

Chapter 2 身體的化學組成

2-1 原子離子及分子

2-2 溶液及溶質

✓ 2-3 有機分子

Chapter 3 細胞生理學

✓ 3-1 細胞的結構

✓ 3-2 基因表現及蛋白質合成

3-3 細胞週期

3-4 酵素

3-5 細胞呼吸及代謝

Chapter 4 細胞及環境的互動

✓ 4-1 細胞外環境

✓ 4-2 細胞間的溝通 (p93-95)

4-3 物質通過細胞膜的運輸方式

4-4 細胞的興奮性

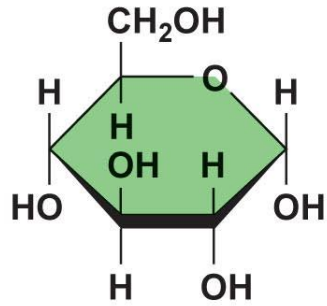
Biomolecules (Organic molecules)

- ❖ Are synthesized by living organisms and contain **carbon atoms**.
- ❖ Four major classes: *carbohydrates, lipids, proteins and nucleotides*.

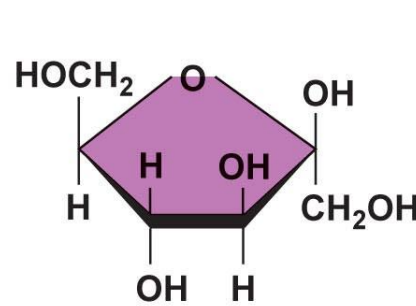
TABLE 2.1 Common Functional Groups Found in Biomolecules

Functional group	Chemical formula	Structure	Chemical property
Hydroxyl	—OH	—O—H	Polar
Sulfhydryl	—SH	—S—H	Polar
Phosphate	—HPO ₄ ⁻	$\begin{array}{c} \text{O} \\ \parallel \\ \text{—O—P—OH} \\ \\ \text{O—} \end{array}$	Polar
Carboxyl	—COOH	$\begin{array}{c} \text{O} \\ \parallel \\ \text{—C} \\ \diagdown \\ \text{OH} \end{array}$	Acid
Amino	—NH ₂	$\begin{array}{c} \text{H} \\ \diagup \\ \text{—N} \\ \diagdown \\ \text{H} \end{array}$	Base

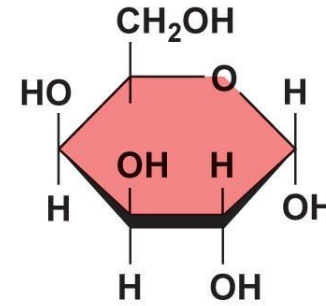
Carbohydrates: $C_n(H_2O)_n = (CH_2O)_n$



Glucose

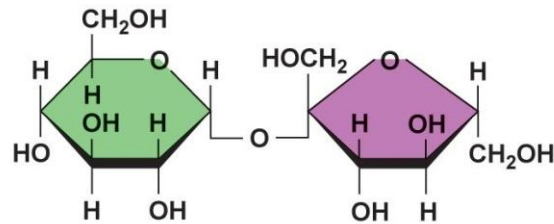


Fructose

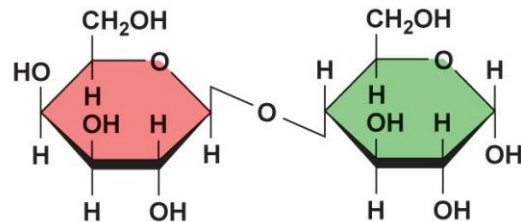


Galactose

(a) Monosaccharides



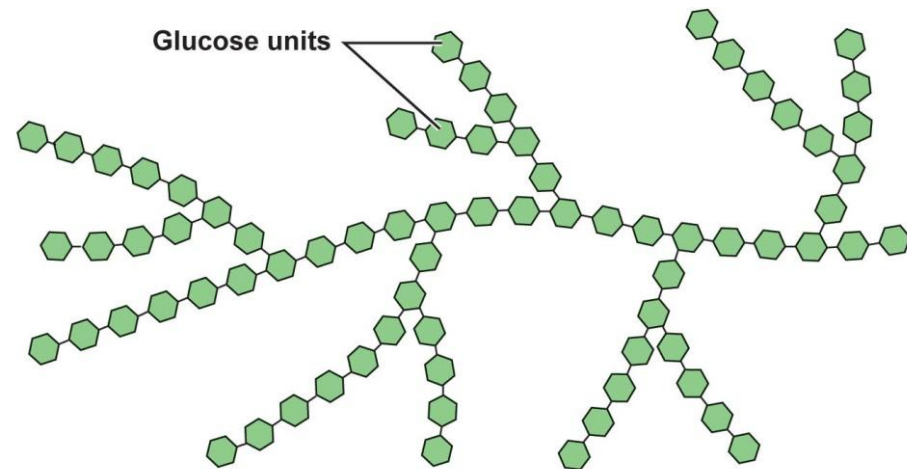
Sucrose
(Glucose + Fructose)



Lactose
(Galactose + Glucose)

(b) Disaccharides

Notice the hydroxyl groups: These make carbohydrates polar.

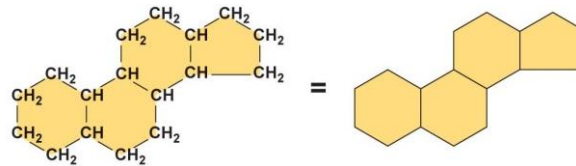
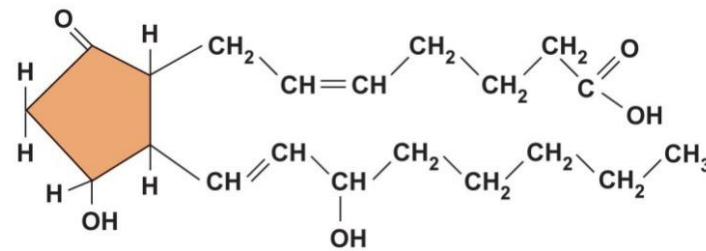
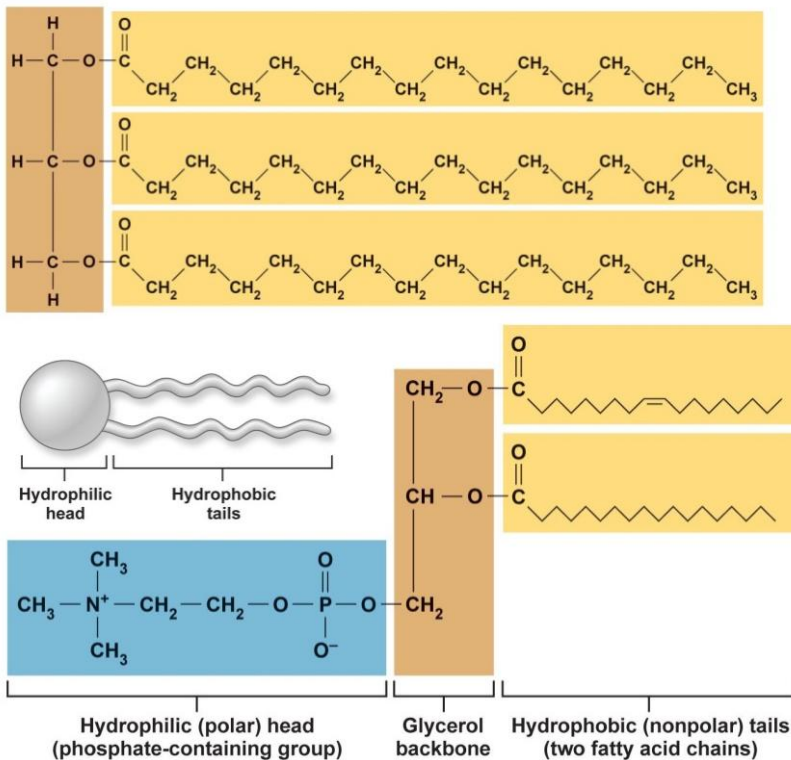


Glycogen

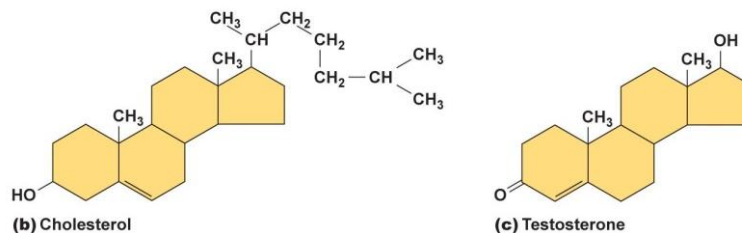
(c) Polysaccharide

Lipids

- ❖ **Nonpolar** molecules do not dissolve in water (fat & oil).
- ❖ Four main classes: *triglycerides*, *phospholipids*, *eicosanoids* and *steroids*.

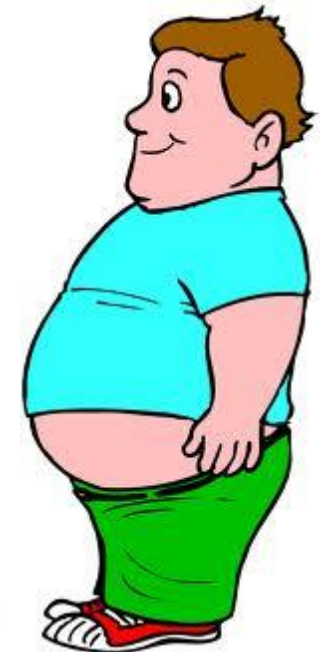


(a) Steroid ring structure



(b) Cholesterol

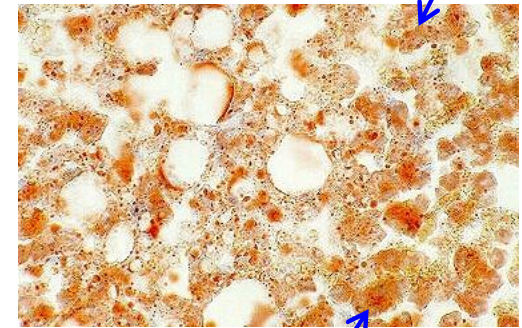
(c) Testosterone



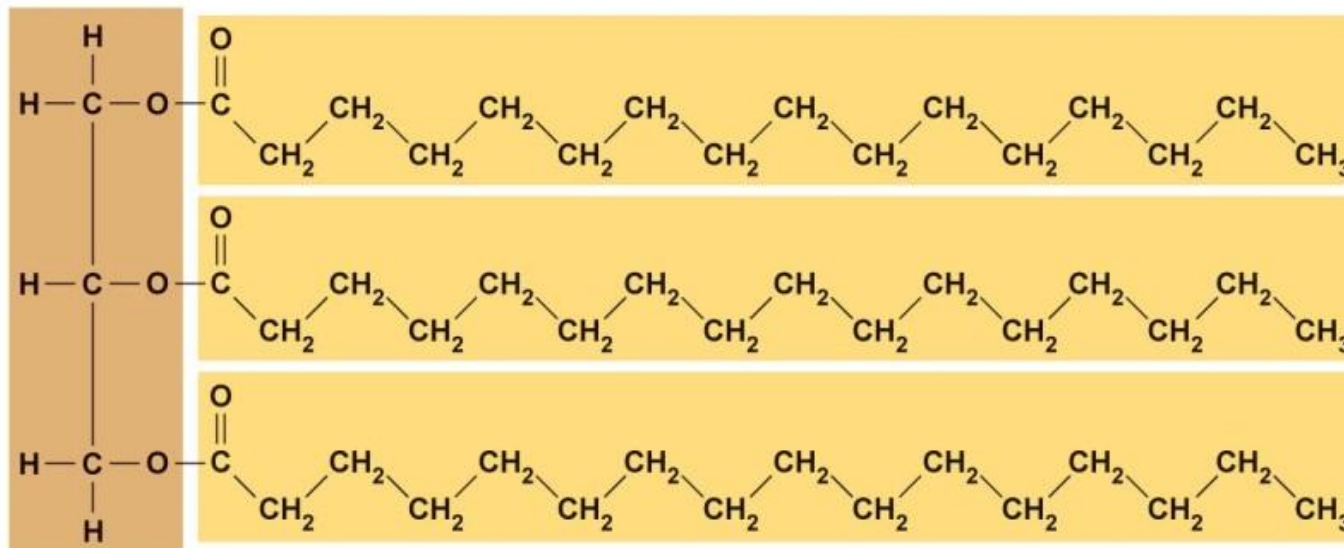
Triglycerides (Neutral fat)

Triglyceride = glycerol + 3 fatty acids

- Glycerol = 3-carbon alcohol
- Fatty acid = long carbon acid chain
 - Saturated fatty acids
 - Unsaturated fatty acids

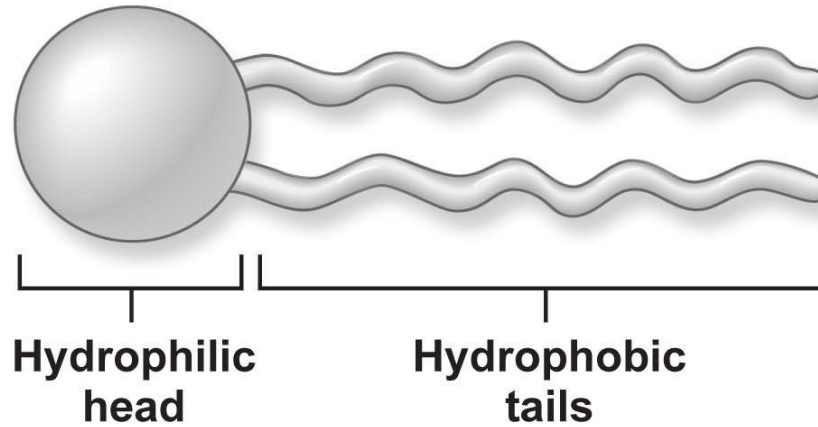


- Fatty acid chains make triglycerides hydrophobic

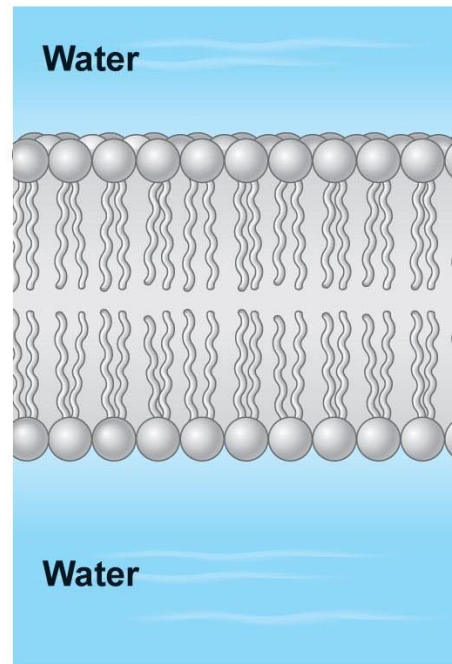


Phospholipids

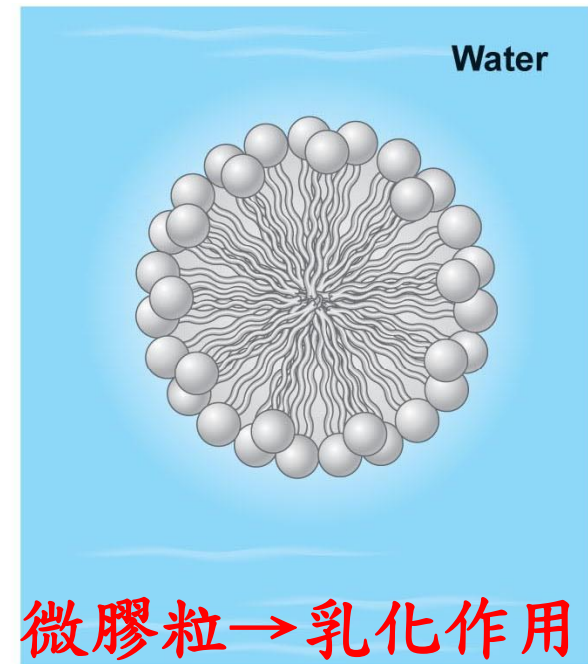
Amphipathic molecules



Structures formed by phospholipids in an aqueous environment



(a) Phospholipid bilayer

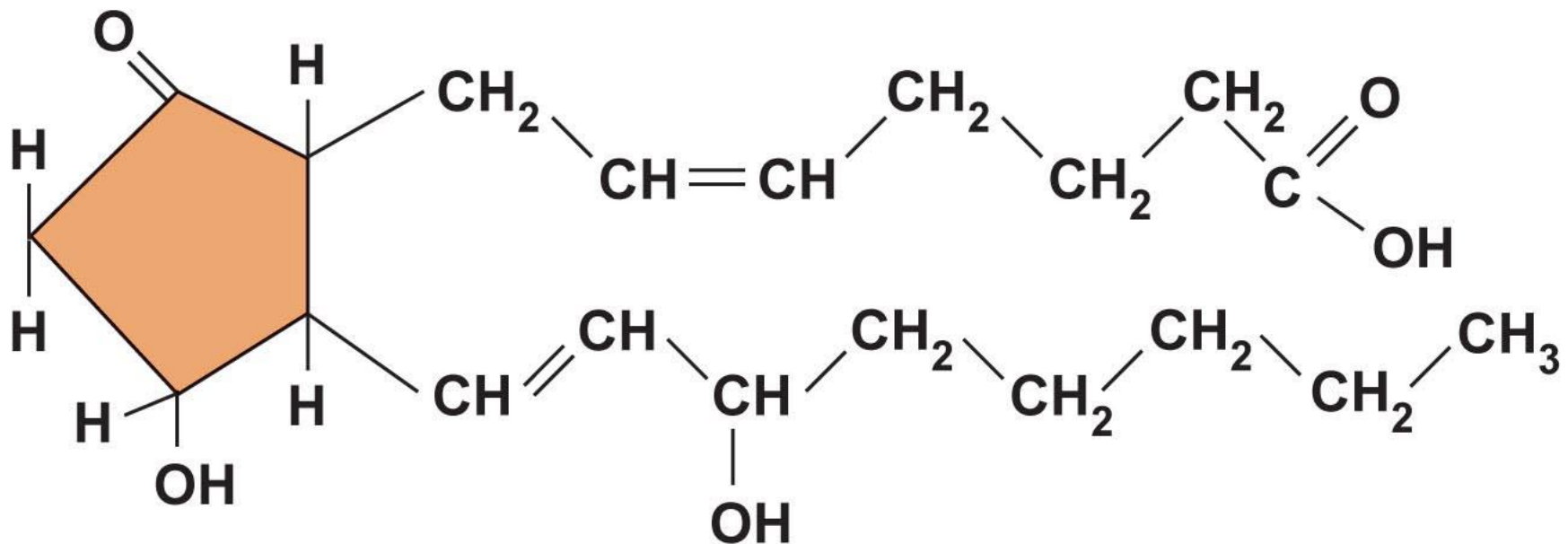


微膠粒 → 乳化作用

(b) Micelle

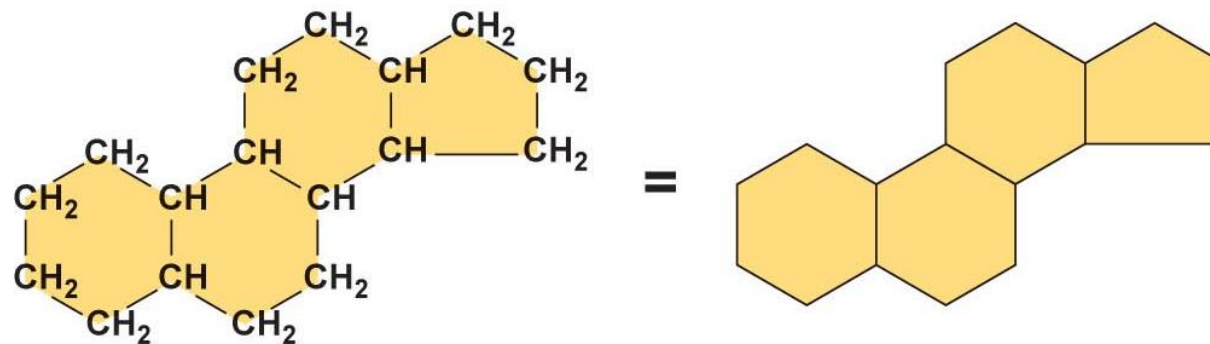
Eicosanoids

- ❖ Modified **20-carbon** unsaturated fatty acids that function in intercellular communication.
- ❖ Polar molecules and include *prostaglandins*, *thromboxanes*, *leukotrienes*.



