.
- Small ions and polar molecules diffuse through the aqueous media in protein pores.
- Glucose and certain other substances cross with the aid of proteins without energy input.
- Na^+ , K^+ , and other substances that maintain concentration gradients inside and outside the cell cross with expenditure of energy and the aid of proteins.

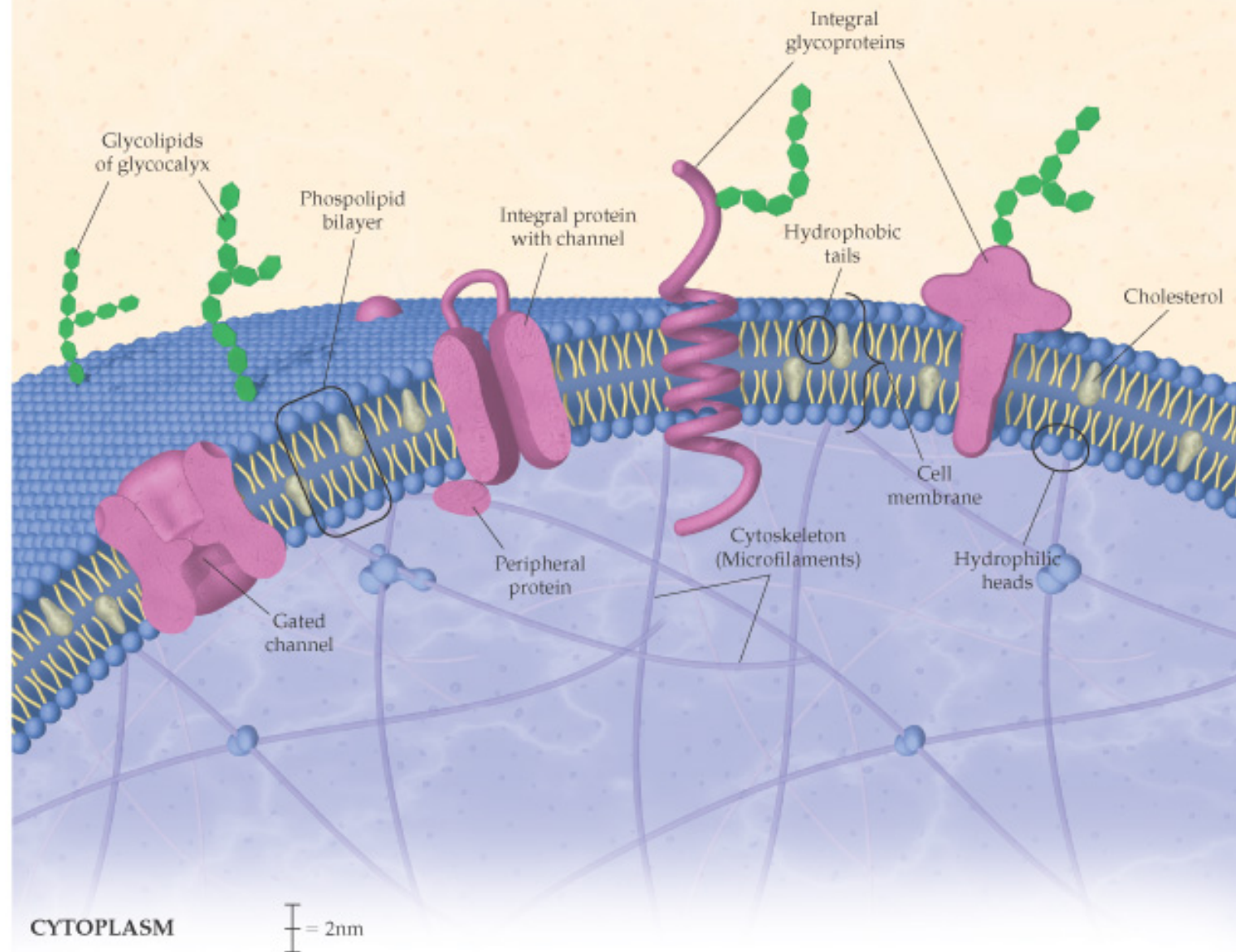


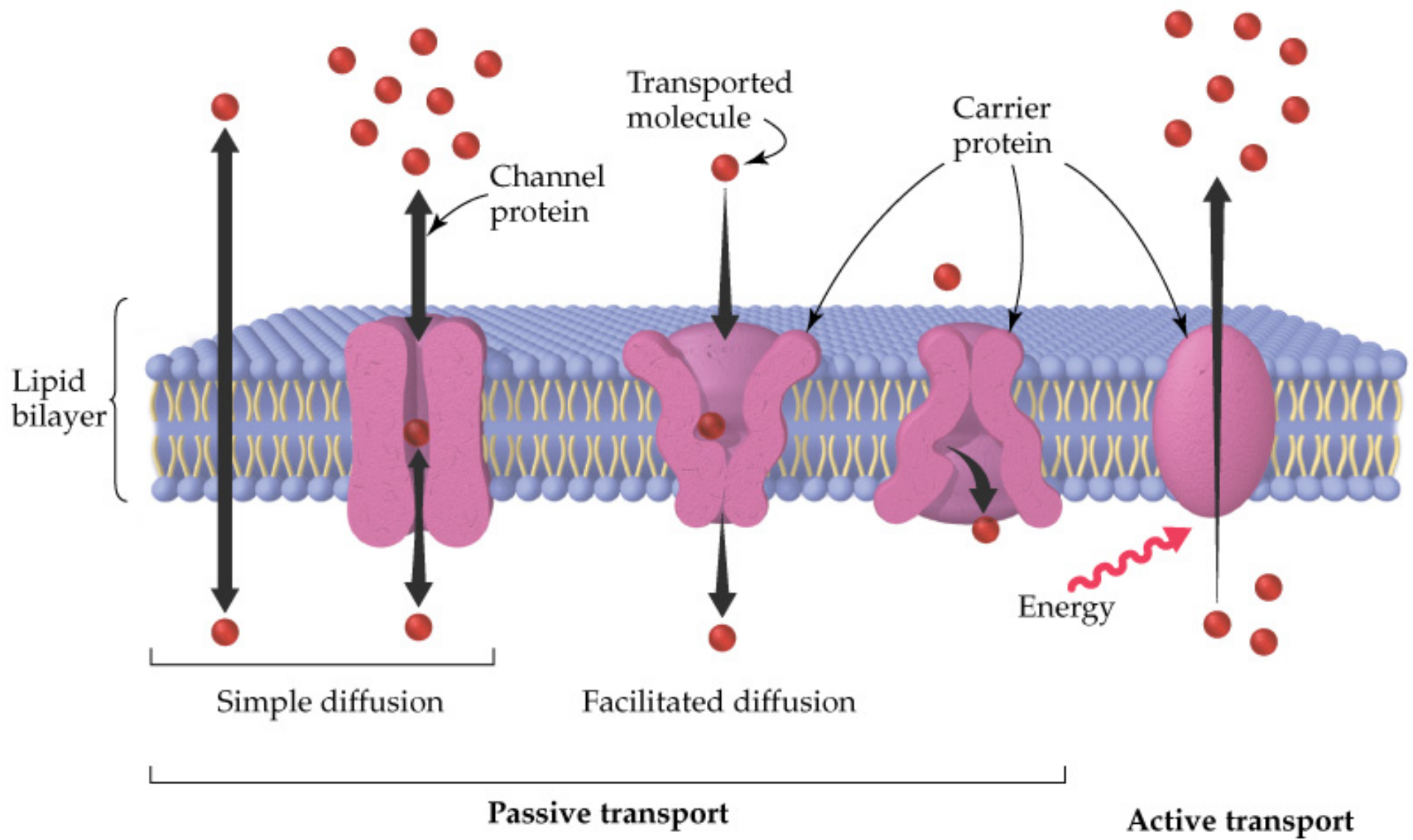
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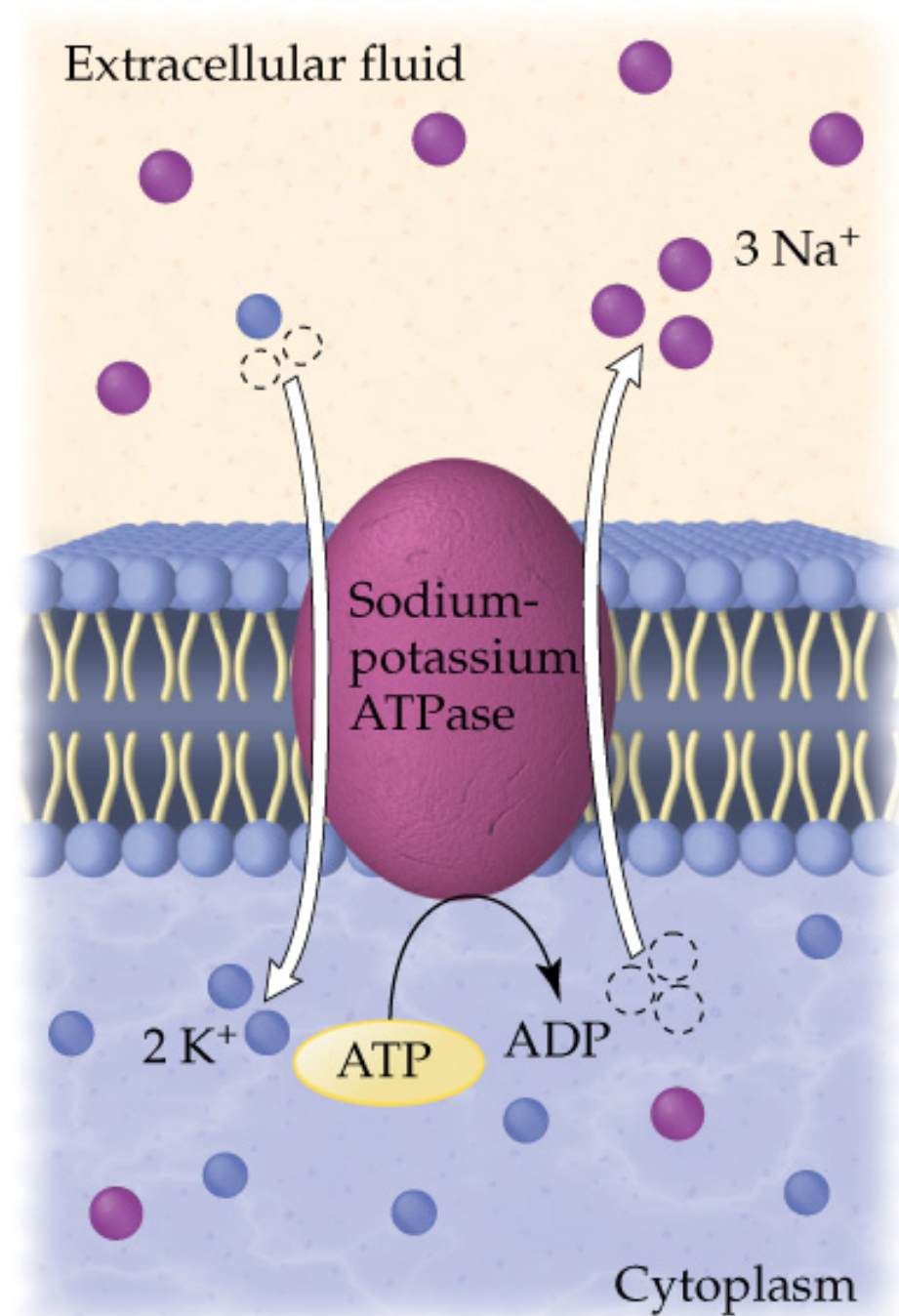


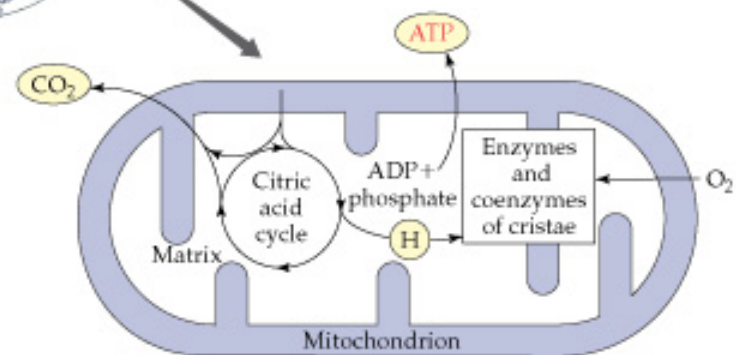
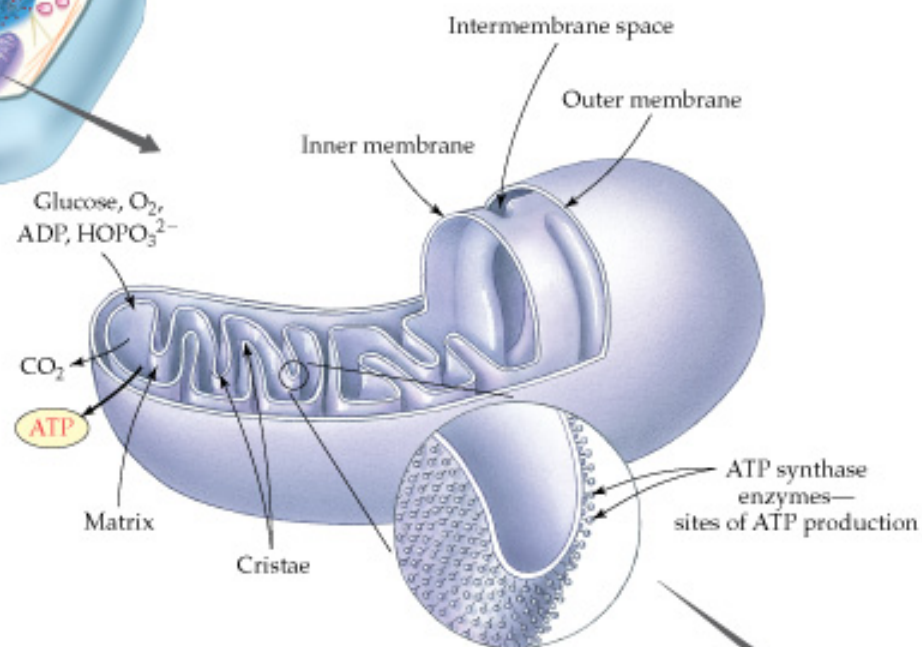
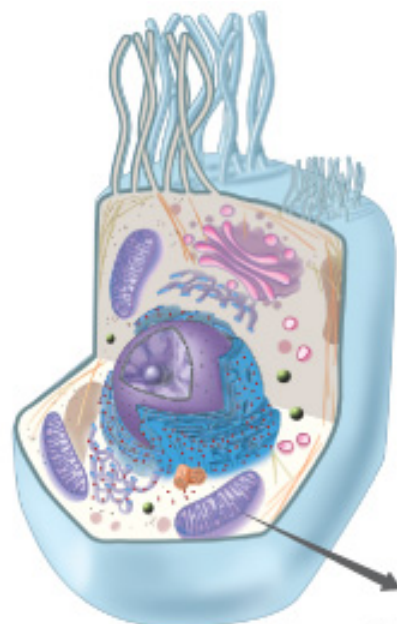


EXTRACELLULAR FLUID





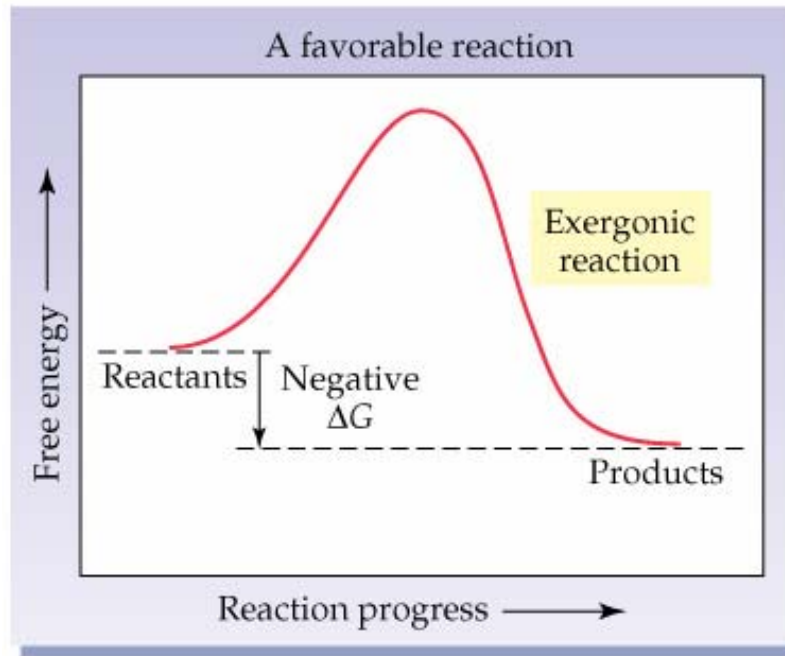




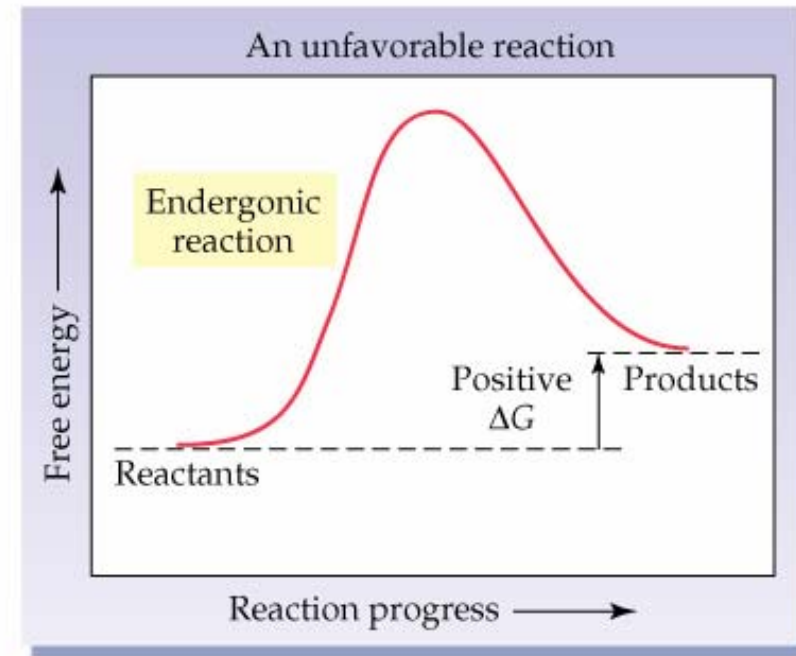
Energy and Biochemical Reactions

- Reactions in living organisms are similar to reactions in a chemical laboratory.
- Spontaneous reactions, those are favorable in the forward direction, release free energy and the energy released is available to do work.
- Spontaneous reactions , also known as *exergonic* reactions, are the source of our biochemical energy.
- Products of exergonic reactions are more stable than the reactants and the free energy change ΔG has a negative value.





