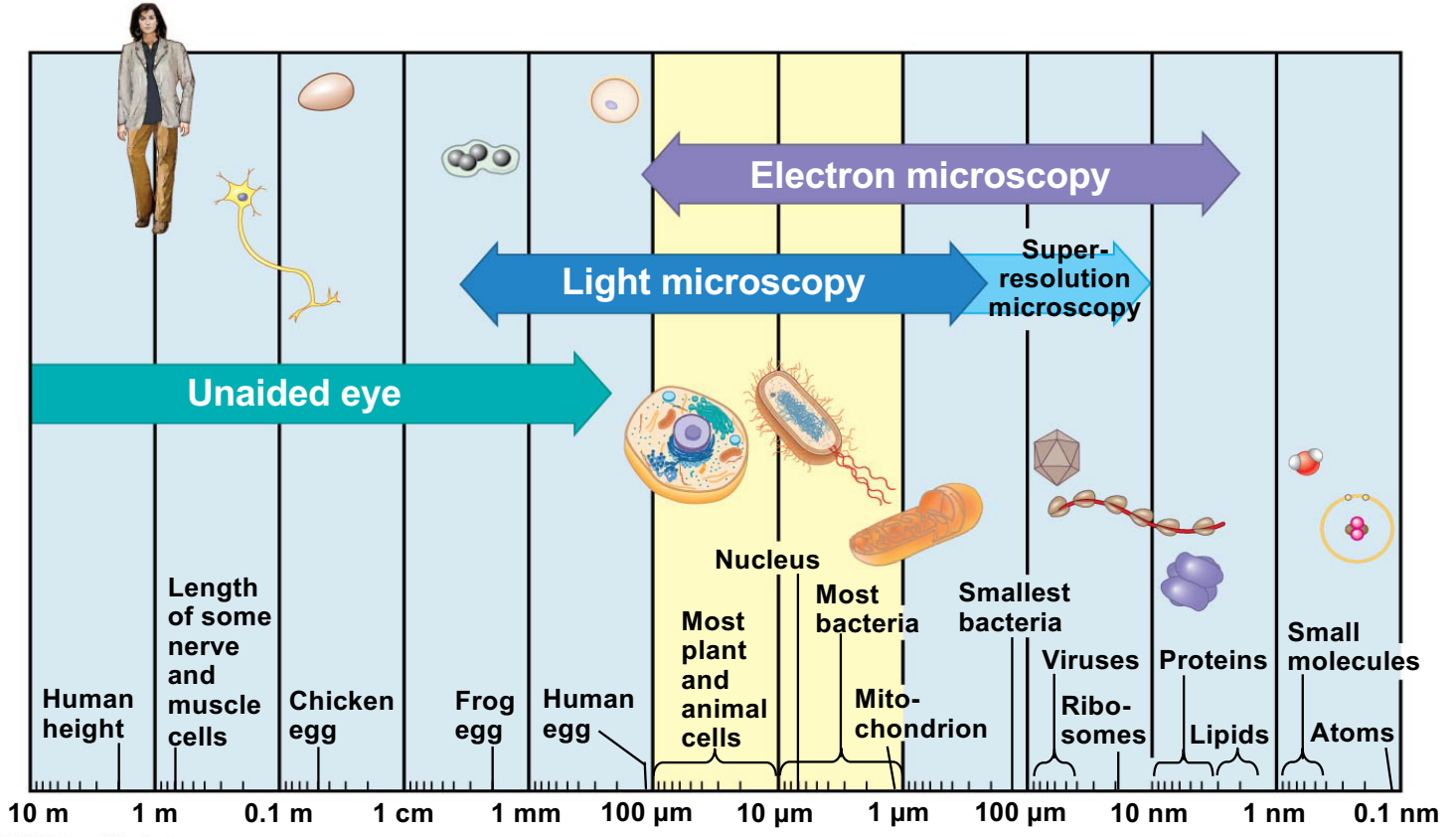
# The Cell

Yang Yang, PhD

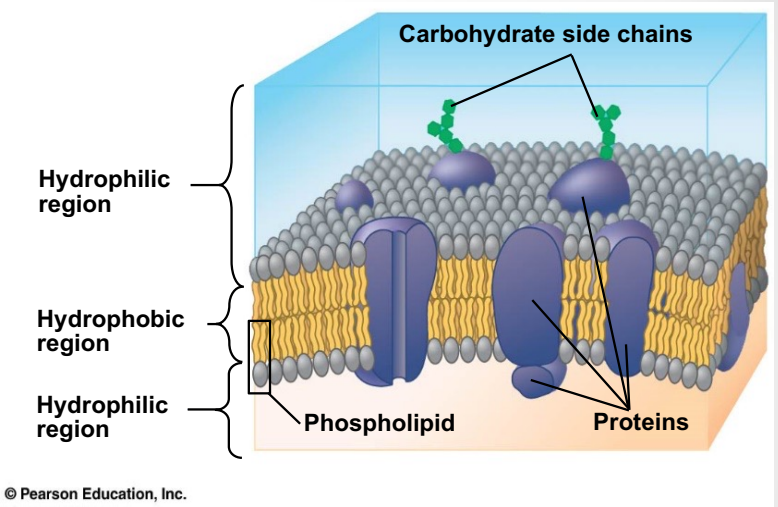
# Cells: The Fundamental Units of Life

- All organisms are made of cells
- Cells can differ substantially from one another but share **common features**



# Basic features of all cells

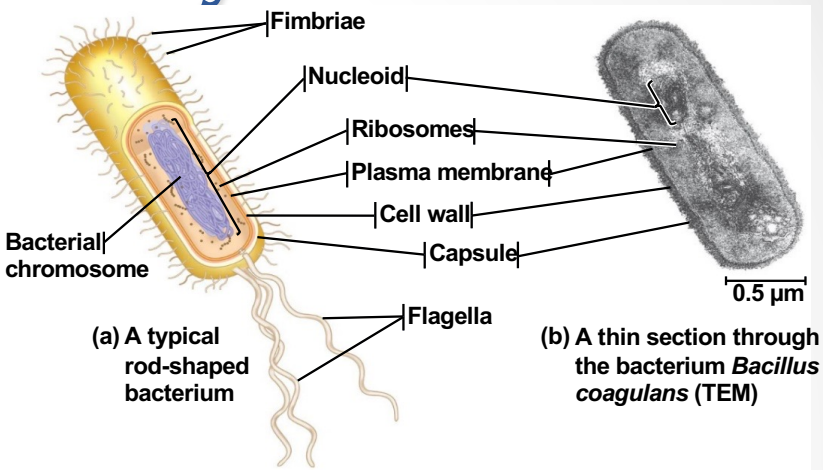
- Plasma membrane 细胞膜/质膜
- Semifluid substance called cytosol 细胞质
- Chromosomes 染色体
- Ribosomes 核糖体

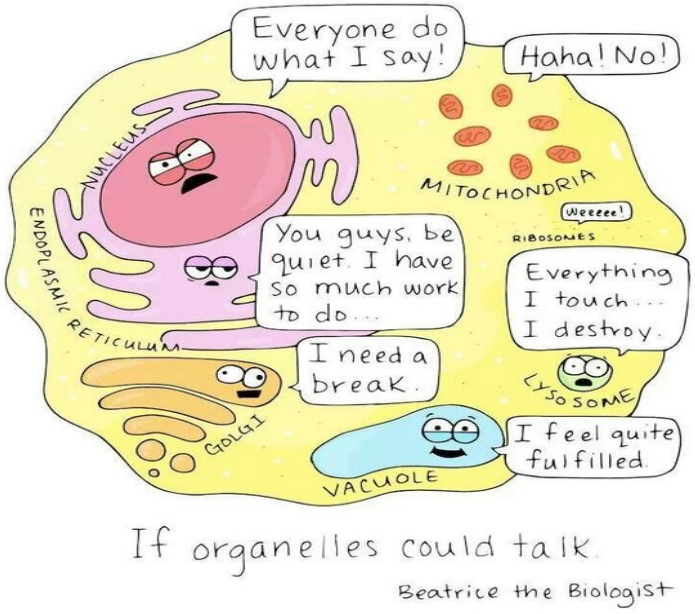


# Prokaryotic vs. Eukaryotic Cells

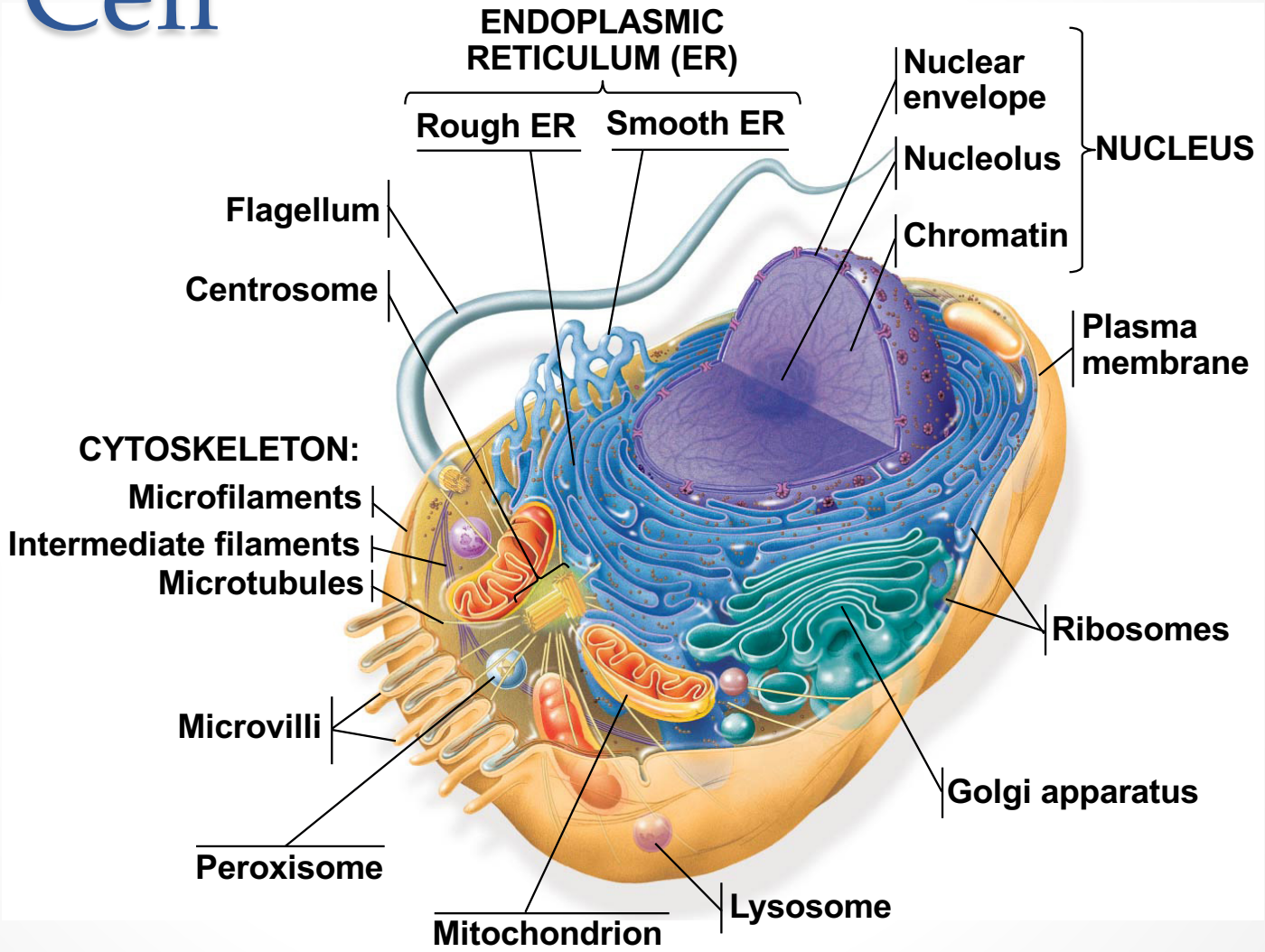
- **Prokaryotic cells原核细胞:** Bacteria
  - No nucleus
  - DNA in an unbound region called the nucleoid 类核
  - No membrane-bound organelles
  - Small (0.1-5um)