Steroids

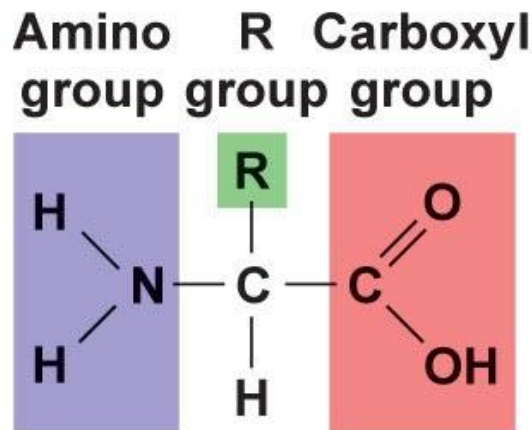
- ❖ 所有類固醇都是從乙醯輔酶A (**acetyl-coenzyme A, acetyl-CoA**) 生物合成路徑所衍生。
- ❖ 不同的類固醇在其附在環上的功能基有所不同，現從植物、動物及真菌中確認的類固醇有數百種。
- ❖ 類固醇在生物系統中最重要的角色就是作為激素如 **Estrogen, Testosterone, Cortisol, Aldosterone**。
- ❖ **Cholesterol** 是一種重要的類固醇，大部分其他類固醇亦是從膽固醇衍生合成而來。



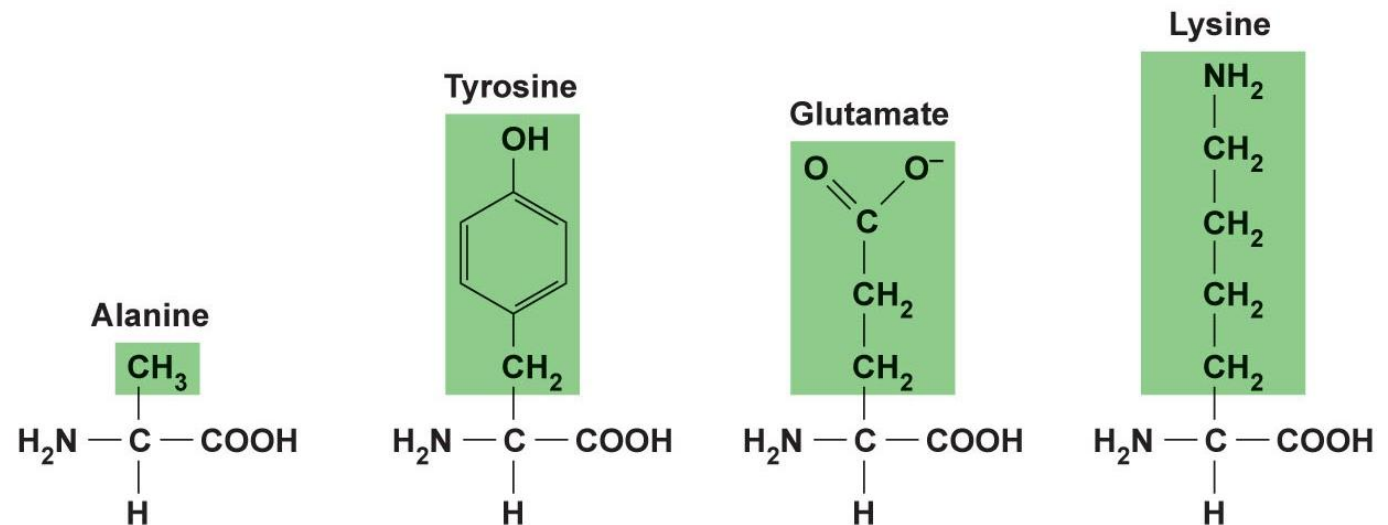
(a) Steroid ring structure

Proteins

- ❖ 16.3% of the body weight (~9.8 kg protein/60 kg BW).
- ❖ Polypeptides=Polymer of amino acids (20 different kinds).
- ❖ Peptides (generally 2–50 aa) & Proteins (greater than 50 aa)



(a) Amino acid



(b) Chemical structures of four amino acids

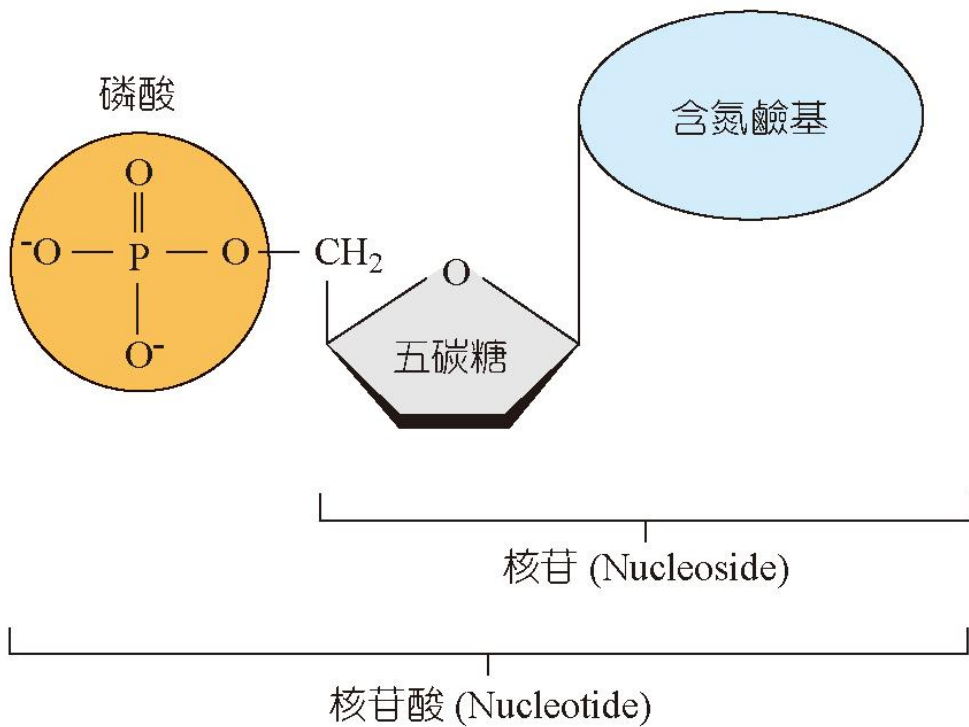
Functions of Proteins

- Construction of human structures
- Repair of human tissue
- Normal metabolism and substances transport
- Osmotic balance (albumin)
- Acid-base balance
- Immune functions
- Various enzymes
- Hormones synthesis
- Neurotransmitters
- Collagen
- Energy sources of life

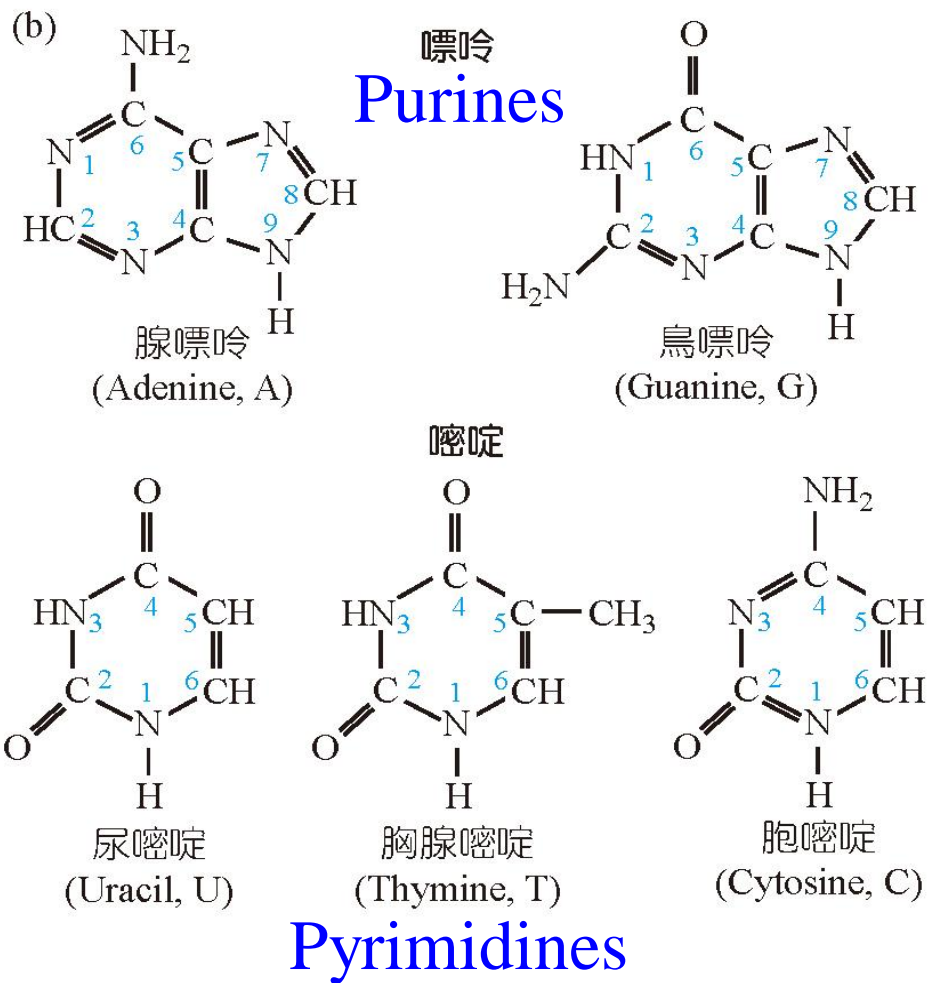


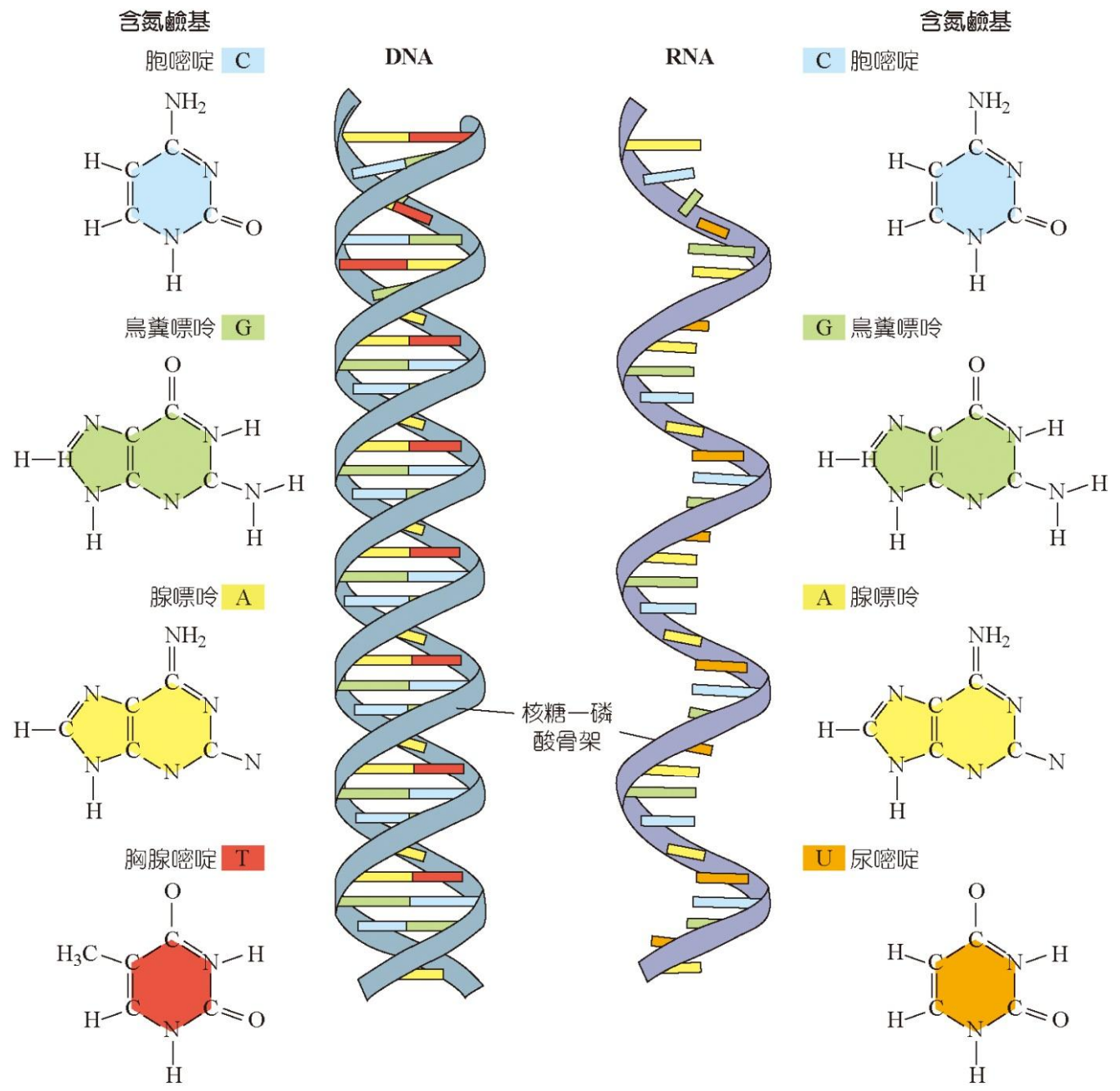
Nucleotides

(a)



(b)



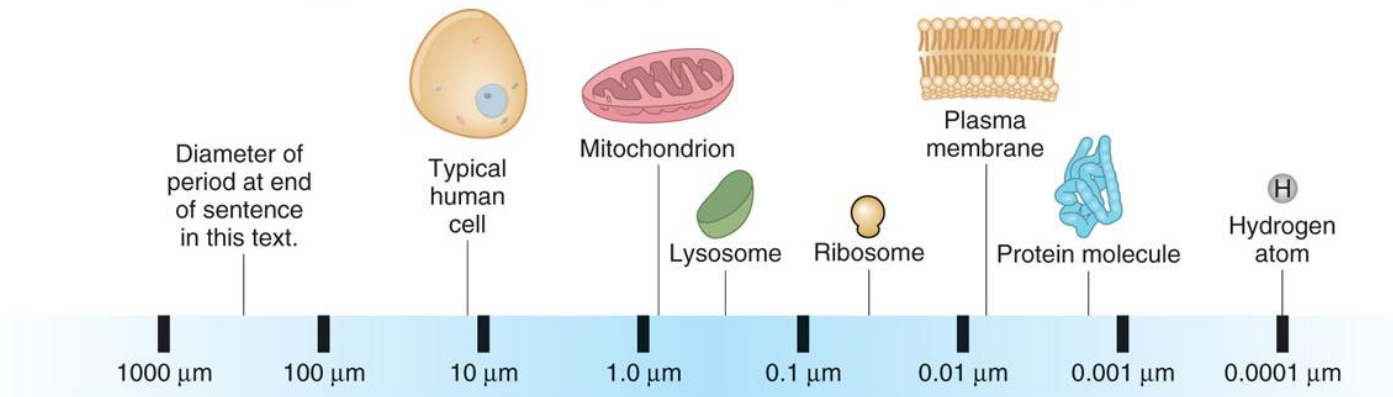


• 圖 2-20 DNA 與 RNA 的結構之比較。

(取代 DNA 中的胸腺嘧啶)

The Generalized Cell

- **Cell Biology** is the study of cellular structure and function.
- The **cell** is a living structural and functional unit of the body.
- The three main parts of a cell are the **plasma membrane**, **cytoplasm**, and **nucleus**.



Can be seen with:

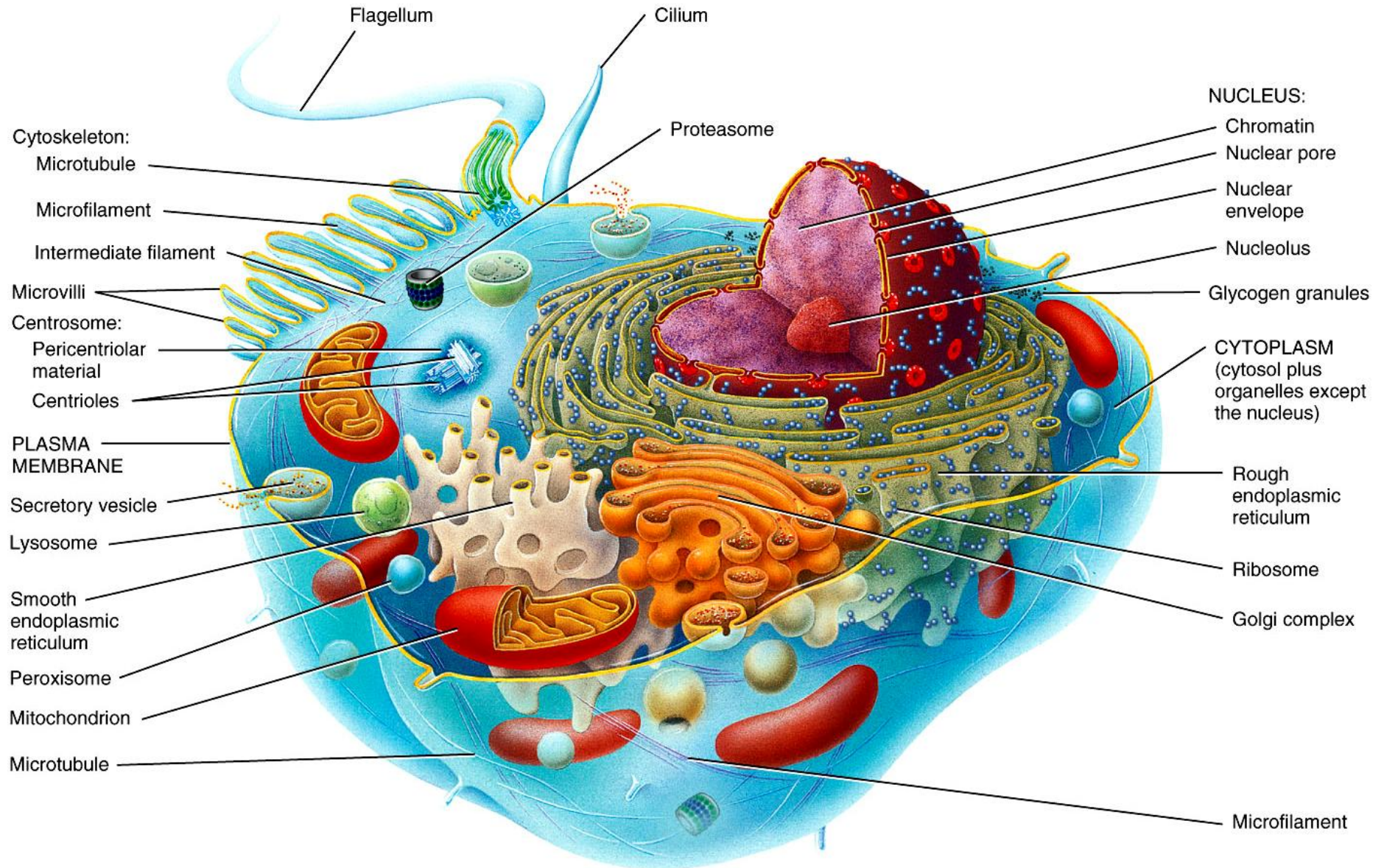
Human eye

Light microscope

Electron microscope

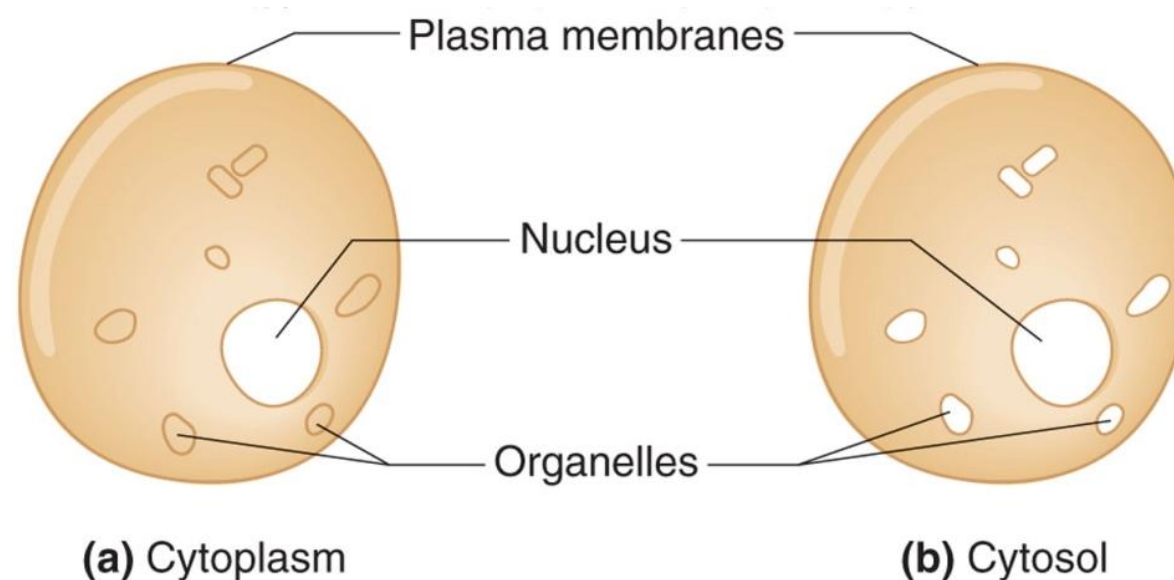
Scanning tunneling microscope

Cell Structure



Cytoplasm - 2 components

- Cytosol** - intracellular fluid, surrounds the organelles
 - the site of many chemical reactions
 - energy is usually released by these reactions
 - reactions provide the building blocks for cell maintenance, structure, function and growth
- Organelles** - specialized structures within the cell



