Biology is the theoretical basis of medicine. The cell is the structural and functional unit of living organisms.

Azerbaijan Medical University
Medical biology and genetics department
Presented by Assistant professor: Suleymanova Leyla

Lecture plan:

- 1. Biology is the theoretical basis of medicine.
- 2. Characteristics of living organism
- 3. Basic properties of cell
- 4. Plasma membrane
- 5. Cytoplasm
- 6. Cytoskeleton
- 7. Organelles of cell
- 8. Nucleus of cell
- 9. Mitosis
- 10.Meiosis
- 11. Cellular Aging and Cell Death

Biology is the theoretical basis of medicine.

- Biology is the science of life which studies the structure, function, growth, origin, evolution and distribution of living organisms.

The main methods of biology:

- **Descriptive**
- **Comparative**
- **Historical**
- **Experimental**

Descriptive method

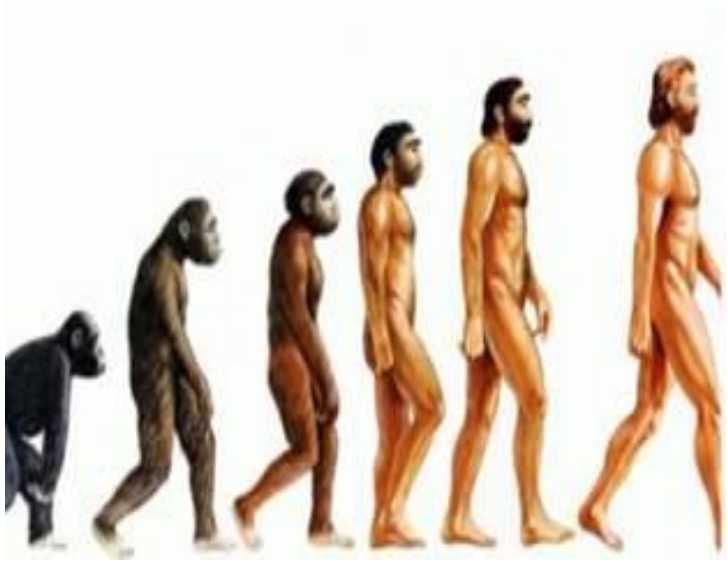
- The descriptive method is based on observation and used for description of new species.

Comparative method

- Comparative method allows to identify the similarities between organisms and their parts. It began to be used from the 17th century.
- This is a dynamic view of nature, where genotypes and phenotypes change over evolutionary time under the influence of natural selection.