(a)

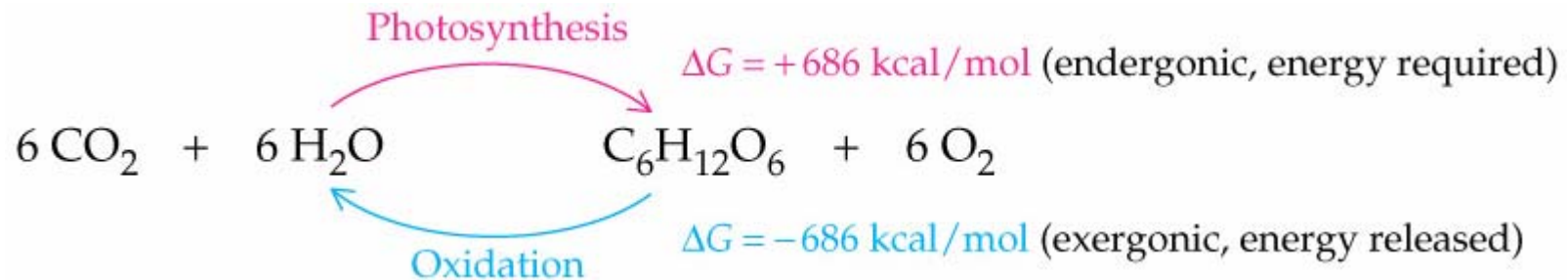


(b)

- Energy diagram of an (a) exergonic and (b) endergonic reaction

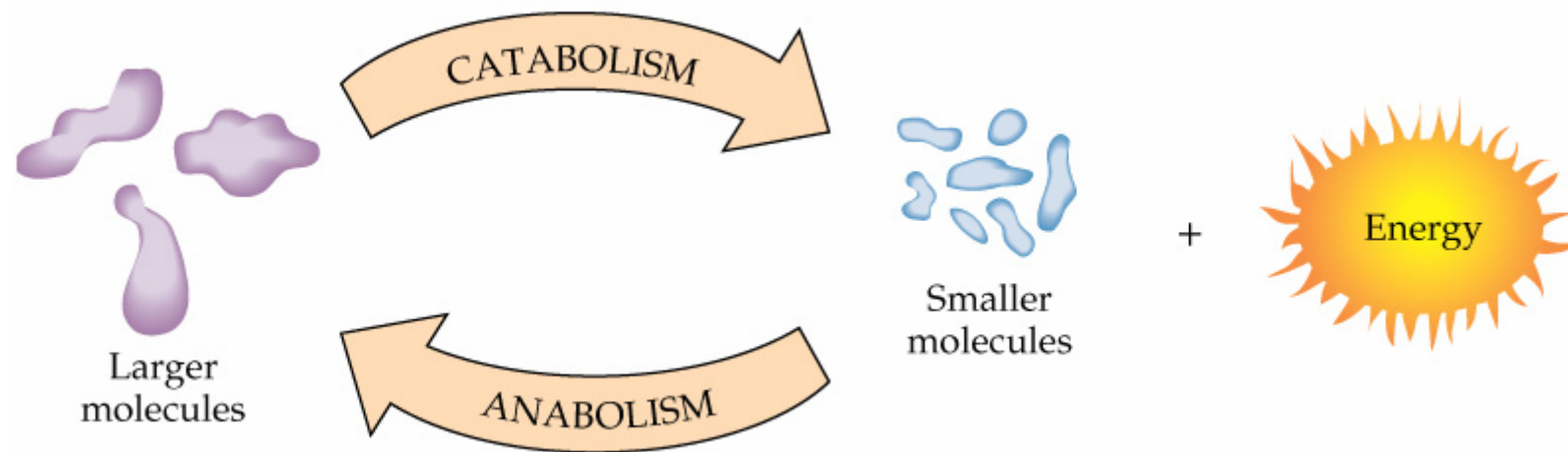


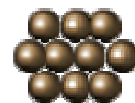
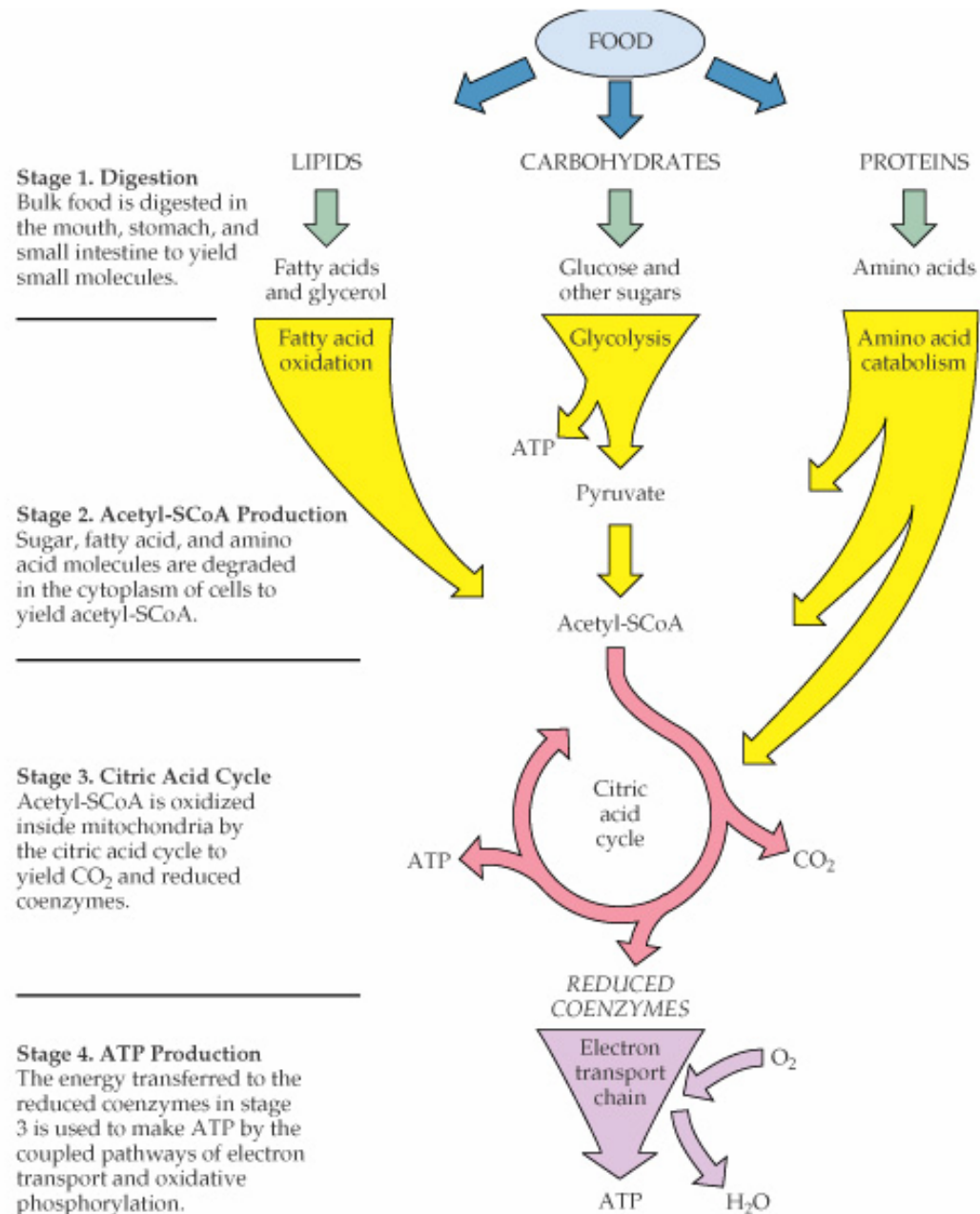
- *Photosynthesis* in plants, converts CO_2 and H_2O to glucose plus O_2 which is the reverse of oxidation of glucose. The sun provides the necessary external energy for photosynthesis (686 kcal of free energy per mole of glucose formed).



- The *mitochondria* is often called the cell's power plants. Within the mitochondria, small molecules are broken down to provide the energy for an organism and also the principle energy carrying molecule adenosine triphosphate (ATP) is produced.







ATP and Energy Transfer

- Adenosine triphosphate (ATP) transport energy in living organisms.
- ATP has three -PO_3^- groups.
- Removal of one of the -PO_3^- groups from ATP by hydrolysis produces adenosine diphosphate (ADP). Since this reaction is an exergonic process, it releases energy.
- The reverse of ATP hydrolysis reaction is known as phosphorylation reaction. Phosphorylation reactions are endergonic.



- Biochemical energy production, transport, and use all depends on the $\text{ATP} \rightleftharpoons \text{ADP}$ interconversions.

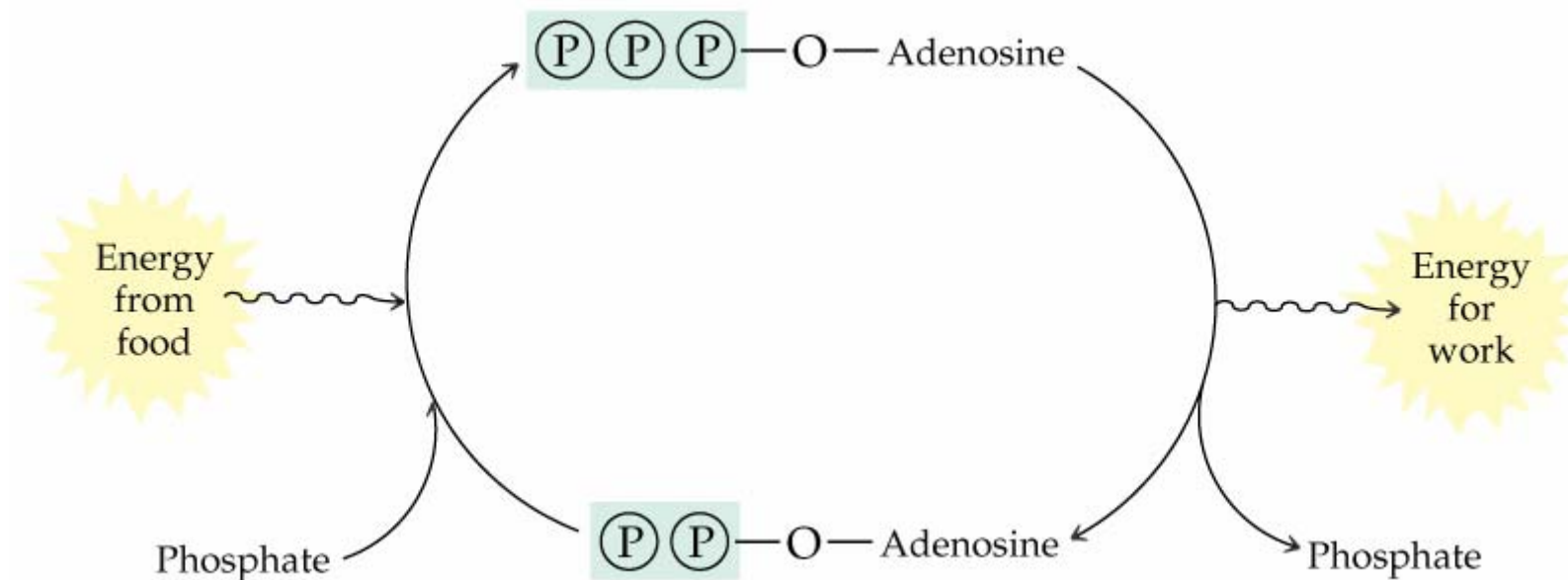
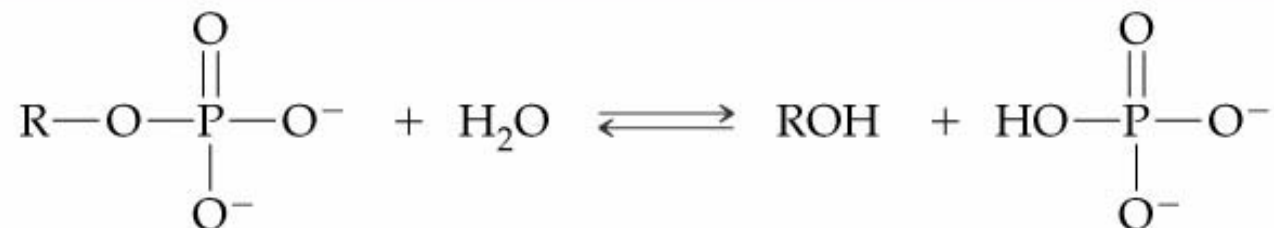


TABLE 21.1 Free Energies of Hydrolysis of Some Phosphates



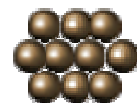
Compound Name	Function	ΔG (kcal/mol)
Phosphoenol pyruvate	Final intermediate in conversion of glucose to pyruvate (glycolysis)—stage 2, Figure 21.5	−14.8
1, 3-Bisphosphoglycerate	Another intermediate in glycolysis	−11.8
Creatine phosphate	Energy storage in muscle cells	−10.3
ATP (→ ADP)	Principal energy carrier	−7.3
Glucose 1-phosphate	First intermediate in breakdown of carbohydrates stored as starch or glycogen	−5.0
Glucose 6-phosphate	First intermediate in glycolysis	−3.3
Fructose 6-phosphate	Second intermediate in glycolysis	−3.3

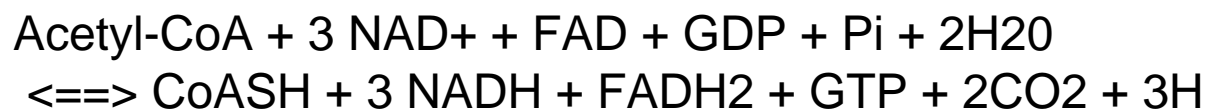
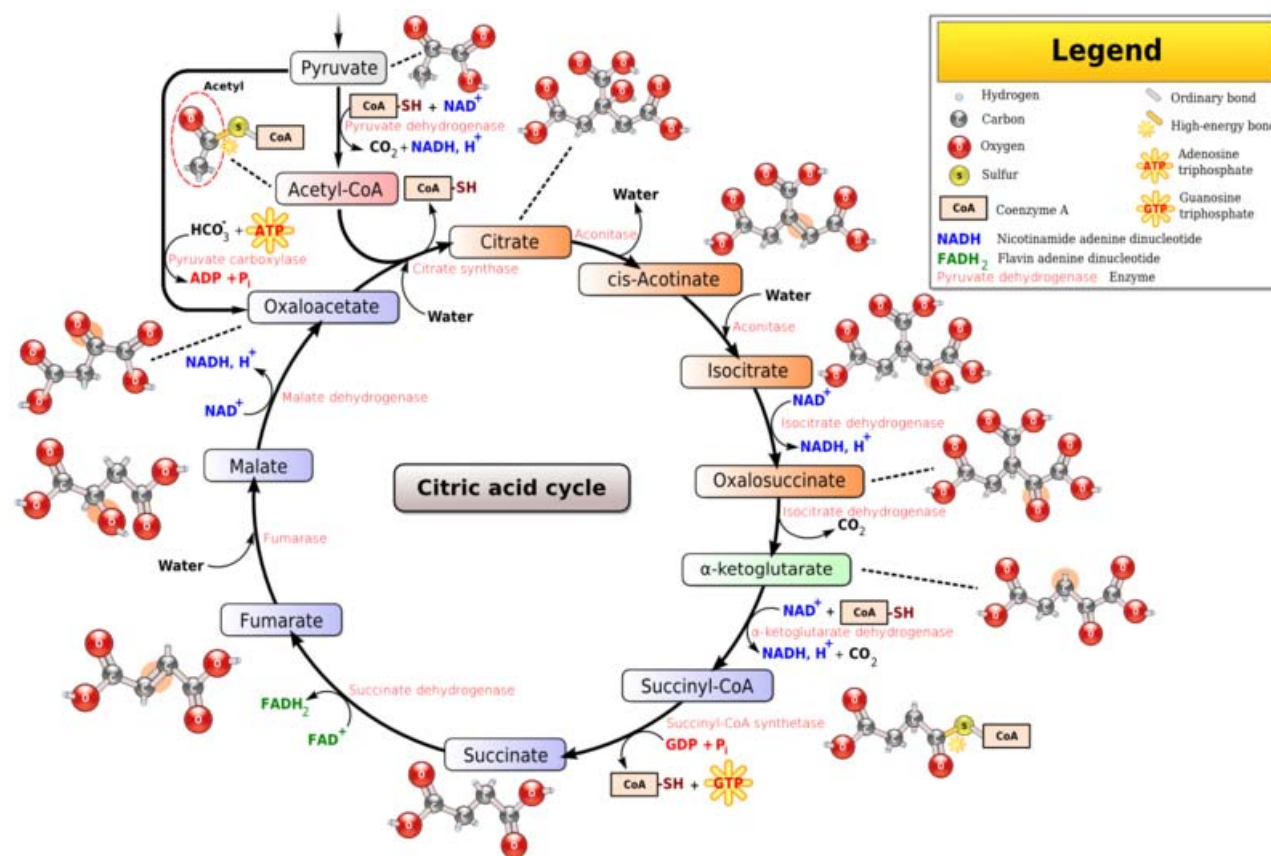


- A few enzymes continuously cycle between their oxidized and reduced forms.