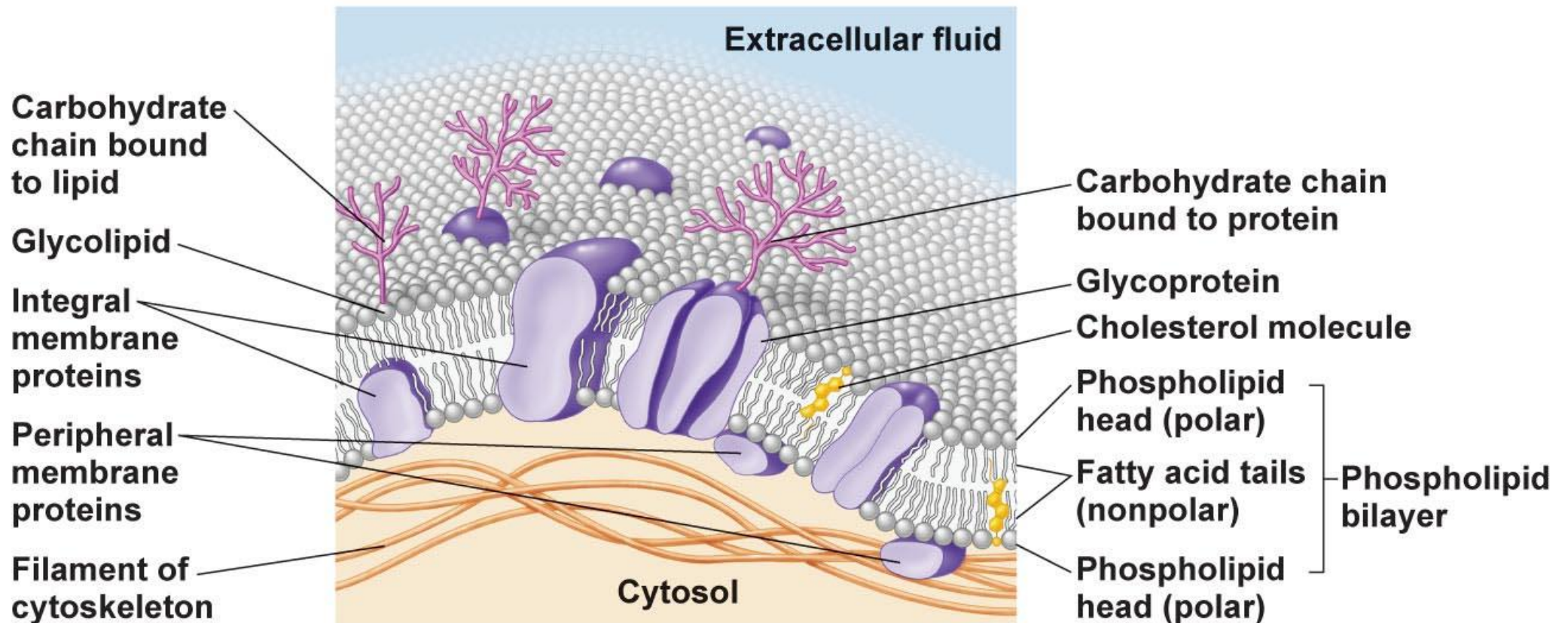
Cell Structures and Functions

Cell part	Structure	Function
<i>Plasma membrane</i>	Lipid bilayer with scattered proteins and cholesterol molecules	Maintains boundary of cell and integrity of cell structure; embedded proteins serve multiple functions
<i>Nucleus</i>	Surrounded by double-layered nuclear envelope	Houses the DNA, which dictates cellular function and protein synthesis
Nucleolus	Dark oval structure inside the nucleus	Synthesis of ribosomal RNA
<i>Cytosol</i>	Gel-like fluid	Cell metabolism, storage
<i>Membranous organelles</i>		
Rough endoplasmic reticulum	Continuous with the nuclear envelope; flattened sacs dotted with ribosomes	Protein synthesis and post-translational processing
Smooth endoplasmic reticulum	Continuous with rough endoplasmic reticulum; tubular structure without ribosomes	Lipid synthesis and post-translational processing of proteins; transport of molecules from endoplasmic reticulum to Golgi apparatus; calcium storage
Golgi apparatus	Series of flattened sacs near the endoplasmic reticulum	Post-translational processing; packaging and sorting of proteins
Mitochondria	Oval-shaped, with an outer membrane and an inner membrane with folds called cristae that project into the matrix	ATP synthesis
Lysosomes	Granular, saclike; scattered throughout the cytoplasm	Breakdown of cellular and extracellular debris
Peroxisomes	Similar in appearance to lysosomes, but smaller	Breakdown of toxic substances, including hydrogen peroxide

Cell Structures and Functions

Cell part	Structure	Function
<i>Nonmembranous organelles</i>		
Vaults	Small, barrel-shaped	Unknown; possibly transport of molecules between nucleus and cytoplasm
Ribosomes	Granular organelles composed of proteins and rRNA; located in cytosol or on surface of rough endoplasmic reticulum	Translation of mRNA to synthesize proteins
Centrioles	Two cylindrical bundles of protein filaments that are perpendicular to each other	Direction of mitotic spindle development during cell division
<i>Cytoskeleton</i>	Composed of protein filaments, including microfilaments, intermediate filaments, and microtubules	Structural support of cell; cell movement and contraction

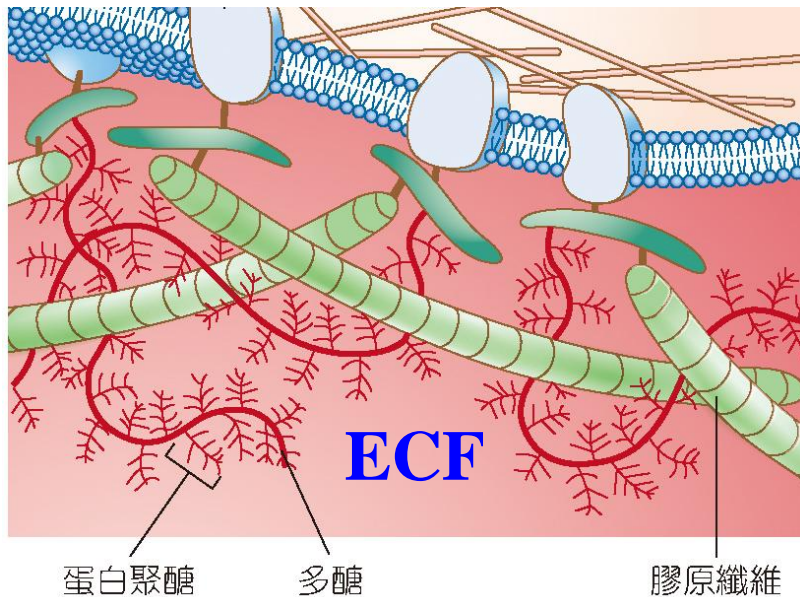
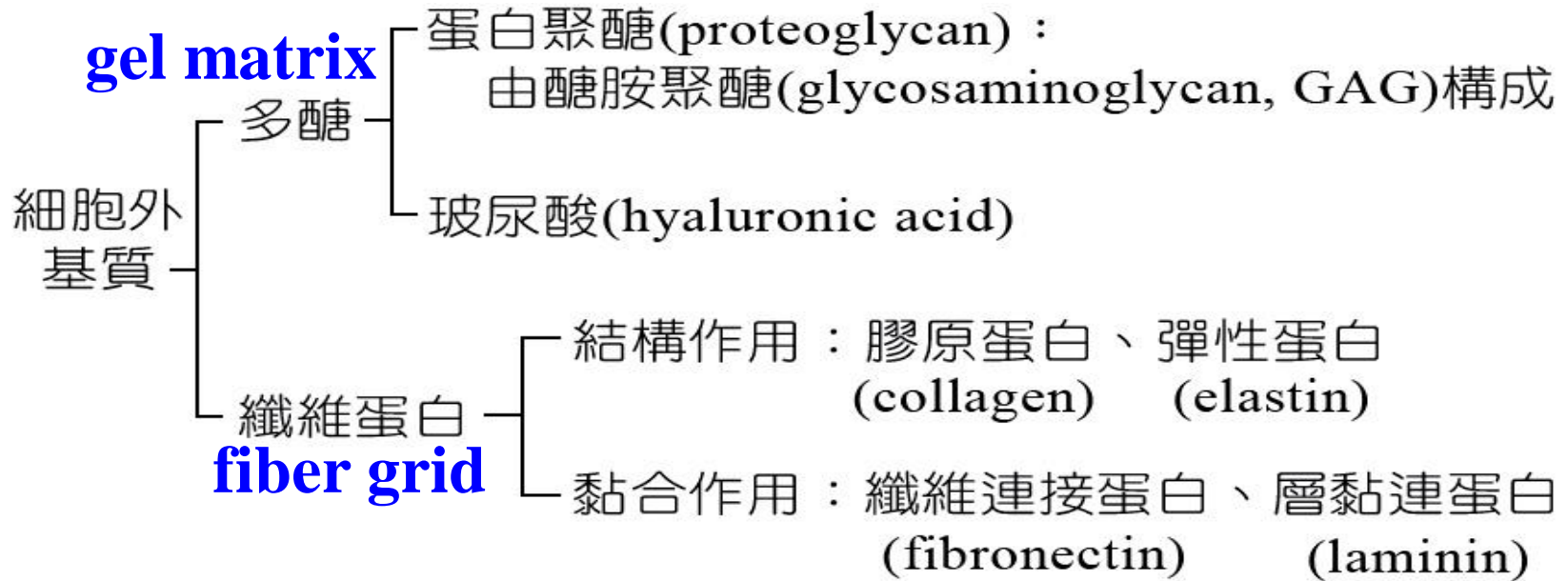
Plasma Membrane (Cell Membrane)



Membrane Functions

- **Barrier** between inside and outside of cell
 - Fluid inside cell = intracellular fluid (ICF)
 - Fluid outside cell = extracellular fluid (ECF)
- Controls entry of materials- **Transport**
- **Receives** chemical and mechanical signals
- Transmits signals between intra- and extra cellular spaces (**cellular communication**)
- Link adjacent cells together by **membrane junctions**
- **Anchor** cells to the extracellular matrix

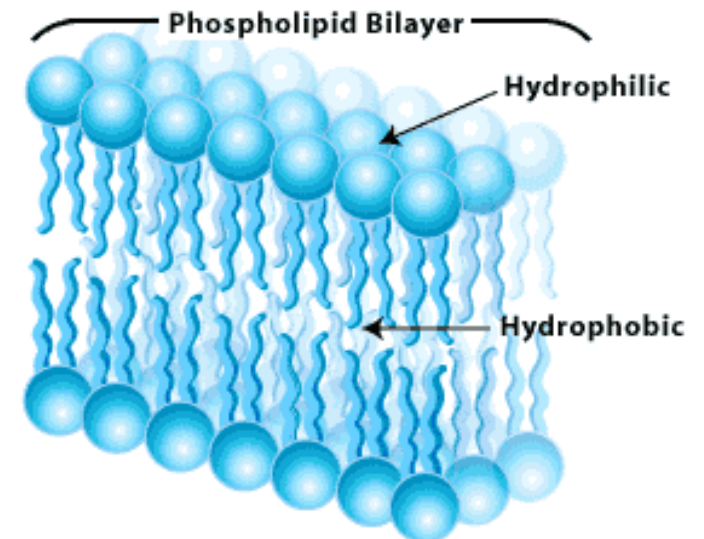
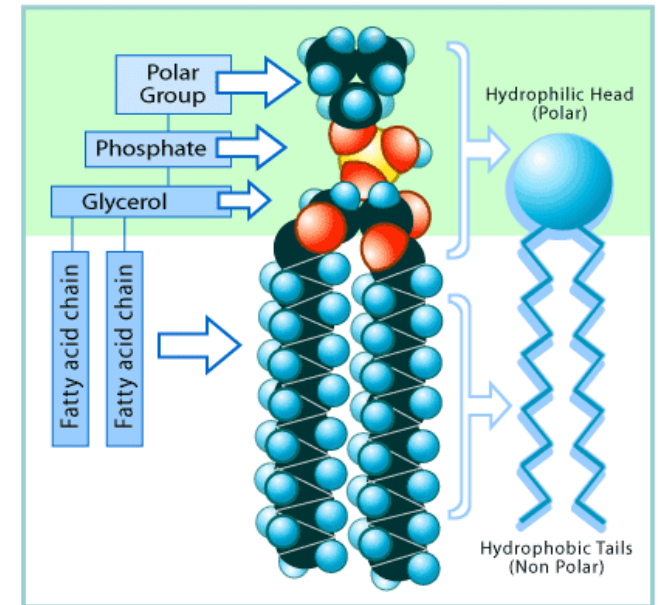
Extracellular Matrix



- 由細胞分泌到細胞外空間的分泌蛋白和多醣所構成的精密有序的網架結構
- 為細胞的生存及活動提供適宜的場所，對細胞產生支持、保護和營養的作用

Membrane Lipid

- 生物膜上的脂質稱為膜脂(membrane lipid)，它是細胞膜的主要成分之一，構成細胞膜的基本骨架。
- 膜脂主要有磷脂質(**phospholipid**)、膽固醇(**cholesterol**)和糖脂(**glycolipid**)三種類型，其中磷脂質含量最高。
- 這三種脂質都是雙性分子(**amphipathic molecule**)，即分子中都具有一個親水性的頭部(極性端)和一個疏水性的尾部(非極性端)。
- 細胞膜的基本骨架為由磷脂分子排成二列形成的脂質雙層(**lipid bilayer**)，其中親水性的頭部朝向膜的兩側，與細胞外或細胞質液接觸；疏水性的尾端則彼此相接，形成膜中間的親脂性區域。



1. 磷脂質：

- 是膜脂中含量最高的脂質，約佔膜脂含量的**50% 以上**，由磷酸根和脂肪酸鏈兩個部分經由甘油基團或鞘氨醇(sphingosine) 結合而成。
- 真核細胞膜中的磷脂質種類主要為
 - 磷脂醯膽鹼(phosphatidylcholine=卵磷脂)
 - 磷脂醯乙醇胺(phosphatidylethanolamine=腦磷脂)
 - 磷脂醯絲胺酸(phosphatidylserine)
 - 鞘磷脂(sphingomyelin)
 - 磷脂醯肌醇(phosphatidylinositol)

2. 膽固醇：

為中性脂質，亦為構成細胞膜的主要成分之一，其分子數與磷脂分子之比可高達1：1。

3. 醣脂：

是含有一個或多個醣基的脂質，普遍存在於細胞的漿膜上，約佔細胞膜外層脂質分子的**5%**。

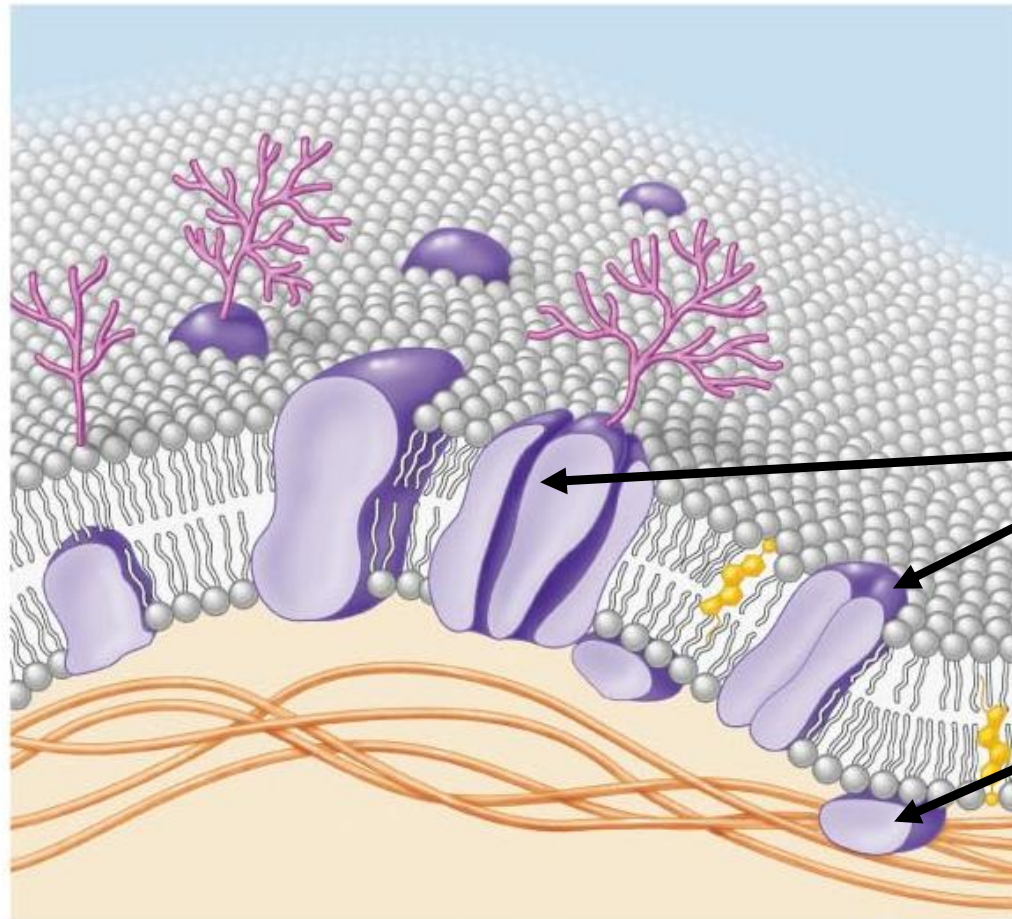
Membrane Protein

– 內在蛋白(intrinsic proteins)