- **Eukaryotic cells真核细胞:** fungi, animals, and plants
  - DNA in a nucleus bounded by nuclear envelope
  - Membrane-bound organelles 膜结合细胞器
  - Larger than prokaryotic cells (10-100um)



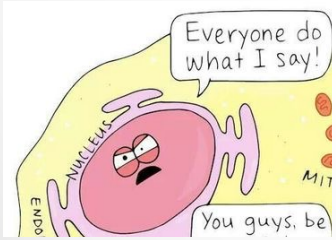



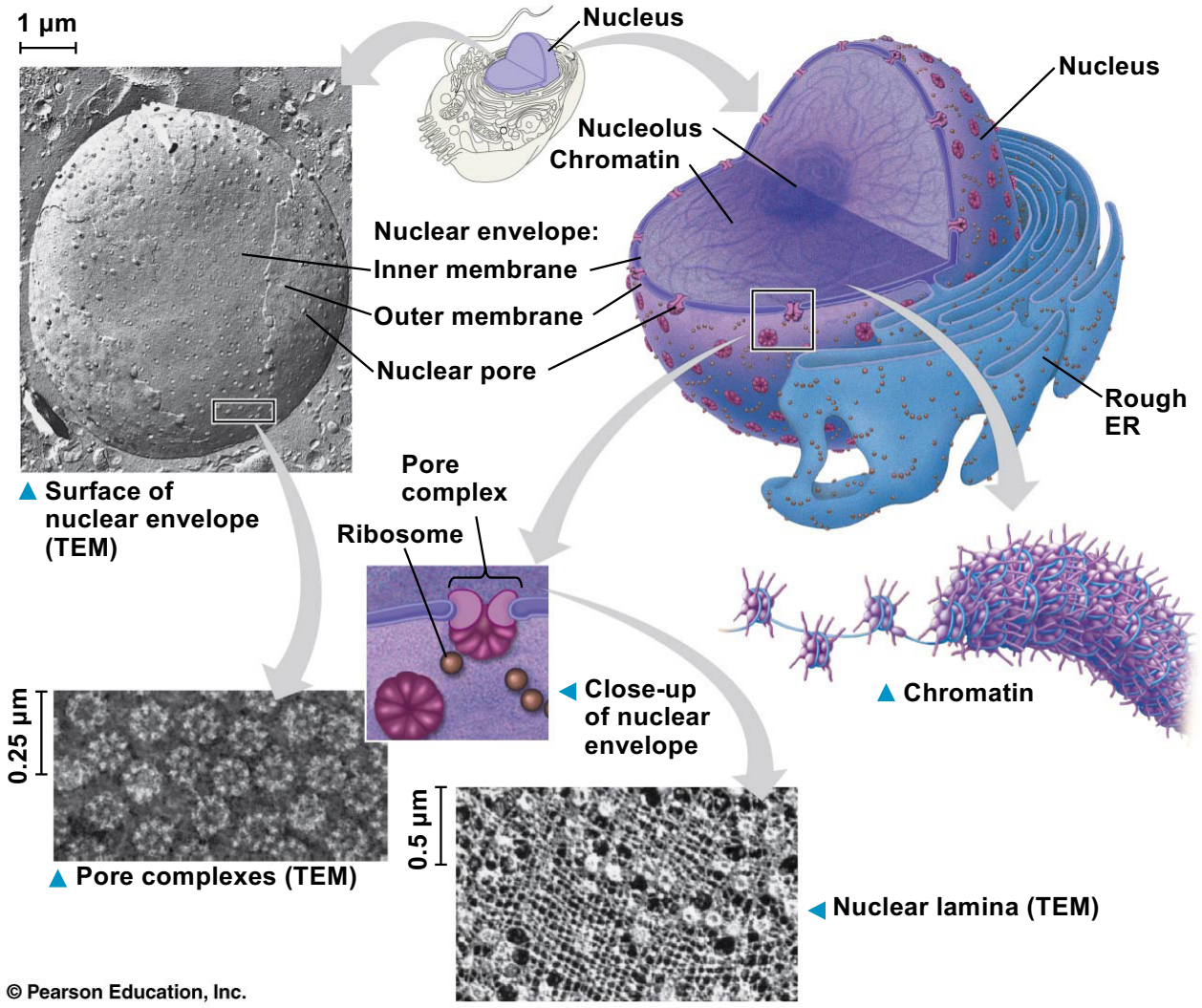
# Animal Cell


ENDOPLASMIC RETICULUM (ER)
Rough ER
Smooth ER
Nuclear envelope
Nucleolus
Chromatin
NUCLEUS
Flagellum
Centrosome
Plasma membrane
CYTOSKELETON:
Microfilaments
Intermediate filaments
Microtubules
Ribosomes
Microvilli
Golgi apparatus
Peroxisome
Lysosome
Mitochondrion

# Nucleus 细胞核

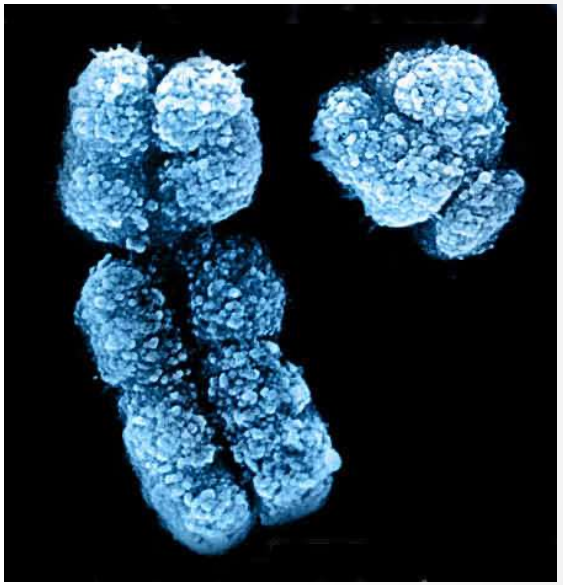
- The **nucleus** contains **most of** the cell’s DNA and genes
- The **nuclear envelope** separates it from the cytoplasm
- The nuclear membrane is a **double membrane**: 2 lipid bilayers
- **Pores** regulate the entry and exit of molecules from the nucleus



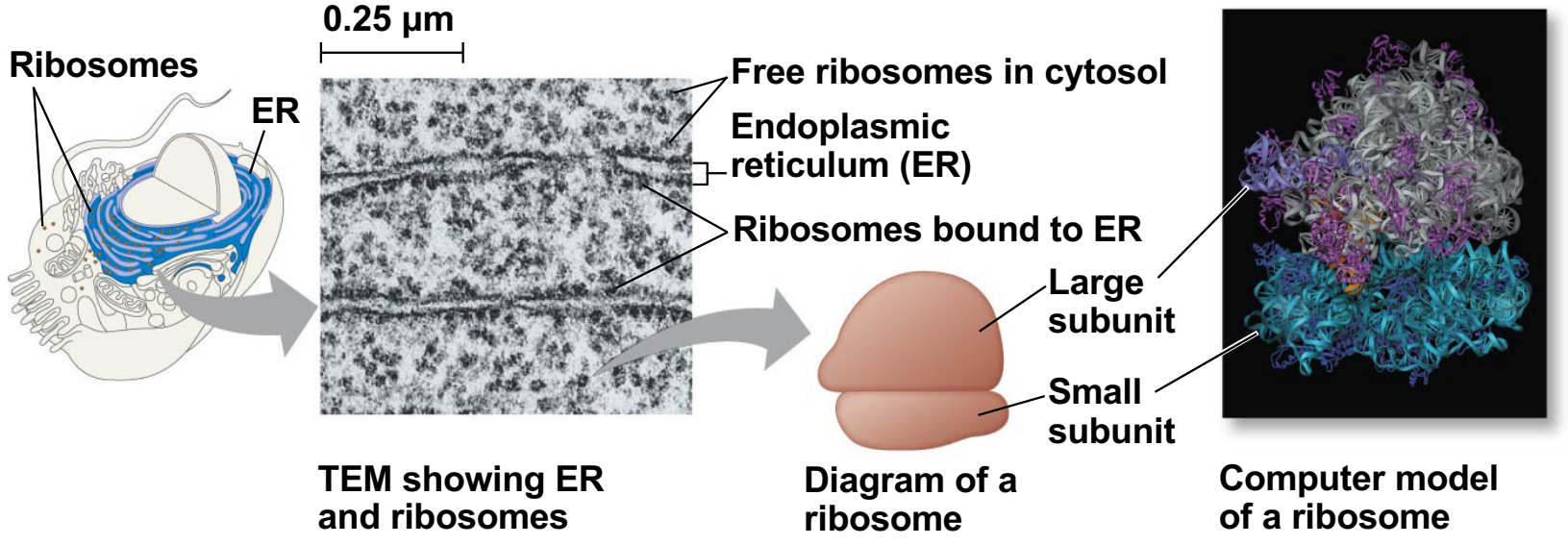
# Nucleus and chromosomes 染色体

- In the nucleus, DNA is organized into discrete units called **chromosomes**
- Each chromosome is composed of **a single DNA molecule** associated with proteins
- The DNA and proteins of chromosomes are together called **chromatin** 染色质
- The **nucleolus** 核仁 is located within the nucleus, and is the site of ribosomal RNA (**rRNA** 核糖体**RNA**) synthesis



# Ribosomes 核糖体: Protein Factories

- **Ribosomes** are made of ribosomal RNA and protein
- Ribosomes carry out **protein synthesis** in two locations
  - In the cytosol **(free ribosomes)**
  - On the outside of the endoplasmic reticulum or the nuclear envelope **(bound ribosomes)**



# The endomembrane system

- Regulates **protein traffic** 蛋白质运输 and performs **metabolic** 代谢 functions in the cell

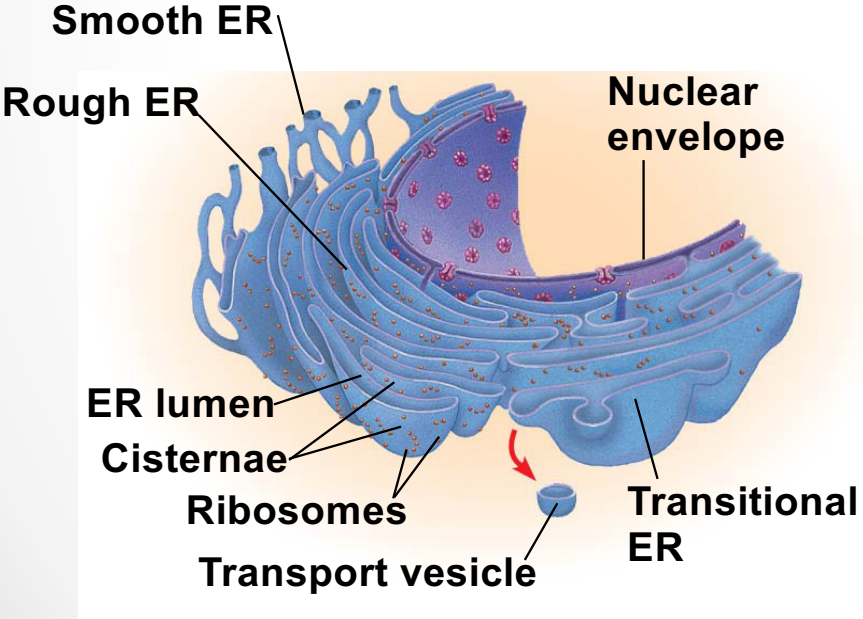
- The **endomembrane system**内膜系统
  - Nuclear envelope 核膜
  - Endoplasmic reticulum (ER) 内质网
  - Golgi apparatus 高尔基体
  - Lysosomes 溶酶体
  - Plasma membrane 细胞膜