Coenzyme	As Oxidizing Agent	As Reducing Agent
Nicotinamide adenine dinucleotide	NAD^+	$NADH/H^+$
Nicotinamide adenine dinucleotide phosphate	$NADP^+$	$NADPH/H^+$
Flavin adenine dinucleotide	FAD	$FADH_2$
Flavin mononucleotide	FMN	$FMNH_2$





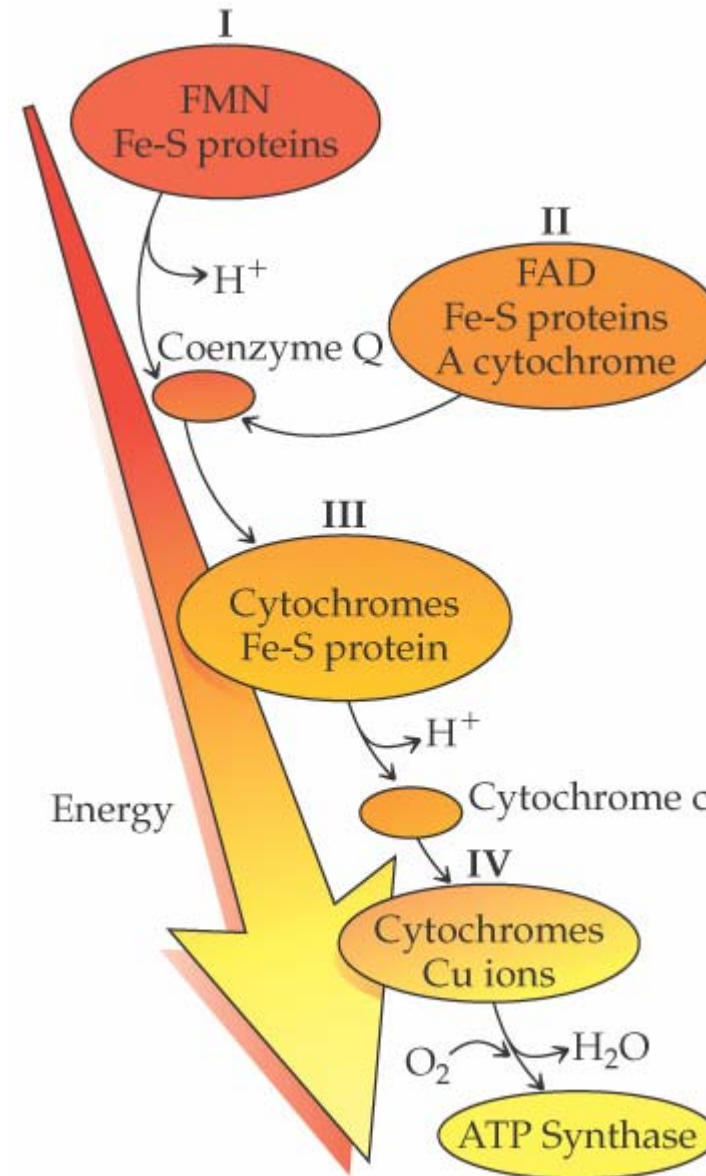
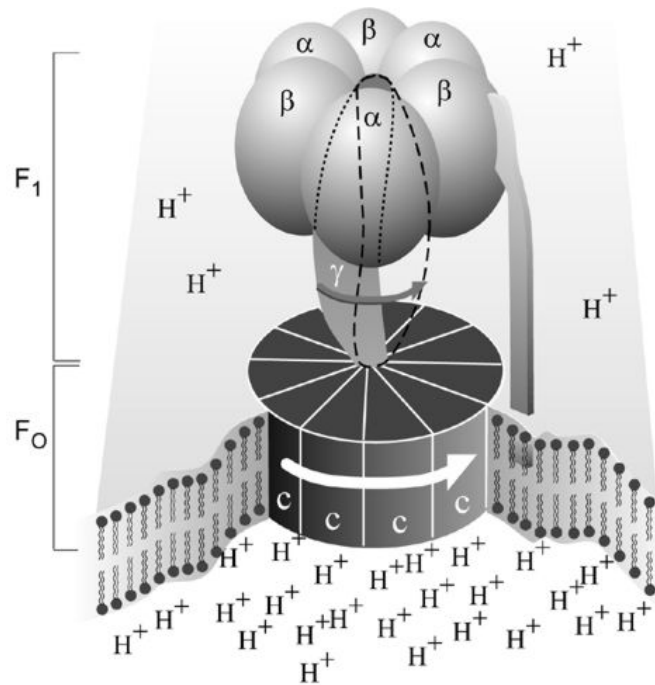
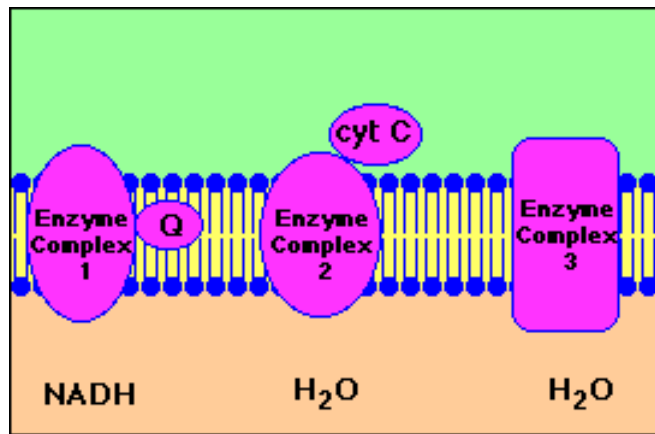
The citric acid cycle



The Electron-Transport Chain and ATP Production

- Electron transport chain: The series of biochemical reactions that passes electrons from reduced coenzymes to oxygen and is coupled to ATP formation. The electrons combine with the oxygen we breathe and with hydrogen ions from their surrounding to produce water.
- Electron transport involves four enzyme complexes held in fixed positions within the inner membrane of mitochondria and two electron carriers move from one complex to another.





• Pathway of electrons in electron transport

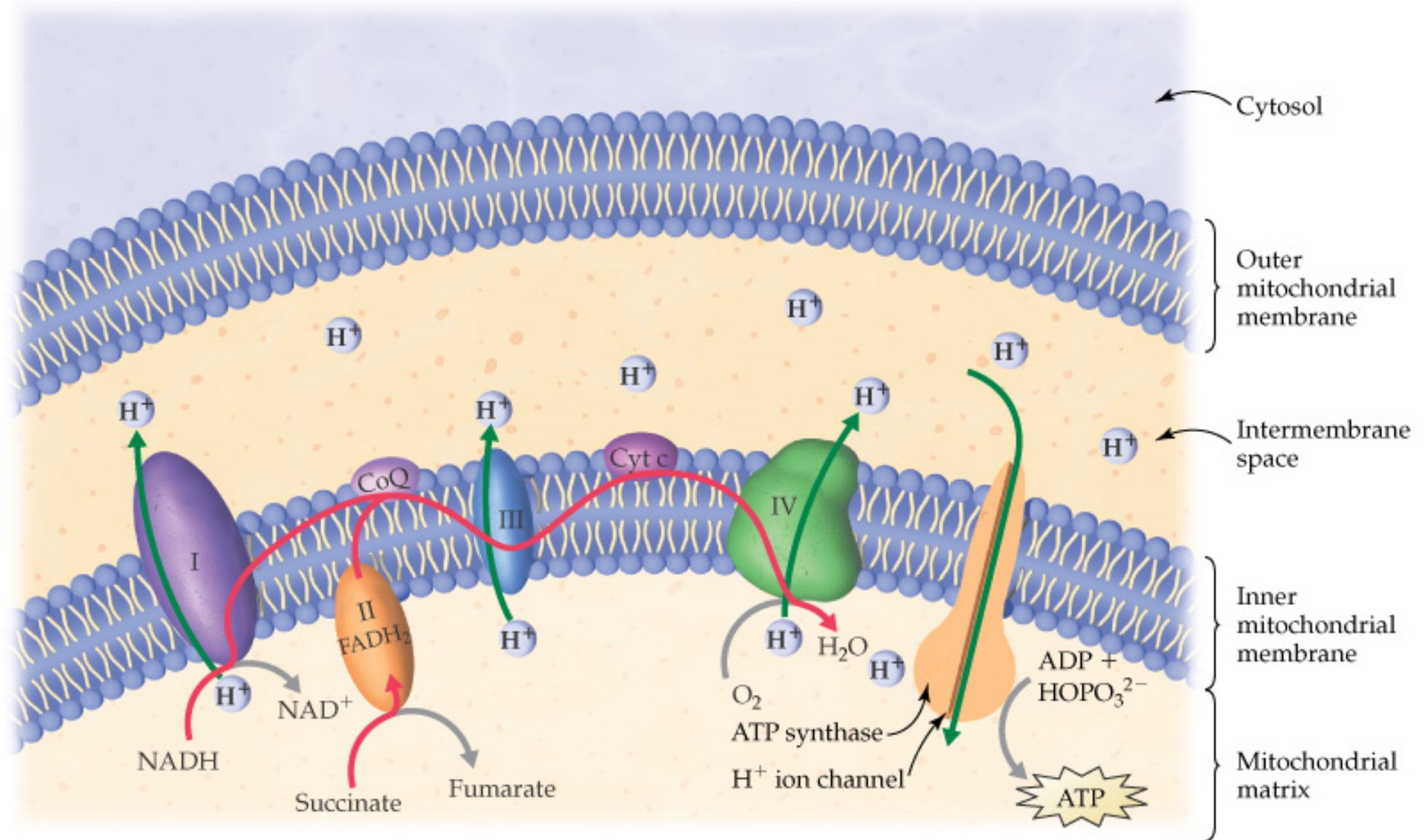


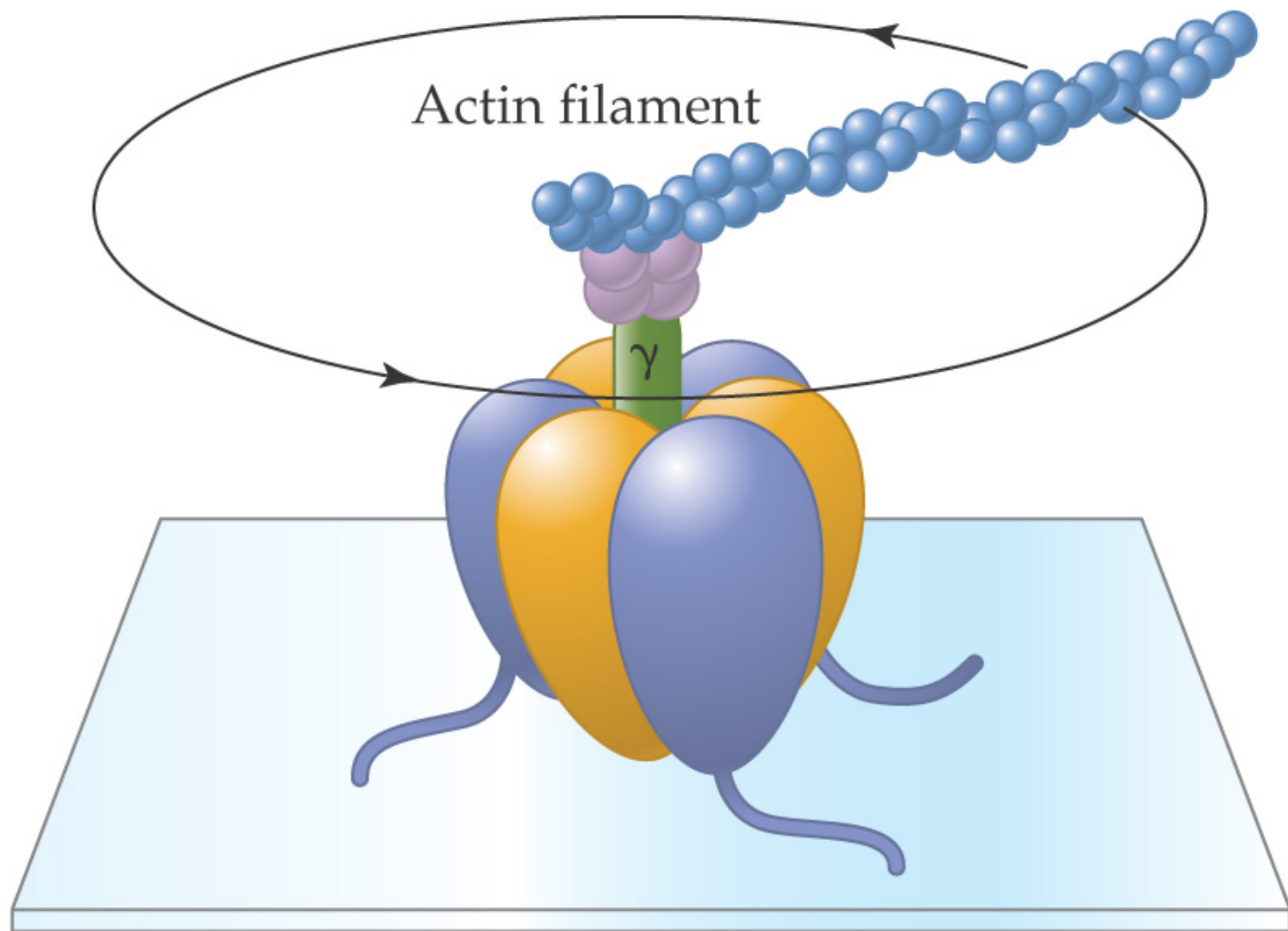
- **ATP Synthesis**

- ADP is converted to ATP by a reaction between ADP and hydrogen phosphate ion. This is both an oxidation and phosphorylation reaction. Energy released in the electron transport chain drives this reaction forward.