- 也稱為整合蛋白(**integral proteins**)，約佔膜蛋白的**70~80%**，一般在功能複雜的細胞膜中較多，反之較少。
- 內在蛋白也是雙性分子，有鑲嵌蛋白(**mosaic protein**)和跨膜蛋白(**transmembrane protein**)兩種形式。
- 鑲嵌蛋白的疏水性部分插入細胞膜內，直接與脂質雙層的疏水性區域相互作用，親水性部分則暴露於膜的外表面或內表面。
- 跨膜蛋白可以單條 α 螺旋穿過脂質雙層，也可以數條 α 螺旋數次折返穿越脂質雙層。
- 膜內在蛋白主要以疏水鍵(hydrophobic bond)或離子鍵(ionic bond)兩種作用與膜牢固結合。

– 外在蛋白(extrinsic proteins)

- 也稱為周邊蛋白(peripheral proteins)，約佔膜蛋白的20~30%，分布在膜的內外表面，主要在內表面，為水溶性蛋白。
- 它們透過靜電作用及離子鍵、氫鍵與膜脂分子的極性頭部結合，或透過與膜內在蛋白親水性部分相互作用，間接與膜結合。

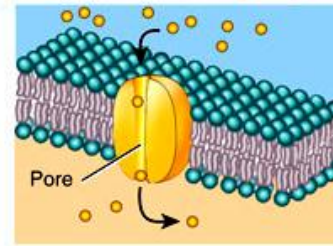


Integral membrane protein (amphipathic)

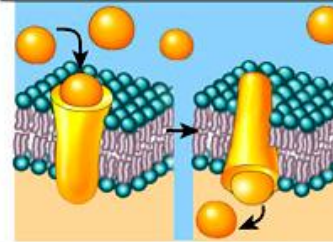
Peripheral membrane protein

Membrane Protein Functions

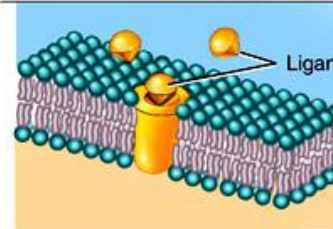
Extracellular fluid Plasma membrane Cytosol



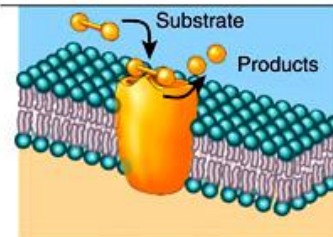
Ion channel (integral)
Allows specific ion (●) to move through water-filled pore. Most plasma membranes include specific channels for several common ions.



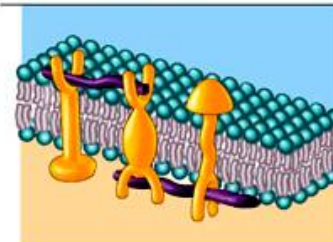
Carrier (integral)
Transports specific substances (●) across membrane by changing shape. For example, amino acids, needed to synthesize new proteins, enter body cells via carriers. Carrier proteins are also known as *transporters*.



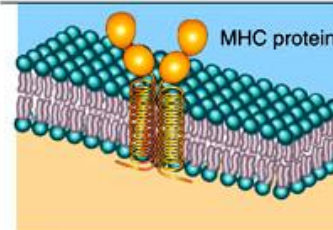
Receptor (integral)
Recognizes specific ligand (◊) and alters cell's function in some way. For example, antidiuretic hormone binds to receptors in the kidneys and changes the water permeability of certain plasma membranes.



Enzyme (integral and peripheral)
Catalyzes reaction inside or outside cell (depending on which direction the active site faces). For example, lactase protruding from epithelial cells lining your small intestine splits the disaccharide lactose in the milk you drink.



Linker (integral and peripheral)
Anchors filaments inside and outside the plasma membrane, providing structural stability and shape for the cell. May also participate in movement of the cell or link two cells together.



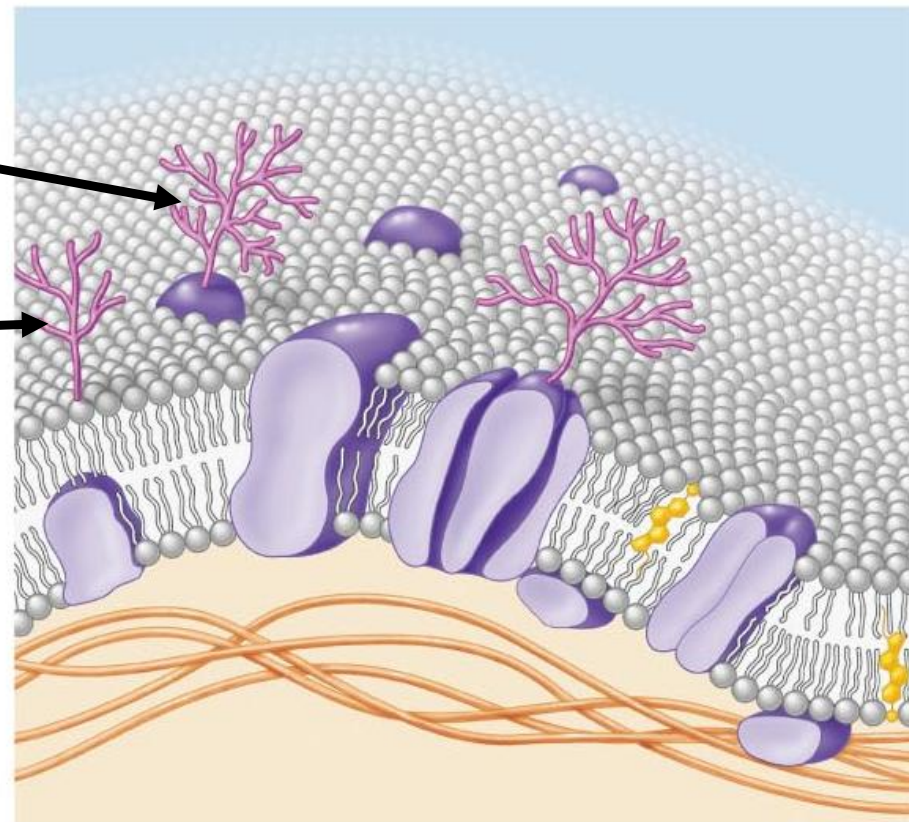
Cell identity marker (glycoprotein)
Distinguishes your cells from anyone else's (unless you are an identical twin). An important class of such markers are the major histocompatibility (MHC) proteins.

Membrane Carbohydrates

- 所有真核細胞的表面均含有醣類，佔膜總重量的**2~10%**。細胞膜上的醣類主要有半乳糖、甘露糖、葡萄糖、葡萄糖胺和唾液酸等。
- 醣蛋白和醣脂上的所有醣類都位於細胞膜的外表面(非細胞質面)，在細胞表面形成細胞外衣(**cell coat=glycocalyx**)。

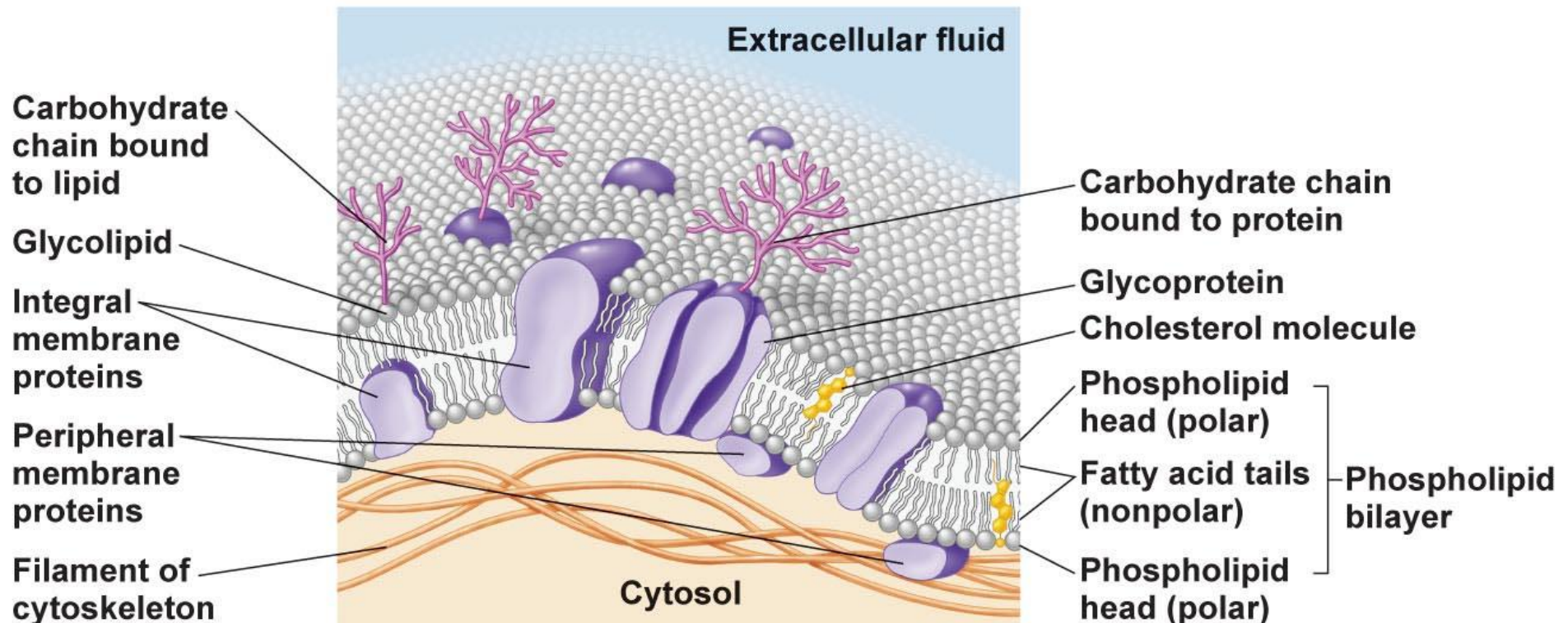
Glycoprotein

Glycolipid



Membrane Cholesterol

- Adds **fluidity** to membrane
 - Interferes with hydrophobic interactions between phospholipids
 - Prevents crystallization of phospholipid
- Decreases **permeability** of membrane to water

