



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
الَّذِي عَلَّمَ بِالْقَلَمِ ۖ عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ ۝

CYTOLOGY

MID | Lecture 1

Introduction to Cell Biology

Reviewed by:

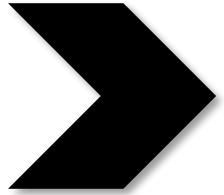
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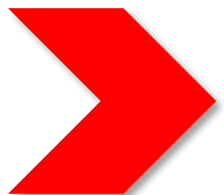
Black: the original slides



Orange: the doctor's explanation/words

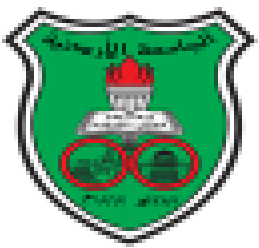


Gray: additional information and explanation



Red: important information

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Course outline (1)

Cell Biology Part

Focus on diseases

- Introduction and biomembranes
- Endoplasmic reticulum and protein sorting
- Golgi apparatus
- Vesicular network
- Mitochondria and mitochondrial diseases
- Peroxisomes
- The nucleus
- Cytoskeletal networks
- The extracellular network
- Cell signaling, proliferation, differentiation, and death
- The biology of cancer

Course outline (2) Molecular Biology Part

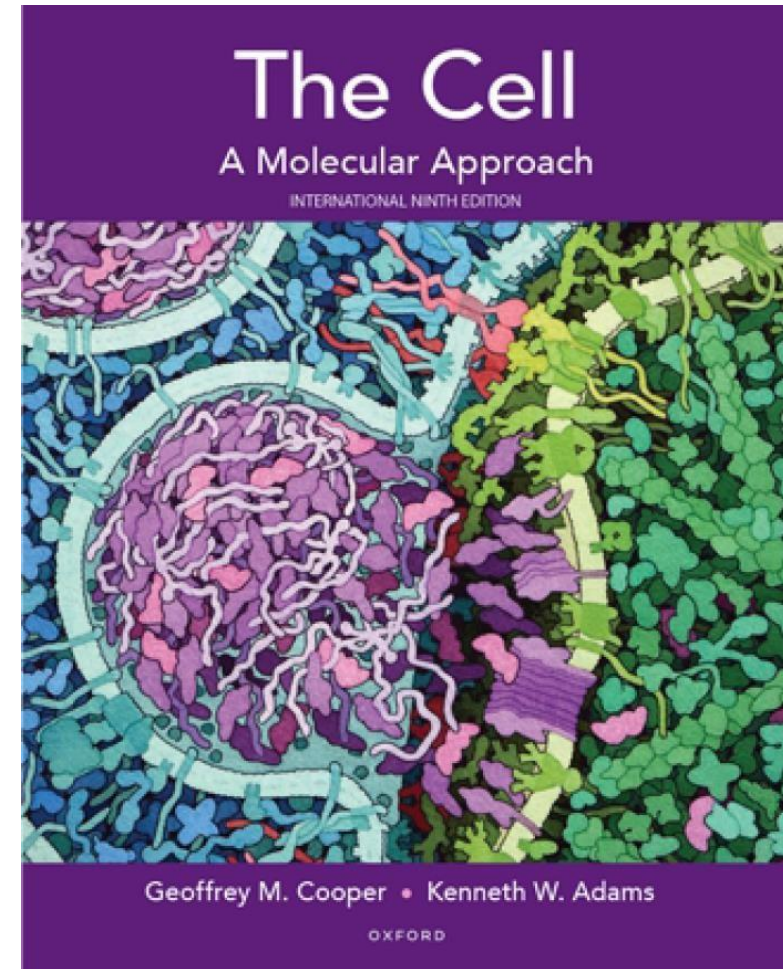


Focus on processes and techniques

- Overview of nucleic acids and gel electrophoresis
- The concept and utilization of the (de/re)naturaton concepts
 - Dot blotting and Southern blotting
- Restriction endonucleases, recombinant DNA technology, DNA cloning, and RFLP
- The central dogma of molecular biology DNA replication
- PCR and DNA sequencing
- The human genome
- Transcription, mechanisms of regulation, and epigenetics
 - Coding and non-coding RNAs
- RNA detection, quantification, and detection
- Translation
- Yeast two-hybrid system
- DNA mutations
- DNA repair and CRISPR-Cas9

The textbook

- **The Cell: A Molecular Approach**, [Geoffrey M. Cooper](#) and Kenneth W. Adams, 9th edition, Sinauer Associates, 2023.



The cell



➤ we classify living creatures to three kingdoms :

1) Eukaryotes (true nucleus and nuclear membrane).

2) Prokaryotes (simply bacteria , don't have nucleus or nuclear membrane or any membrane bound organelle).

3) Archaea (something in between , they have prokaryotic and eukaryotic features , some of them exist in the dead sea).

➤ We will focus on eukaryotic cells and their organelles .

➤ In addition to nucleus , Eukaryotic cells has :

1) Mitochondrion.

2) Lysosomes.

3) Golgi apparatus.

4) Endoplasmic reticulum.