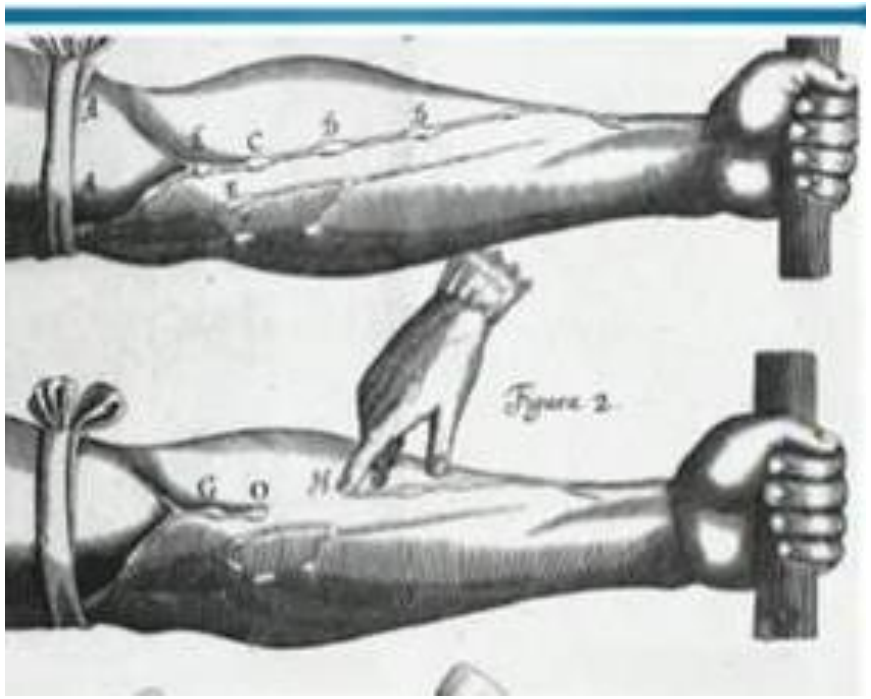
Historical method

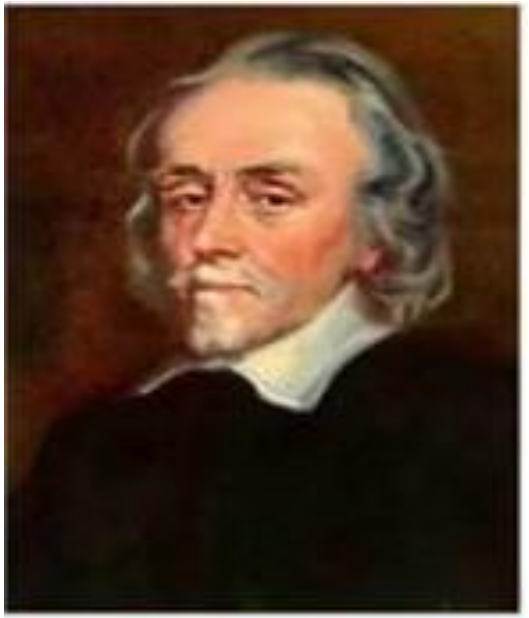
- The historical method makes possible to comprehend the facts obtained earlier and to compare them with previously known results.