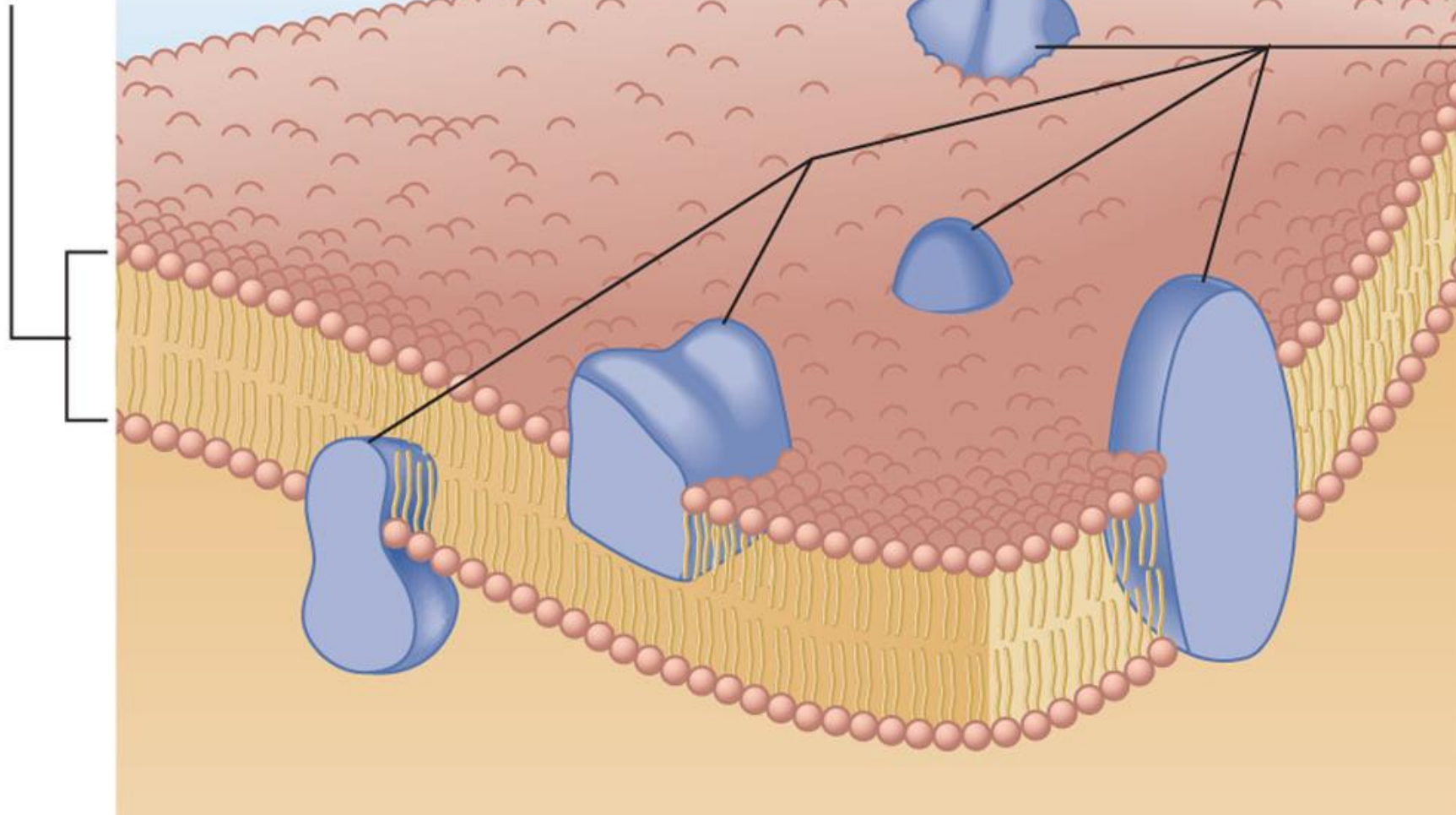


Fluid-Mosaic Model of Membranes

1972, Singer & Nicolson

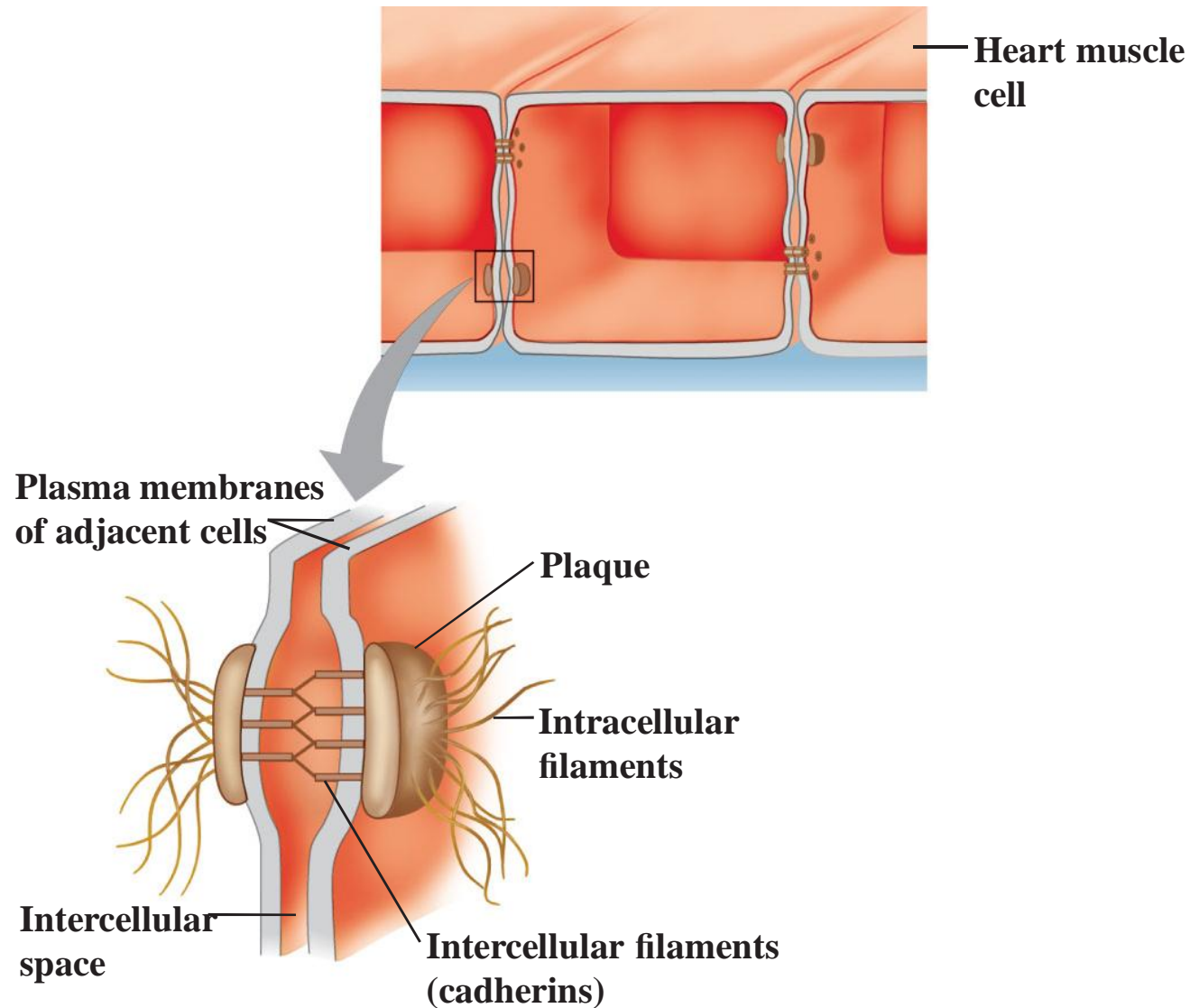
Phospholipid bilayer

Proteins



Membrane Junctions

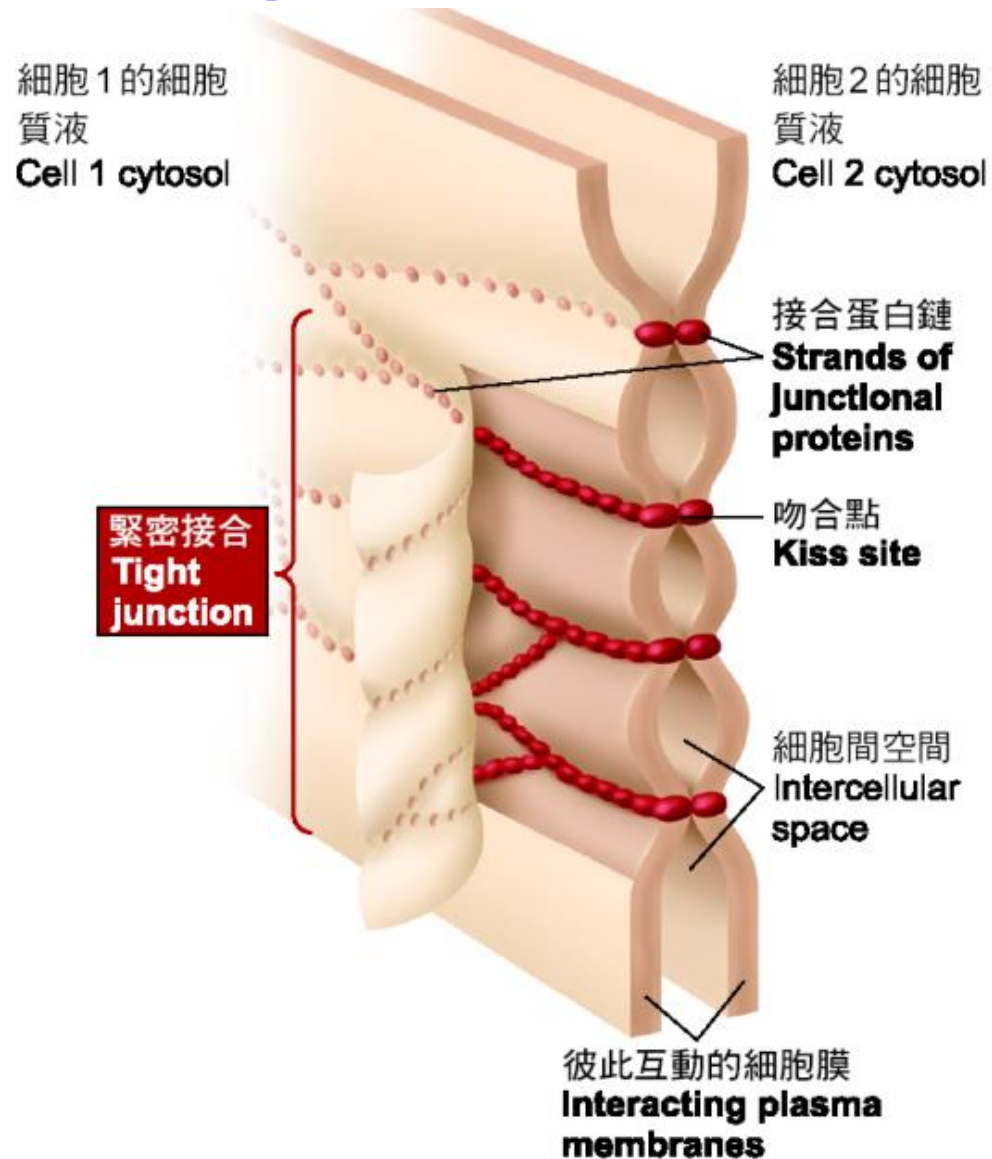
Desmosome



(a) Desmosome

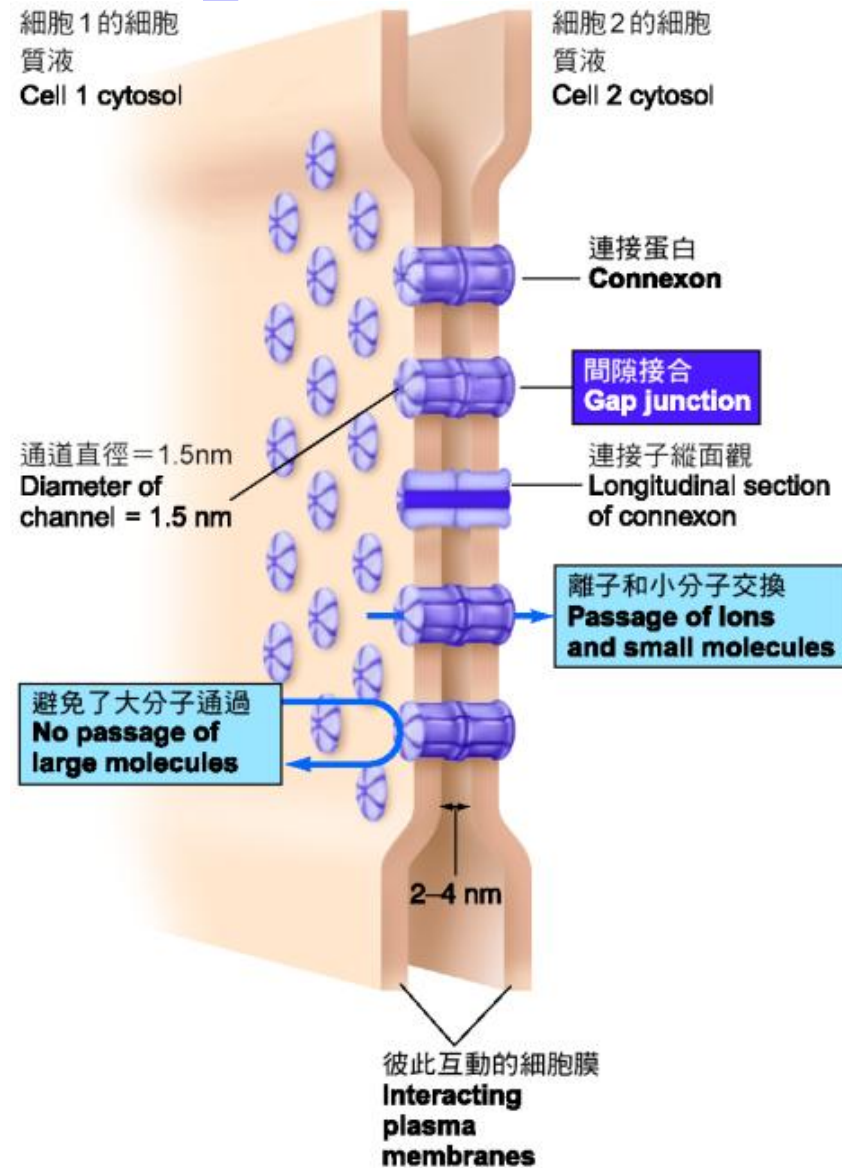
Membrane Junctions

Tight Junction



Membrane Junctions

Gap Junction



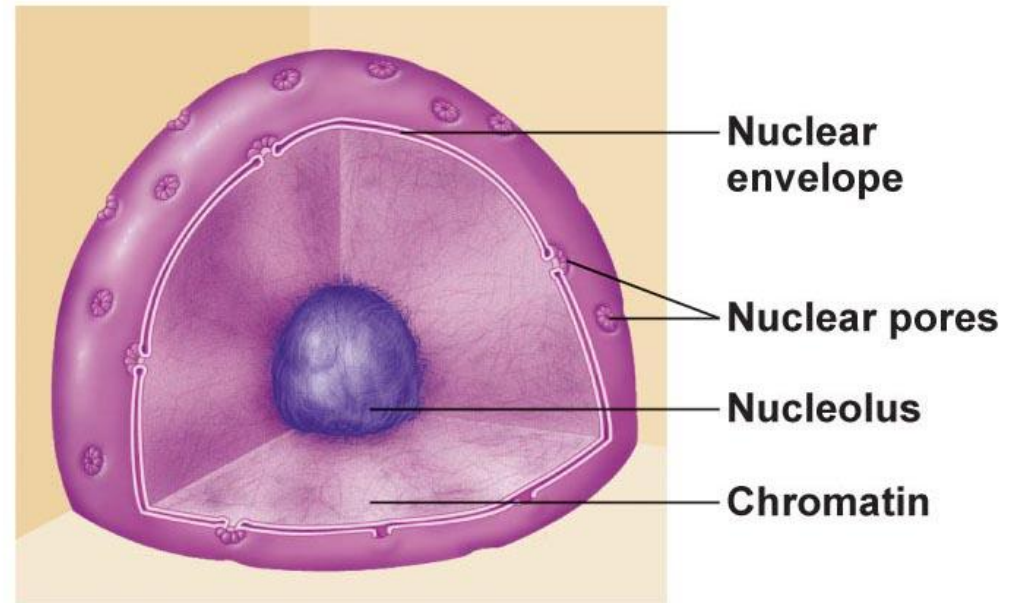
Nucleus

● Structure

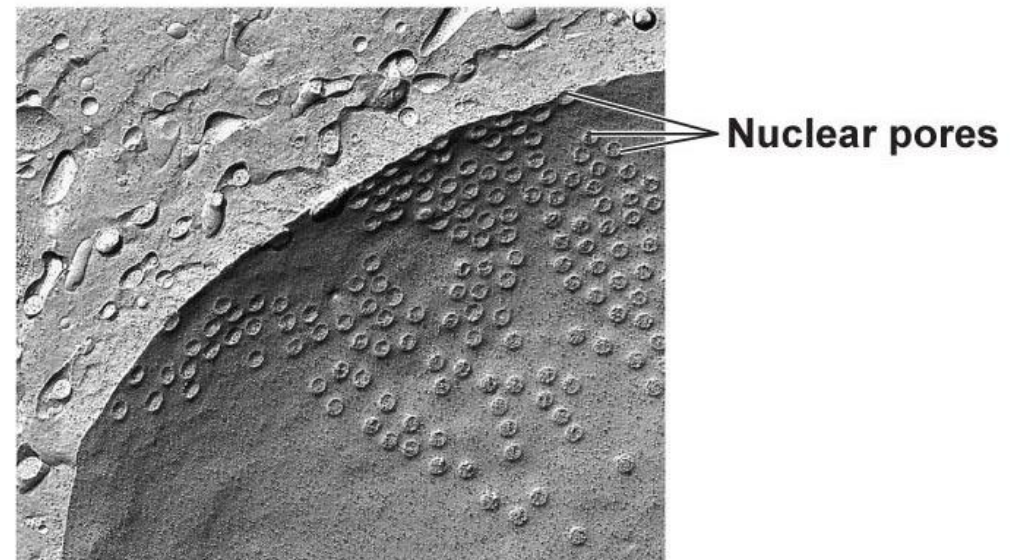
- Nuclear envelope
- Nuclear pores
- Nucleolus—site of rRNA synthesis

● Function

- Transmission and expression of genetic information
 - Contains DNA—stores genetic code
 - DNA transcribed to RNA—necessary to express code



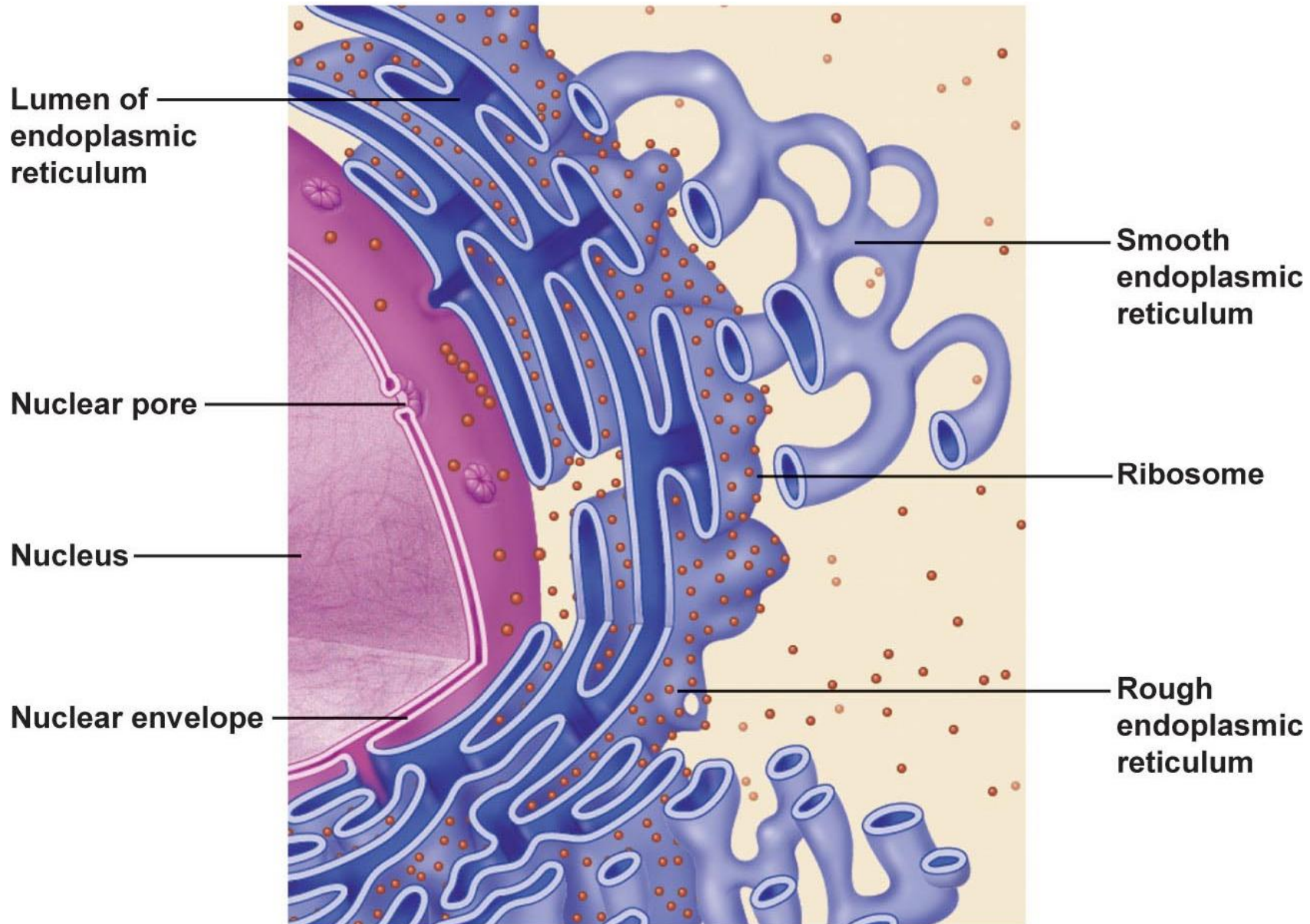
(a)



(b)

- 細胞核的直徑一般為5~10 μm ，通常位於細胞的中央。
- 一個真核細胞通常只含有一個細胞核，但在有些可有雙核甚至多核如肝細胞、腎小管細胞和軟骨細胞有雙核，破骨細胞有多達數百個細胞核。
- 染色質(chromatin)是細胞核內能被鹼性染料著色的物質，呈伸展、分散的細絲網狀，是遺傳訊息的載體。
- 染色體(chromosome)則是由染色質盤繞折疊而成的短棒狀小體。
- 染色質和染色體實質上是同一物質在細胞週期的不同階段，執行不同生理功能時呈現的兩種不同的存在形式。
- 核仁(nucleolus)，在光學顯微鏡下為均質、海綿狀的球體是真核細胞的細胞核中最明顯的結構。
- 核膜(nuclear envelope)對於維持細胞核相對穩定的內環境與基因表現的準確性和高效率，以及參與蛋白質合成及細胞分裂中染色體的定位和分離等具有重要作用。

Endoplasmic Reticulum (ER)



rER

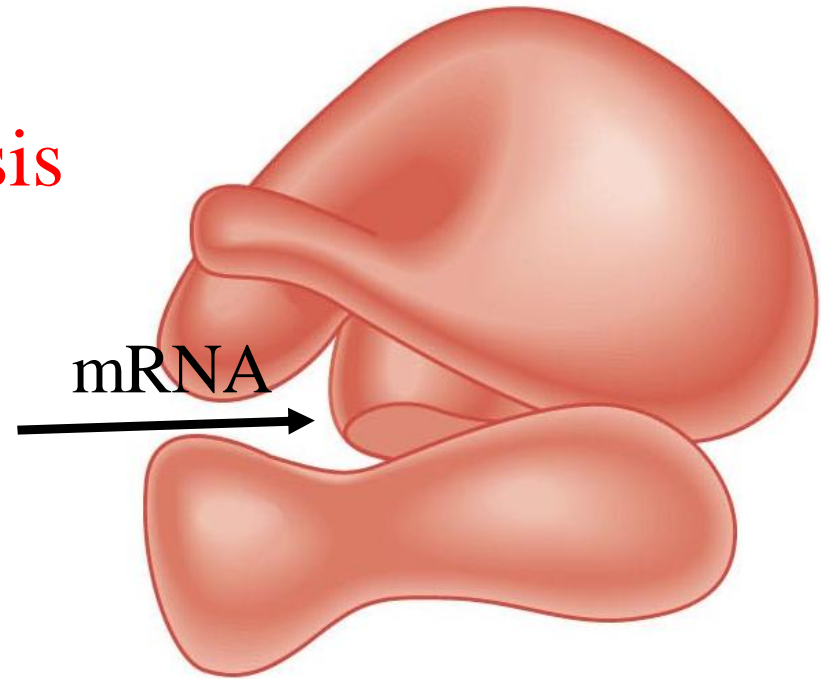
- Functions in **synthesis of proteins** to be packaged into vesicles
 - Exported out of cell
 - Incorporated into plasma membrane
 - Destined for certain organelles

sER

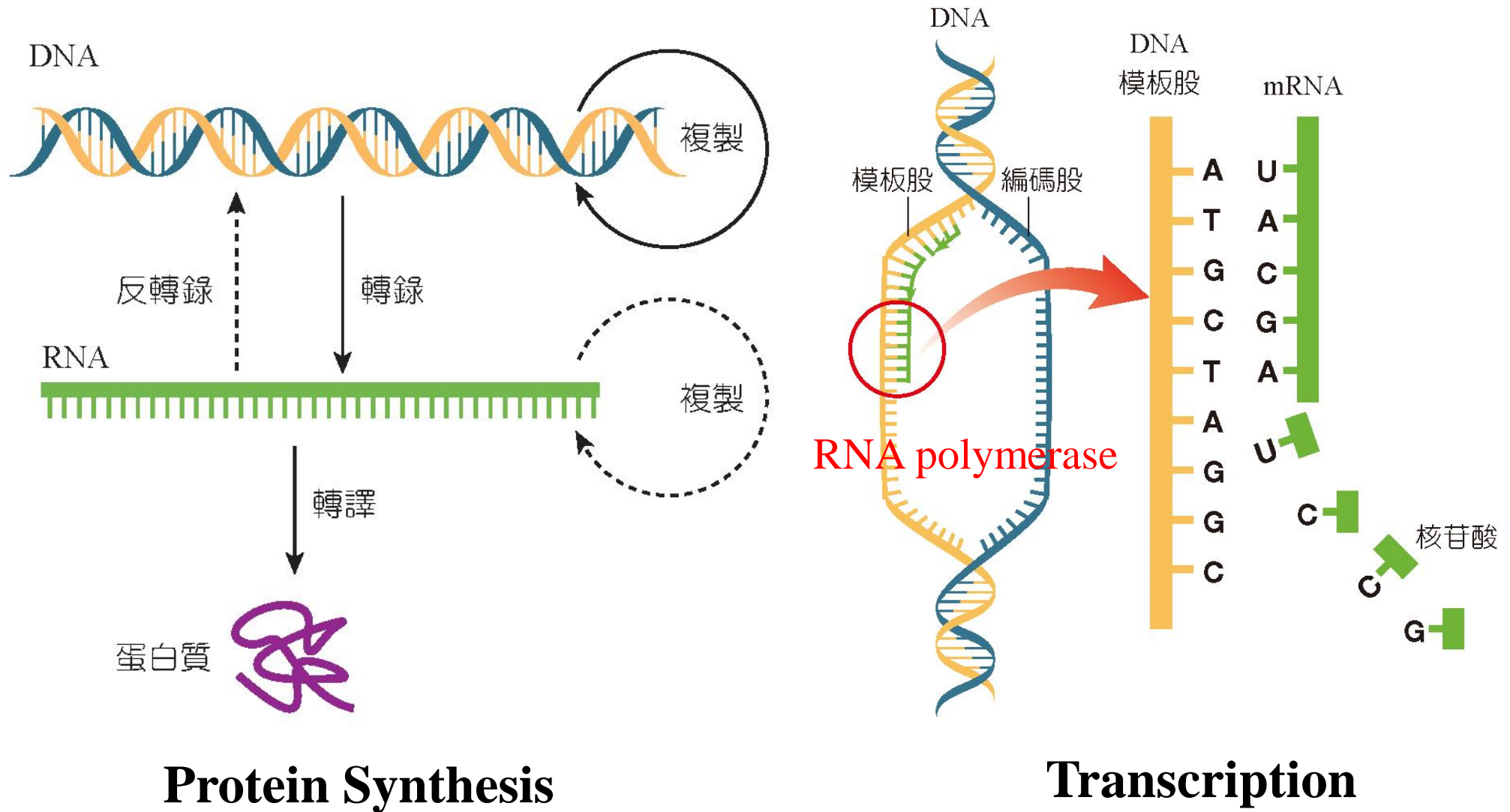
- Functions in **lipid synthesis**, including triglycerides and steroids
- Stores **calcium (sarcoplasmic reticulum)**
- Specialized in **some cells**
Example: Smooth ER in the liver contains **detoxification enzymes(cytochrome P450 enzyme system)**.