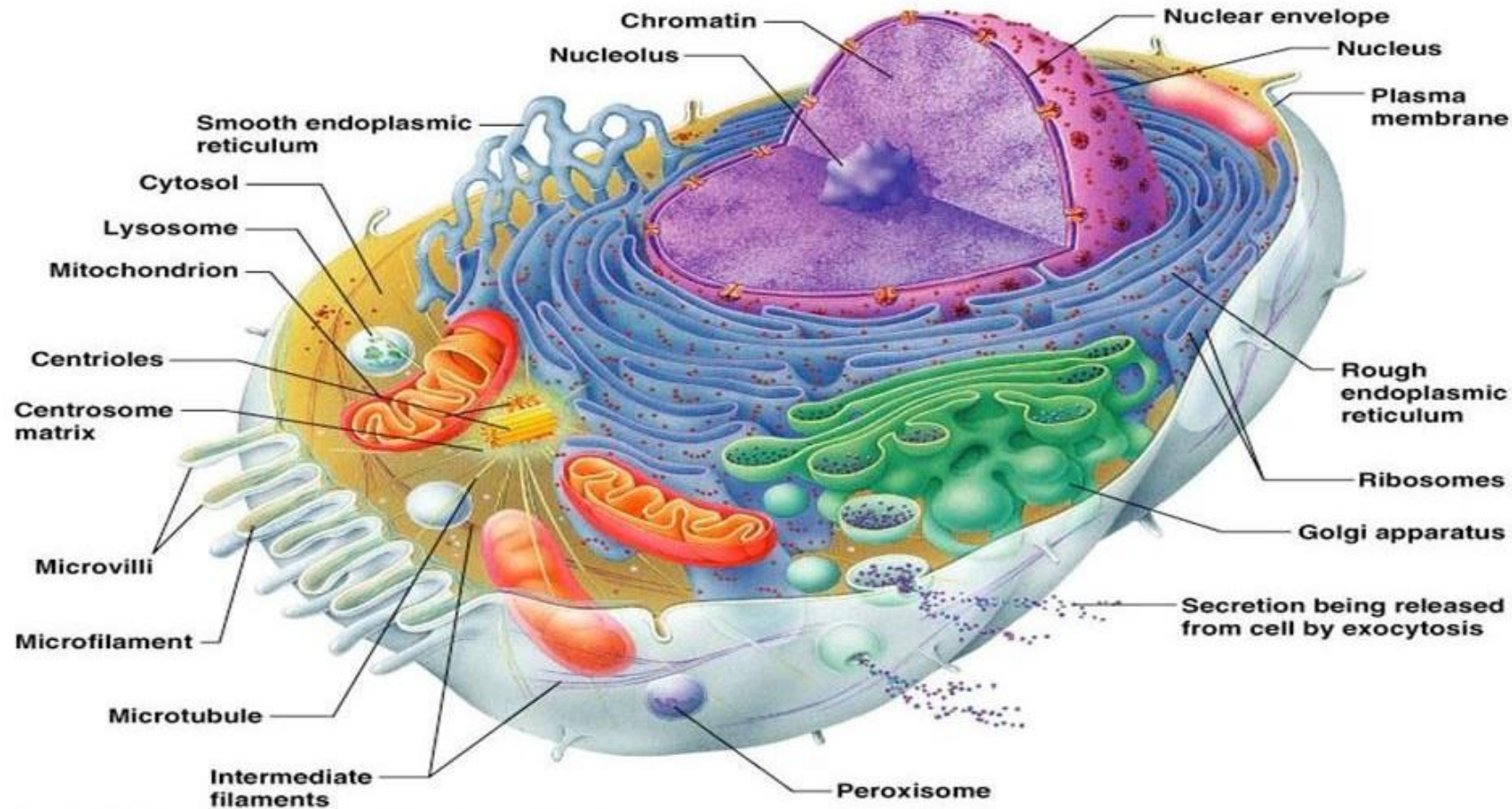
5) Peroxisomes.

➤ And many other structures (as shown in the next slide).

Mitochondria : plural
Mitochondrion : single

The cell

Organelles don't swim alone in the cytosol, instead they are attached to each other by cytoskeletal components (microtubules, microfilaments, intermediate filaments)



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What organisms do we use to study cells?

The idea is that we want to study human cells, but we can't do experiments on human because it is not ethical.

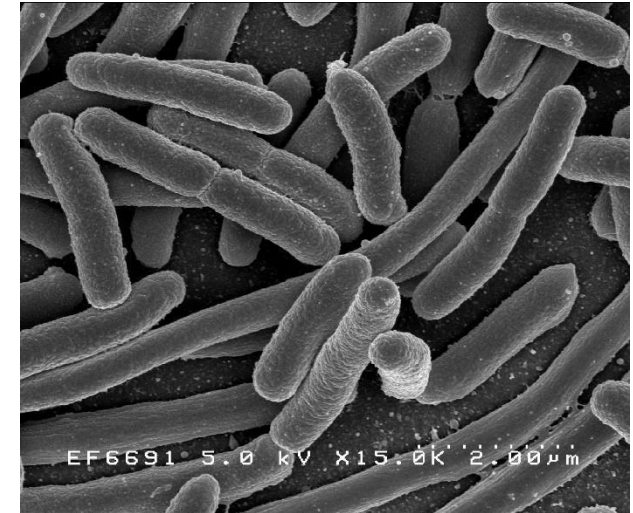
We use model systems (which are organisms) to study and understand cells. They can be as primitive as viruses and bacteria and they can be more advanced.

- **Escherichia coli (E. coli)**

- Bacteria, why? Because :

- 1) **its molecular mechanisms are similar to molecular mechanisms of human cells.**
- 2) **unicellular.**
- 3) **They are the most studied type of bacteria.**
- 4) **It includes up to 4000 protein coding genes.**
- 5) **Exist in rotten meat it can be fatal.**

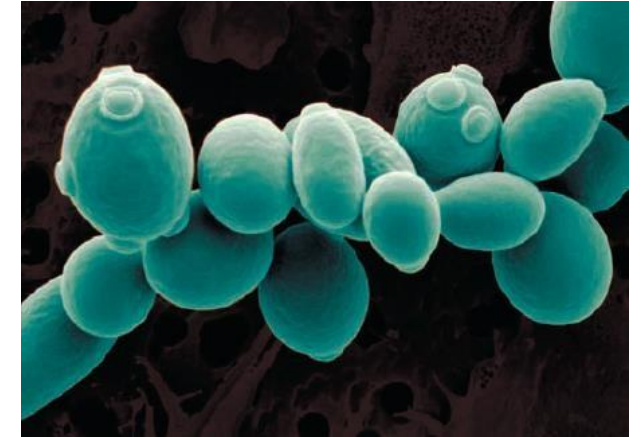
- So, by simple cells I can understand complex systems like human cells.



- Yeast (*Saccharomyces cerevisiae*)

What makes Yeast good as a model for understanding human cells that :

- They are **eukaryotes cells** : have nucleus and nuclear membrane.
- their **molecular system is complex** like humans (the same cellular mechanism in both),but its still relatively simple.
- they have **linear chromosomes** like humans (4 chromosomes) but in bacteria it is single and circular.
Its nucleus has 6000 genes.
- **unicellular** (so easier to study).
- as an example (*saccharomyces cerevisiae*).



But there is problem that they **aren't differentiable** so there is no nervous or digestive system etc.



There is a protein called RAS protein :

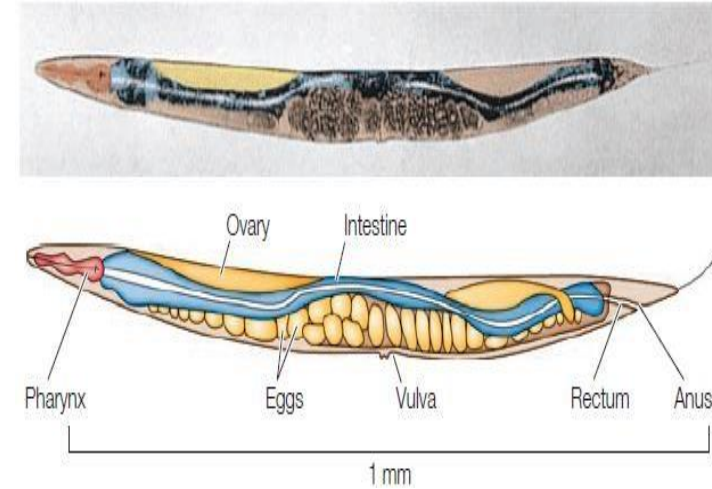
It's a small monomeric G-Protein activated by GTP found in specific types of yeast and viruses.