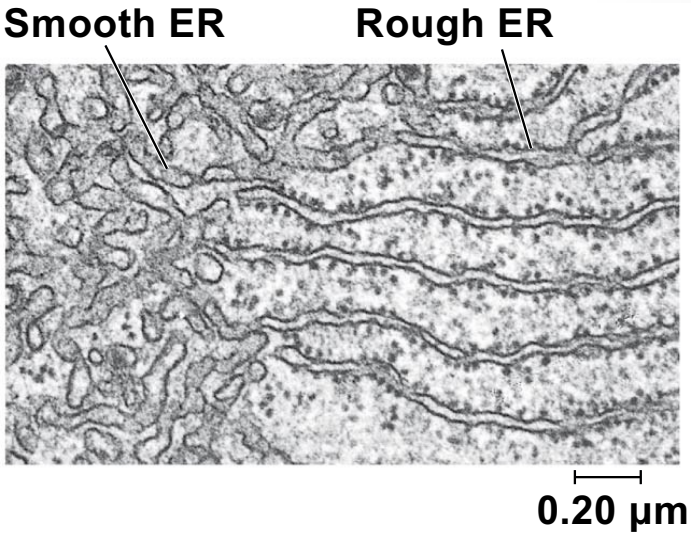
- These components are either **continuous** or connected via transfer by **vesicles** 囊泡

# Endoplasmic Reticulum:

## Biosynthetic Factory

- The **endoplasmic reticulum (ER)内质网** accounts for more than half of the total membrane in many eukaryotic cells
- The ER membrane is **continuous with the nuclear envelope**
- Two distinct regions of ER：**Smooth ER光面内质网** & **Rough ER粗面内质网**



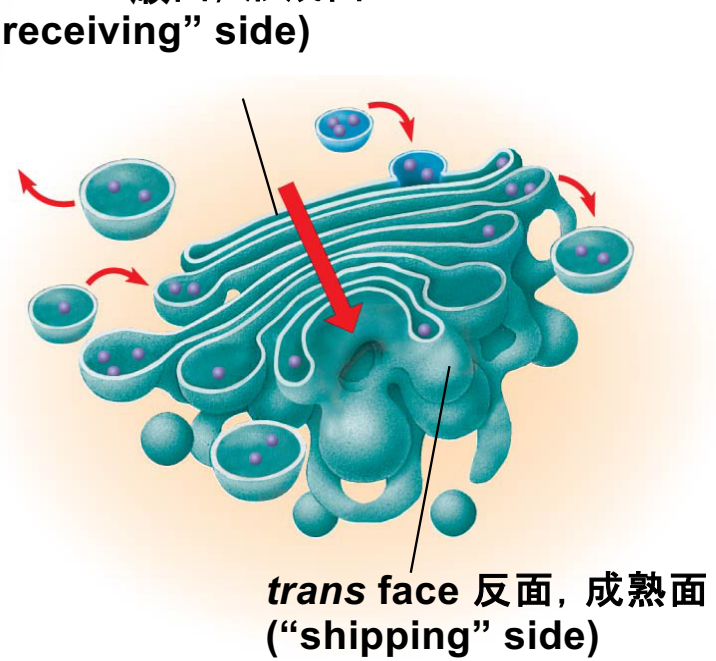
# Functions of smooth ER and rough ER

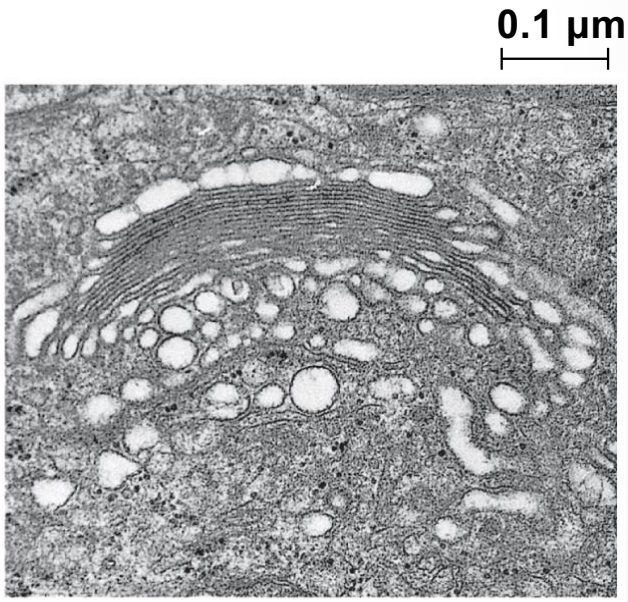
- The smooth ER
  - Synthesizes **lipids** 脂类
  - Metabolizes carbohydrates
  - **Detoxifies** 解毒 drugs and poisons (liver cell)
  - Stores calcium ions

- The rough ER
  - With **ribosomes**, which secrete **glycoproteins** 糖蛋白
  - Distributes **transport vesicles转运囊泡**, secretory proteins surrounded by membranes
  - **Membrane factory** for the cell: make phospholipids 磷脂.

# The Golgi Apparatus 高尔基体

- Shipping and Receiving Center 收发中心
  - Modifies products of the ER
  - Manufactures macromolecules
  - Sorts and packages materials into transport vesicles

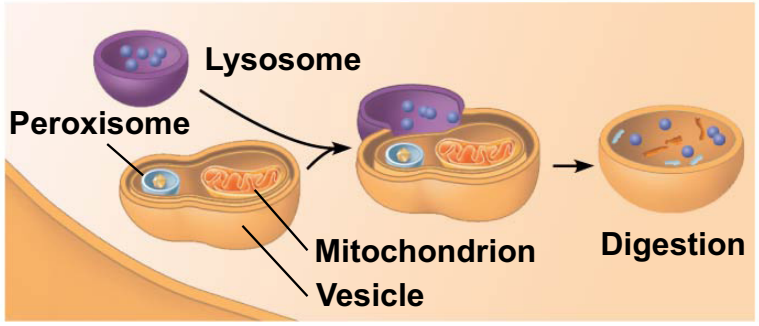


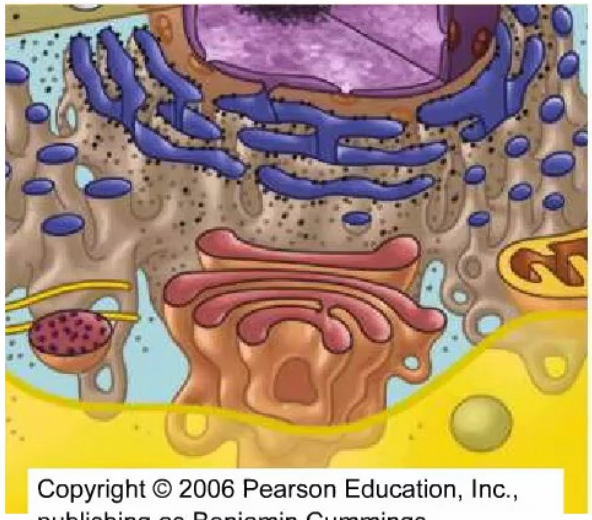

TEM of Golgi apparatus

# Lysosomes 溶酶体: Digestive Compartments

- A **lysosome** contains **hydrolytic enzymes** 水解酶 that can digest macromolecules
- The enzymes work best in the **acidic** environment inside the lysosome
- Lysosomes also use enzymes to **recycle** the cell’s own organelles and macromolecules

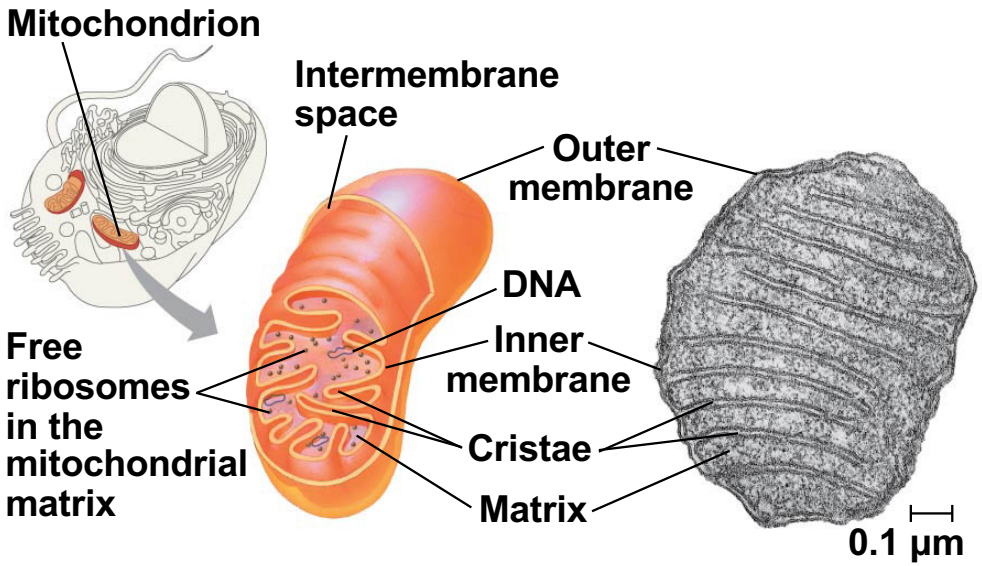




**Autophagy: lysosome breaking down damaged organelles**

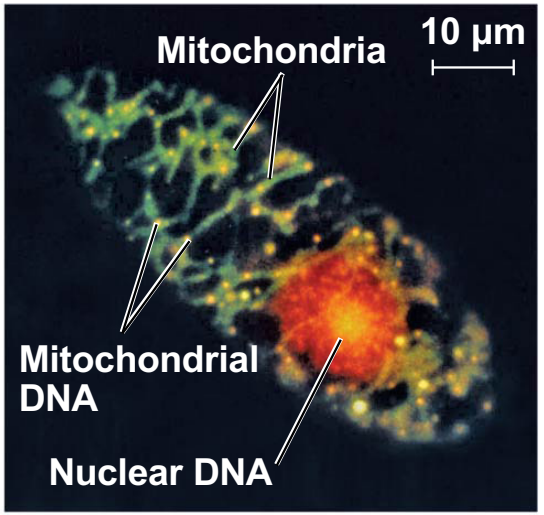


# Mitochondria 线粒体

- Mitochondria are in nearly all eukaryotic cells
- They have a smooth outer membrane and an inner membrane folded into **cristae** 嵴
- Cristae present a large surface area for enzymes that synthesize **ATP**