Experimental method

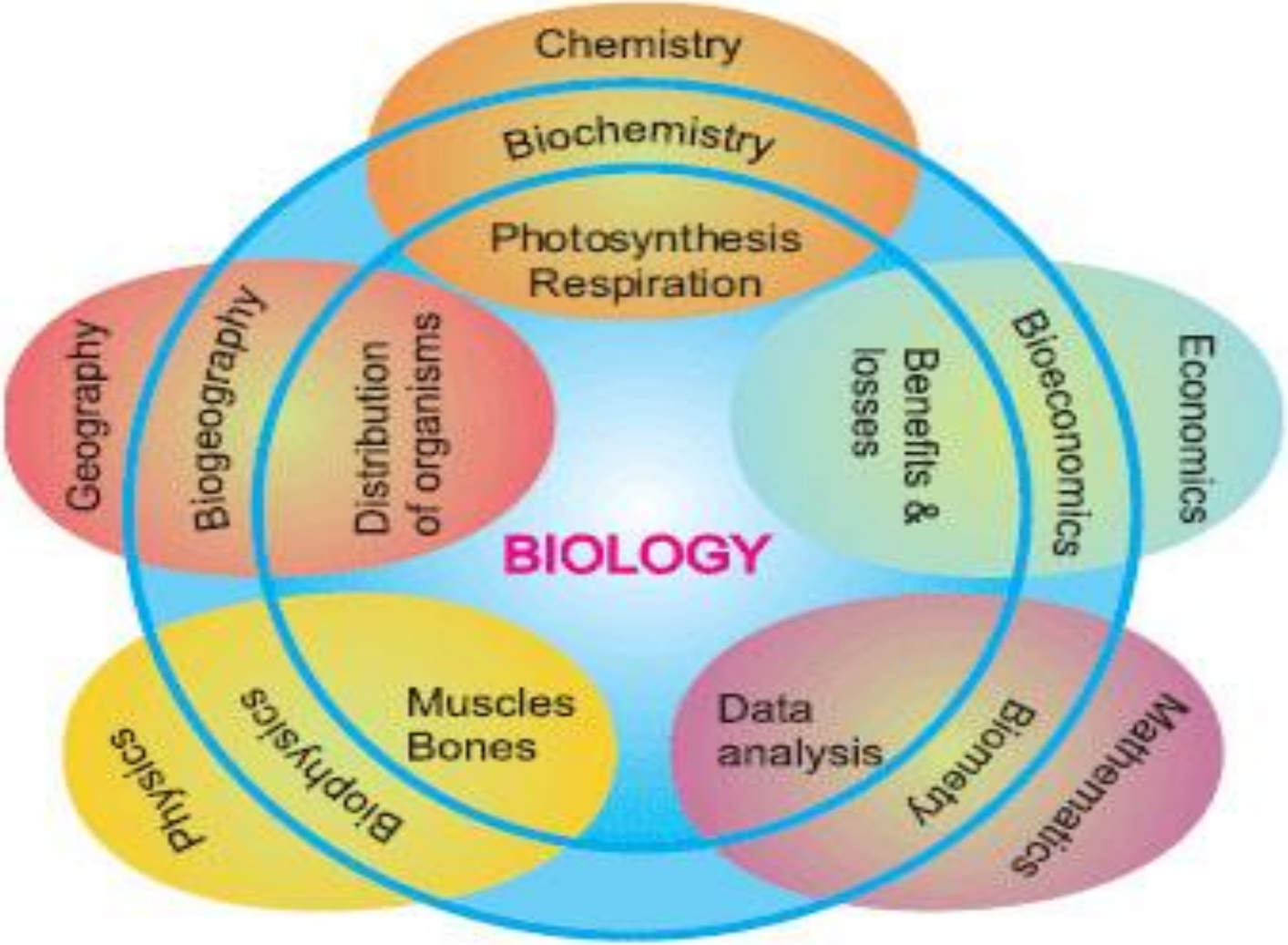
- The application of this method is associated with the name of William Garvey, who used it in his experiments on studying blood circulation.