It causes cells to grow and proliferate and it's a Proto-oncogene (**a gene that is in a highly active state can cause cancer**) although it still has normal functions such as regulating cell division.

Over 90% of pancreatic cancer is caused by mutations of RAS gene as well as 50% of colon cancer cases.

So in order to study the effect of the RAS gene on humans, it has been studied in yeast and viruses.

- **Caenorhabditis elegans** (C-Elegans)
 - it is a microscopic worm
 - it is complex **multicellular systems** (opposite to yeast, its cells are **differentiable**).
 - It has (1079) cells (we know every single cell and its function).
 - when it matures they become (959) cells.
The decline of cells is because of **cell programmed death (apoptosis)** which use **the same proteins genes and mechanisms** in human body. therefore, they could be easily studied by this worm.
Using C-elegans helped us understand the way cell differentiation and apoptosis happen.





Drosophila melanogaster (fruit fly) :

Fruit fly has been studied to understand symmetry and cell differentiation.

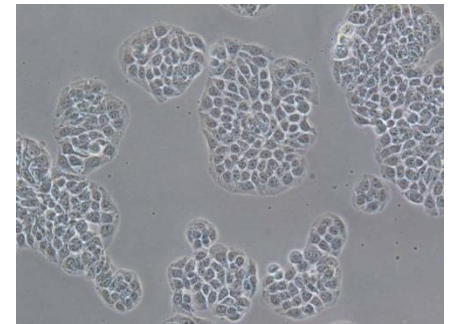
It is symmetrical (right and left, head and tail).

It is composed of different systems and organelles ex. nervous and GI.

It is also studied to understand how Metastasis occurs (the spread of cancer from its original location to other locations within the body).

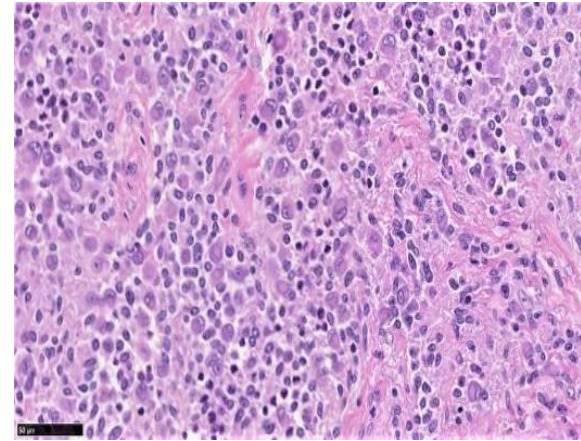


- Mice (more complicated)
 - Mice better than monkeys, rabbits and other animals because they reproduce very fast, its also unethical to use primates such as apes or dogs.
 - Mice have the same number of protein-coding genes as in humans, but different regulation mechanisms gives completely different creatures.
- Cultured cells and tissues (specifically human cells)
 - We isolate these cells (mainly cancer cells) from a human and then grow them. The problem here is they do not exist in a real system to work effectively (isolated from other kinds of cells) .



- They are immortal so they continue to divide and they can be manipulated easily by changing DNA to understand their behavior and function of proteins.
- Also we could use tissues section like in histology using a lot of methods like immunohistochemistry to study the molecular composition of these cells.

Experiments can be done at humans but only in the last stages in what is called clinical trials to check whether specific drugs are functional or not.



Nobel prize 2026



Karl Deisseroth

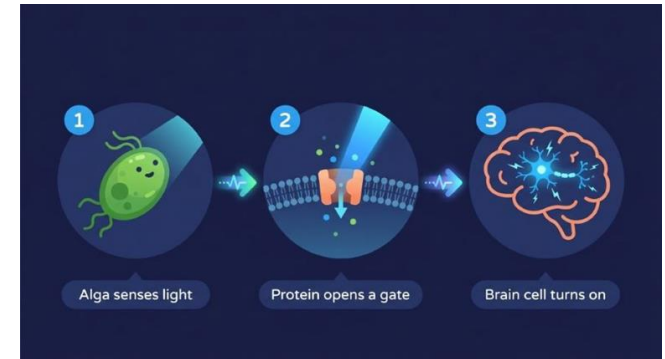


Peter Hegemann



Georg Nagel

**Nobel Prize Winners in Physiology
or Medicine 2026 Announced**





Nobel Prize 2026 for medicine has been given due to the discovery of a protein called channelrhodopsin in a type of algae.

Algae are found in water and composed of single cells , when pointing light at specific part of the plate the algae moves towards it, this lead to the discovery of channelrhodopsin which is a channel protein that can be activated by light.

When the gene for this protein was given to mice changes in the mice behavior and physiological changes occurred in them when exposed to light.

Nucleus

Nuclear envelope: membrane enclosing the nucleus. Protein-lined pores allow material to move in and out.

Chromatin: DNA plus associated proteins.

Nucleolus: condensed region where ribosomes are formed.

Peroxisome: metabolizes waste

Endoplasmic reticulum

Rough: associated with ribosomes; makes secretory and membrane proteins.

Smooth: makes lipids.

Cytoskeleton

Microtubules: form the mitotic spindle and maintain cell shape.

Centrosome: microtubule-organizing center.

Intermediate filaments: fibrous proteins that hold organelles in place.

Microfilaments: fibrous proteins; form the cellular cortex.

Plasma membrane

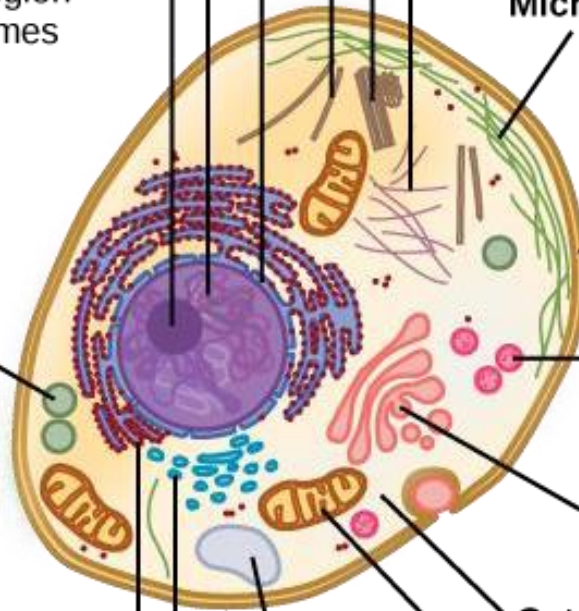
Lysosome: digests food and waste materials.