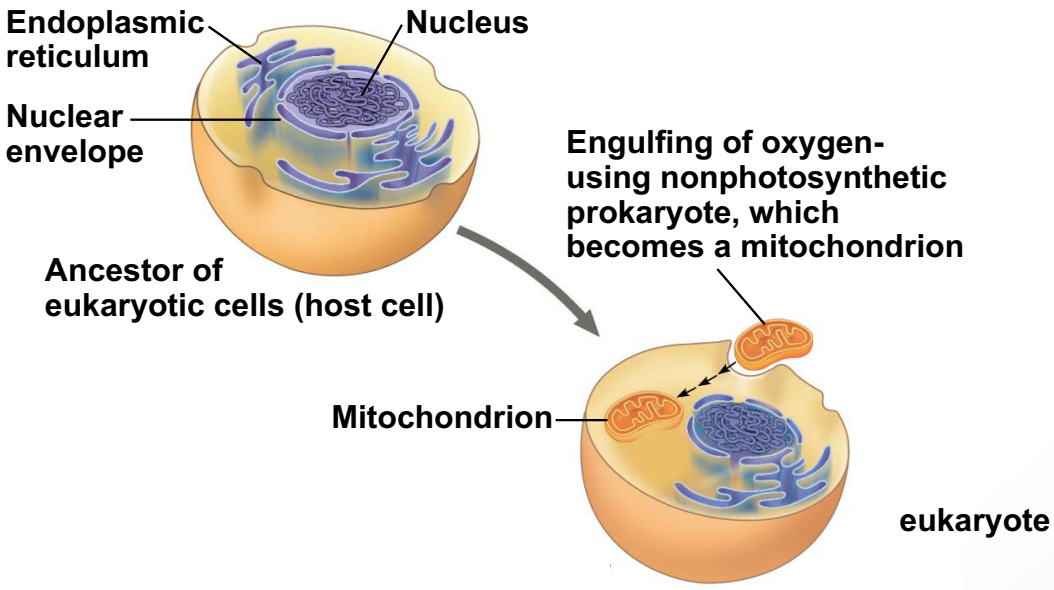

(a) Diagram and TEM of mitochondrion




(b) Network of mitochondria in *Euglena* (LM)

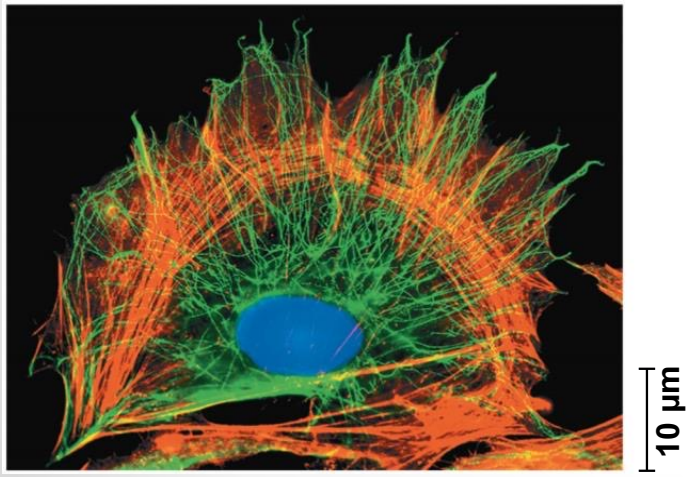
# The Evolutionary Origin of Mitochondria

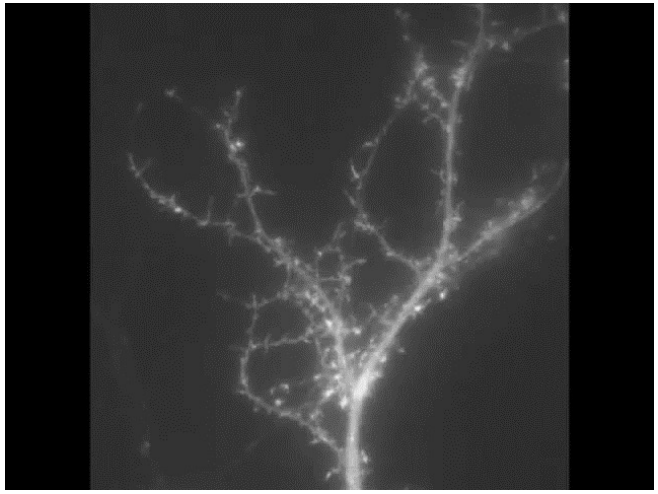
- Mitochondria: similarities with **bacteria** 细菌
  - Enveloped by a **double membrane**
  - Contain **free ribosomes** and **circular DNA** molecules
  - Grow and reproduce somewhat independently in cells
- **Endosymbiont theory** 内共生学说 suggests that an early ancestor of eukaryotes engulfed an oxygen-using prokaryotic cell



# The cytoskeleton 细胞骨架

- The **cytoskeleton** organizes the cell's structures and activities, anchoring many organelles
- It is composed of 3 types of molecular structures
  - **Microtubules** 微管 are the thickest of the three components of the cytoskeleton
  - **Microfilaments** 微丝, also called **actin** filaments, are the thinnest components
  - **Intermediate filaments**中间丝 are fibers with diameters in a middle range



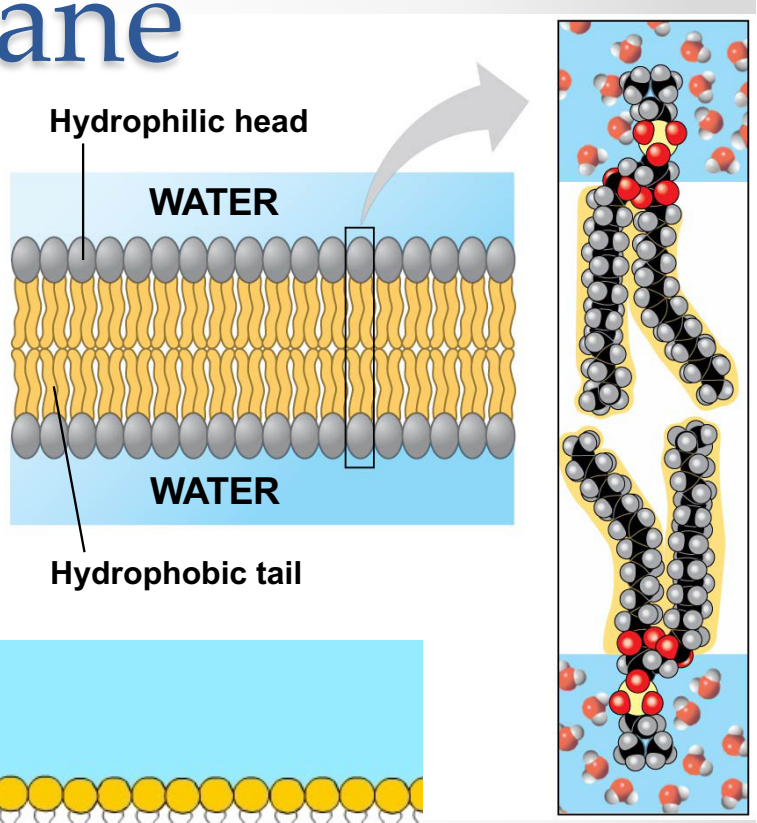



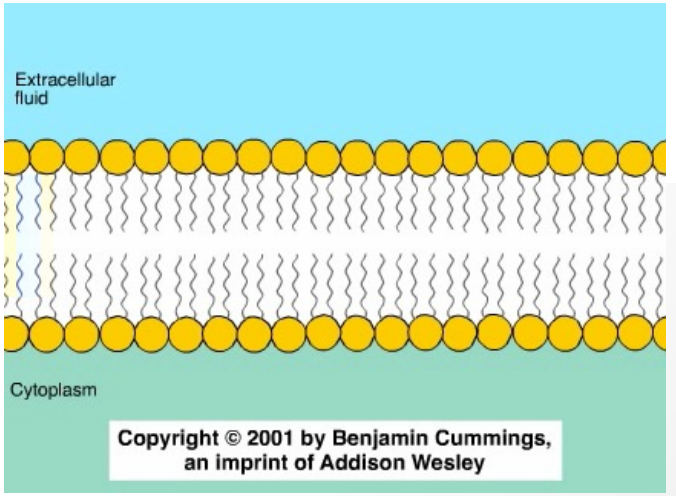
Actin Visualization in Dendrites

Movement of Organelles

# Cellular membrane

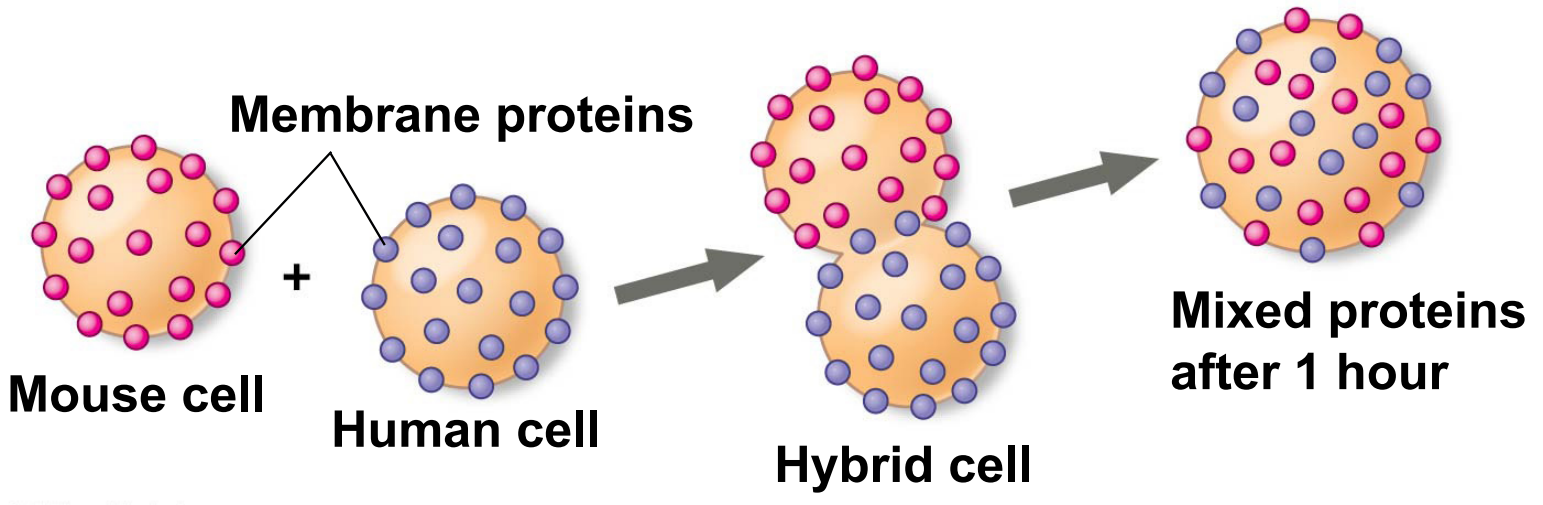
- **Phospholipids磷脂** are the most abundant lipid in the plasma membrane
- Phospholipids contain **hydrophobic** 疏水 and **hydrophilic** 亲水 regions
- The **fluid mosaic model 流动镶嵌模型** states that a membrane is a fluid structure with a “mosaic” of various proteins embedded in it
- **Proteins** are embedded in the membrane