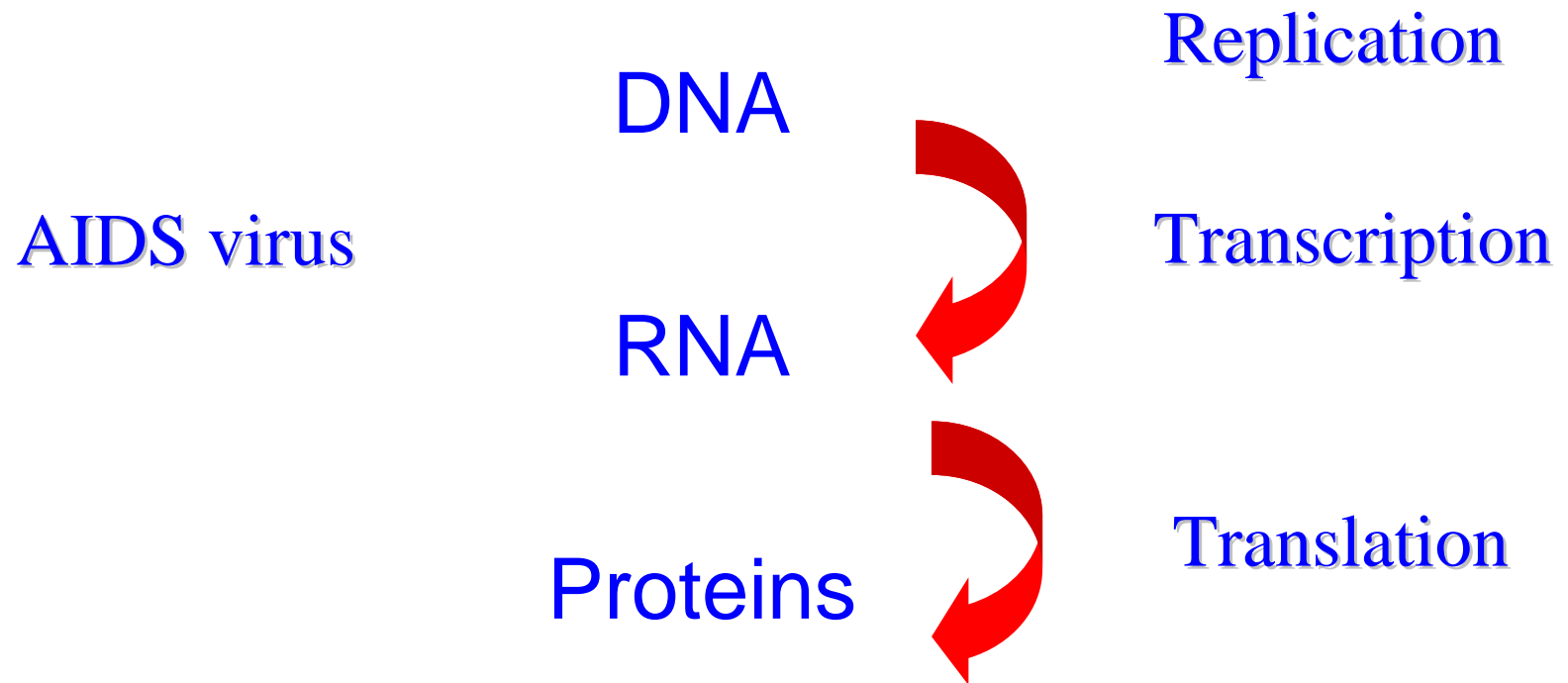
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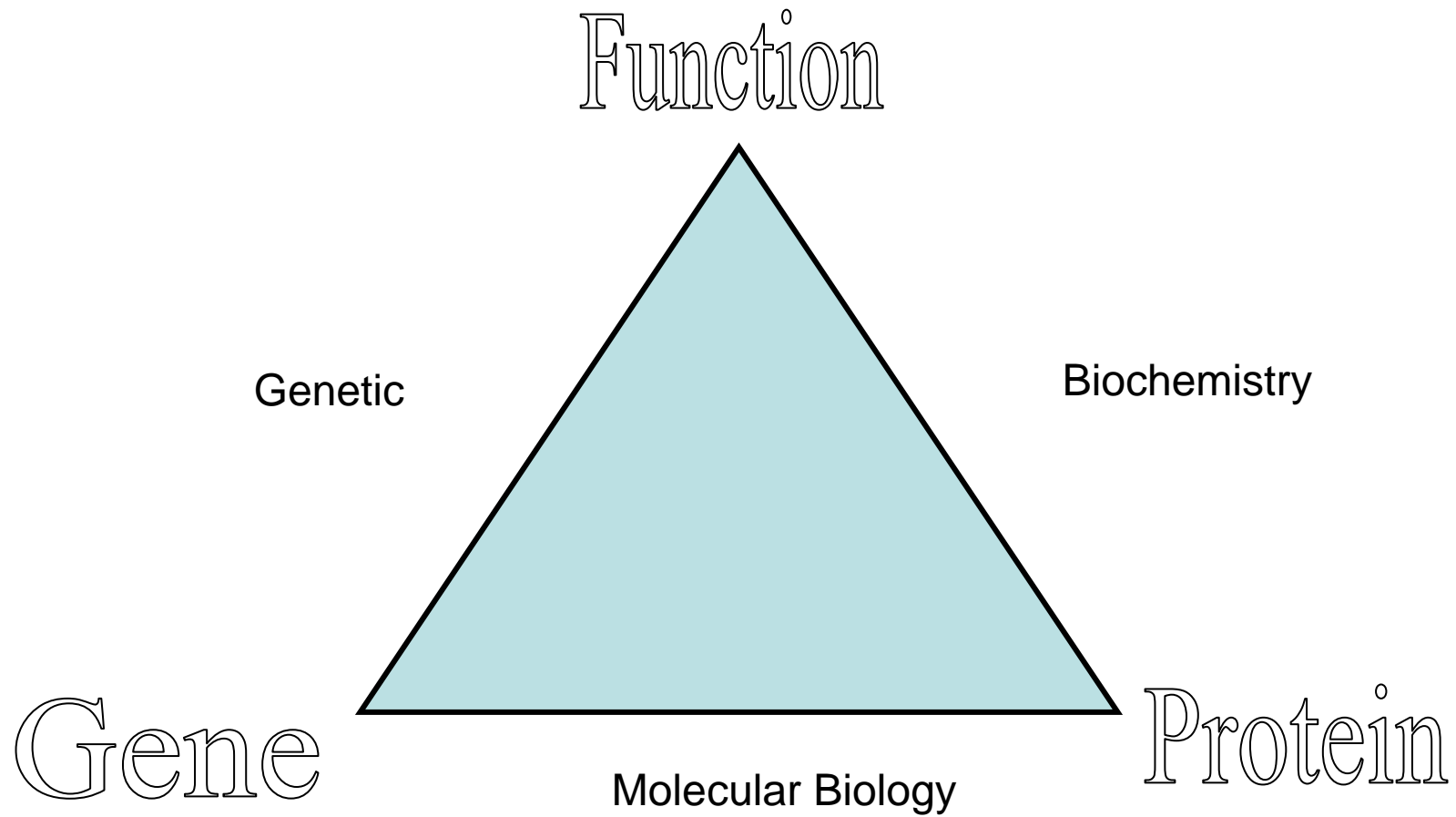


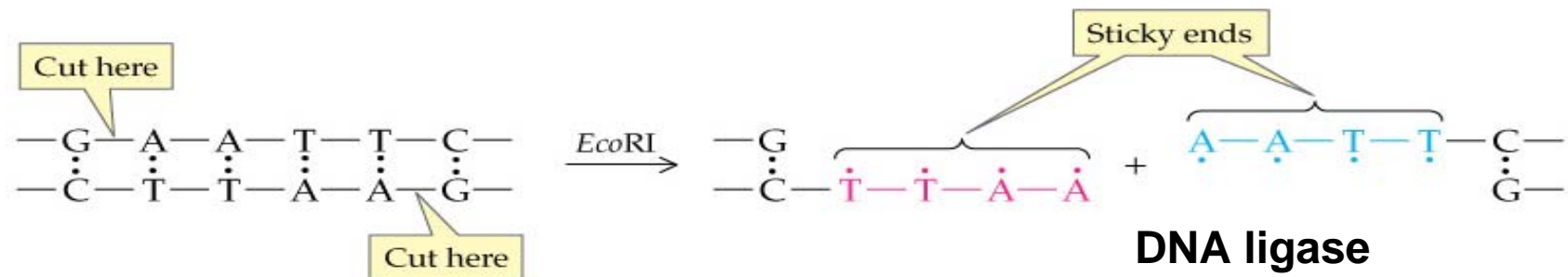


Central Dogma

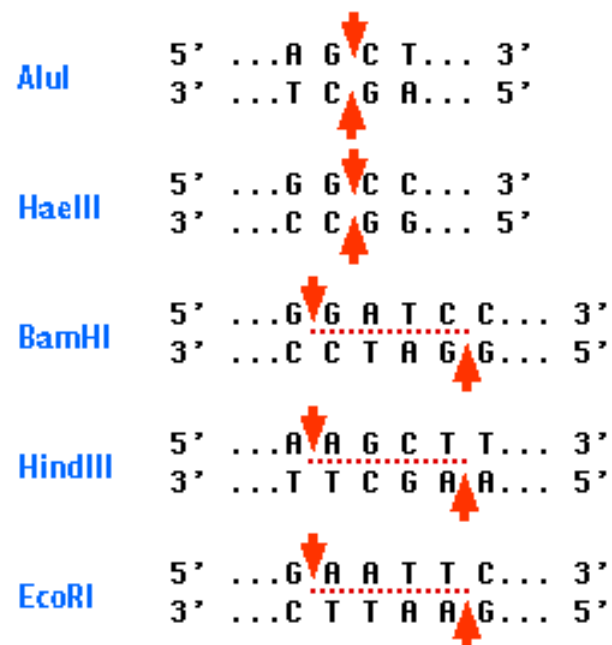


Recombinant DNA



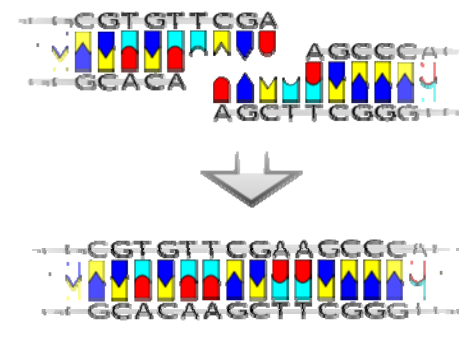
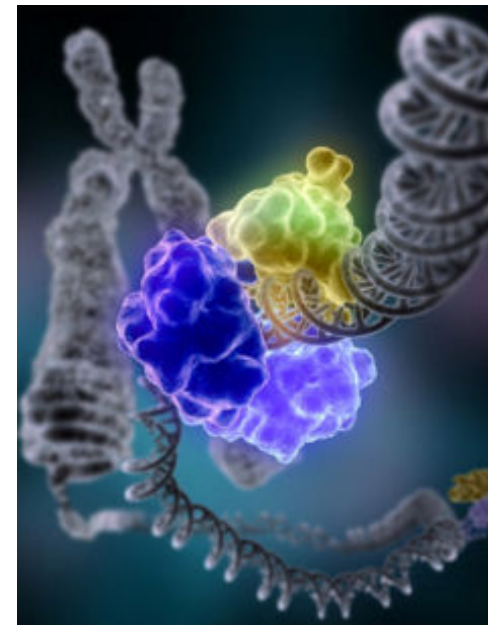


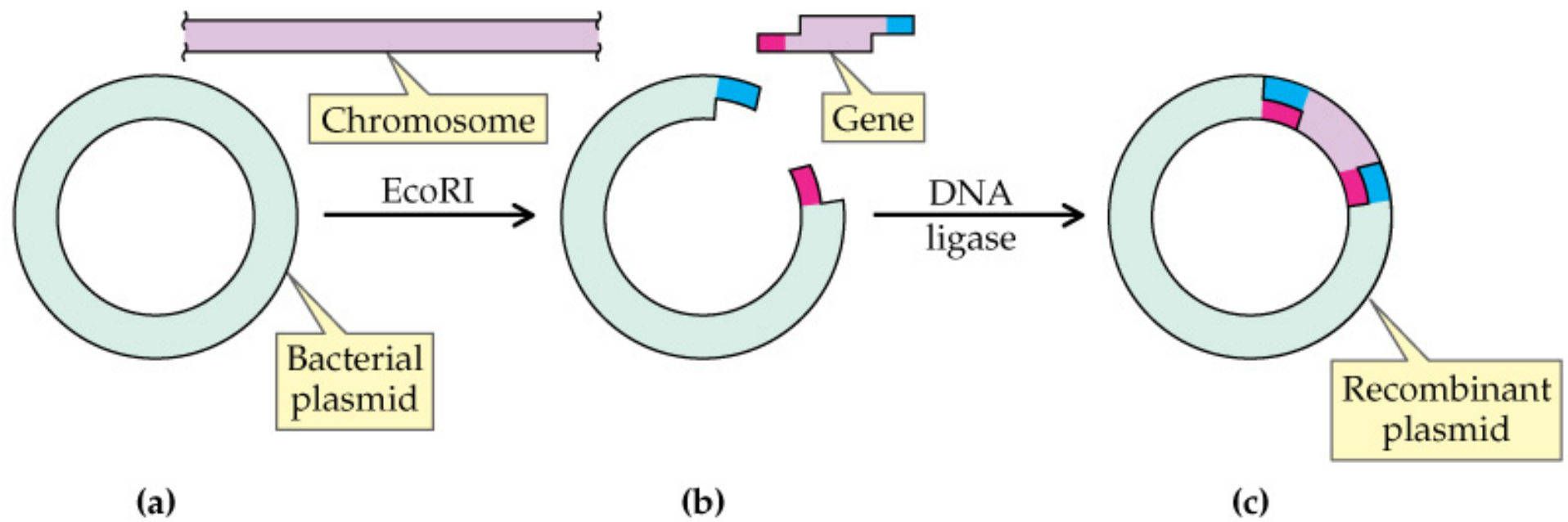
Restriction Enzyme



AluI and **HaeIII** produce blunt ends

BamHI, **HindIII** and **EcoRI** produce "sticky" ends



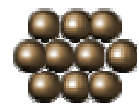
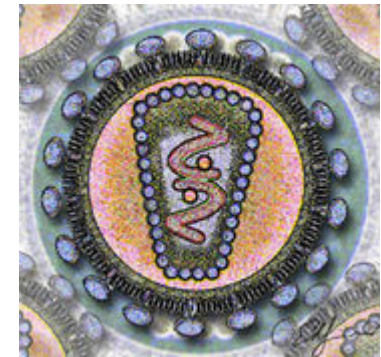
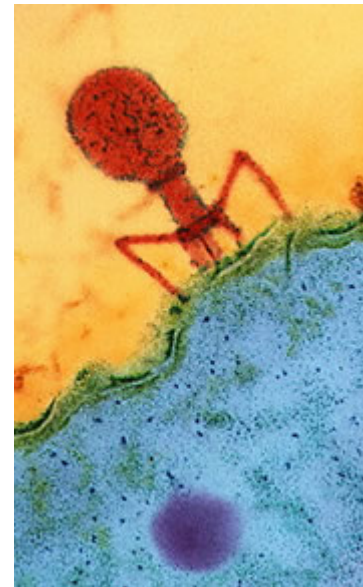
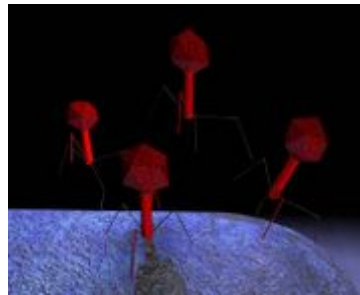
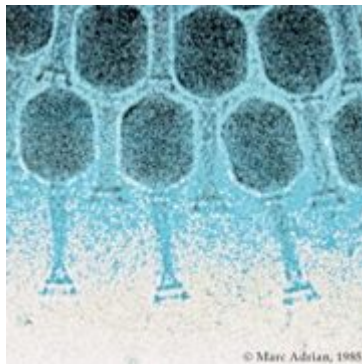
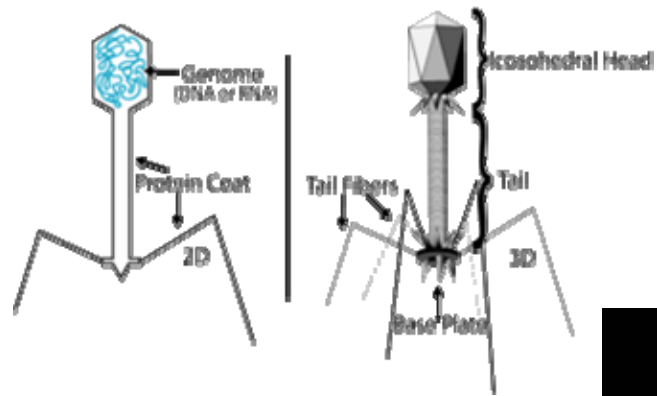


Life

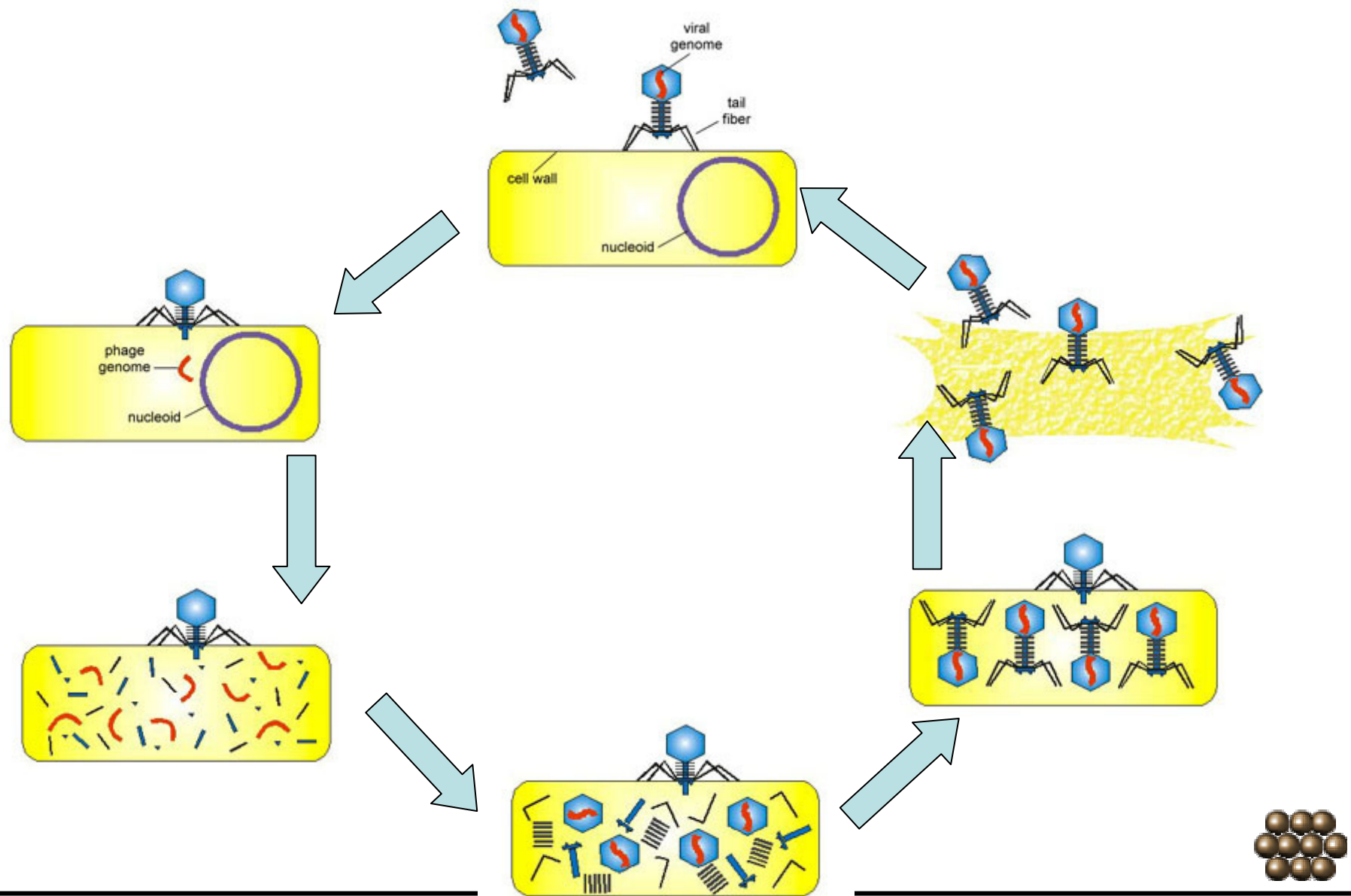
- Replication: reproduction
- Function: catalytic functions
- RNA world:
- Virus is not alive



Virus



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.