Golgi apparatus: modifies proteins.

Cytoplasm

Mitochondria: produce energy.

Vacuole



For more understanding :

[Cell Cross Section | BioDigital Human Platform](#)

Organelles

TABLE 4-2 *Organelles*

Organelle	Function
Mitochondrion	transfers energy from organic compounds to ATP Regulates apoptosis as well
Ribosome	organizes the synthesis of proteins
Endoplasmic reticulum (ER)	prepares proteins for export (rough ER); synthesizes steroids, regulates calcium levels, breaks down toxic substances (smooth ER)
Golgi apparatus	processes and packages substances produced by the cell
Lysosome	digests molecules, old organelles, and foreign substances
Microfilaments and microtubules	contribute to the support, movement, and division of cells
Cilia and flagella	propel cells through the environment; move materials over the cell surface
Nucleus	stores hereditary information in DNA; synthesizes RNA and ribosomes
Cell wall*	supports and protects the cell
Vacuole*	stores enzymes and waste products
Plastid*	stores food or pigments; one type (chloroplast) transfers energy from light to organic compounds

*Cell walls, large vacuoles, and plastids are found in the cells of plants and some other eukaryotes, but not in the cells of animals.



Major molecular components of cells

➤ Macromolecules :

1. Nucleic acids
 2. Carbohydrates
 3. Proteins
 4. Lipids (50% of mass of plasma membranes, 40% proteins and about 10% sugar molecules. 30% of mitochondrial membranes)
- Molecules function by interacting with each non-covalently.

Which governs the biochemical life of the cell. Ex : interaction between ligand and its receptor is non covalent interaction (electrostatic , hydrophobic, Hydrogen bond ..)



How do we study cell components?

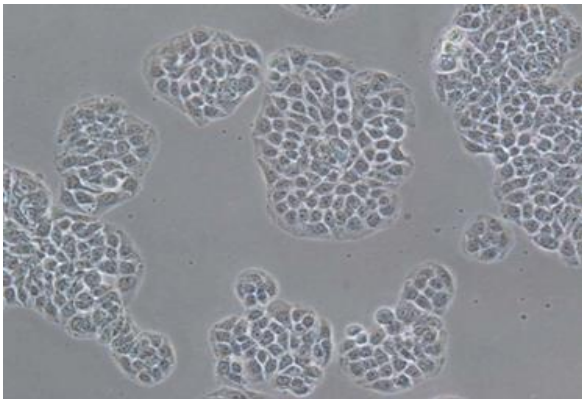
Cell and protein detection

1. Microscopy
2. Cell Fractionation

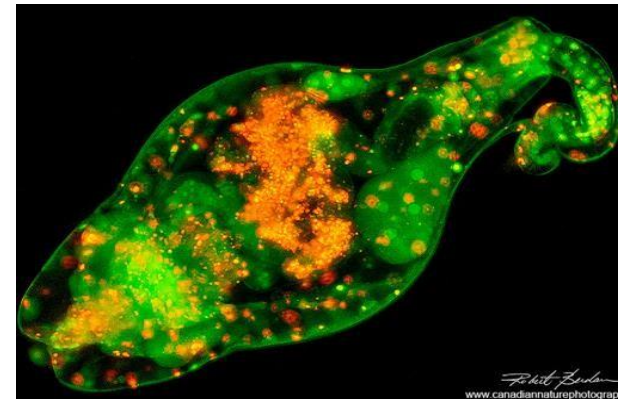
Microscopy

Light Microscopy :

- Immunofluorescence: antibodies (have specific tag molecule which makes the antibody fluorescent) that targets specific proteins inside the cell so the protein lights up (this light comes from antibodies not proteins as there are some colorful enzyme-dependent reaction, so if antibodies bind to that specific protein a color-producing reaction will occur). This technique shows whether a cell has a specific protein or not.



Light Microscopy Image

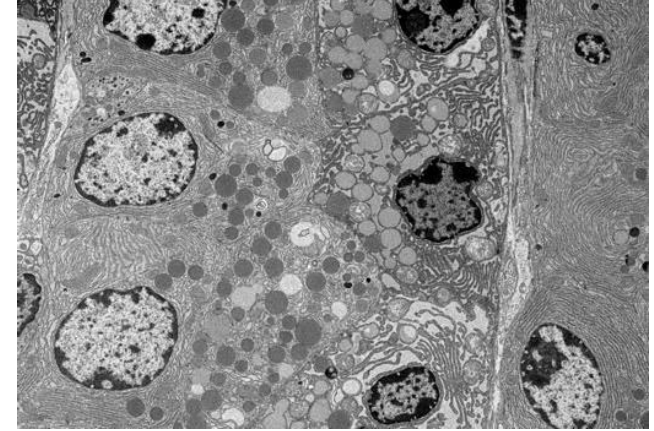


Immunofluorescence image

Electron microscope:

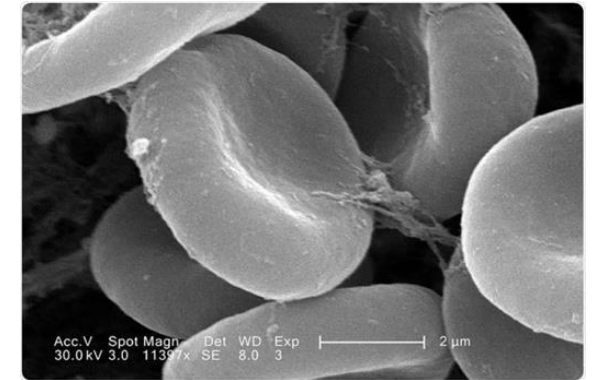
-Zooming into specific organelles (peroxisomes, mitochondria..) with high magnification.

-It has high resolution so I can look at specific molecules like glycogen and DNA but not nucleic acids.



Electron microscope image.