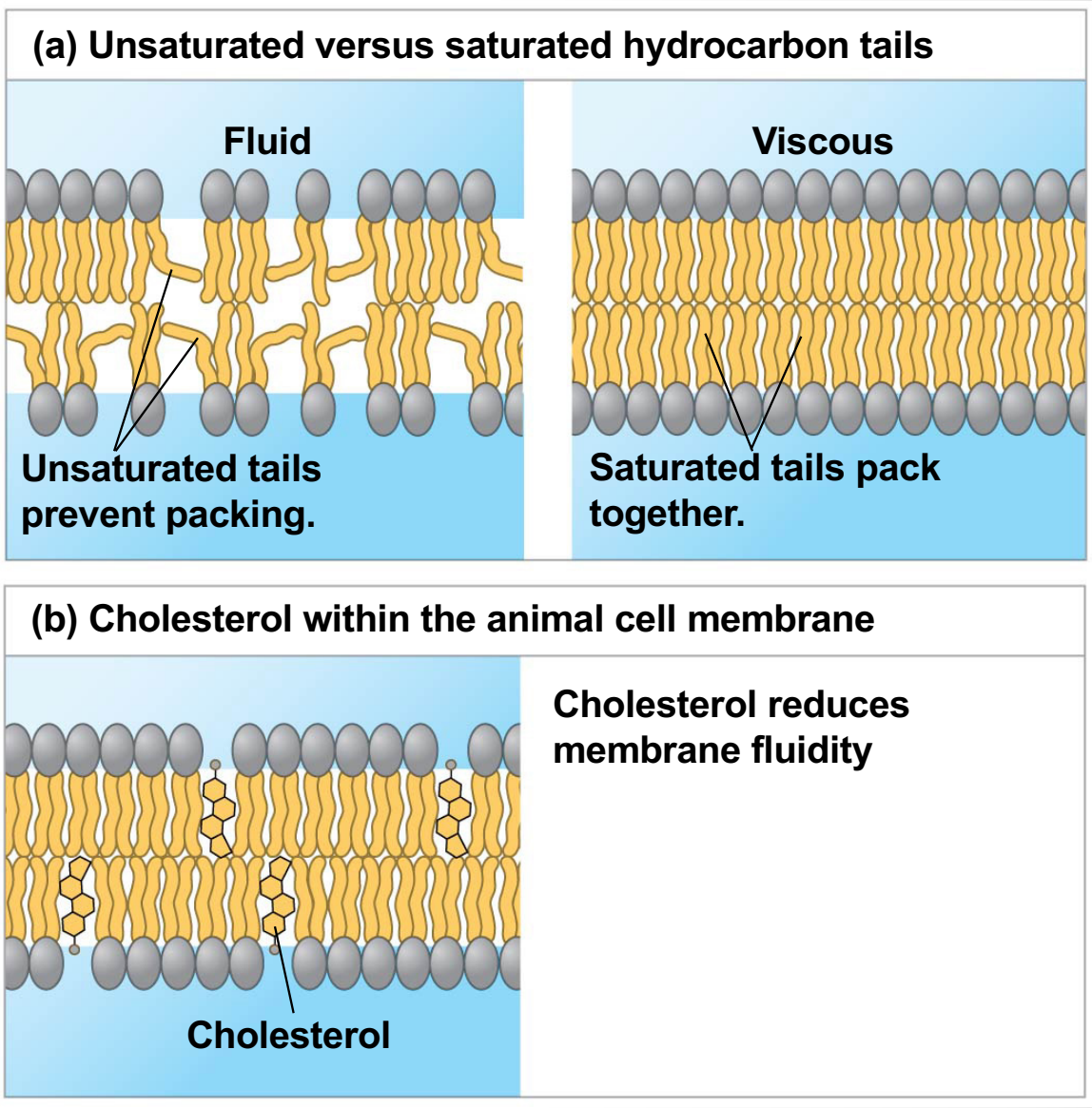



# The Fluidity of Membranes 流动性

- Phospholipids in the plasma membrane can move within the bilayer
- Most of the lipids, and some proteins, drift laterally 侧向移动

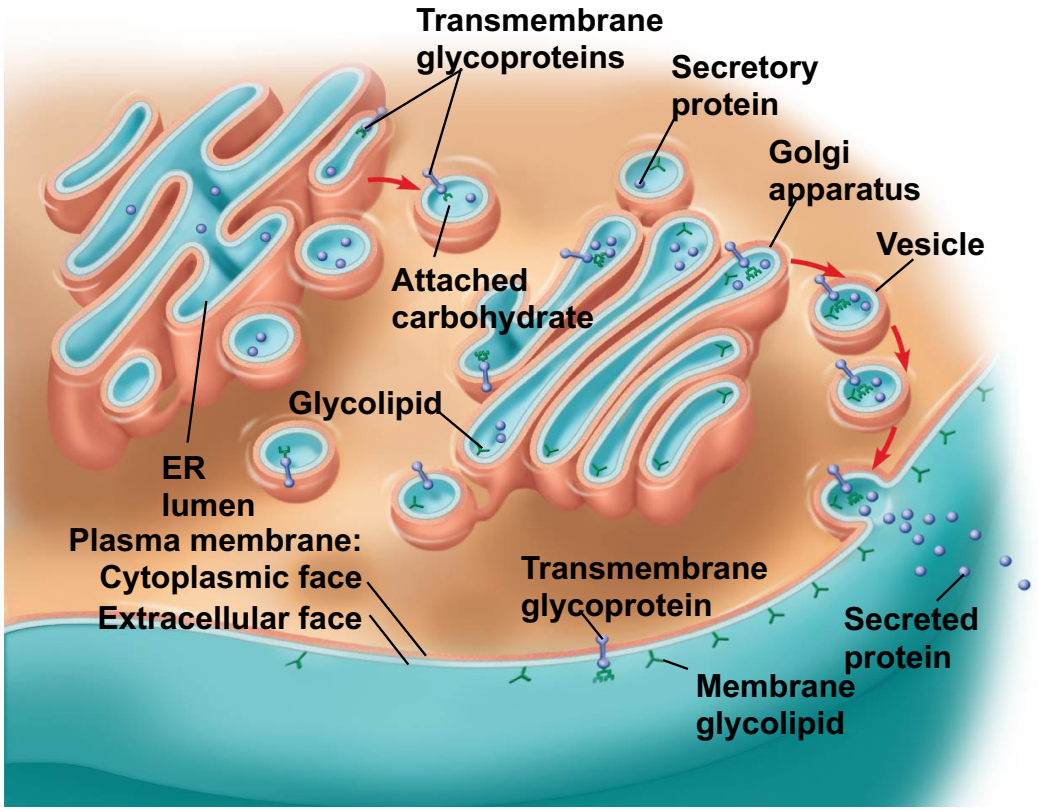


- Membranes rich in **unsaturated fatty acids** 不饱和脂肪酸 are more fluid than those rich in saturated fatty acids
- **Cholesterol**胆固醇 reduces membrane fluidity



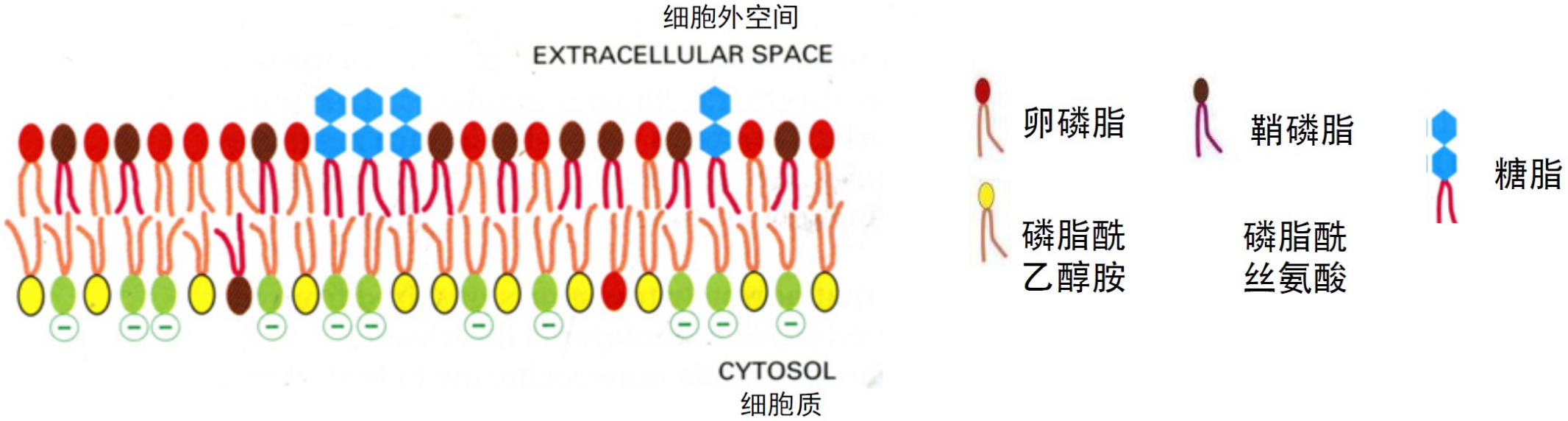
# Sidedness of Membranes 方向性

- Membranes have distinct inside and outside faces: **asymmetrical** 不对称 distribution of proteins, lipids, and associated carbohydrates



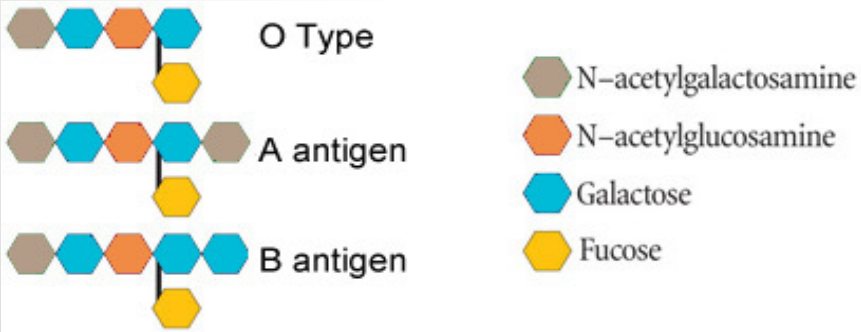
# Membrane Asymmetry 不对称性

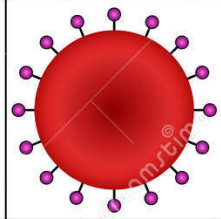
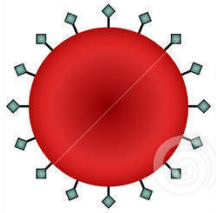
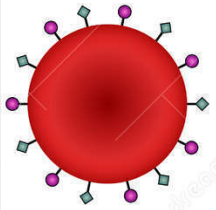
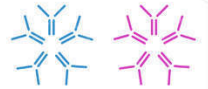
- **Asymmetry** of **Red blood cell 红细胞** membrane