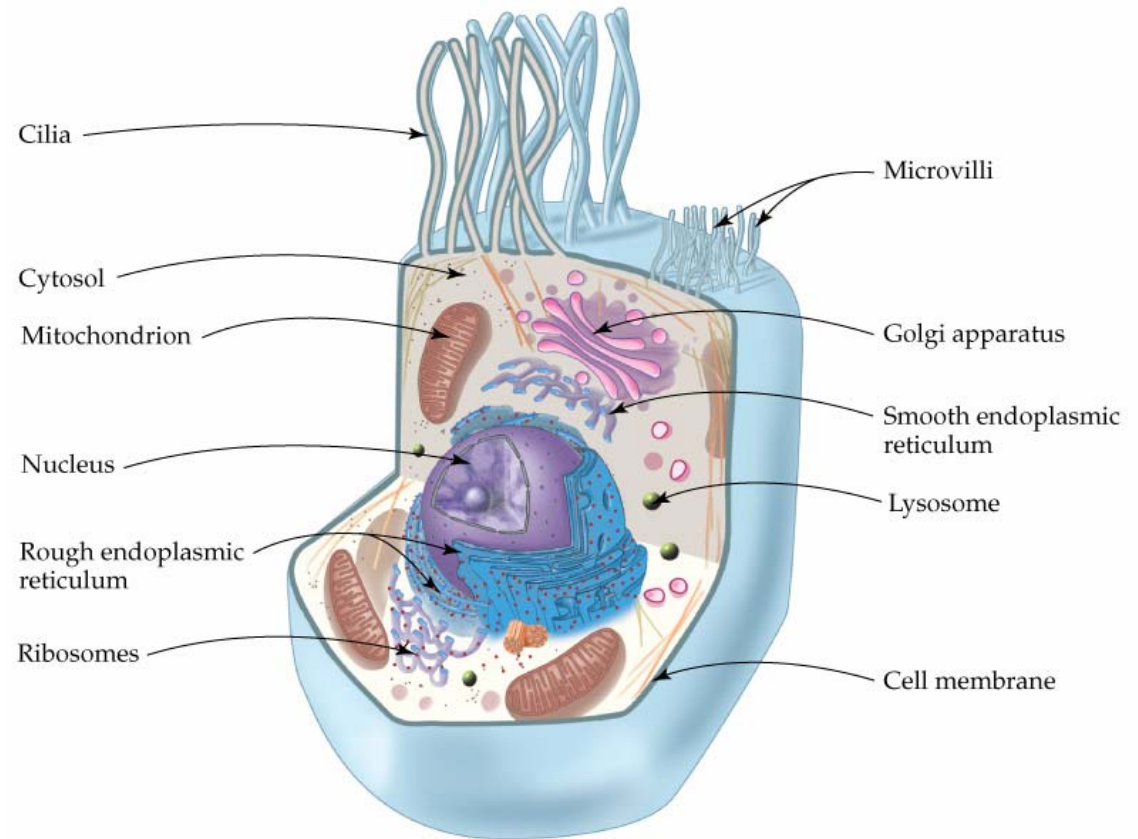
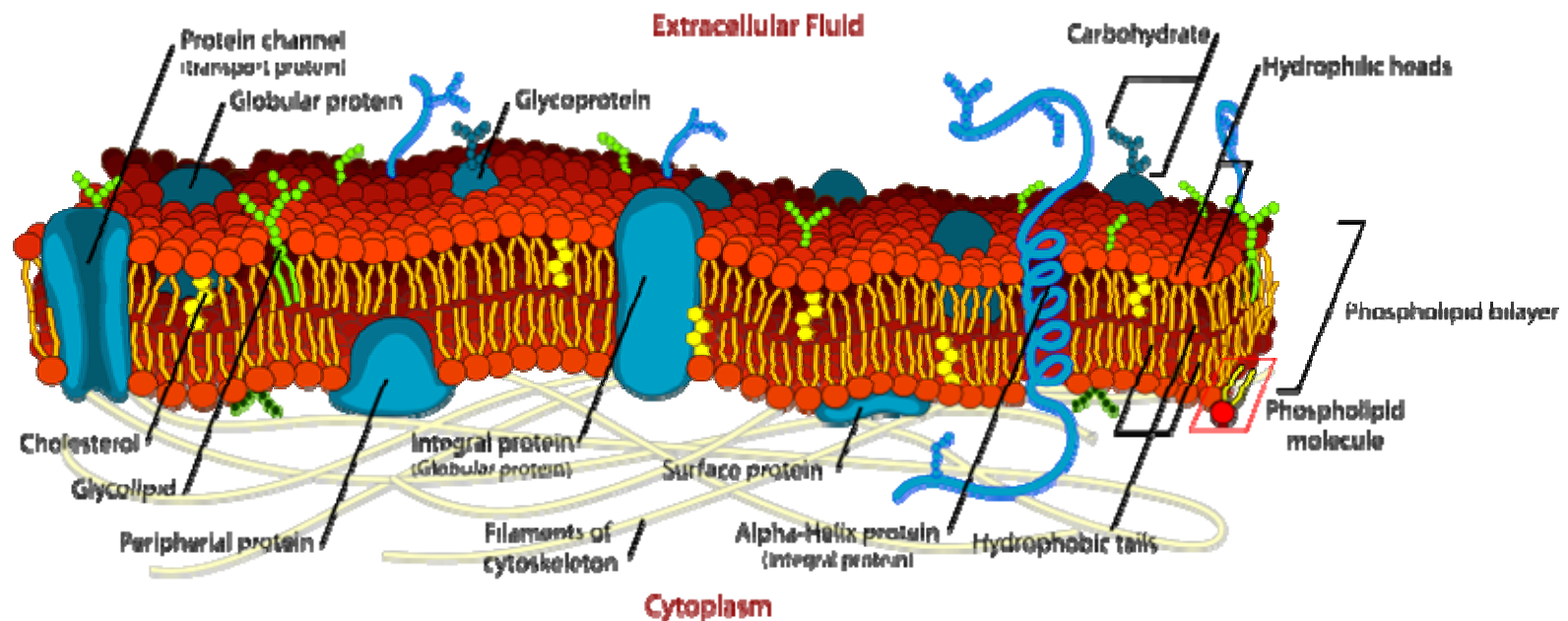


Fig 21.3 A generalized eukaryotic cell.

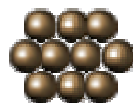


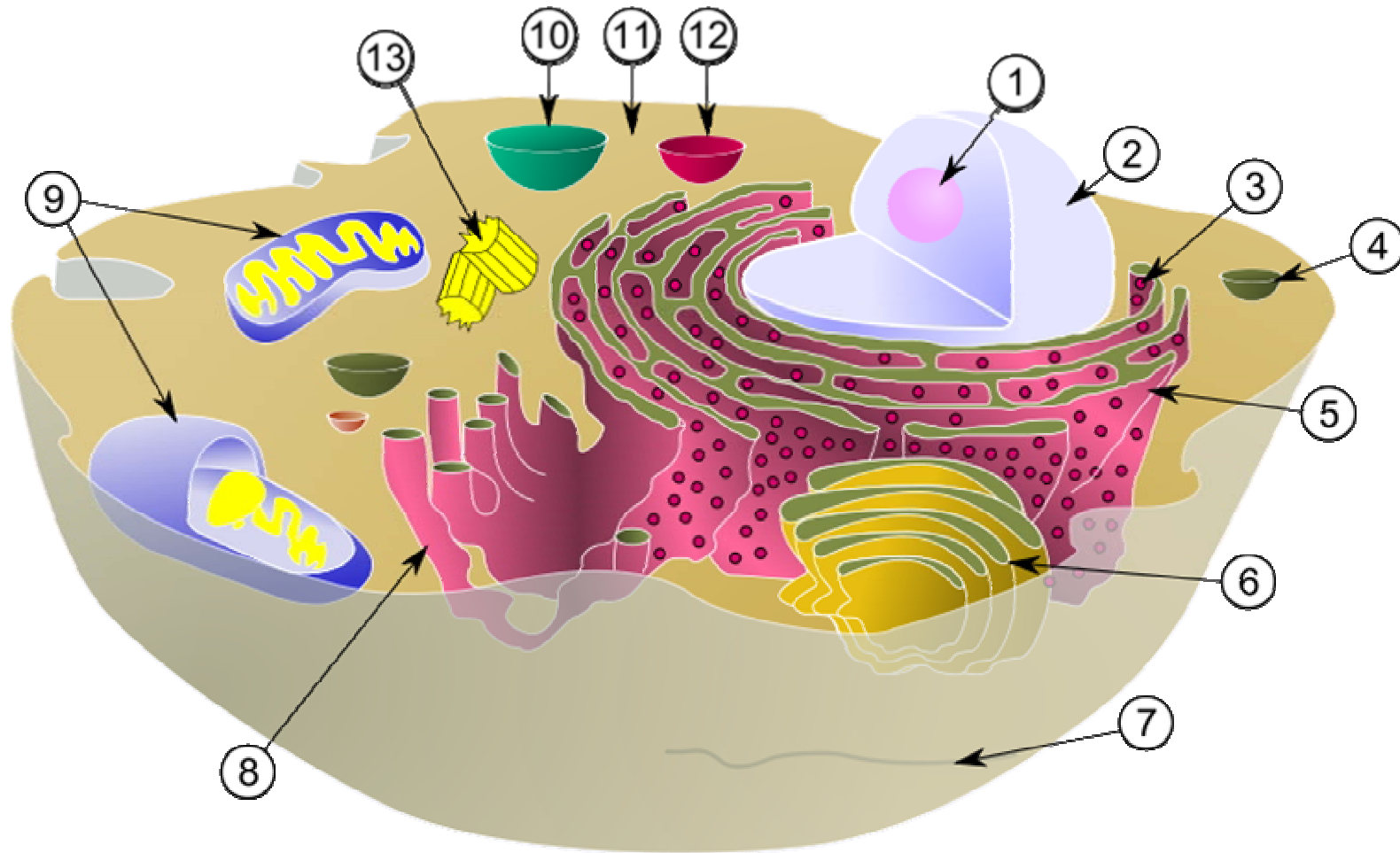
Cell Membrane



Characteristic diffusivities

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

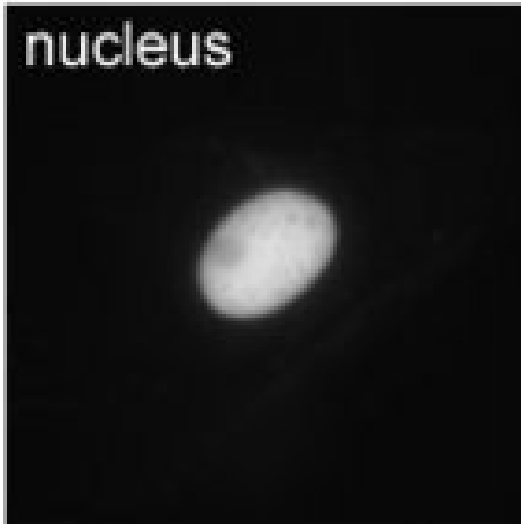




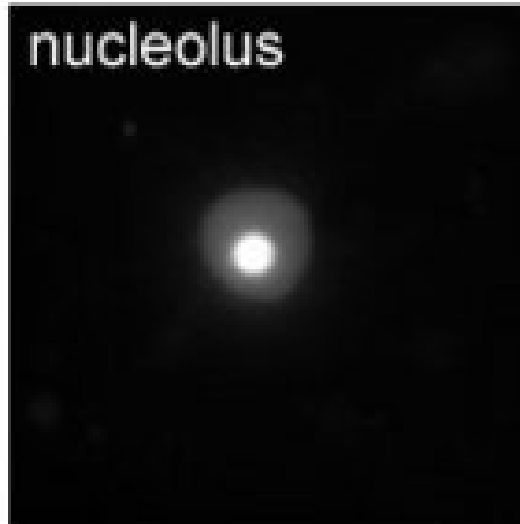
•Schematic showing the cytoplasm, with its components (or *organelles*), of a typical animal cell. Organelles: (1) nucleolus (2) nucleus (3) ribosome (4) vesicle (5) rough endoplasmic reticulum (6) Golgi apparatus (7) cytoskeleton (8) smooth endoplasmic reticulum (9) mitochondria (10) vacuole (11) cytosol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



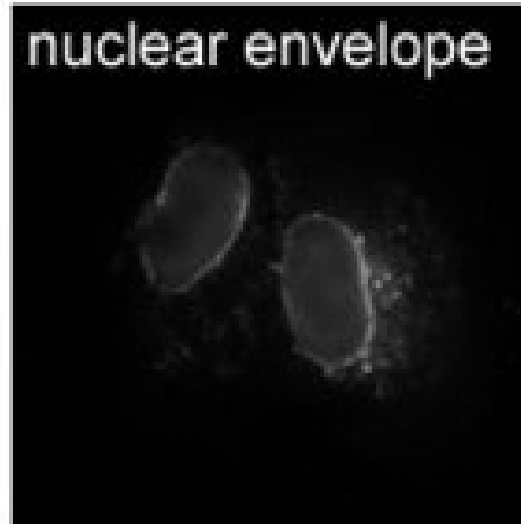
nucleus



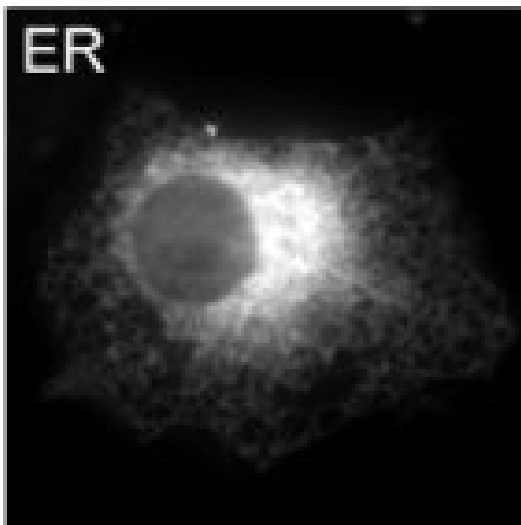
nucleolus



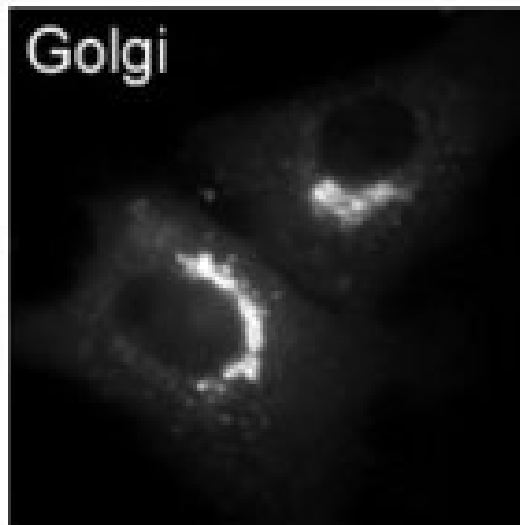
nuclear envelope



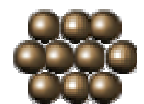
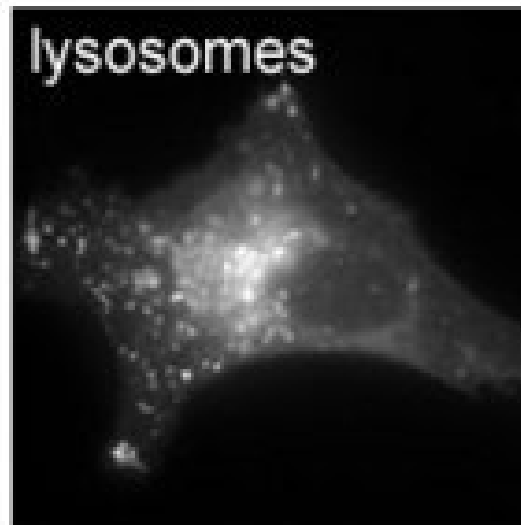
ER