Ribosomes

- Ribosomes = **rRNA** and **proteins** (15~25 nm)
- Important in **protein synthesis**
- Fixed
 - Attached to **endoplasmic reticulum (rER)**
- Free
 - Loose in **cytosol**



Transcription & Translation



mRNA

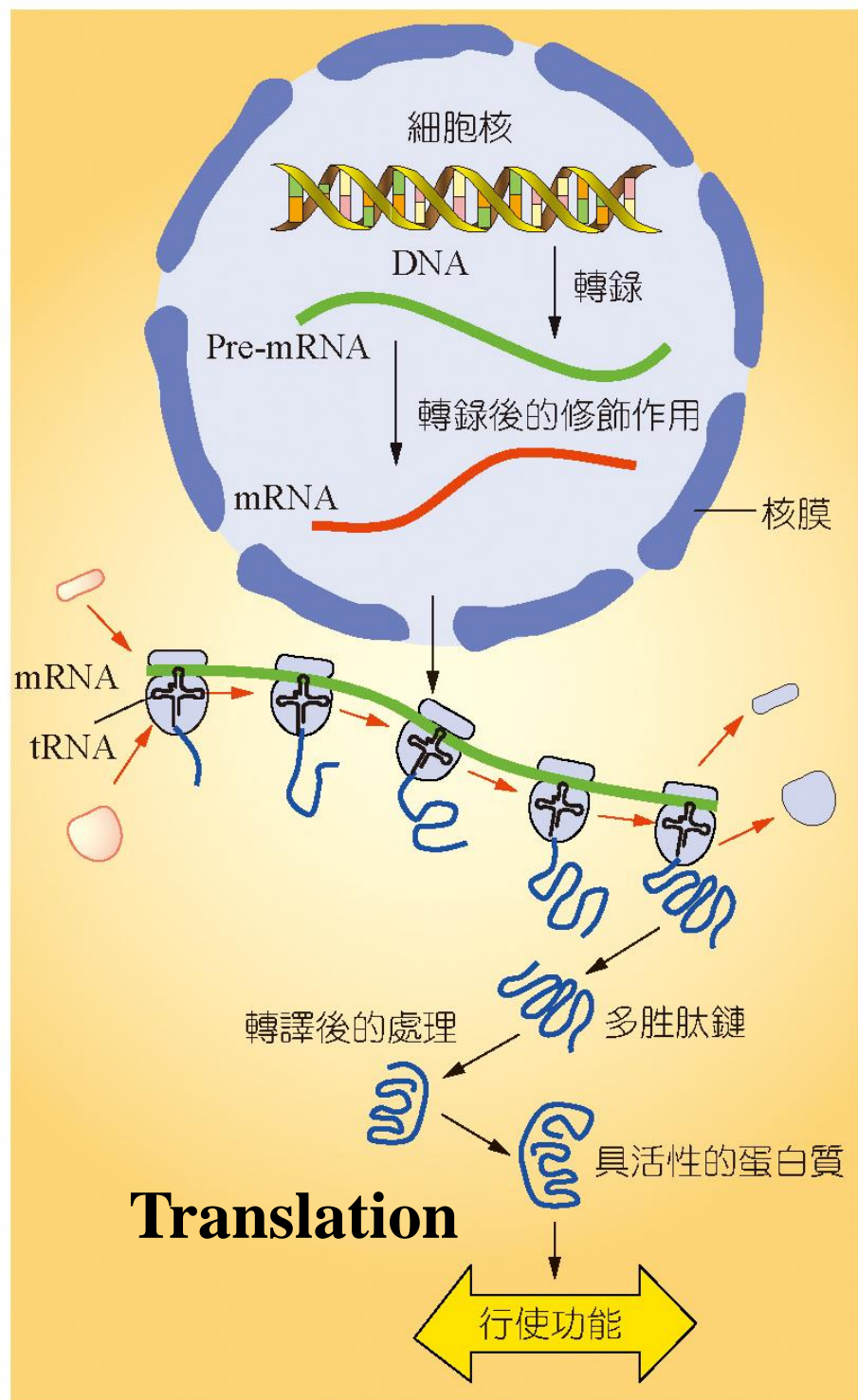
攜帶有蛋白質合成訊息

rRNA

參與核糖體組成和功能

tRNA

參與蛋白質合成中胺基酸運輸





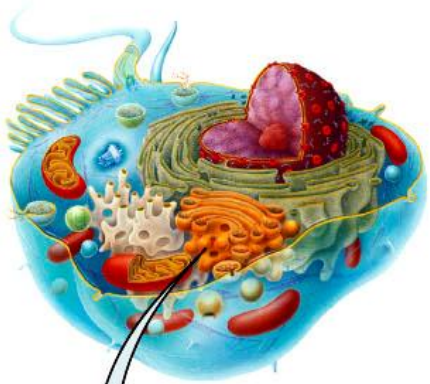
亨丁頓氏症 (Huntington's Disease)

亨丁頓氏症又稱遺傳性舞蹈症 (hereditary chorea)，由位於第 4 對染色體上稱作 huntingtin 的缺損基因所導致，其編碼區 5' 端 $(CAG)_n$ 的動態突變可導致疾病的發生，且 $(CAG)_n$ 重複的多寡與發病的早晚、嚴重程度呈正比。正常人的 $(CAG)_n$ 重複次數為 9~34 次，亨丁頓氏症患者則大於 36 次，最多可超過 120 次。

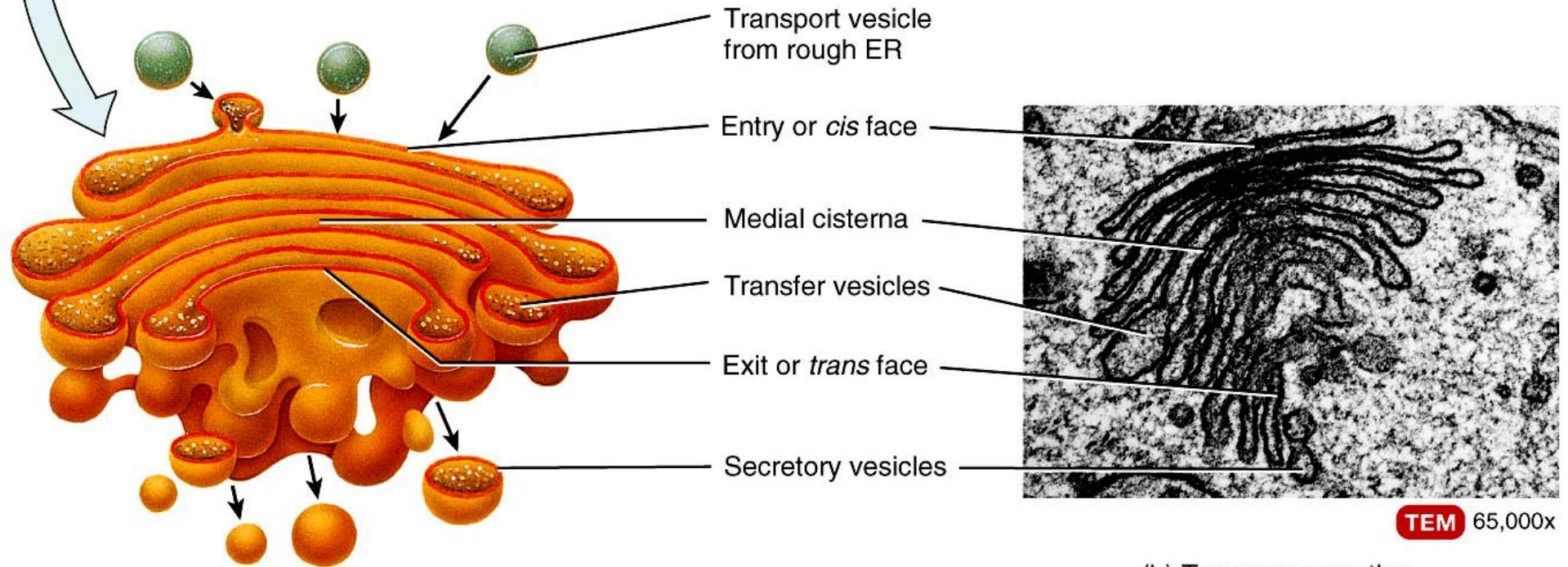
該病常見於 30~45 歲時緩慢發病，患者有 大腦基底核的病變，可引起廣泛的腦萎縮，主要

損害位於尾狀核、豆狀核（主要是殼核）和額葉。臨床表現為進行性加重的舞蹈樣不自主運動（不能控制的痙攣和書寫動作）和智能障礙。患者的舞蹈樣運動的動作快，而且波及全身肌肉，但以顏面和上肢最明顯。隨著病情加重，可出現語言不清，甚至發音困難，最終出現癡呆。此外，患者常有欣快表情、生活懶散、衣著不整、妄想或幻想，部分病例可有癲癇發作。

Golgi Apparatus



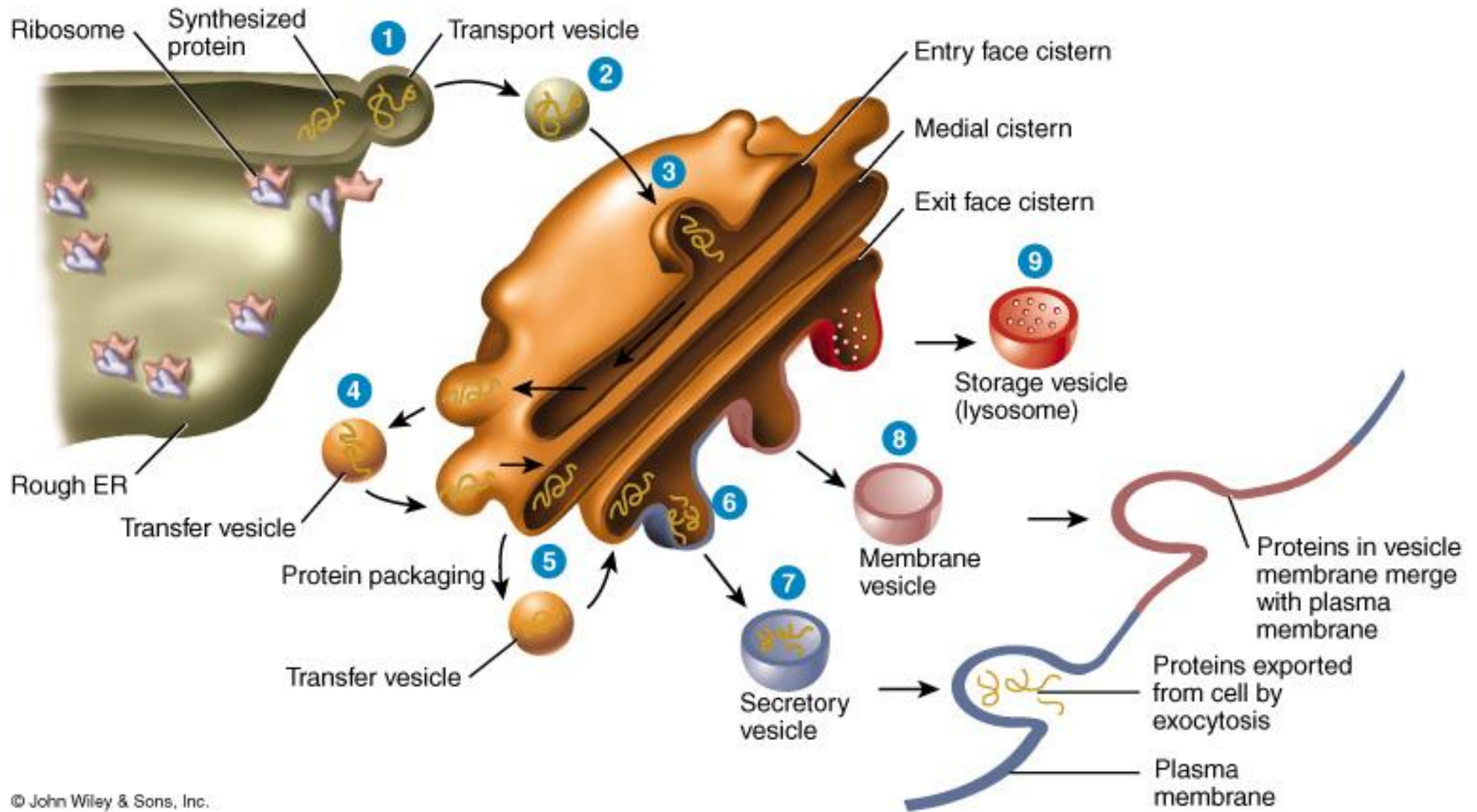
- consists of 3-20 flattened, **membranous sacs** called **cisternae**
- **modify**, **sort**, and **package** proteins for transport to different destinations
- proteins are **transported** by various vesicles



(a) Details

(b) Transverse section

Processing & Packaging



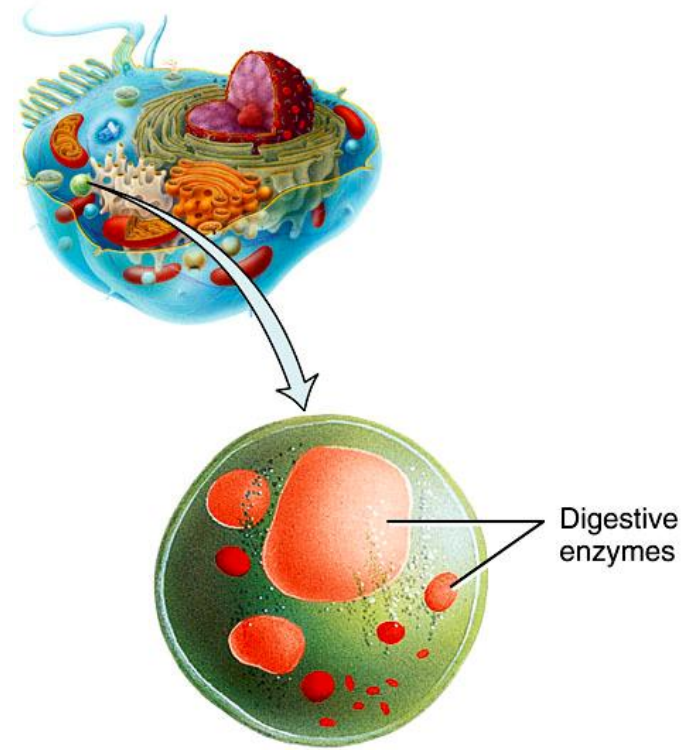
Lysosomes

■ Membranous vesicles

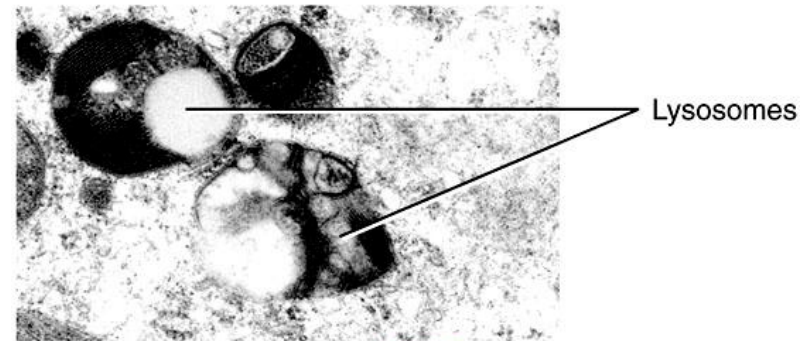
- formed in Golgi complex
- filled with digestive enzymes (>50)
- pumps in H^+ ions until internal pH reaches 5.0

■ Functions

degrade cellular or foreign substances



(a) Lysosome

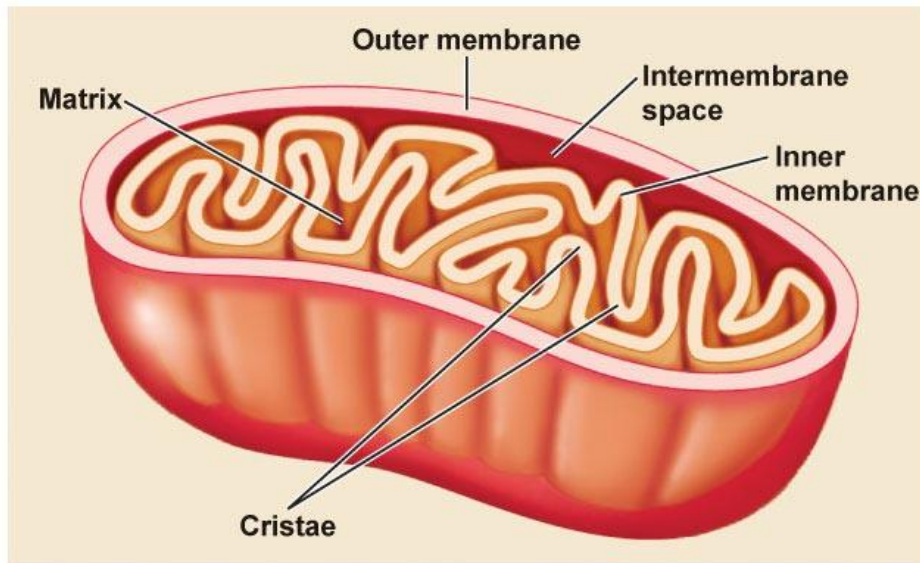


TEM 11,700x

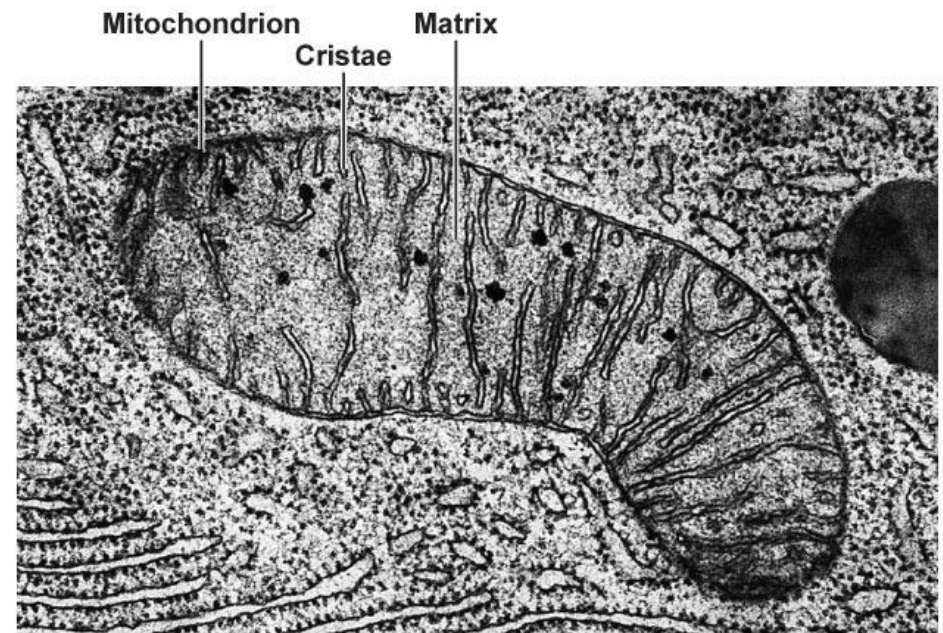
(b) Several lysosomes

Mitochondrion

“powerhouses” of the cell



(a)