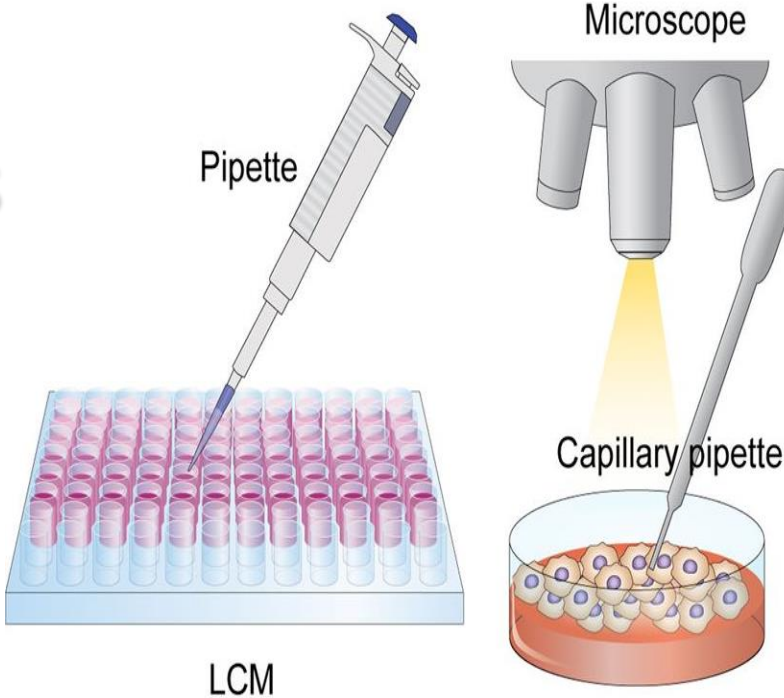
William Harvey
(1578–1657)