-Scanning electron microscope : 3D image that determine the studied structure's shape



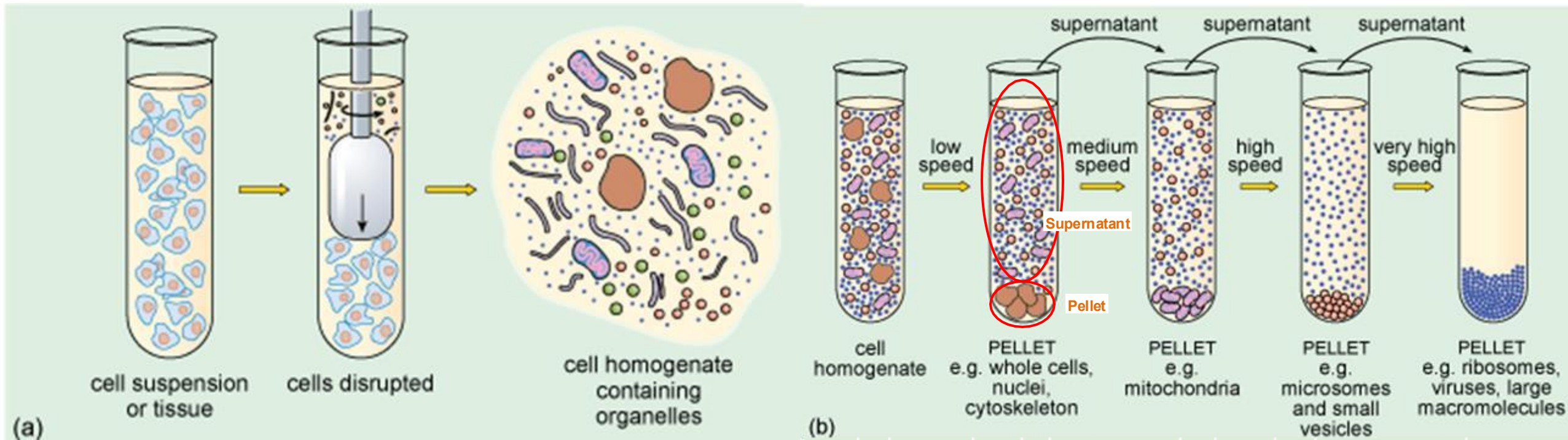
Scanning electron microscope image.



-A human has about 20,000 genes that express specific proteins (this is the total number from different types of cells), however, a specific type of cell doesn't have this many genes, it might have 5000 or so depending on the cell type and the proteins it synthesizes (muscle cell, blood cell, neurons..)

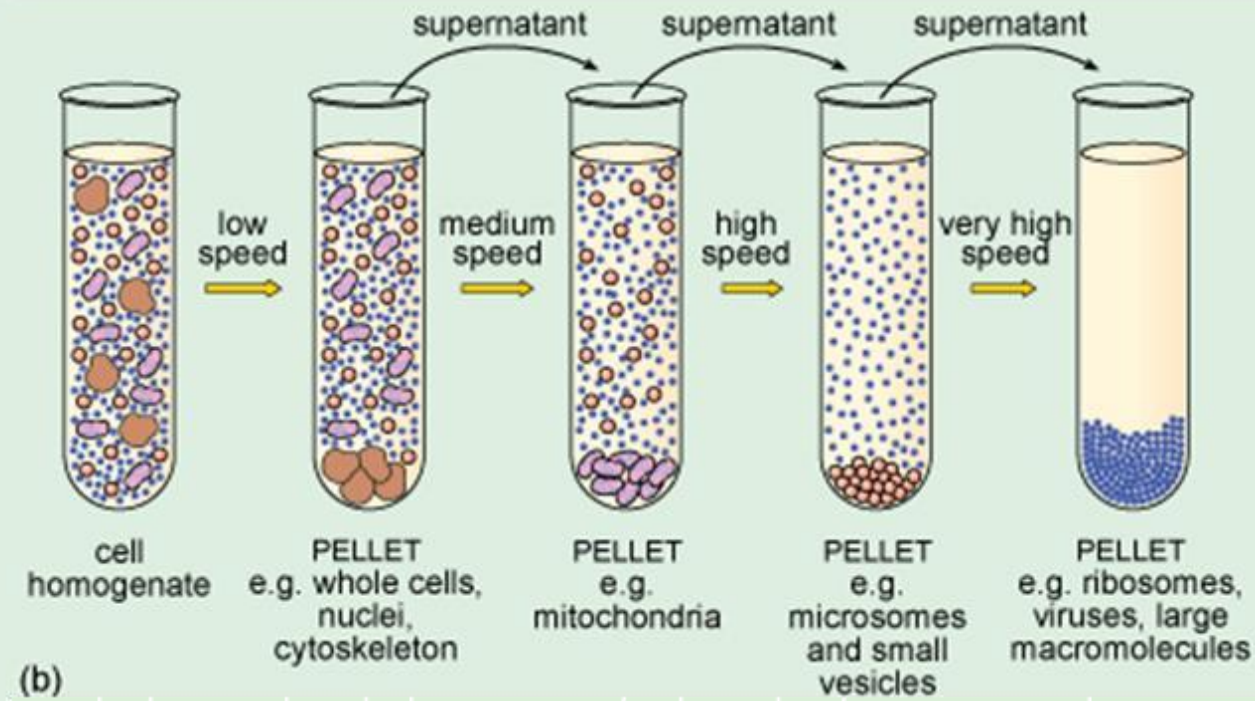
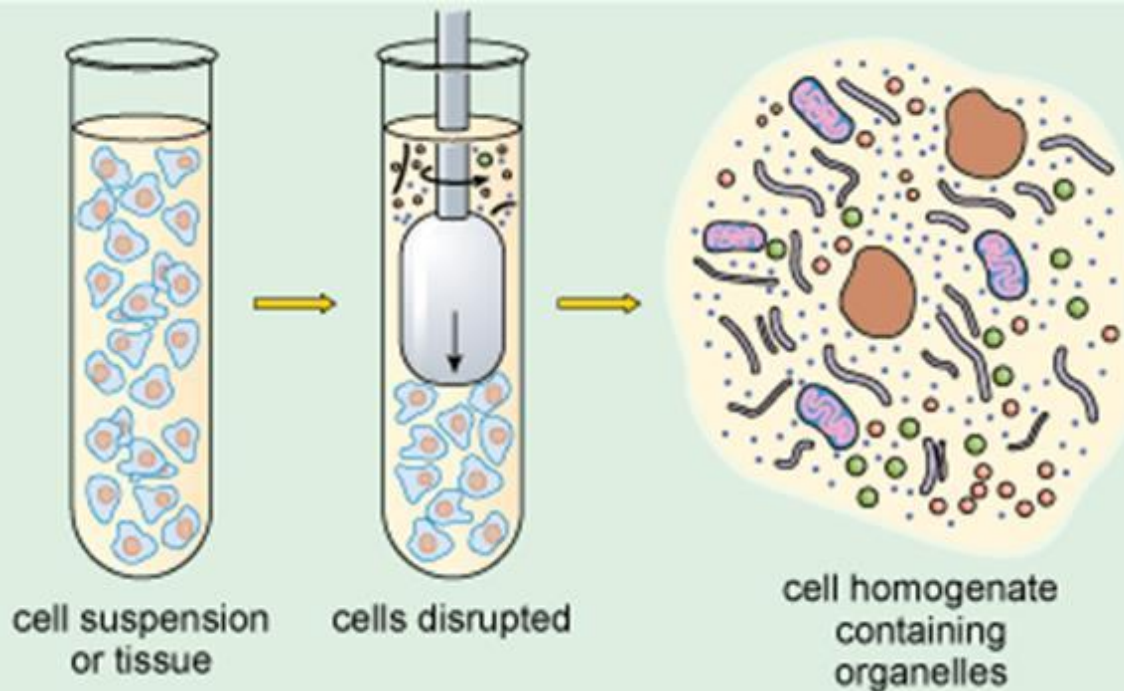
Cell Fractionation