# ABO blood type

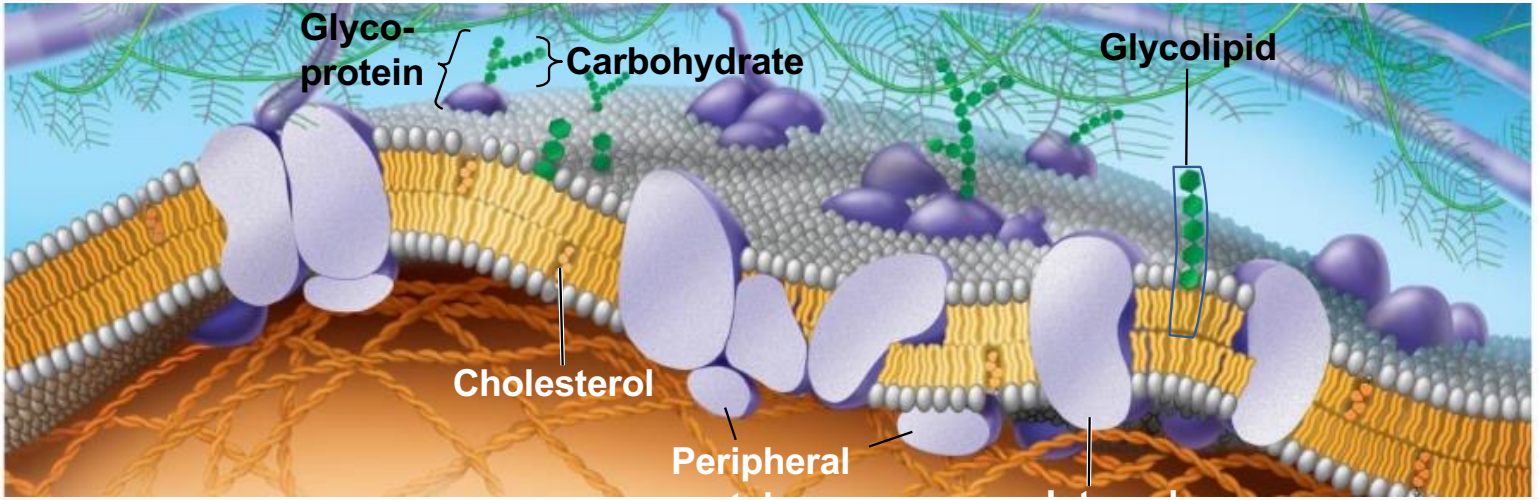
- Human blood types **A**, **B**, **AB**, and **O** reflect variation in the carbohydrate of **glycoproteins** 糖蛋白 and **glycolipids**糖脂 on **red blood cell membrane**




| Group | A | B | AB | O |
|---|---|---|---|---|
| Red Blood Cell Type |  |  |  |  |
| Antigens Present |  Antigen A |  Antigen B |  Antigen A & B | None |
| Antibodies Present |  Anti-B |  Anti-A | None |  Anti-A & Anti-B |

# Membrane Proteins

- Proteins determine most of the membrane’s specific functions
- **Peripheral proteins** 膜周边蛋白 are bound to the surface of the membrane
- **Integral proteins** 膜内在蛋白 penetrate the hydrophobic core (**transmembrane proteins** 跨膜蛋白)



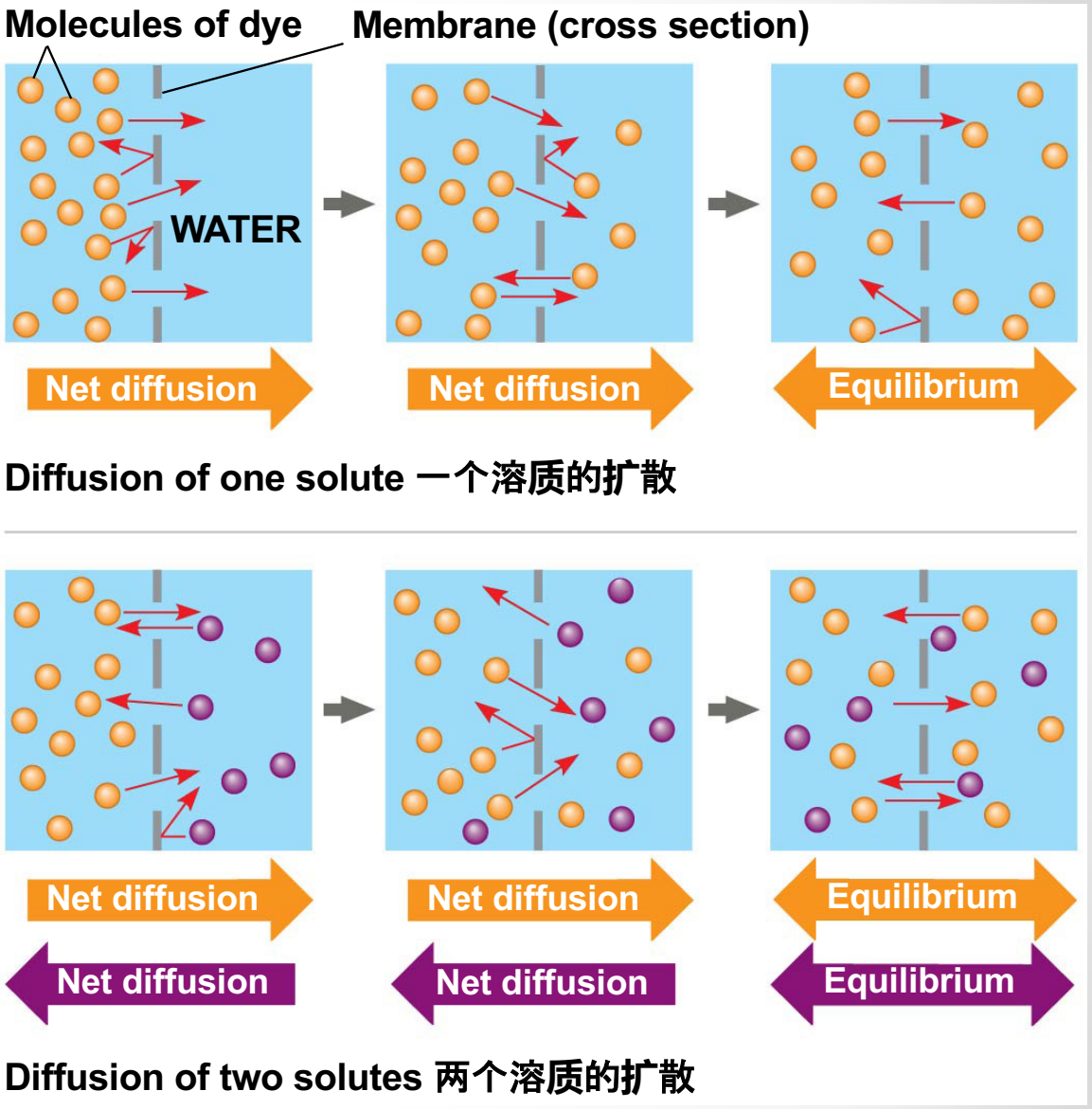
# Selective permeability

- A cell must exchange materials with its surroundings
- Plasma membranes are **selectively permeable选择性通透**
- **Hydrophobic** 疏水 molecules can dissolve in the lipid bilayer and pass through the membrane rapidly ($CO_2$, $O_2$)
- **Hydrophilic** 亲水 molecules and **polar** 极性 molecules **do not** cross the membrane easily ($H_2O$, ions)
- **Transport proteins** allow passage of hydrophilic substances across the membrane (**channel proteins**)

# Passive transport
# 被动运输

- Diffusion of a substance across a membrane with **no energy investment**

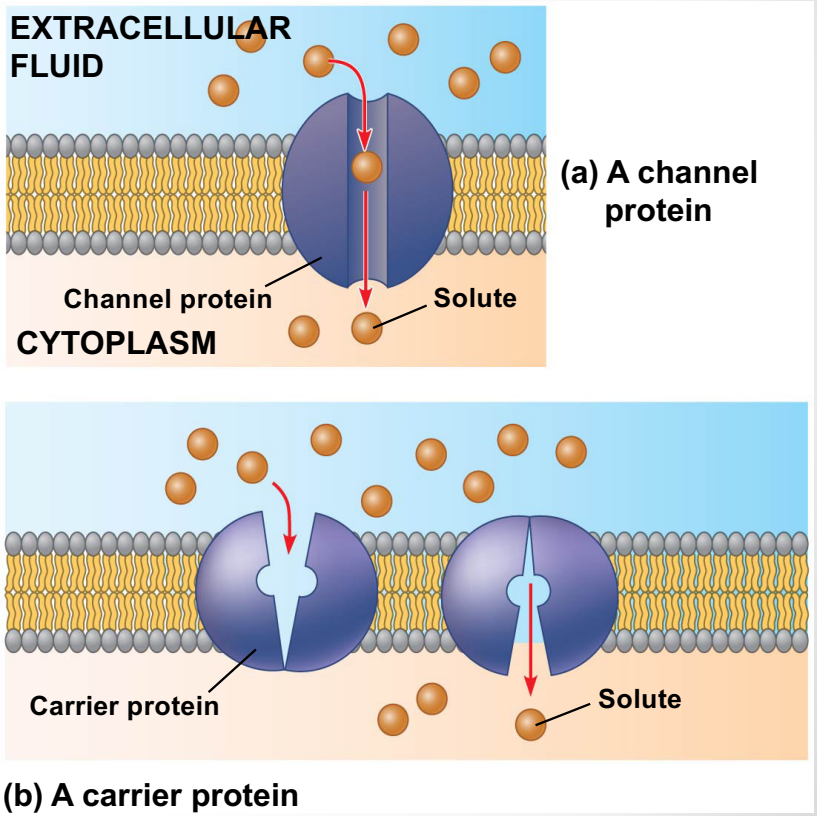
- At dynamic **equilibrium**, as many molecules cross the membrane in one direction as in the other



# Facilitated Diffusion 易化/协助扩散: Passive Transport Aided by Proteins

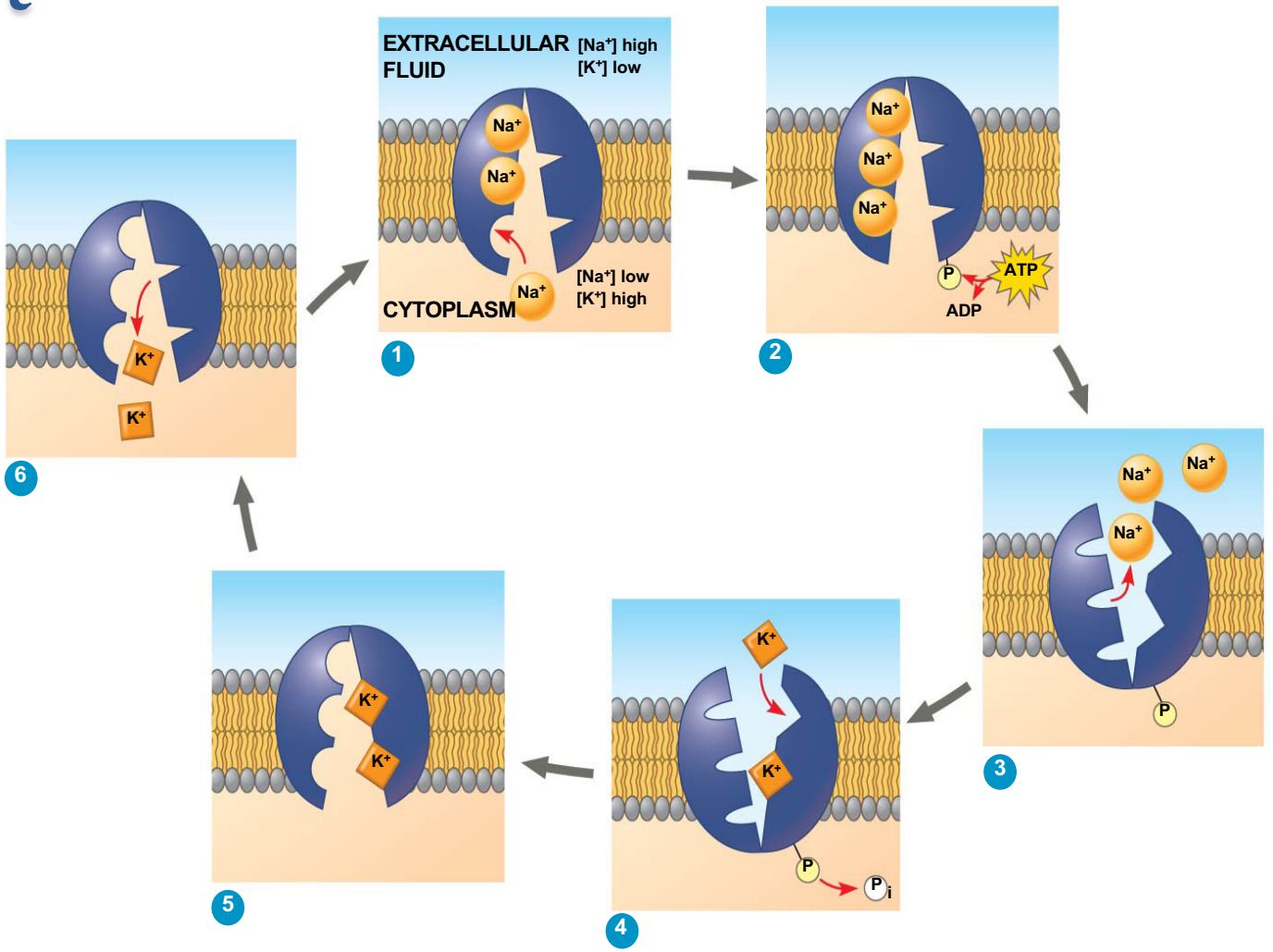
- **Channel proteins** 通道蛋白 provide corridors that allow a specific molecule or ion to cross the membrane
  - **Ion channels** facilitate the diffusion of ions
  - Some ion channels, called **gated channels**, open or close in response to a stimulus