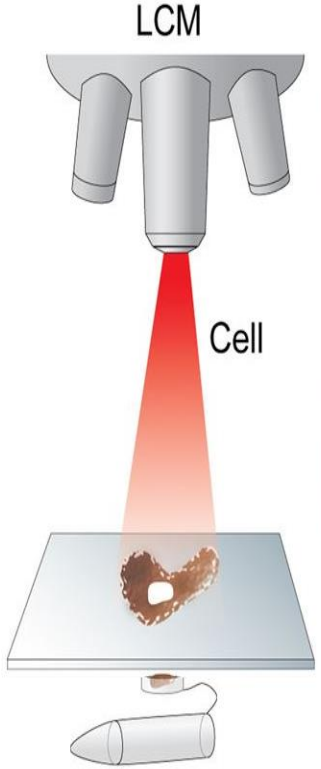
Relationship of Biology to Other Sciences



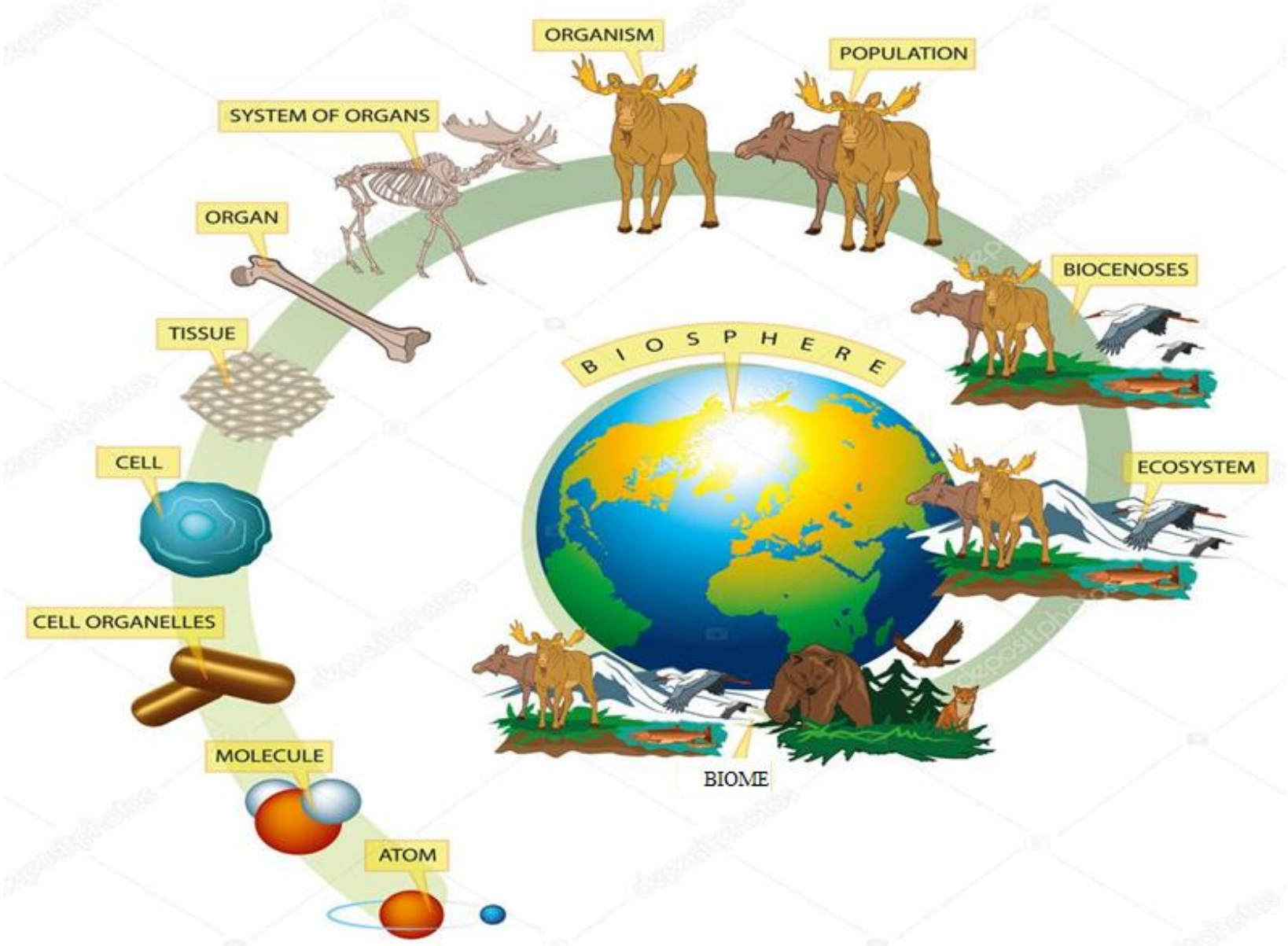
Biological techniques

- Biological techniques are methods or procedures that are used to study living things. They include experimental and computational methods, approaches, protocols and tools for biological research.