When I want to study a specific protein, how can I isolate it? We break the cells, hence different organelles are now released from the cell (nucleus, mitochondria, ..) so now **we use centrifugation**, the sample spins at different speeds, which gives rise to **heavy things sinking (pellet)** and **light things will be in liquid above and we call this liquid (supernatant)**.

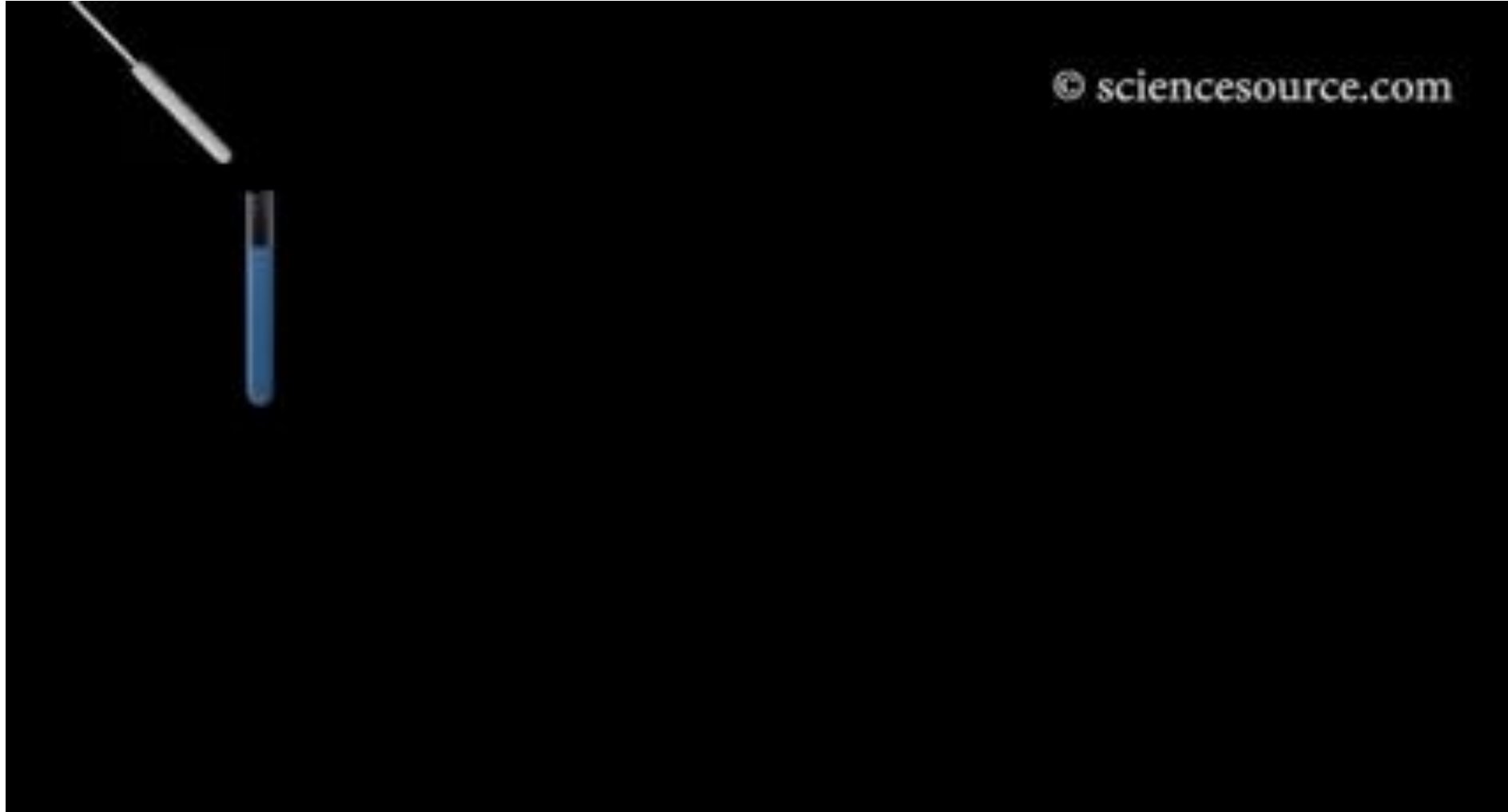


Cell Fractionation

The speed is being increased progressively. At low speed, the whole unbroken cells sink and nuclei and cytoskeleton, then we take the liquid (supernatant) to other tube and increase the speed (medium 5000 revolution per minute) there will be new pellet consist of mitochondria (*by this now I have mitochondrial protein alone*), then once again centrifugation with higher speed, the pellet will contain vesicle organelles like lysosome and peroxisomes, finally, really high speed 100000 revolutions/min is used, very light structures will make the pellet like ribosomes, macromolecule.