(b)

More prevalent in physiologically active cells:
muscles, liver and kidneys

Mitochondrion Structure

- 粒線體是由兩層膜圍成的封閉的囊狀結構，兩層膜套疊在一起，互不相連，並將粒線體內部分隔成兩個獨立的空間。
- 基質(matrix)充滿膠狀物質，其主要成分是各種可溶性蛋白質和脂質。
- 與催化克氏循環、脂肪酸氧化、胺基酸分解、蛋白質合成等有關的酵素都存在於基質中(ETC/ cristae of inner membrane)。
- 含有粒線體獨特的雙股環狀DNA及核糖體，具相對獨立的遺傳訊息複製、轉錄和轉譯系統(半自主性胞器)。
- 蛋白質是粒線體的主要組分，含量約佔粒線體組成的65~70%，多數分布在內膜和基質中。
- 粒線體是細胞中含酵素種類最多的胞器之一(~120)，分布在粒線體的各個部分中。

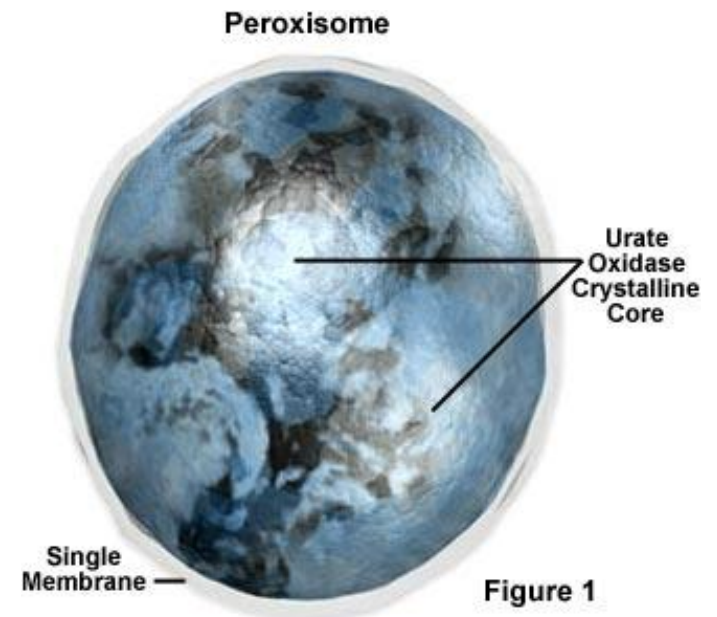
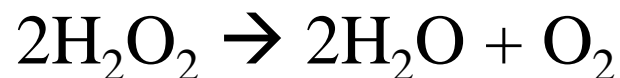
Peroxisomes

- Function

Degrade certain waste molecules

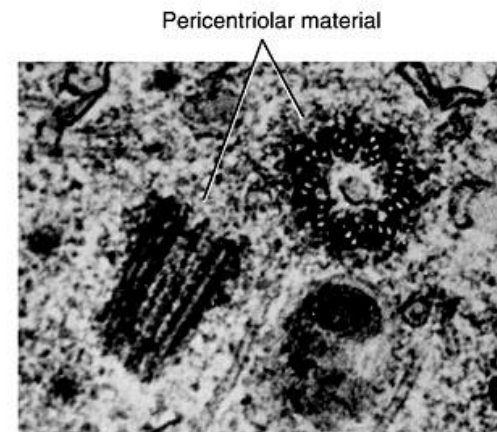
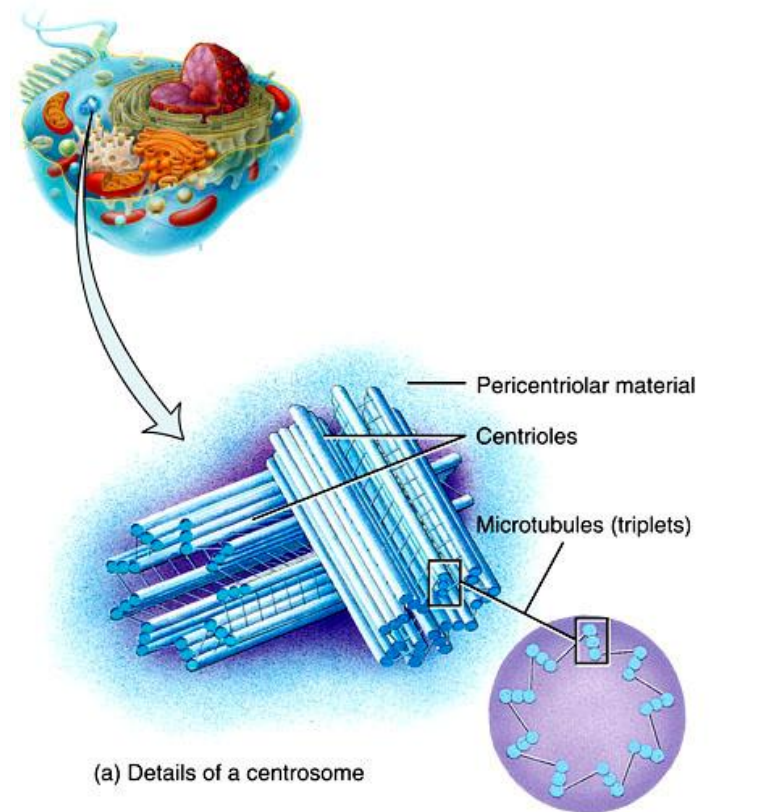
- Amino acids
- Fatty acids
- Toxic foreign substances (alcohol, abundant in the liver)

- By-product of degradation = H_2O_2
Contain **catalase, oxidase, peroxidase**, etc.



Centrosome

- Found near nucleus
- **Pericentriolar area**
 - formation site for mitotic spindle and microtubules
- Centrosome
 - **2 centrioles** (90 degrees to each other)
 - 9 clusters of 3 microtubules (9+0 array)
 - role in formation of cilia & flagella
 - role in cellular energy metabolism (ATPase)



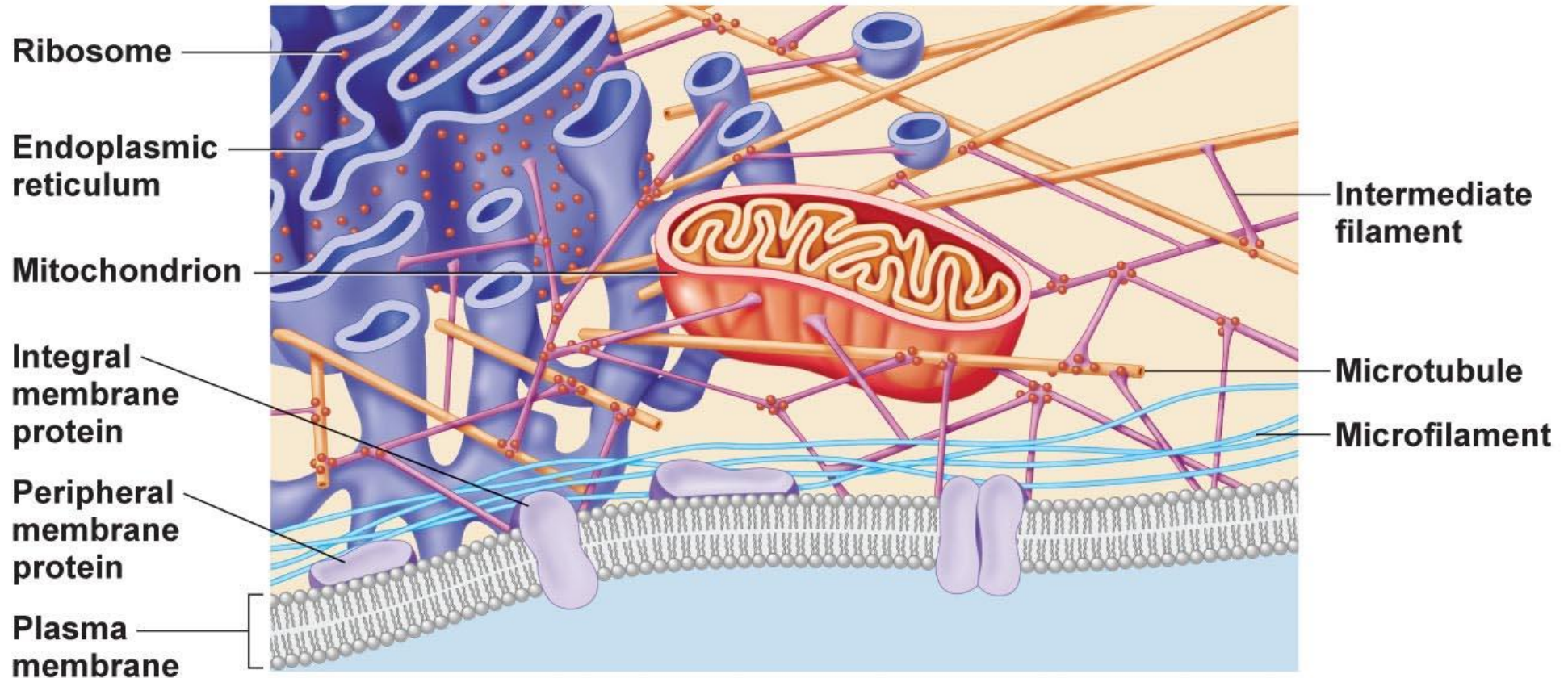
Longitudinal section Transverse section

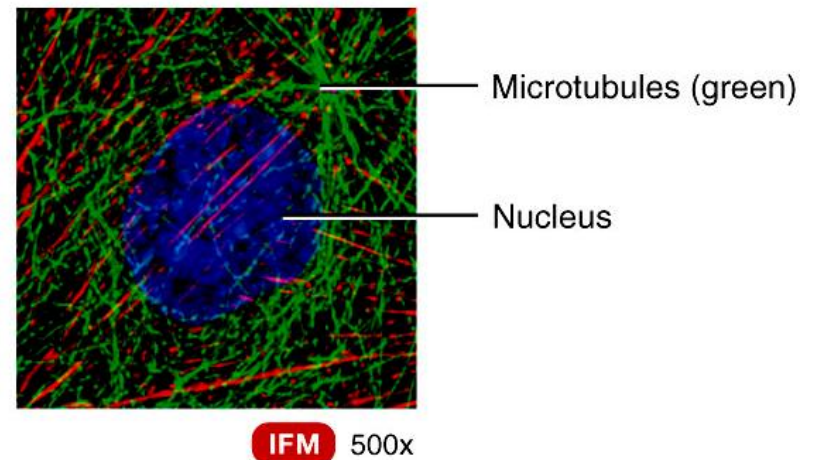
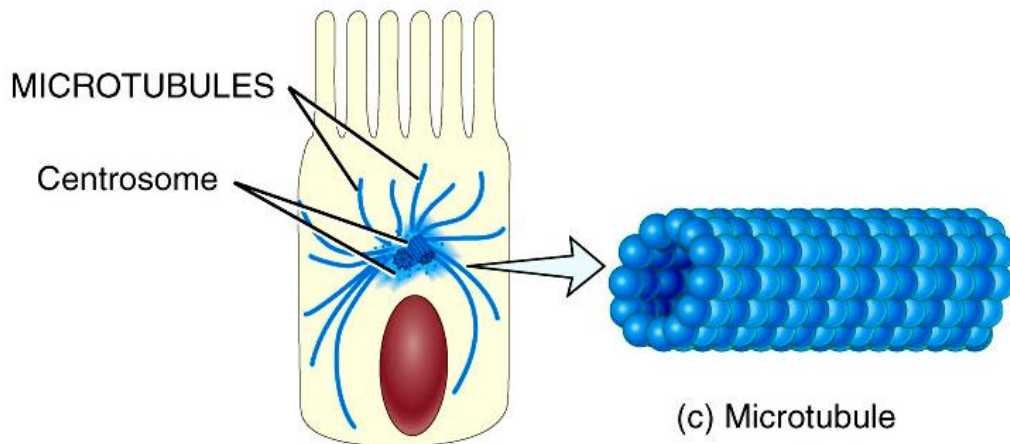
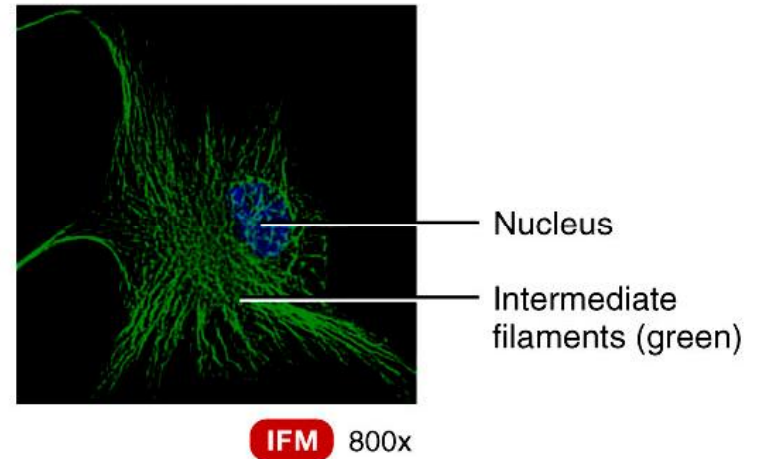
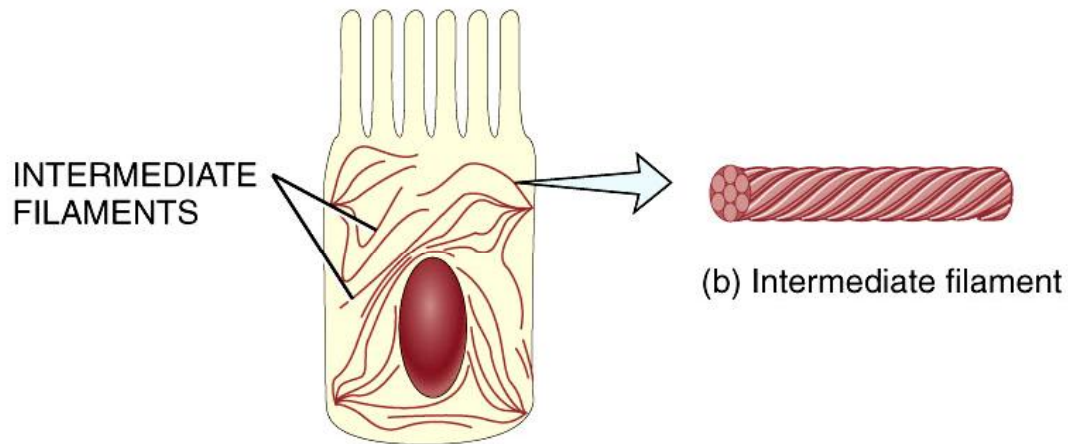
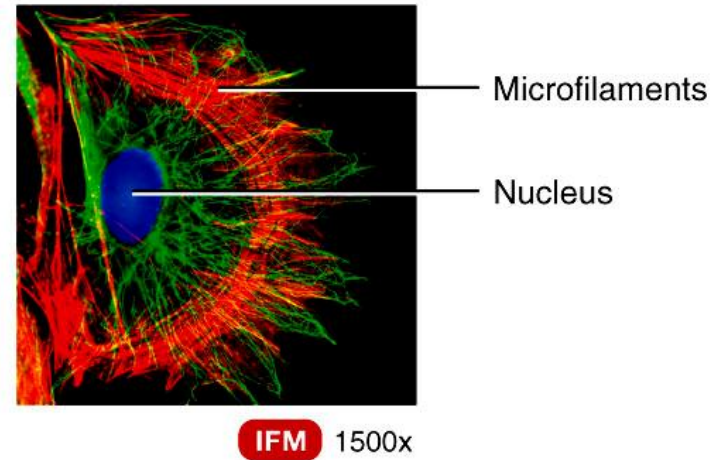
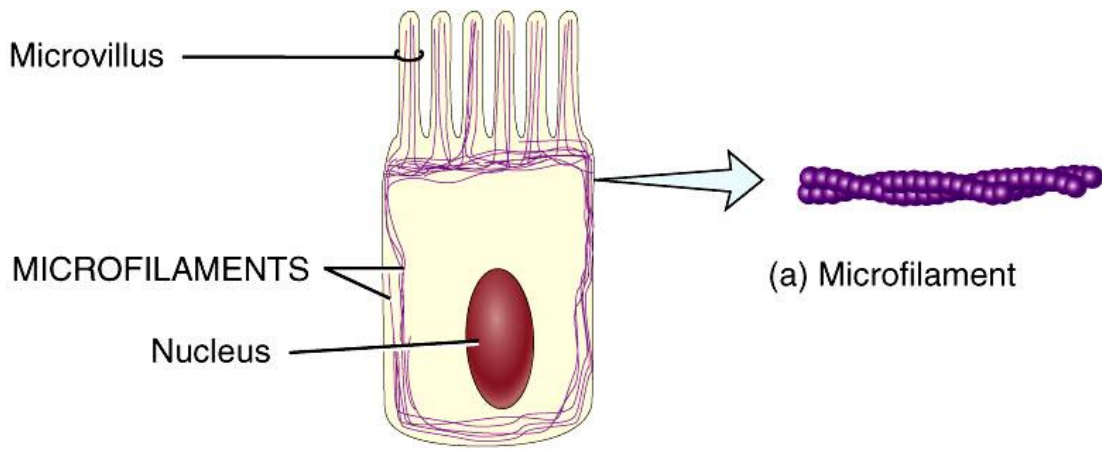
(c) Centrioles

Cytoskeleton

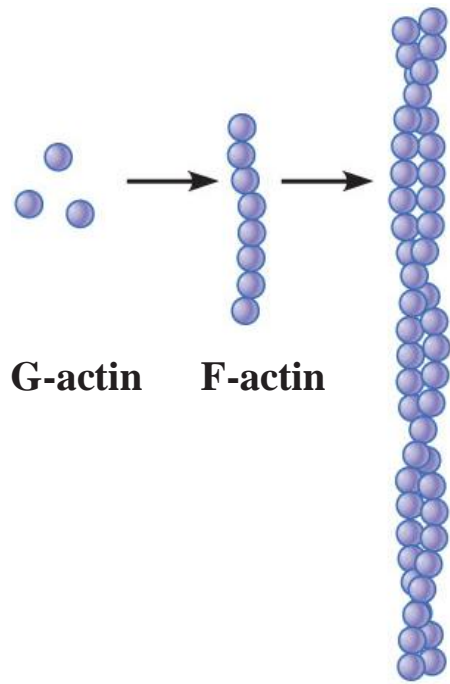
- Network of protein filaments throughout the cytosol
- Functions
 - Mechanical support and structure
 - Intracellular transport of materials
 - Suspension of organelles
 - Formation of adhesions with other cells
 - Contraction
 - Movement