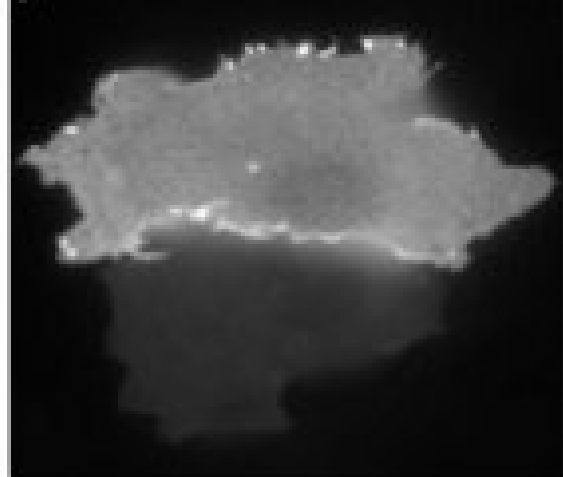
Golgi



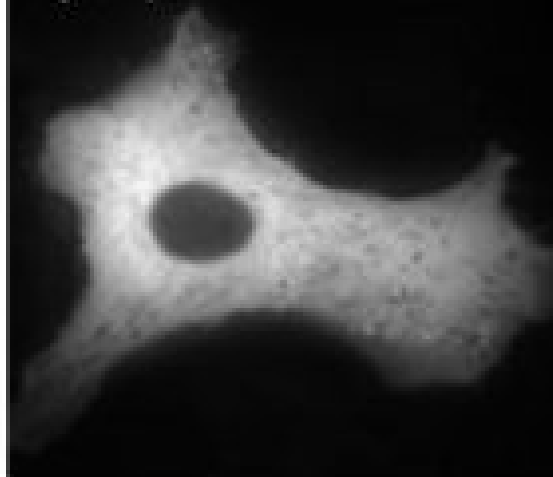
lysosomes



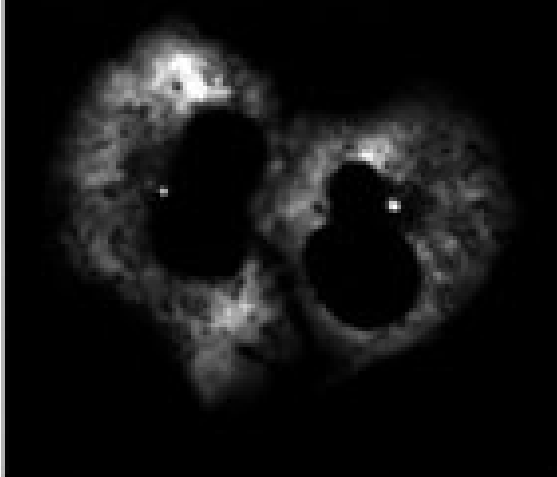
plasma membrane



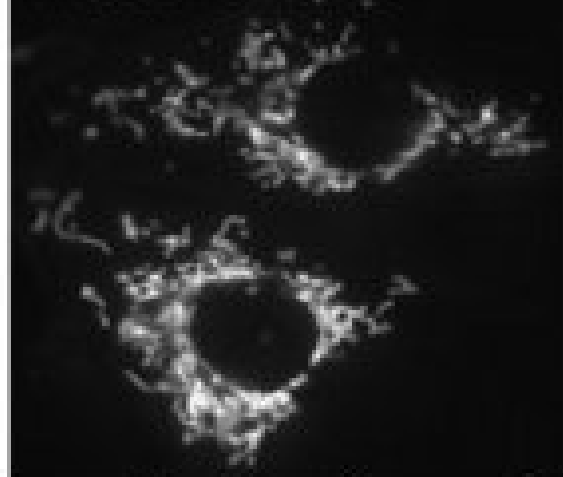
cytoplasm



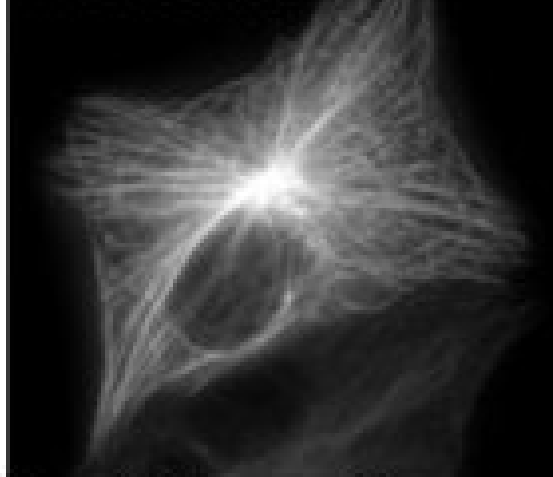
centrosomes



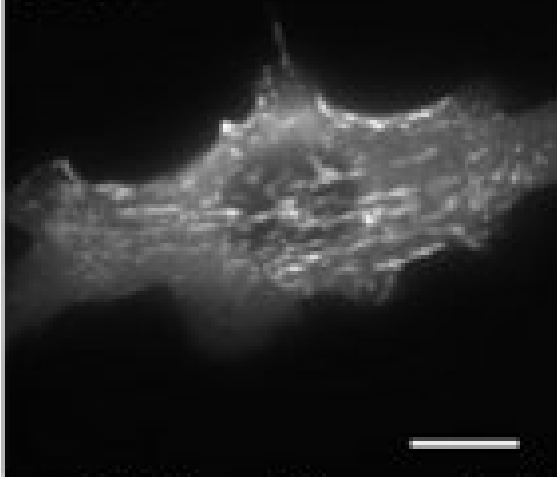
mitochondria



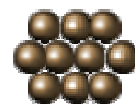
microtubules



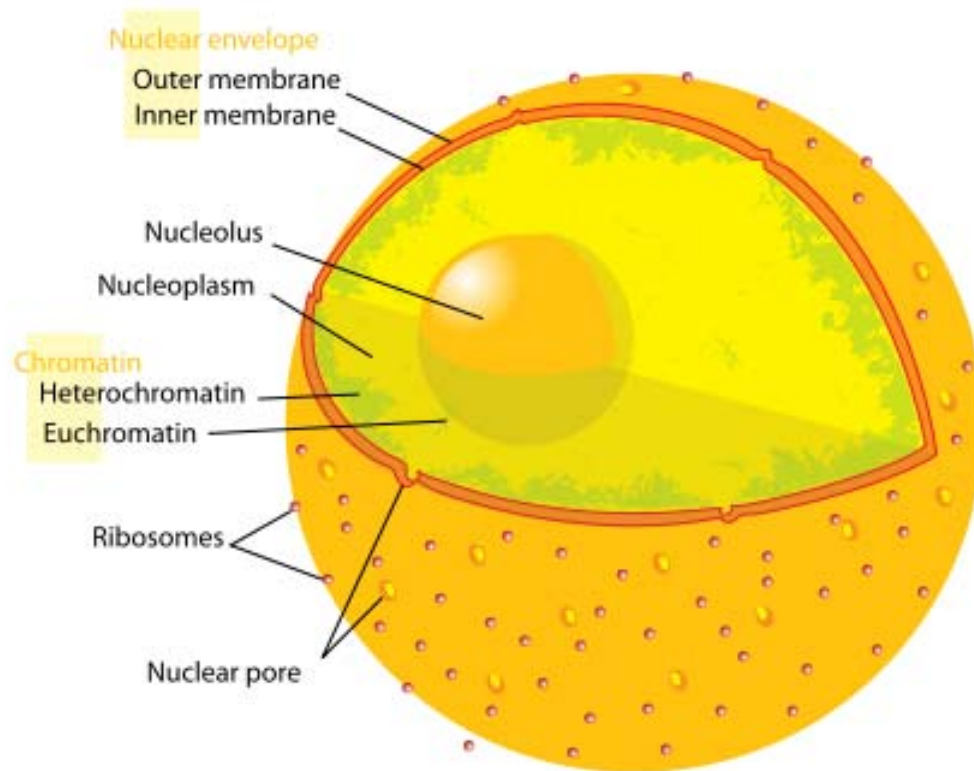
actin



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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



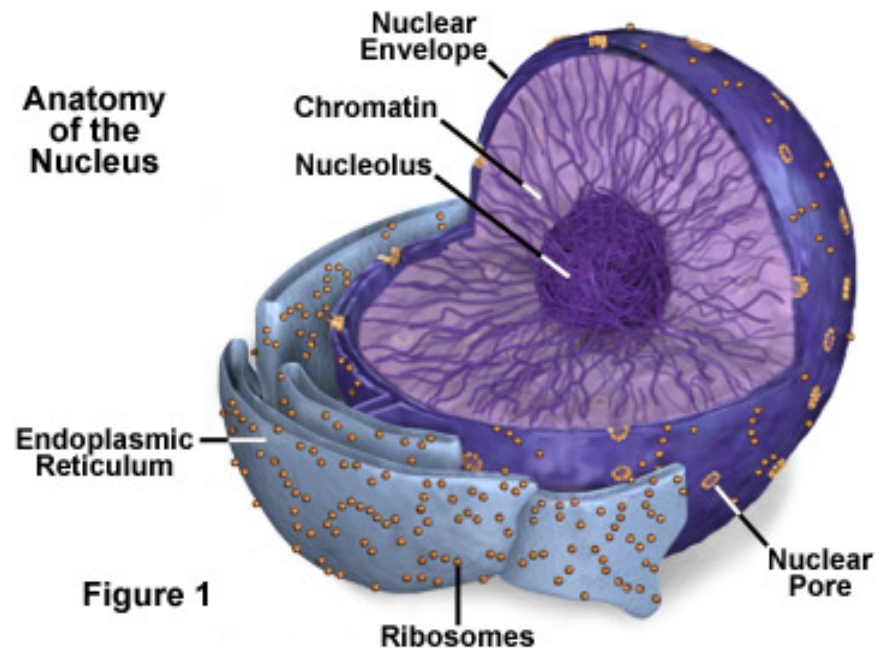
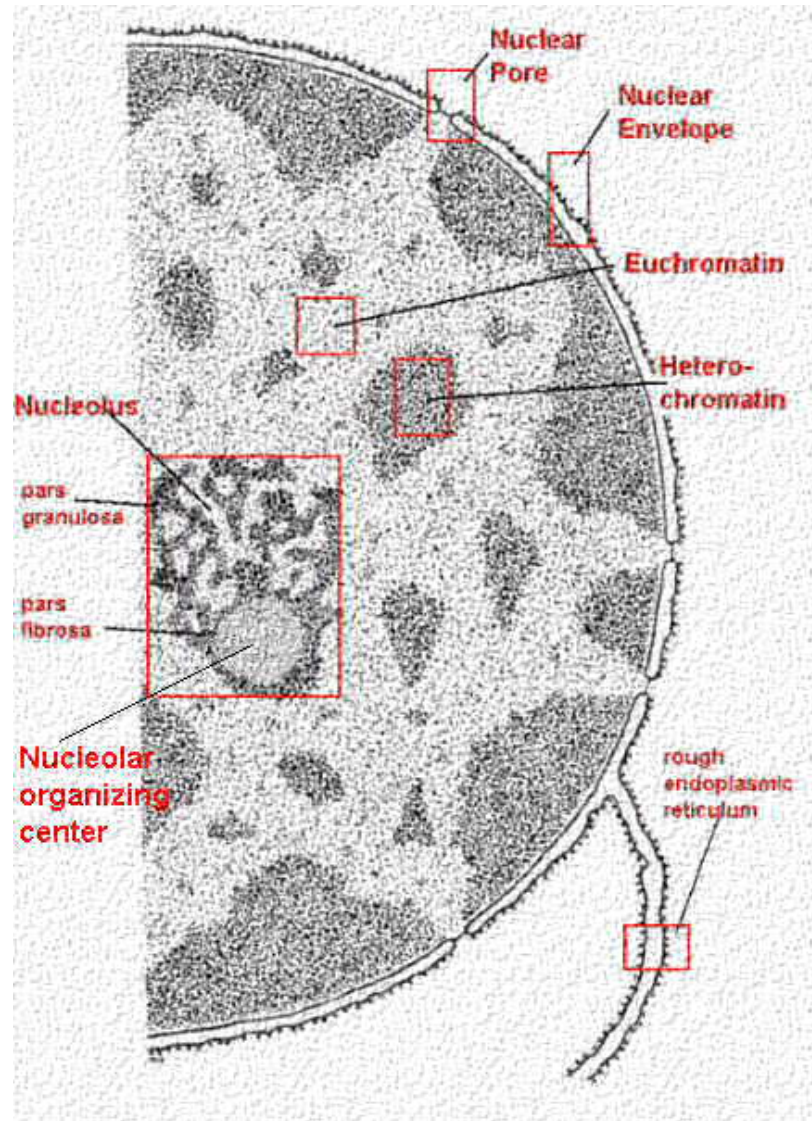
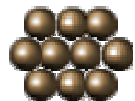


Figure 1

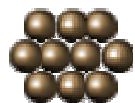
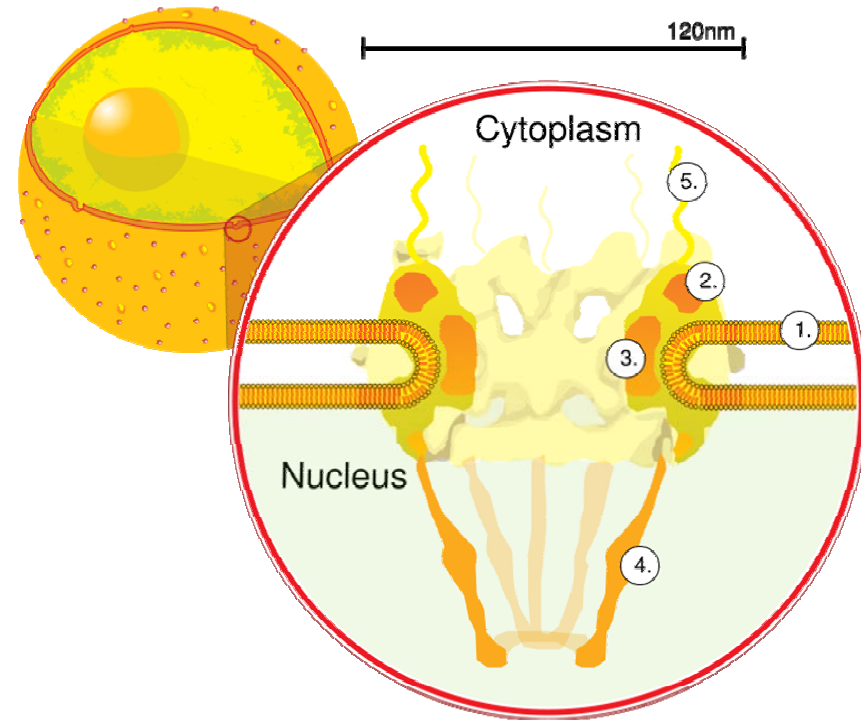
The main roles of the nucleolus are to synthesize rRNA and assemble ribosomes

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



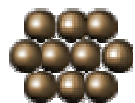
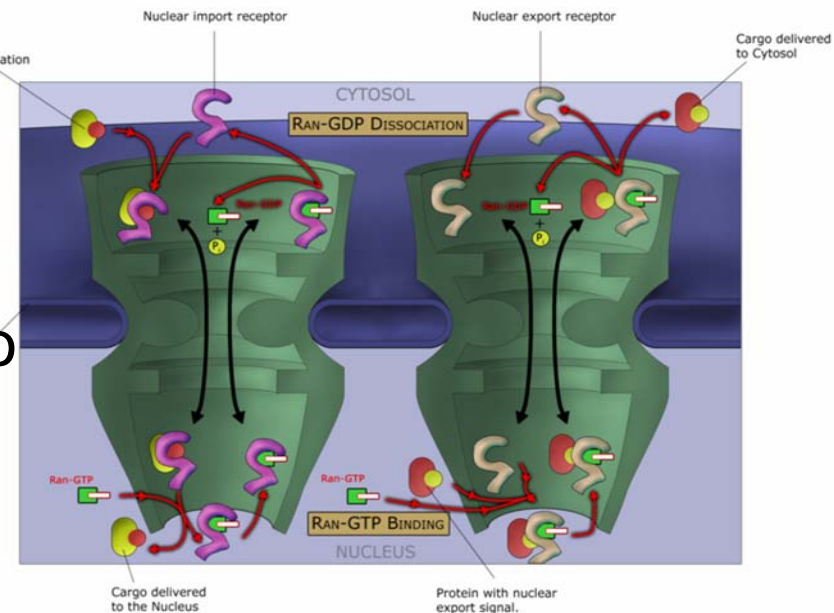
Nuclear pores

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



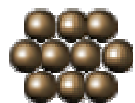
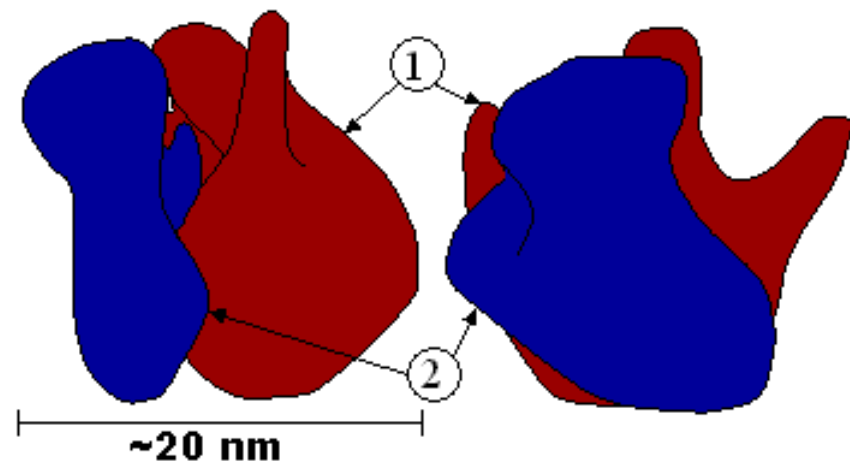
Nuclear localizing sequence (NLS)

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).