- **Carrier proteins** 转运蛋白 undergo a subtle change in shape that translocates the solute-binding site across the membrane

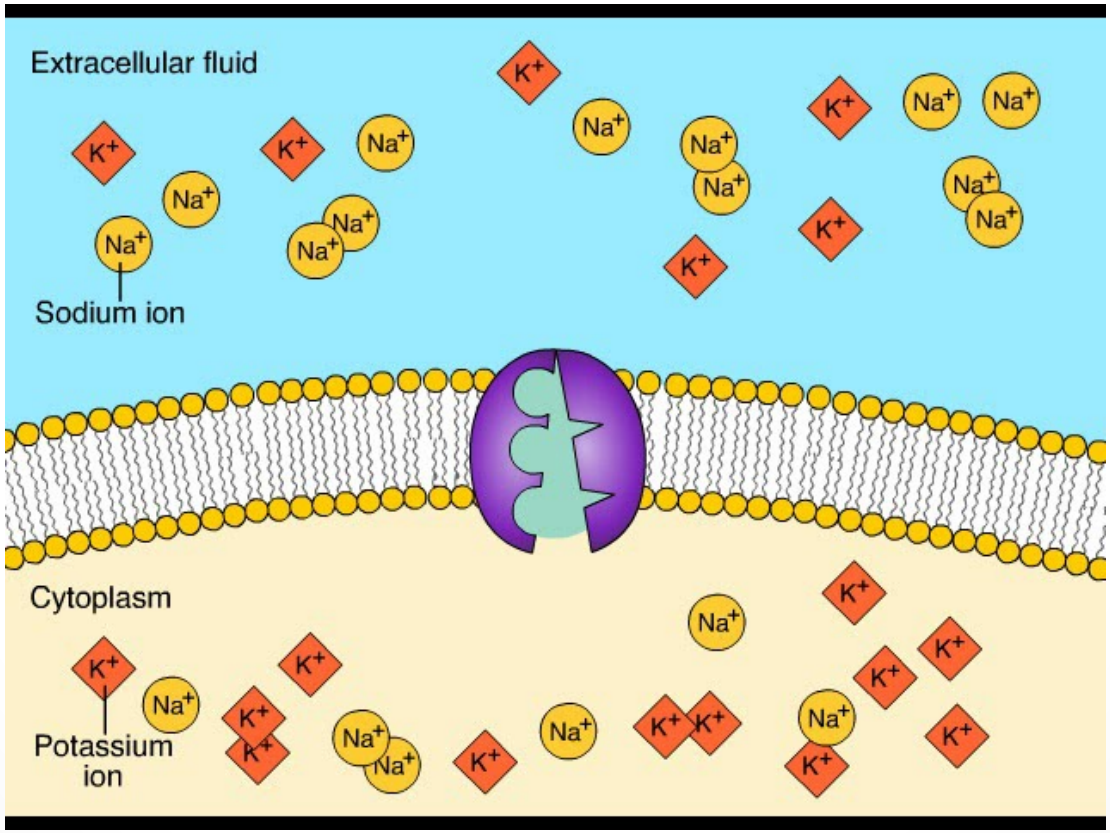


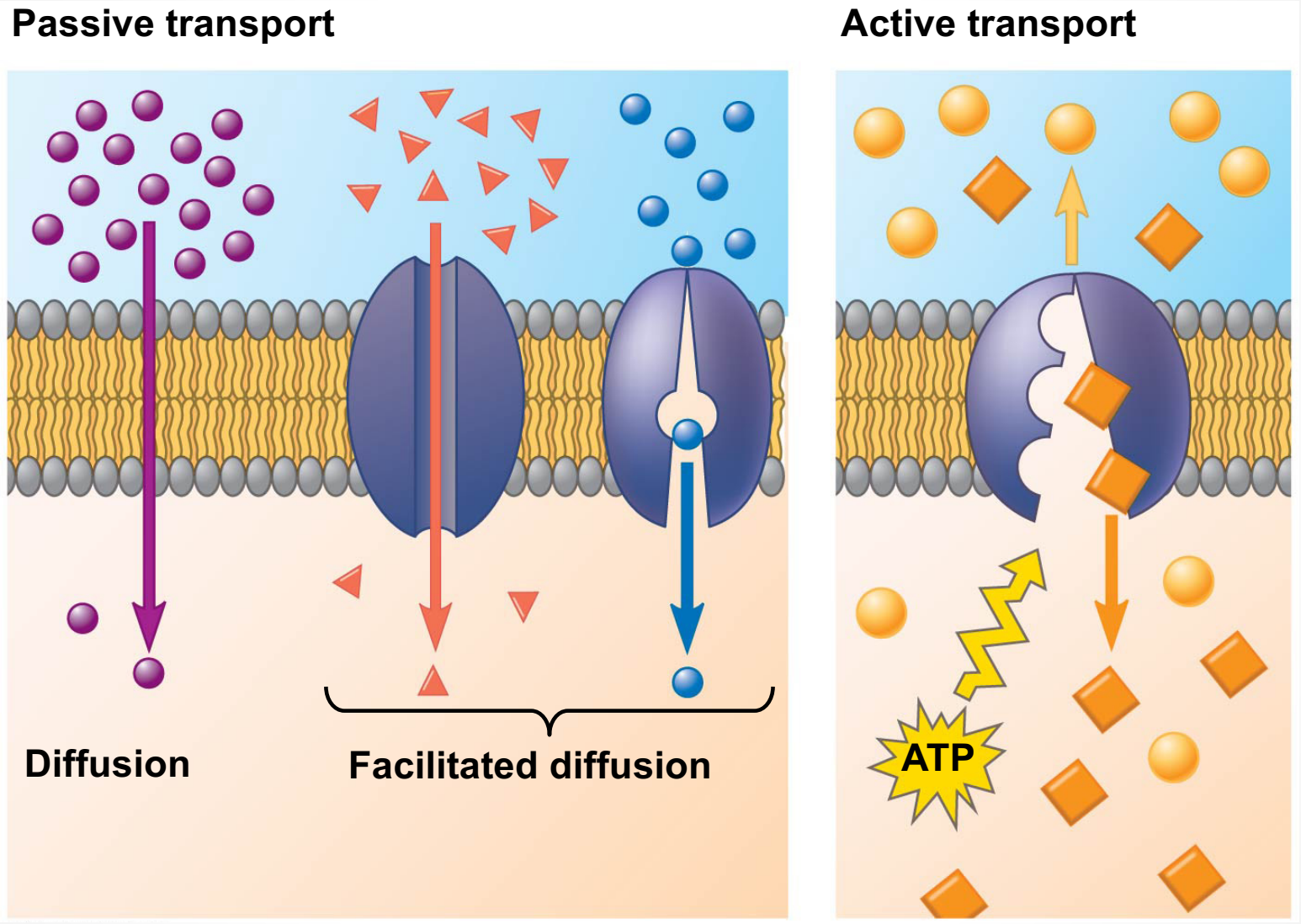
# Active transport
# 主动运输

- Uses **energy** to move solutes against their gradients
- Performed by **specific proteins** embedded in the membranes
- The **sodium-potassium pump** is one type of active transport system