Cytoskeletal Filaments

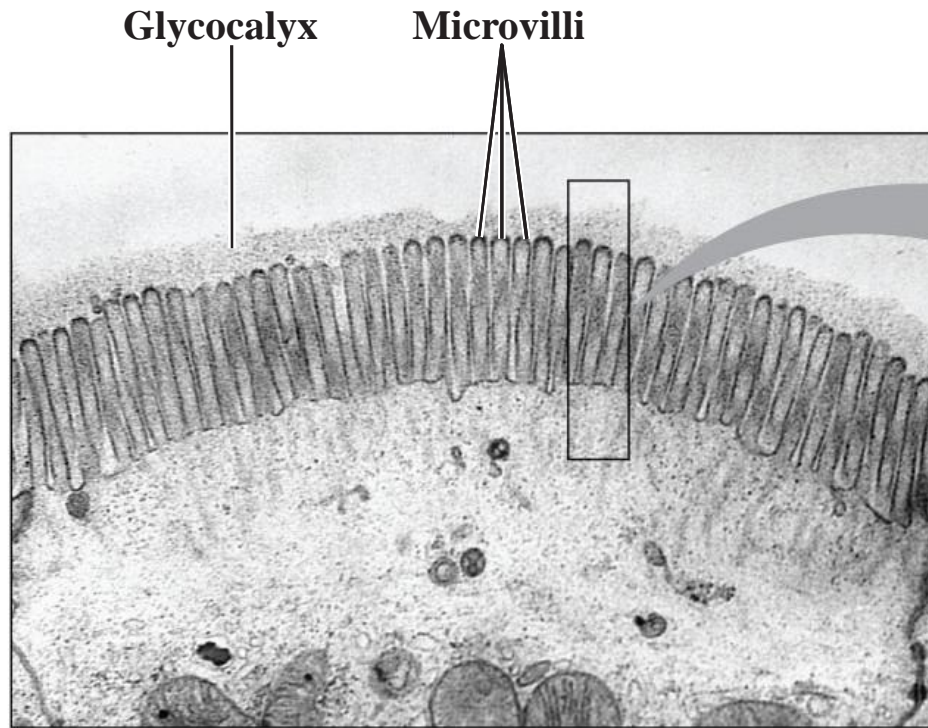




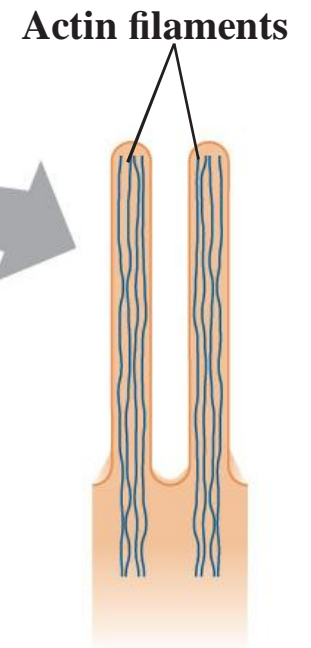
Microfilaments



**Microfilament
(actin)**



(b)



Microvilli

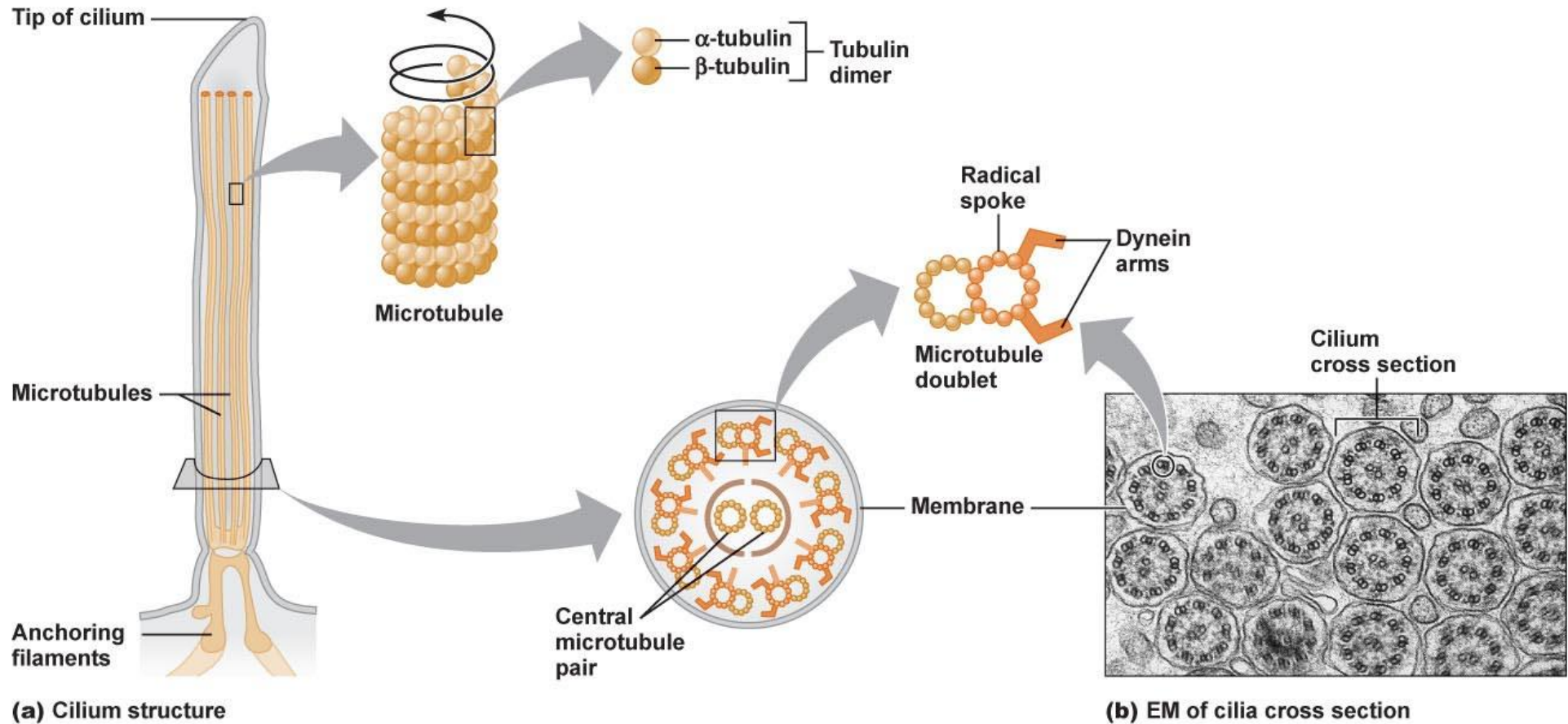
Microfilaments Functions :

- 1. 構成細胞的支架，維持細胞的形態**
- 2. 參與肌肉收縮**
- 3. 參與細胞分裂**
- 4. 參與細胞運動**
- 5. 參與細胞內物質運輸**
- 6. 參與細胞內訊息的傳輸**
- 7. 構成細胞間的連接構造**

Intermediate Filament Functions :

1. 促成細胞網狀骨架結構的完整
2. 為細胞提供機械強度支持
3. 參與細胞接合
4. 參與細胞內訊息傳遞和物質運輸
5. 參與維持細胞核膜穩定
6. 參與細胞分化
7. 參與基因表現

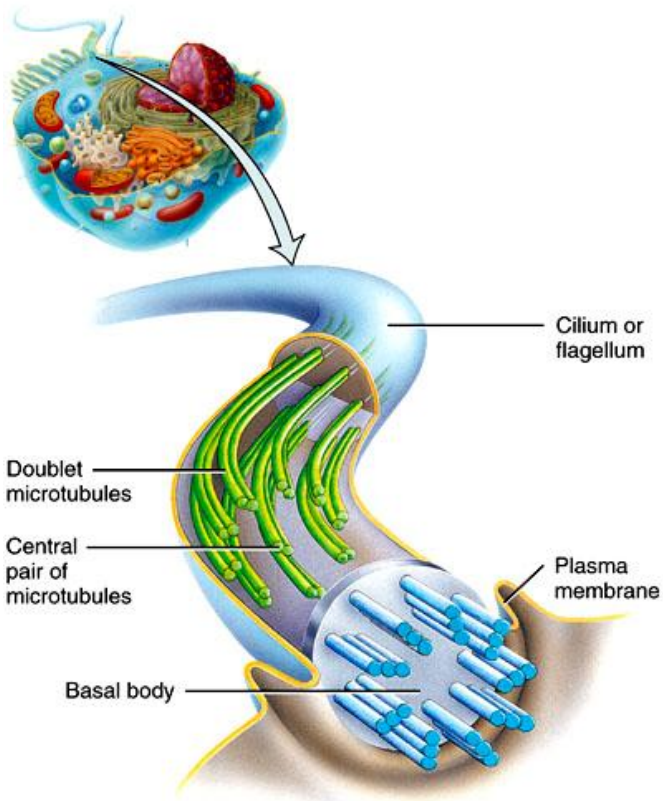
Microtubules



Microtubules Functions :

- 1. 構成細胞內網狀支架，維持細胞形態**
- 2. 參與細胞內物質運輸**
- 3. 維持細胞內胞器的定位和分布**
- 4. 參與中心粒、纖毛和鞭毛的形成**
- 5. 參與染色體運動，調節細胞分裂**
- 6. 參與細胞內訊息傳輸**

Cilia and Flagella



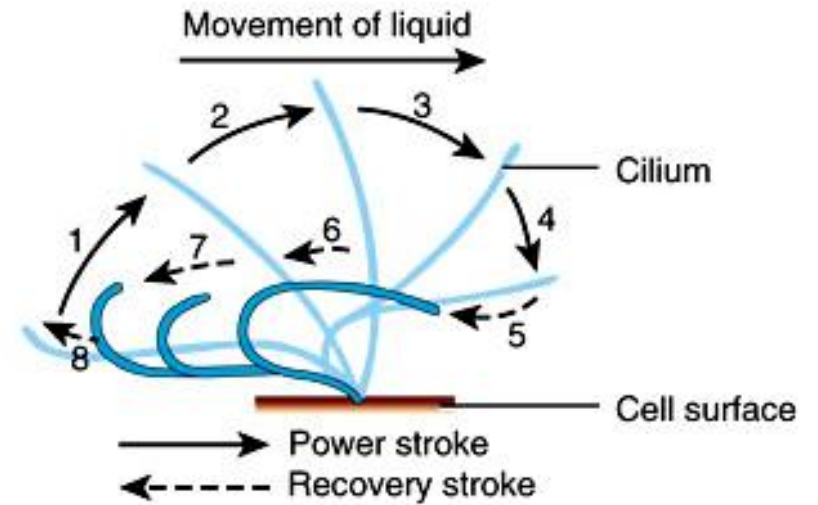
(a) Arrangement of microtubules in a cilium or flagellum



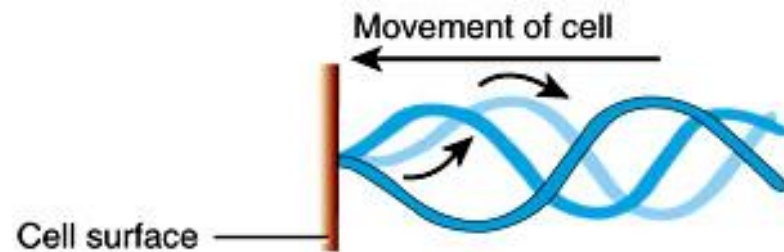
Cilia
(b) Cilia lining the trachea



(c) Flagellum of a sperm cell



(b) Ciliary movement

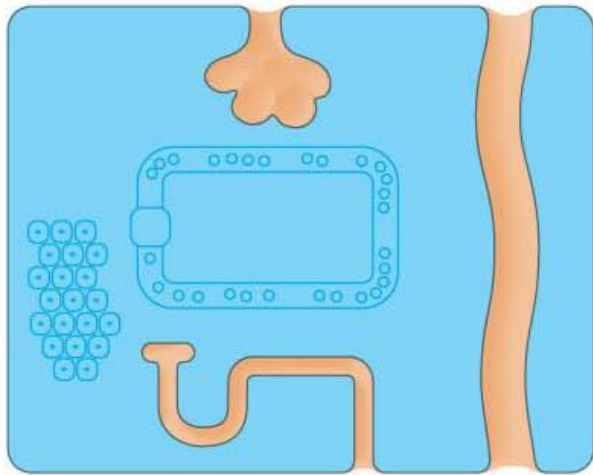


(c) Flagellar movement

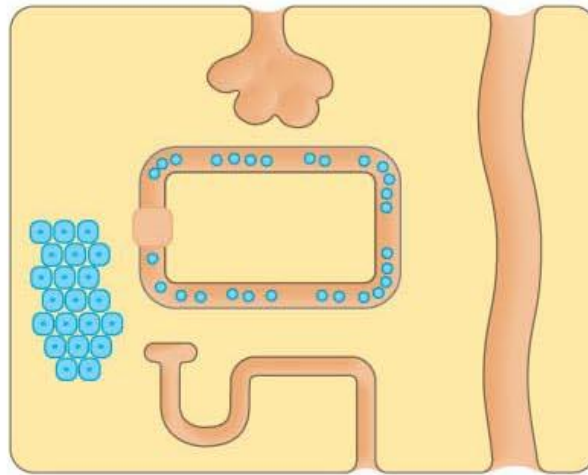
Body Fluid Compartments

- Maintaining the volume and composition of body fluids are important
 - **Body fluids** (TBW = total body water) are defined as dilute, watery solutions containing dissolved chemicals inside or outside of the cell
 - **Intracellular Fluid (ICF)**
 - Fluid within cells
 - **Extracellular Fluid (ECF) = “internal environment”**
 - Fluid outside cells
 - **Interstitial fluid** (3/4) is ECF between cells and tissues
 - **Blood Plasma** (1/4) is ECF within blood vessels

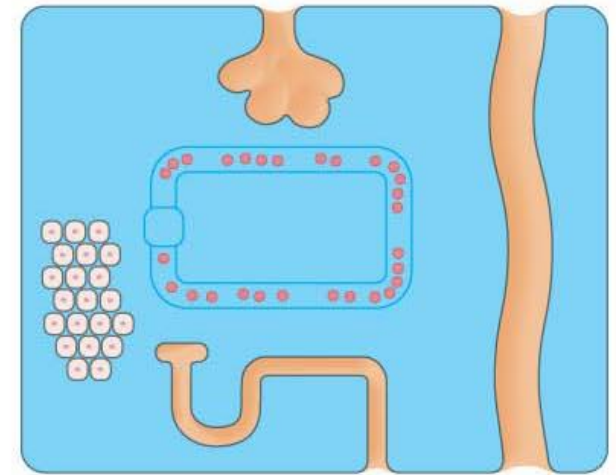
Body Fluid Compartments



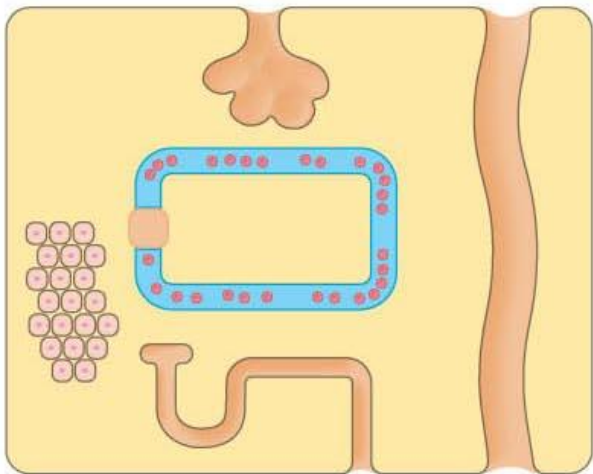
(a) Total body water (TBW)



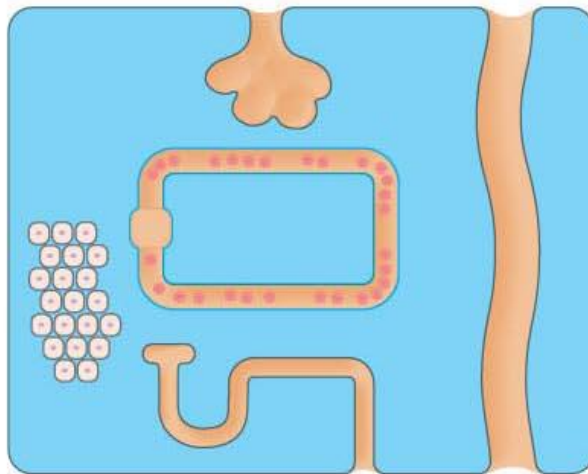
(b) Intracellular fluid (ICF)



(c) Extracellular fluid (ECF)



(d) Plasma

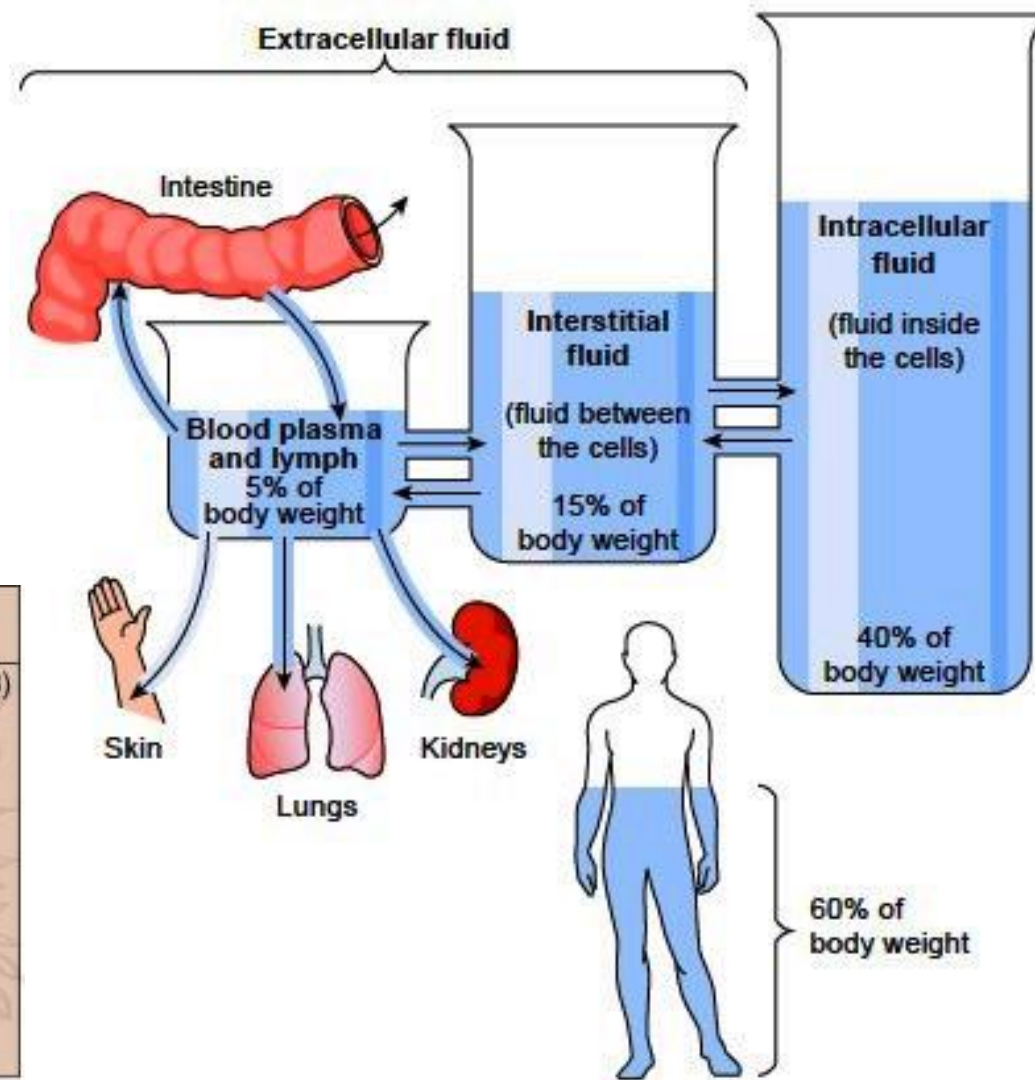


(e) Interstitial fluid (ISF)

Body fluid	Volume (L)
TBW	42
ICF	28
ECF	14
Plasma	3
ISF	11

(f) Distribution of TBW

Total Body Water



Intracellular Water (2/3)	Extracellular Water (1/3)	
	Interstitial (2/3)	Blood (1/3)
25	Na	140
150	K	4.5
15	Mg	1.2
0.01	Ca	2.4
2	Cl	100
6	HCO ₃	25
50	Phos	1.2