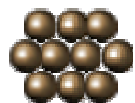
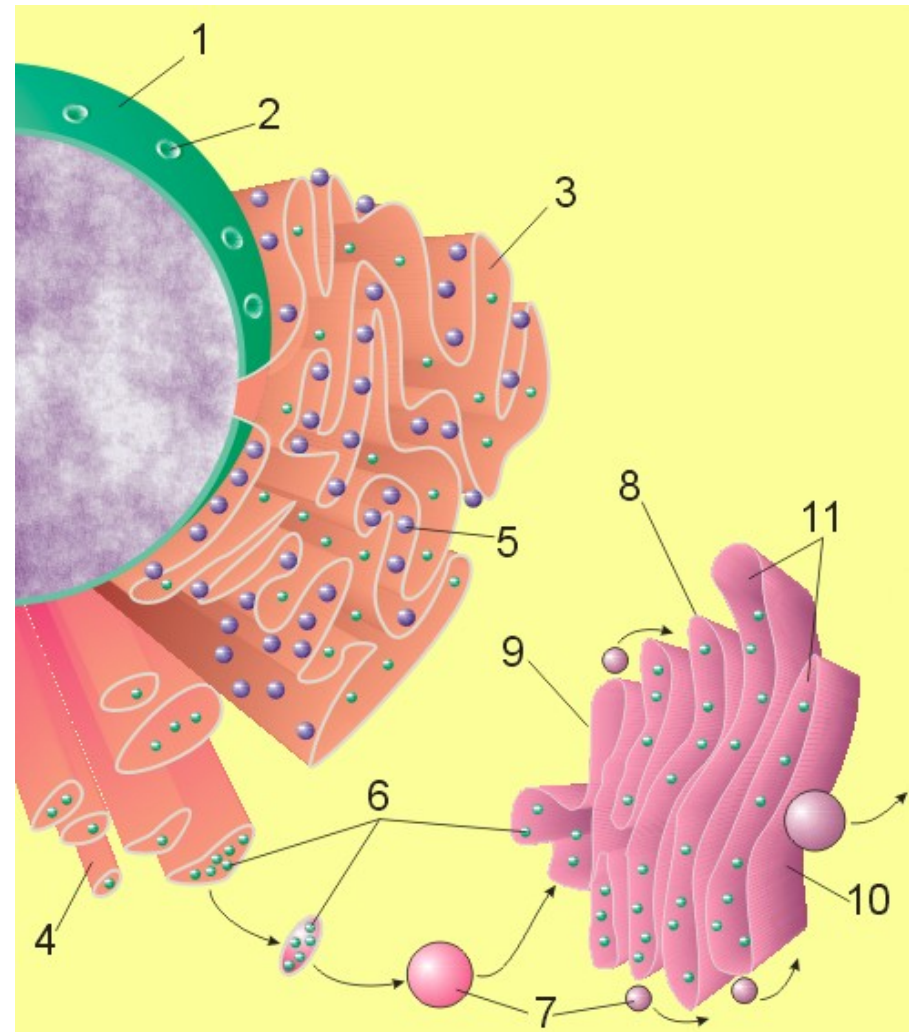
Ribosome

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.



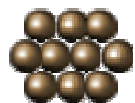
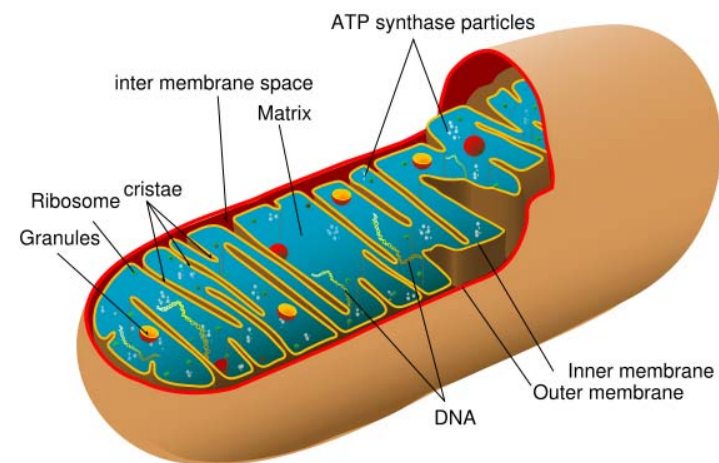
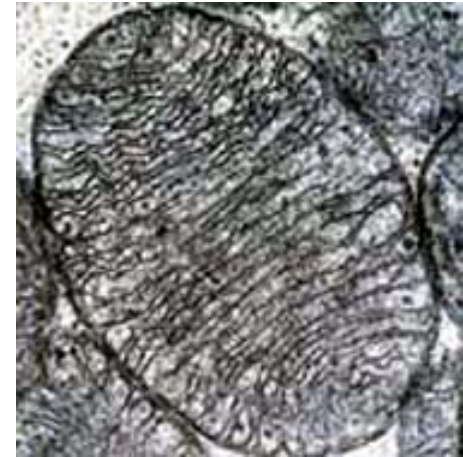
Golgi apparatus

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.



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.

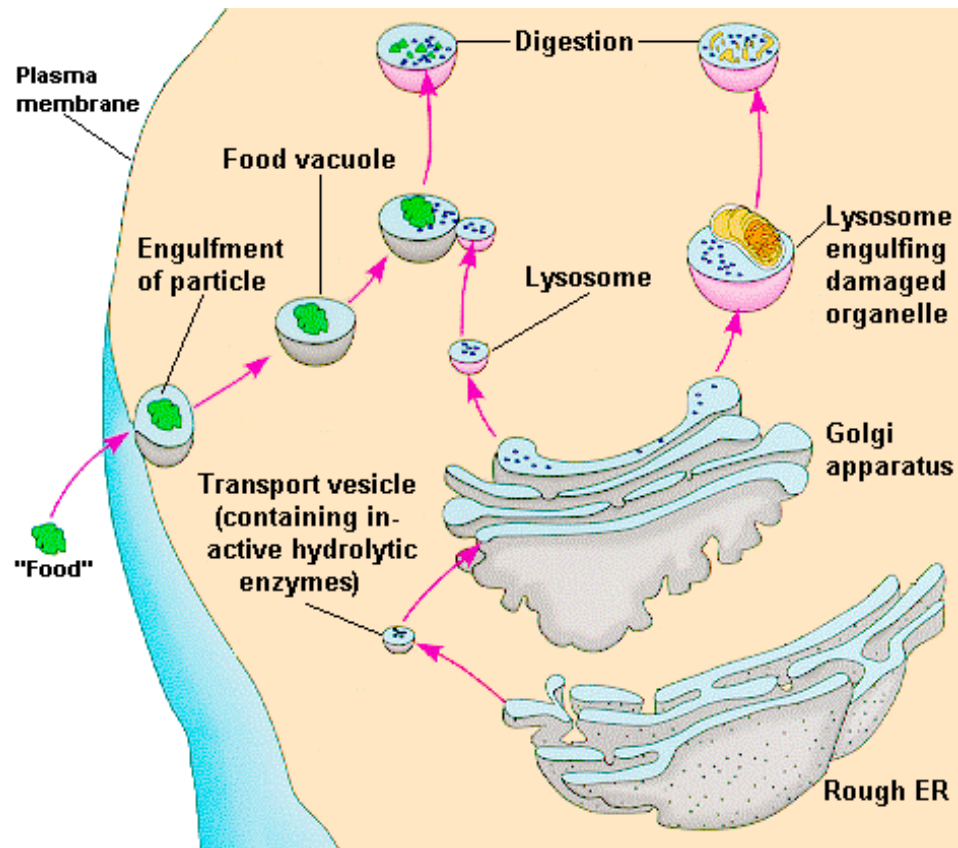


Lysosomes

- **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.



Lysosome



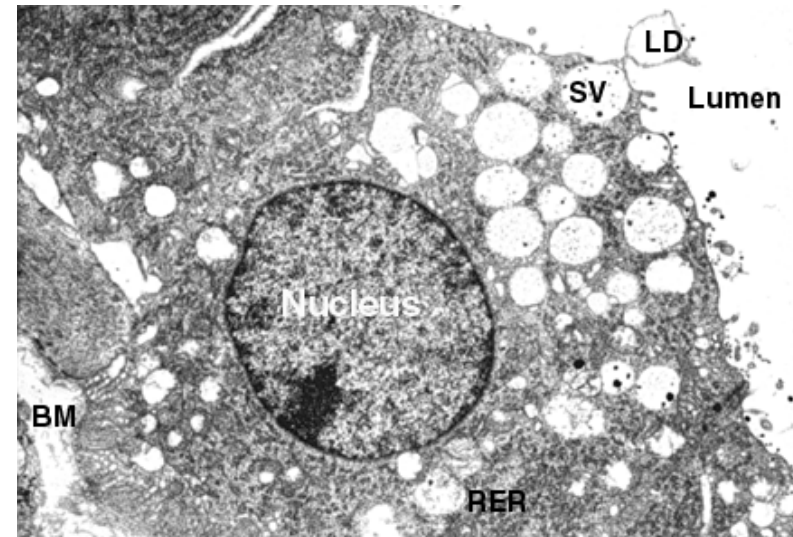
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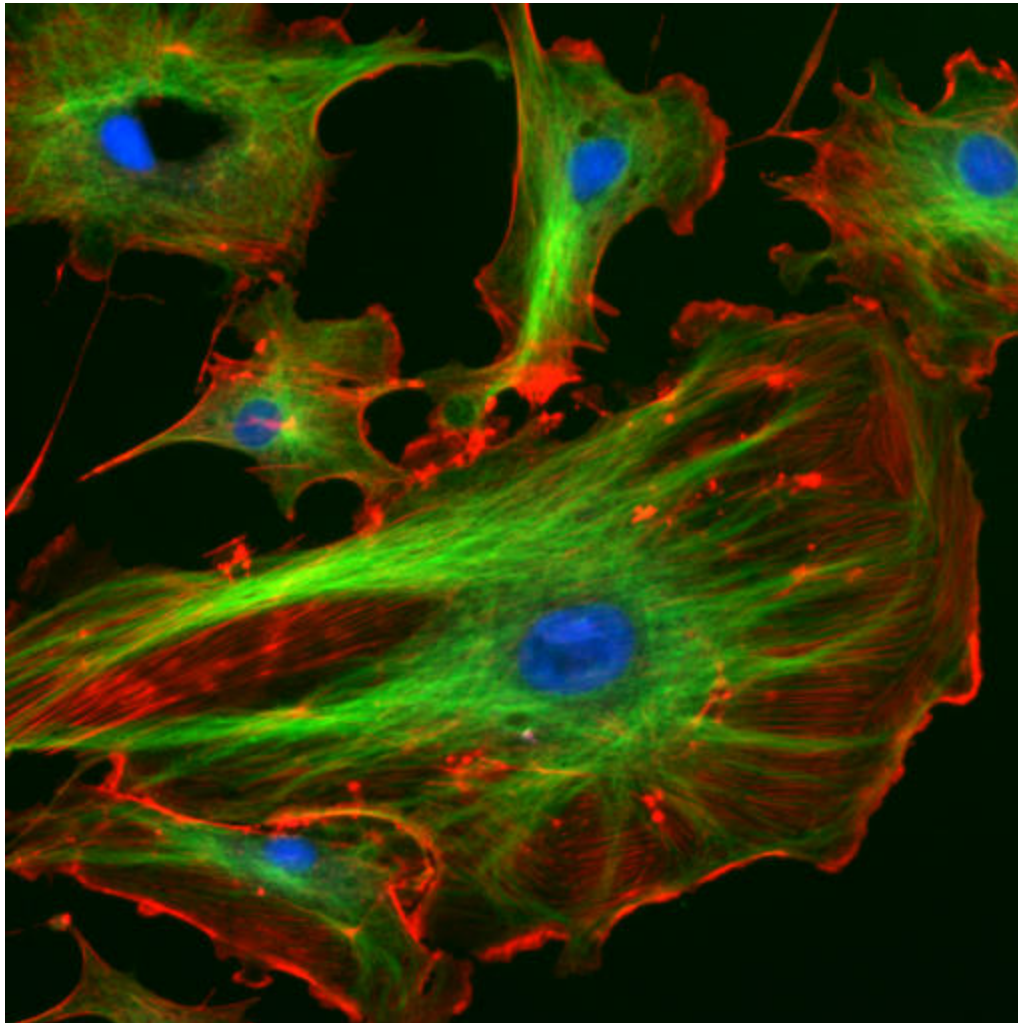
Vesicle

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.



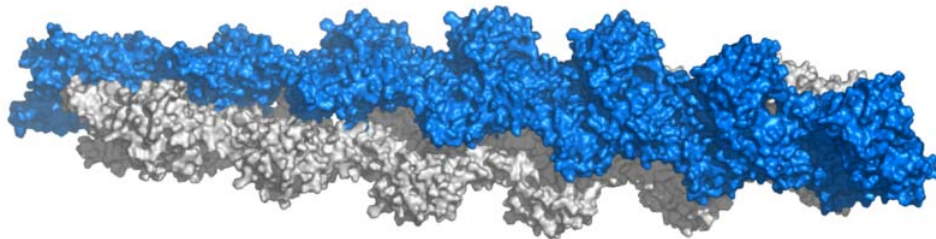
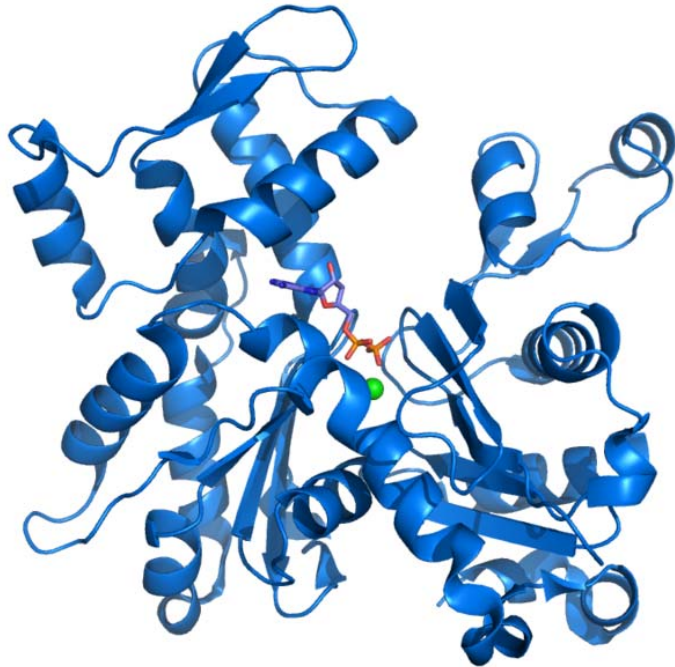
Cytoskeleton



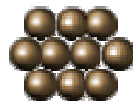
The eukaryotic cytoskeleton. Actin filaments are shown in red, microtubules in green, and the nuclei are in blue.