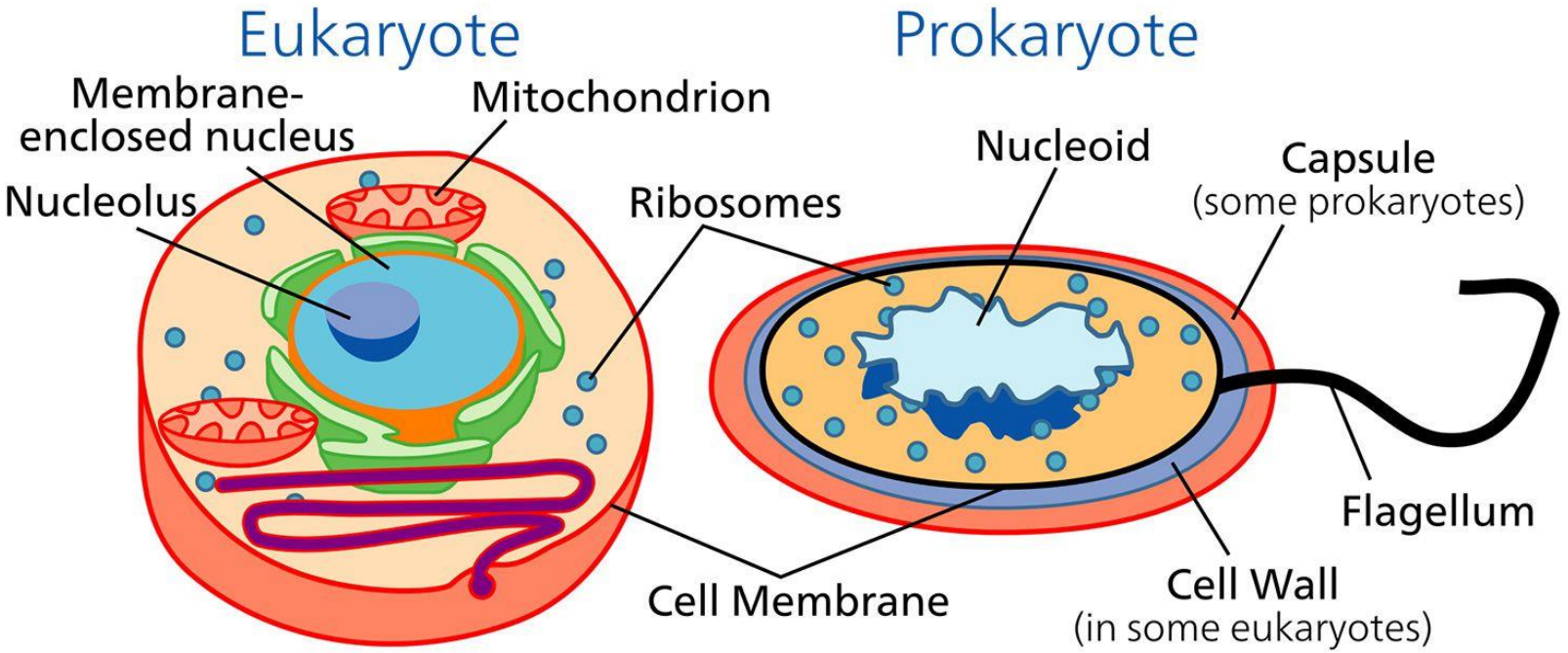
Levels of Organization of Living Things



Characteristics of living organism

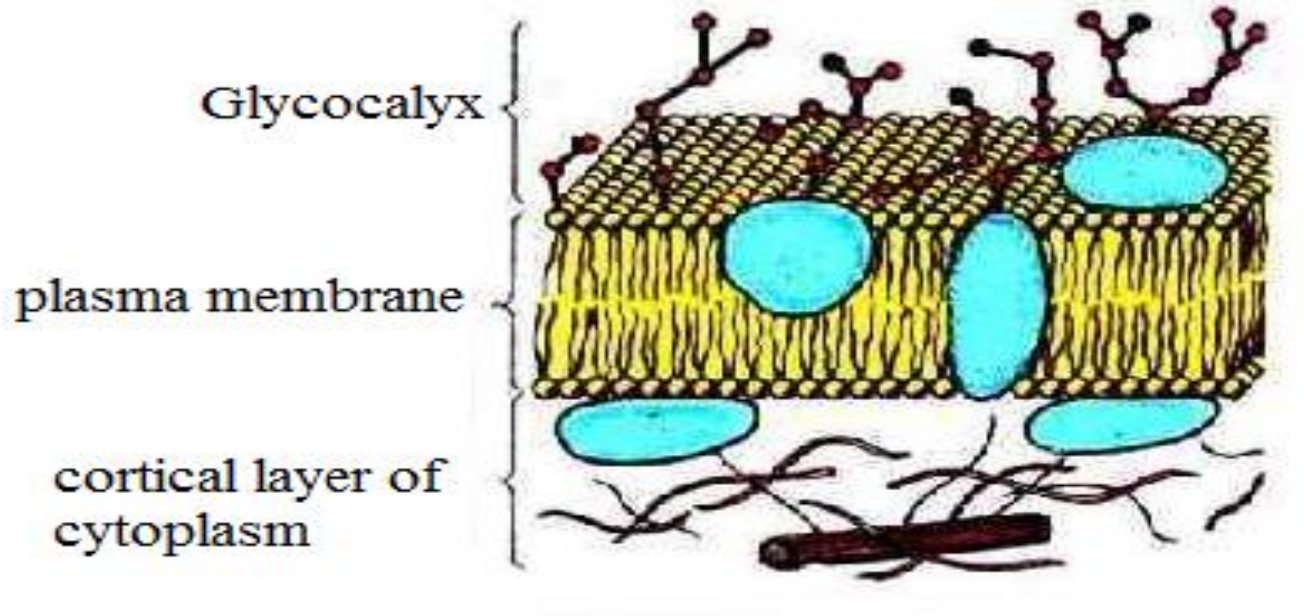
- **Day-to-day survival**
  - order
  - adaptations
  - metabolism
  - movement
  - responsiveness
- **Survival over time**
  - reproduction
  - development
  - genes
- **Change over time**
  - evolution