<https://www.facebook.com/reel/792265814706206>



Biochemical composition of plasma membranes

Memorize the underlined numbers(not the exact numbers but approximately)



Membrane	Protein (%)	Lipid (%)	Carbohydrate (%)	Weight fraction of protein	Ratio of protein to lipid
Plasma membranes					
Myelin Coating the axon	18	<u>79</u>	3	0.18	<u>0.23</u>
Blood platelets	33—42	<u>51—58</u>	7.5	0.4	0.7
Mouse liver cells	46	54	2—4	0.46	0.85
Human erythrocytes	<u>49</u>	43	8	0.49	<u>1.1</u>
Amoeba	54	42	4	0.54	1.3
Rat liver cells	58	42	(5—10)*	0.58	1.4
HeLa cells	60	40	2.4	0.6	1.5
Nuclear envelope of rat liver cells	59	35	2.9	0.59	1.6
Retinal rods, bovine	51	49	4	0.51	1.0
Mitochondrial outer membrane	<u>52</u>	48	(2—4)*	0.52	<u>1.1</u>
Sarcoplasmic reticulum	67	33	—	0.67	2.0
Chloroplast lamellae, spinach	70	30	(6)*	0.7	2.3
Mitochondrial inner membrane	<u>76</u>	24	(1—2)*	0.76	3.2
Gram-positive bacteria	75	25	(10)*	0.75	3.0
<i>Halobacterium</i> purple membrane	75	25		0.75	3.0

Large amounts of protein are needed for ATP synthesis



Biochemical composition of plasma membranes

There are different types of membranes like plasma ,nuclear ,and mitochondrial membranes (which are inner and outer) and there are different type of cells like immune cells, red blood cells , neural cells, so we don't expect they have the same composition of membranes. An example regarding to function is mitochondrial inner membrane, look at proteins' percent (should be high due to electron transport proteins (76%), but the outer membrane has (52%)) .

Myelin	18	<u>79</u>	3	0.18	<u>0.23</u>
Mitochondrial inner membrane	<u>76</u>	24	(1—2)*	0.76	32
Retinal rods, bovine	51	49	4	0.51	1.0
Mitochondrial outer membrane	<u>52</u>	48	(2—4)*	0.52	<u>1.1</u>



Lipid composition of organelles

Memorize the underlined numbers(not the exact numbers but approximately)

Table 1: Head group composition of the membranes of some mammalian liver cells, erythrocytes , and nerve cells in weight percent. Adapted from Jamieson and Robinson (1977). Abbreviations: PC = phosphatidylcholines, PE = phosphatidylethanolamines, PS = phosphatidylserines, PI = phosphatidylinositols, SM = sphingomyelin, CL = cardiolipin.

Membrane	PC	PE	PS	PI	SM	CL	Glycolipid	Cholesterol	Others
Erythrocyte (human)	20	18	7	3	18	–	3	20	11
Plasma (rat liver)	18	12	7	3	12	–	8	19	21
ER	48	19	4	8	5	–	tr	6	10
Golgi	25	9	3	5	7	–	0	8	43
Lysosome	23	13	–	6	23	≈ 5	–	14	16
Nuclear membrane	44	17	4	6	3	1	tr	10	15
Mitochondria	38	29	0	3	0	<u>14</u>	tr	<u>3</u>	13
Neurons	48	21	5	<u>7</u>	4	–	3	<u>11</u>	1
Myelin	11	17	9	1	8	–	<u>20</u>	<u>28</u>	6

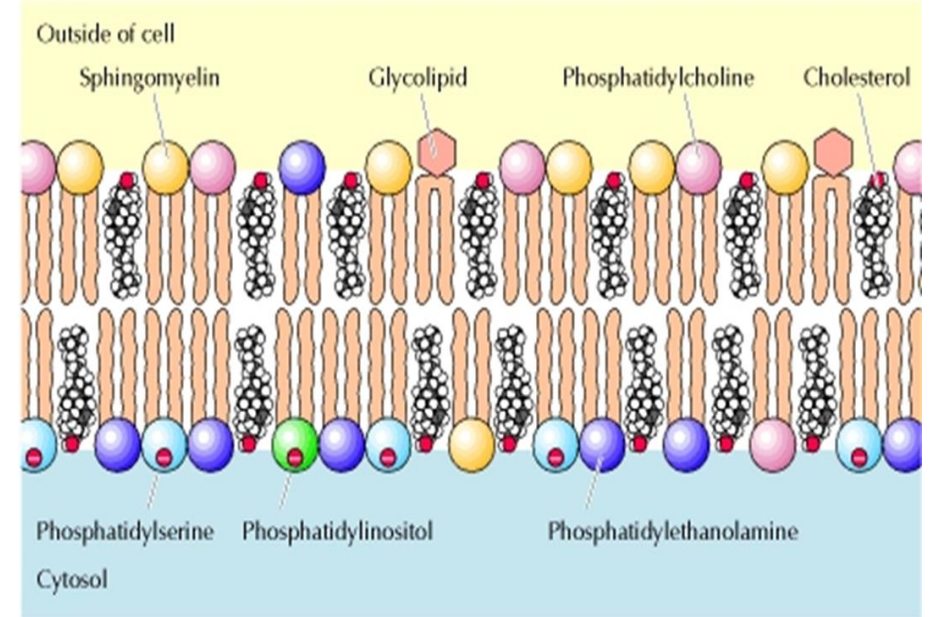
Myelin a high amount of lipids (especially glycolipids)

Cholesterol is an essential component of animal plasma membranes. It is not present in bacteria and plant cells, but the latter cells contain sterols.

Composition and properties of plasma membranes



- The phospholipids (mainly glycerophospholipids) are **asymmetrically** distributed between the two halves of the membrane bilayer.
- The outer leaflet: @choline, **sphingomyelin**
- The inner leaflet: @ethanolamine, @serine, @inositol (minor)
- @inositol has a role in cell signaling.
- Glycolipids are found **exclusively** on the outer membrane. For cell-cell interactions (immune system)