Actin



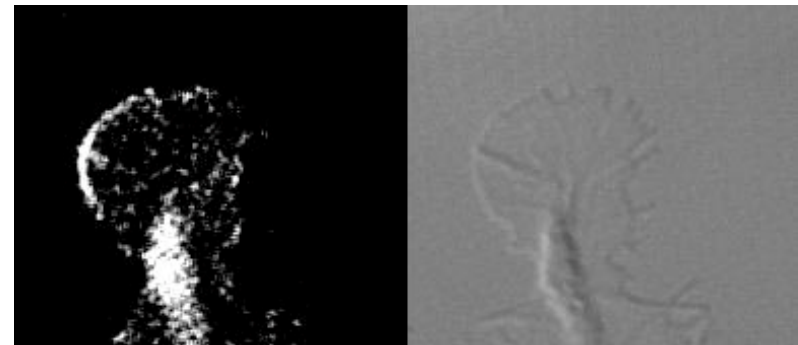
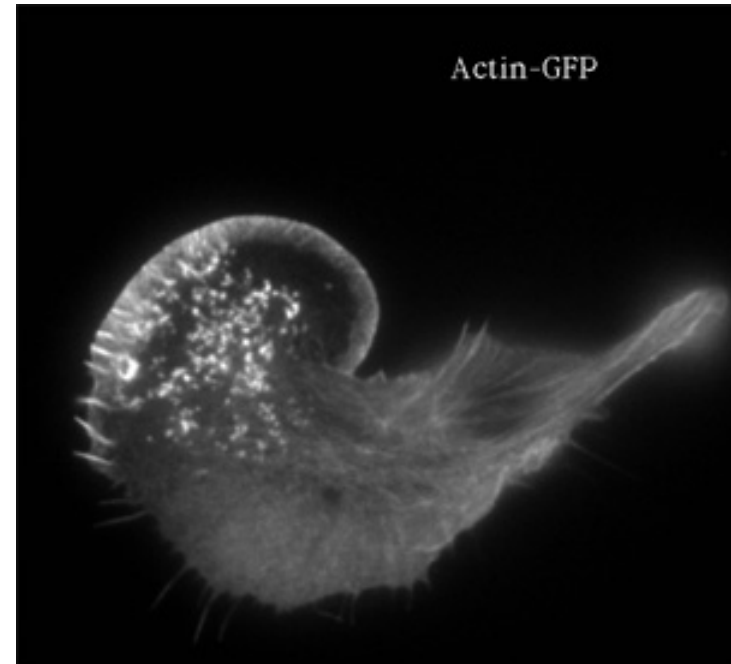
- **Actin** is a globular structural, 42 kDa, [protein](#) that polymerizes in a helical fashion to form **actin filaments** (or **microfilaments**). These form the cytoskeleton, a three-dimensional network inside the eukaryotic cell. Actin filaments provide mechanical support for the cell, determine 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

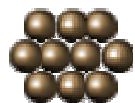
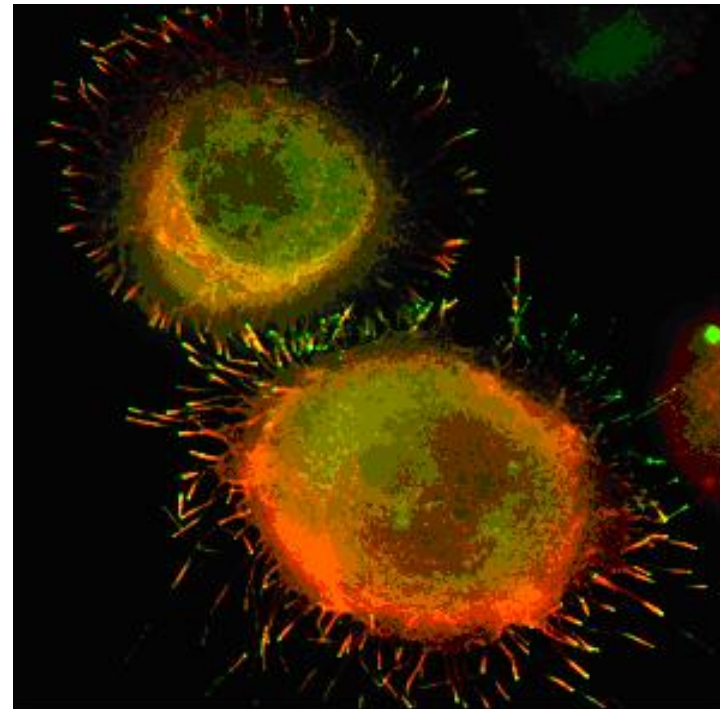
The **lamellipodium** is a cytoskeletal actin projection on the mobile edge of the cell. It contains a two-dimensional actin mesh; the whole structure pulls the cell across a substrate. Within the lamellipodia are ribs of actin called microspikes, which, when they spread beyond the lamellipodium frontier, are called filopodia (Small, et al, 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 $1\ \mu\text{m}$ to $5\ \mu\text{m}$ in breadth and are approximately $0.2\ \mu\text{m}$ thick. Lamellipodia are found primarily in very mobile cells, crawling at a speeds of $10\text{-}20\ \mu\text{m}/\text{minute}$ 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.



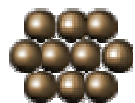
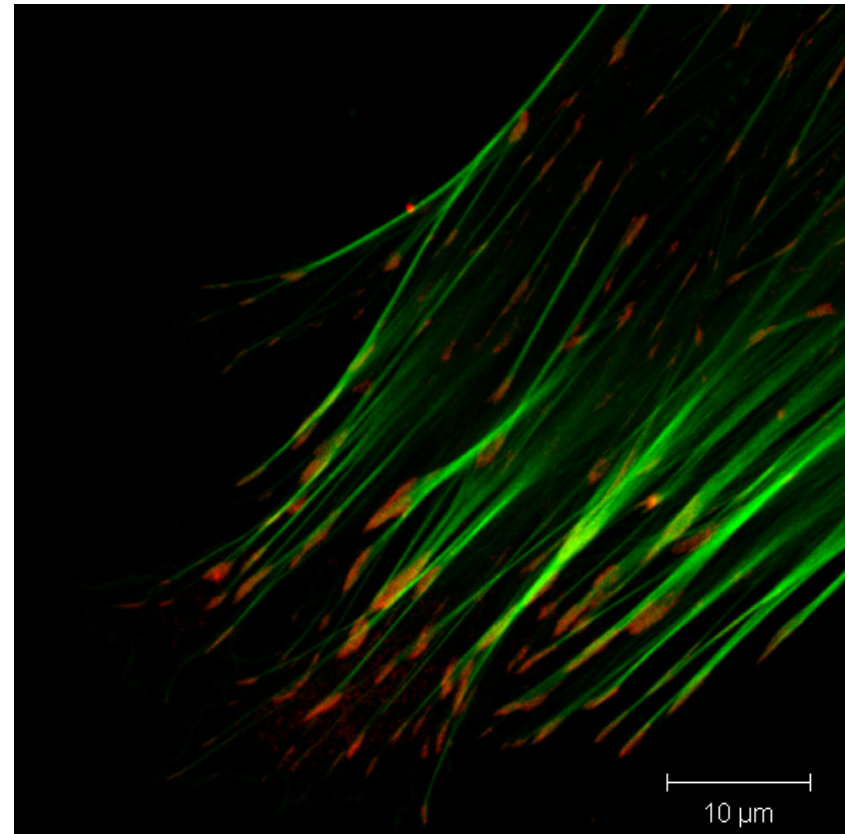
Filopodia

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

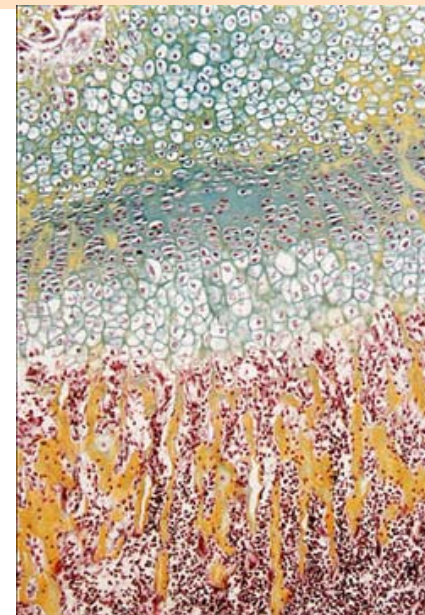
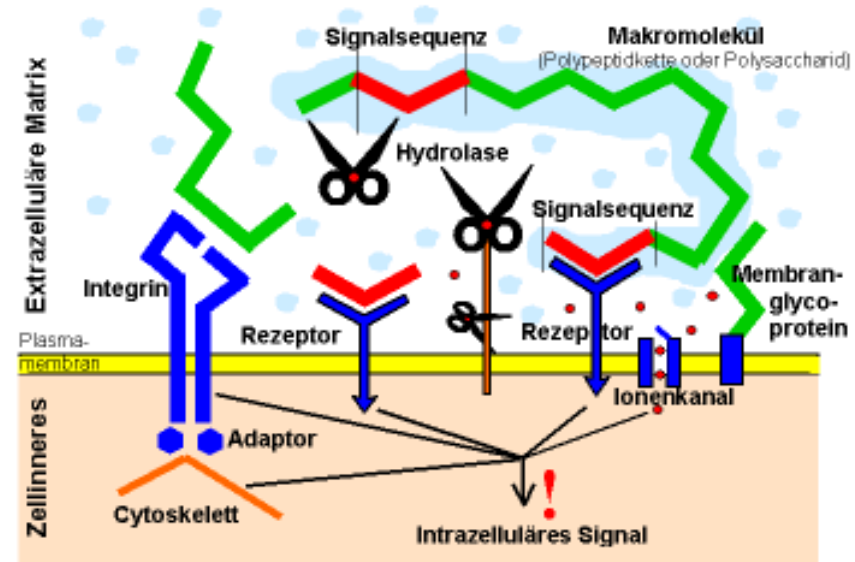
- In cell biology, '**Focal Adhesions**' are specific types of large macromolecular assemblies through which both mechanical force and regulatory signals are transmitted. More precisely, **FAs** can be considered as sub-cellular macromolecules that mediate the regulatory effects (e.g. cell anchorage)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

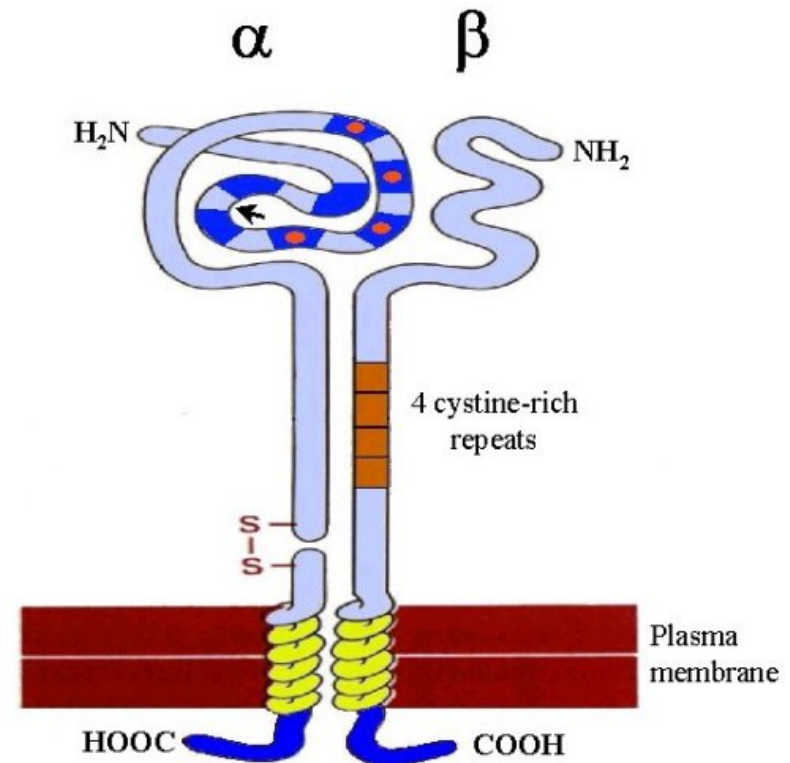


Integrin

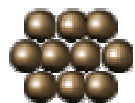
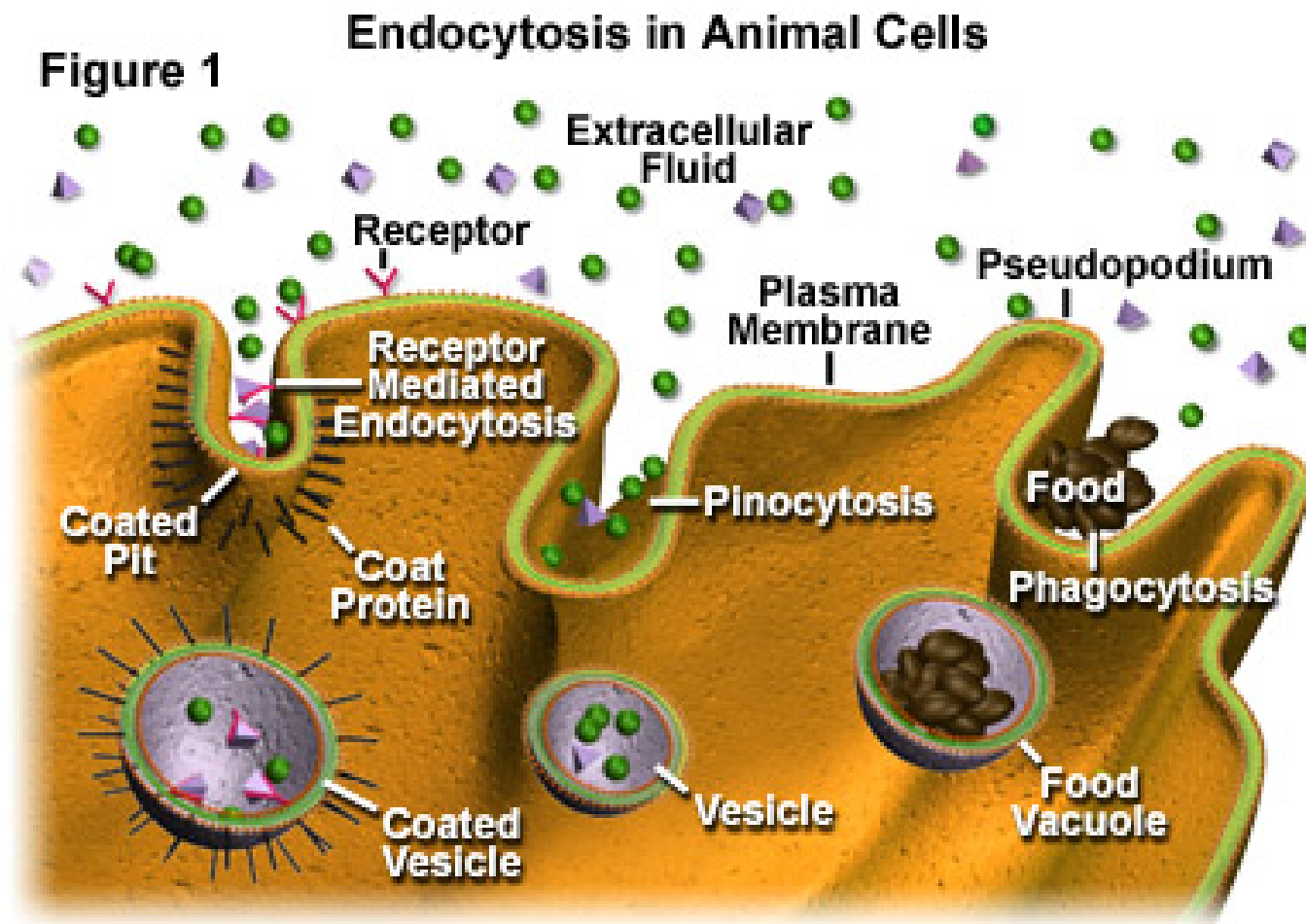
An **integrin**, or **integrin receptor**, is an integral membrane protein in the plasma membrane of cells. It plays a role in the attachment of a cell to the [extracellular matrix](#) (ECM) and to other cells and in signal transduction from the ECM to the cell. There are many types of integrin, and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

Schematic drawing of a typical integrin dimer

Arrow shows the region where an I domain is inserted in some α subunits. Not all α subunits are posttranslationally cleaved. Internal disulphide bonds within subunits are not shown. Dark blue regions in the head segment of the α subunit represent homologous repeats. Those with the EF-hand consensus sequence are marked with red circles to denote binding sites for divalent metal ion.



Endocytosis



Endocytosis

- Phagocytosis is the process by which cells ingest large objects, such as cells which have undergone apoptosis, bacteria, or viruses. The membrane folds around the object, and the object is sealed off into a large vacuole known as a phagosome.
- Pinocytosis is a synonym for endocytosis. This process is concerned with the uptake of solutes and single molecules such as proteins.
- Receptor-mediated endocytosis is a more specific active event where the cytoplasm membrane folds inward to form coated pits. These inward budding vesicles bud to form cytoplasmic vesicles.



Endocytosis pathways

- Macropinocytosis is the invagination of the cell membrane to form a pocket which then pinches off into the cell to form a vesicle filled with extracellular fluid (and molecules within it). The filling of the pocket occurs in a non-specific manner. The vesicle then travels into the [cytosol](#) and fuses with other vesicles such as [endosomes](#) and [lysosomes](#).
- Clathrin-mediated endocytosis is the specific uptake of large extracellular molecules such as proteins, membrane localized receptors and ion-channels. These receptors are associated with the cytosolic protein clathrin which initiates the formation of a vesicle by forming a crystalline coat on the inner surface of the cell's membrane.
- [Caveolae](#) consist of the protein caveolin-1 with a bilayer enriched in cholesterol and glycosphingolipids. Caveolae are flask shaped pits in the membrane that resemble the shape of a cave (hence the name caveolae). Uptake of extracellular molecules are also believed to be specifically mediated via receptors in caveolae.