Prokaryotic and Eukaryotic Cells



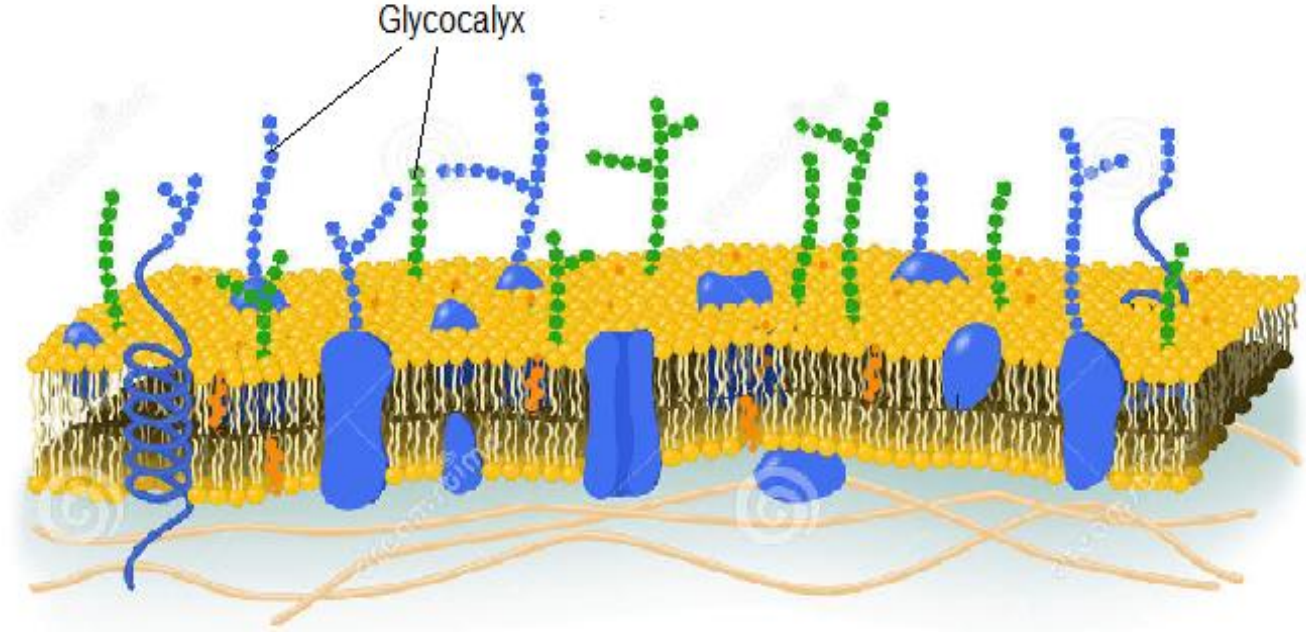
The surface complex of animal cell

- The surface complex of animal cell consists of glycocalyx, the plasma membrane and the cortex (cortical layer) of the cytoplasm located under it.



Glycocalyx

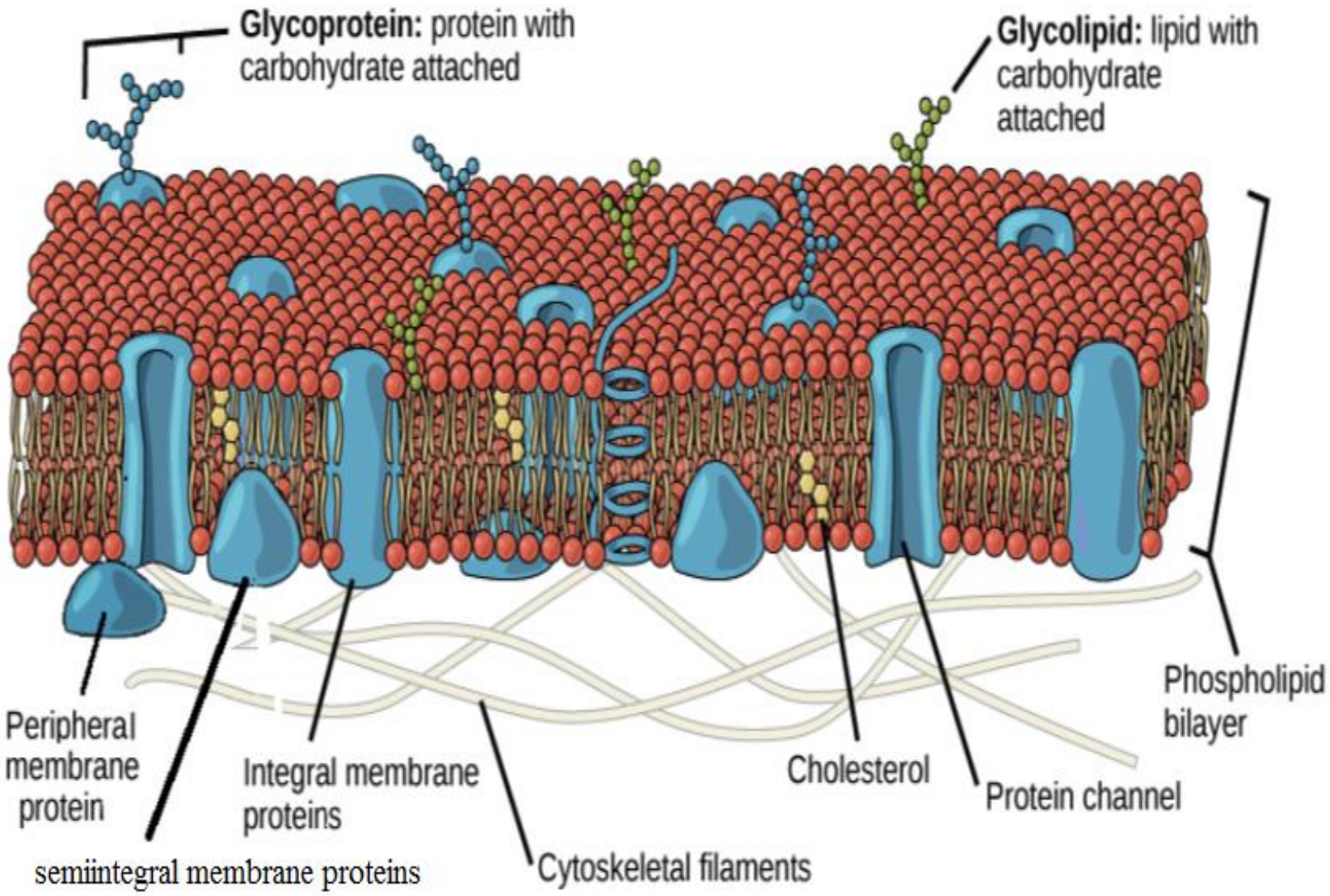
- The glycocalyx, also known as the pericellular matrix, is a glycoprotein and glycolipid covering that surrounds the cell membranes of some bacteria, epithelia, and other cells.