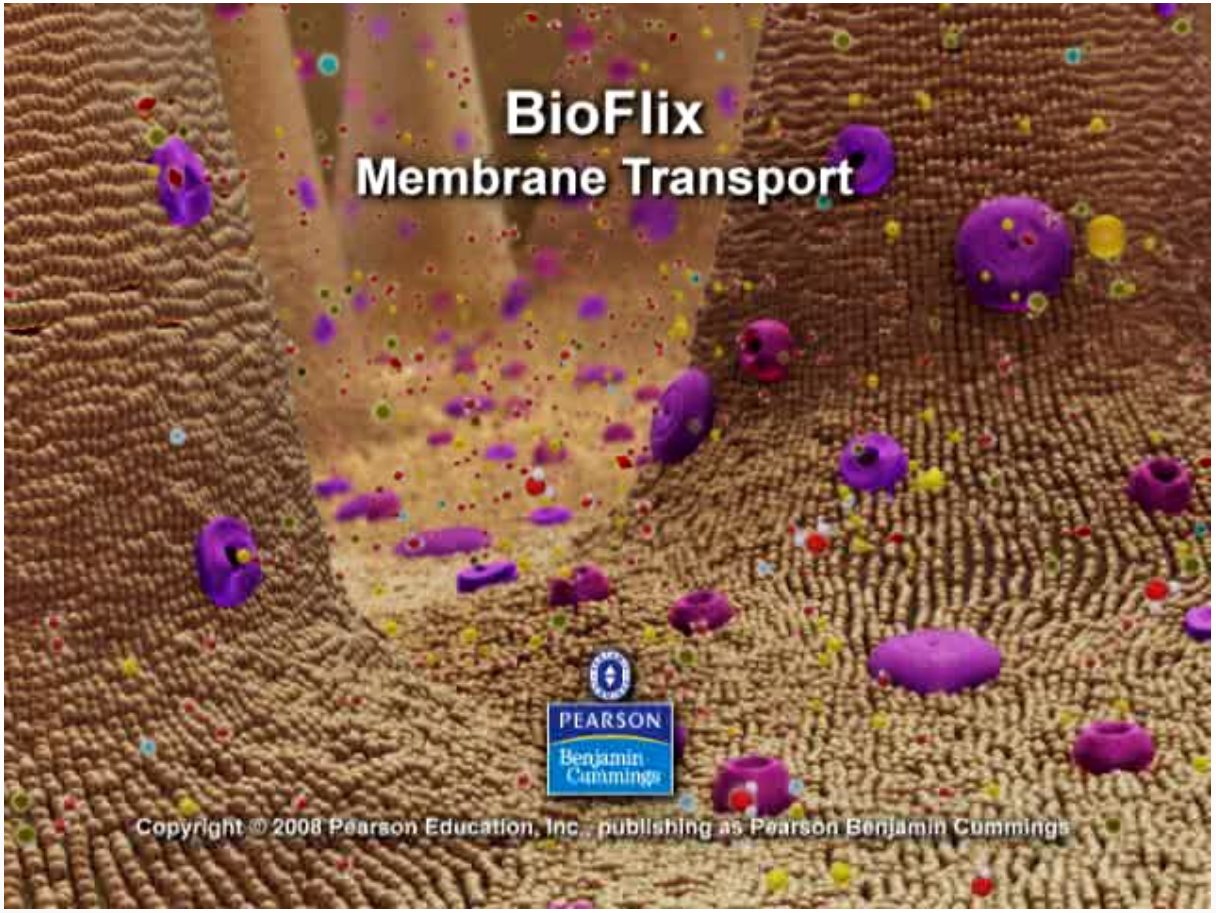


# Animation: Active Transport

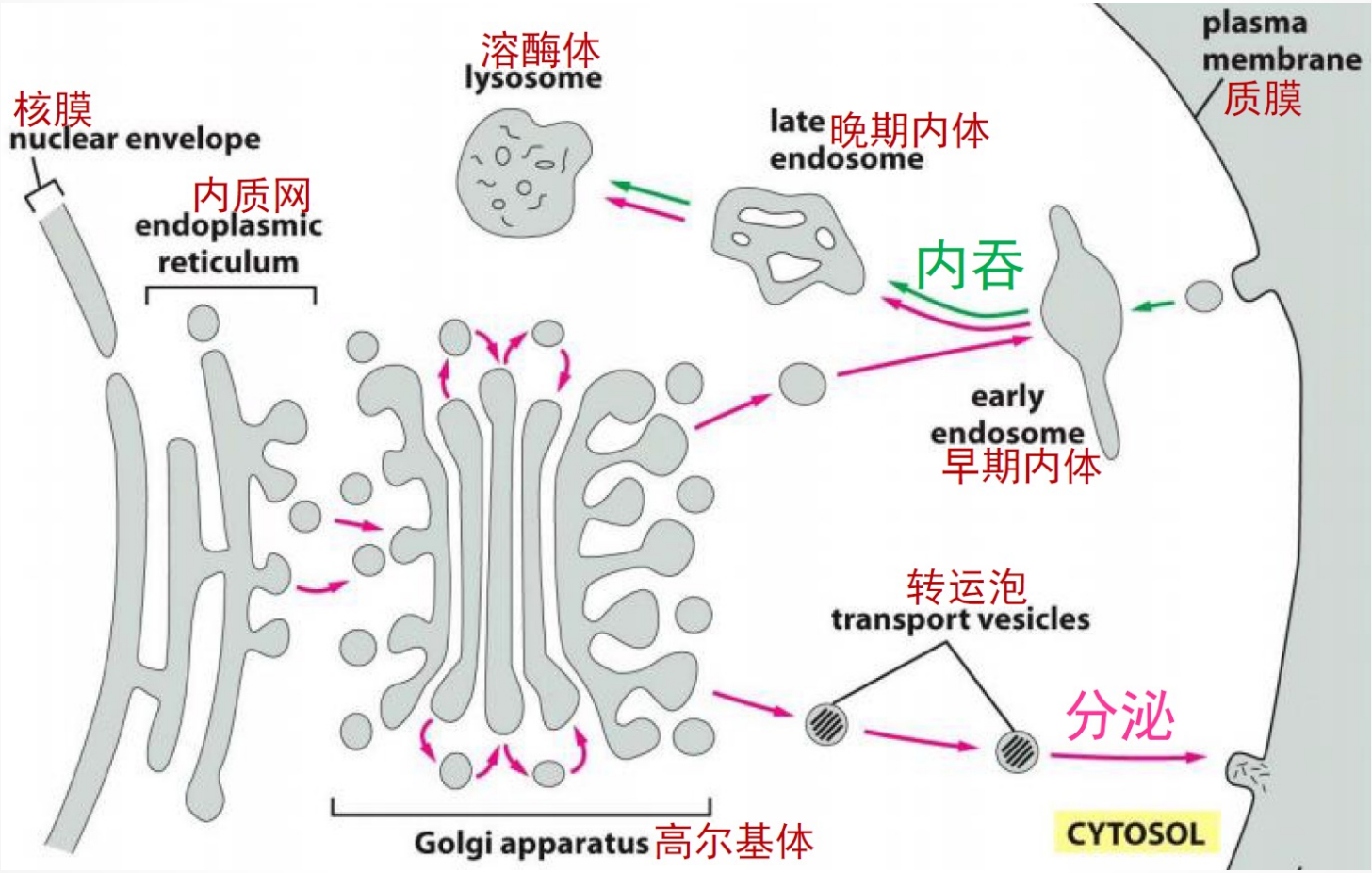



Passive transport
Active transport
Diffusion
Facilitated diffusion
ATP

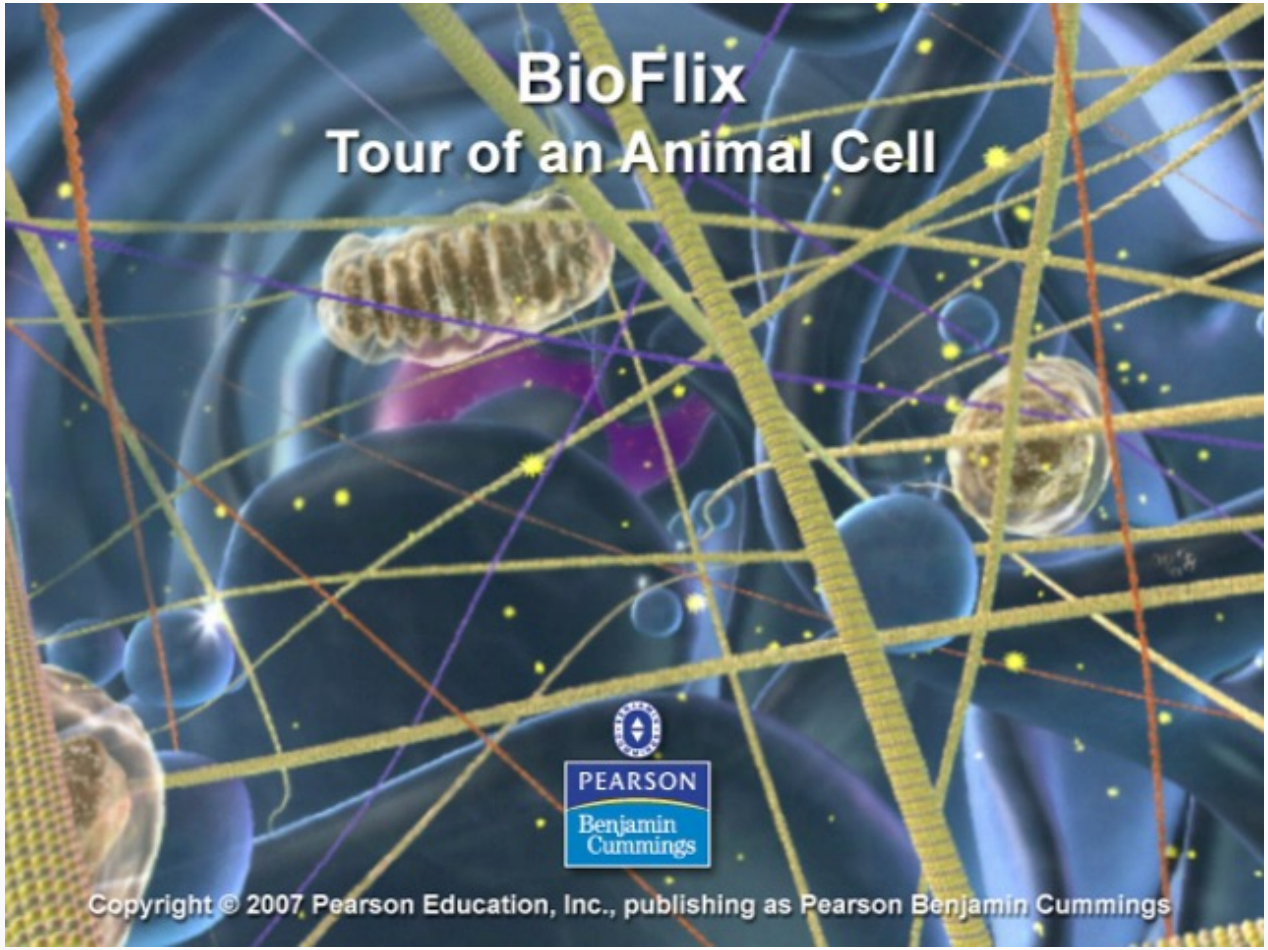
# BioFlix: Membrane Transport



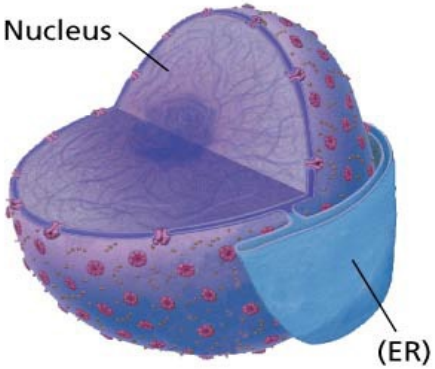
# The Endomembrane System: *A Review*

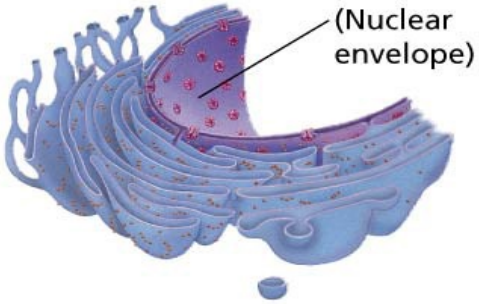
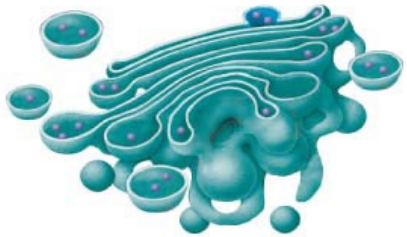


# Tour of an Animal Cell



# Summary

| | Cell Component | Structure | Function |
|---|---|---|---|
| The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes (pp. 102–104) | Nucleus  (ER) | Surrounded by nuclear envelope (double membrane) perforated by nuclear pores; nuclear envelope continuous with endoplasmic reticulum (ER) | Houses chromosomes, which are made of chromatin (DNA and proteins); contains nucleoli, where ribosomal subunits are made; pores regulate entry and exit of materials |
| | Ribosome  | Two subunits made of ribosomal RNA and proteins; can be free in cytosol or bound to ER | Protein synthesis |

| | Cell Component | Structure | Function |
|---|---|---|---|
| The endomembrane system regulates protein traffic and performs metabolic functions in the cell (pp. 104–109) | Endoplasmic reticulum   | Extensive network of membrane-bounded tubules and sacs; membrane separates lumen from cytosol; continuous with nuclear envelope | Smooth ER: synthesis of lipids, metabolism of carbohydrates, $Ca^{2+}$ storage, detoxification of drugs and poisons<br>Rough ER: aids in synthesis of secretory and other proteins from bound ribosomes; adds carbohydrates to proteins to make glycoproteins; produces new membrane |
| | Golgi apparatus  | Stacks of flattened membranous sacs; has polarity (*cis* and *trans* faces) | Modification of proteins, carbohydrates on proteins, and phospholipids; synthesis of many polysaccharides; sorting of Golgi products, which are then released in vesicles |
| | Lysosome  | Membranous sac of hydrolytic enzymes (in animal cells) | Breakdown of ingested substances, cell macromolecules, and damaged organelles for recycling |