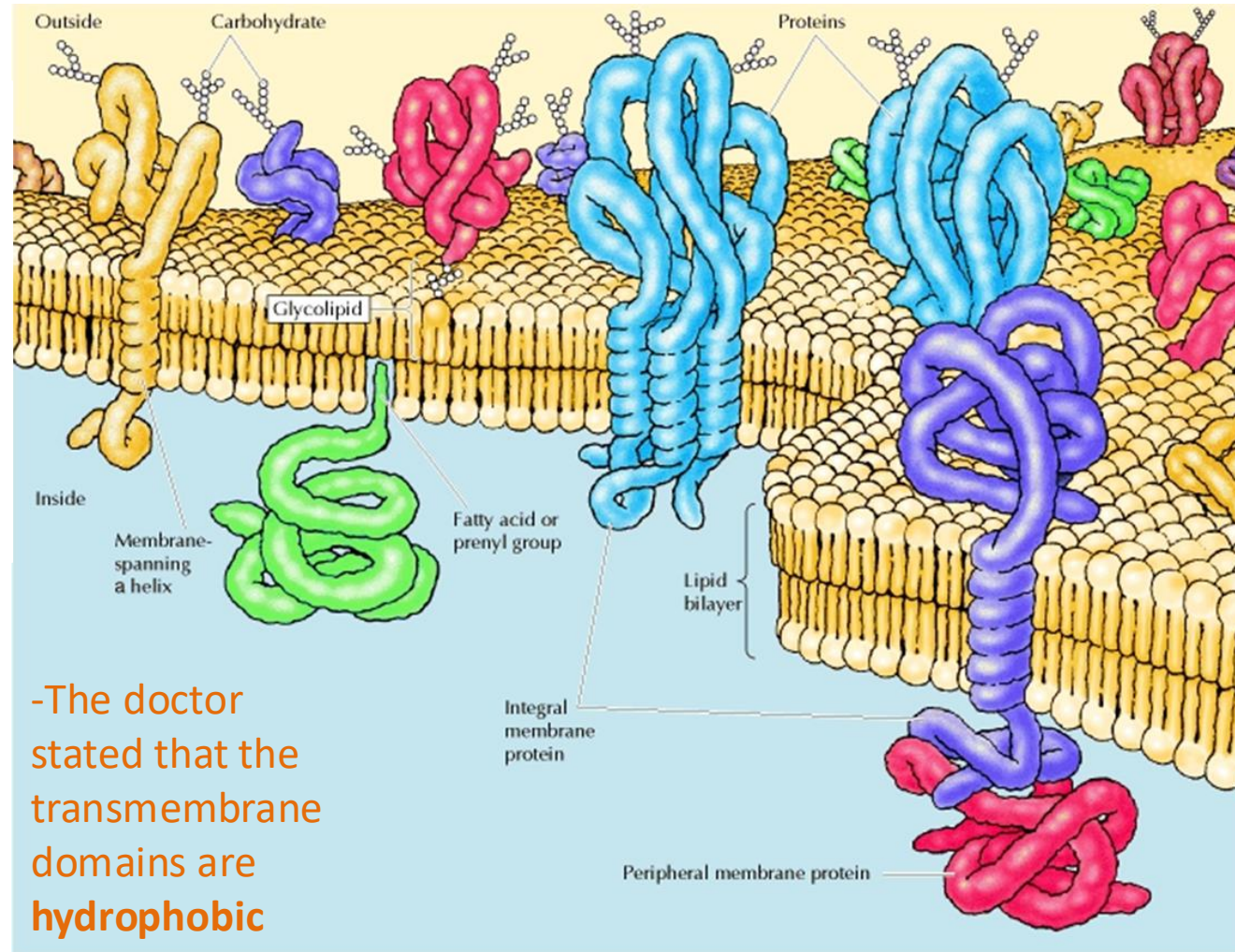
@ = Phosphatidyl...

Membrane proteins



-proteins can have different ways in association with the membrane. for example , many proteins integrate into the membrane(once or more, hence they have one or more transmembrane domaine)

-These transmembrane proteins are alpha helices in eukaryotes, beta strands in prokaryotes.



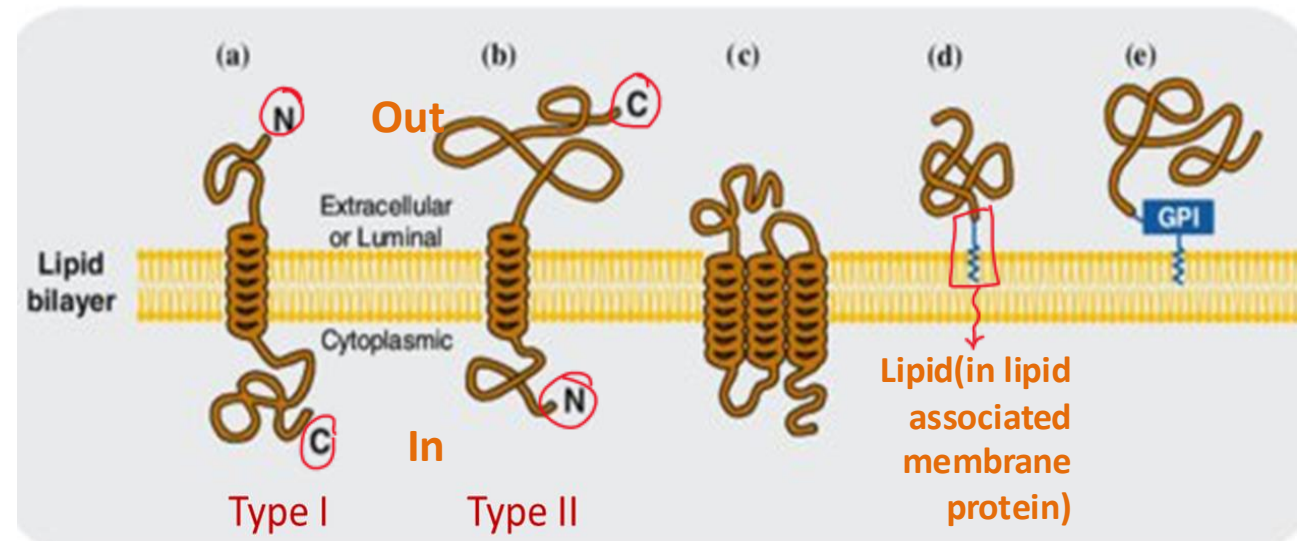
-The doctor stated that the transmembrane domains are **hydrophobic**

-Some proteins are partially integrated into the membrane, and some proteins associate with a lipid molecule that in turn binds the membrane.

-We also have proteins that are associated with a phospholipid in the membrane by an electrostatic interaction.

Types of membrane proteins

- Peripheral membrane proteins are indirectly and loosely associated with membranes through protein-protein interactions, mainly ionic bonds.
- Integral membrane proteins have some of their **helical** parts inserted into the lipid bilayer.
- Single-pass (type I or II) or multi-pass proteins.
- Lipid-anchored membrane proteins (myristoylation, palmitoylation , glycosyl-phosphatidylinositol)



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$V_0 \rightarrow V_1$			
$V \rightarrow V_1 V_2$			

Additional resources:

References Used:

Prof. Mamoun Ahram recorded lecture

Extra References for The Reader to Use:

The Cell: A Molecular Approach

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بإخلاص النية في سعيكم ودراستكم لله تعالى ، عسى
الله ان يوفقنا وإياكم لكل ما يحب ويرضى. 
اللهم يسر علينا وأفتح لنا فتوح العارفين ووفق كلاً منا
في دنياه وآخرته.

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