Glycocalyx

- Protection: Cushions the plasma membrane and protects it from chemical injury.
- Immunity to infection: Enables the immune system to recognize and selectively attack foreign organisms.
- Defence against cancer: Changes in the glycocalyx of cancerous cells enable the immune system to recognize and destroy them.
- Transplant compatibility: Forms the basis for compatibility of blood transfusions, tissue grafts, and organ transplants.
- Cell adhesion: Binds cells together so that tissues do not fall apart.
- Inflammation regulation: Glycocalyx coating on endothelial walls in blood vessels prevents leukocytes from rolling/binding in healthy states.
- Fertilization: Enables sperm to recognize and bind to eggs.
- Embryonic development: Guides embryonic cells to their destinations in the body.

Plasma membrane

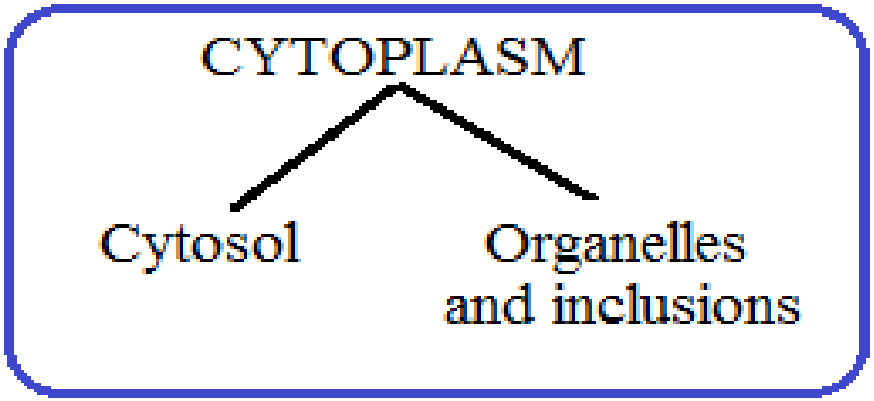


Function of plasma membrane

- Protection
- Selective permeability
- Cell recognition
- Cytoplasmic bridges in plasmodesmata and gap junction
- Endocytosis and exocytosis

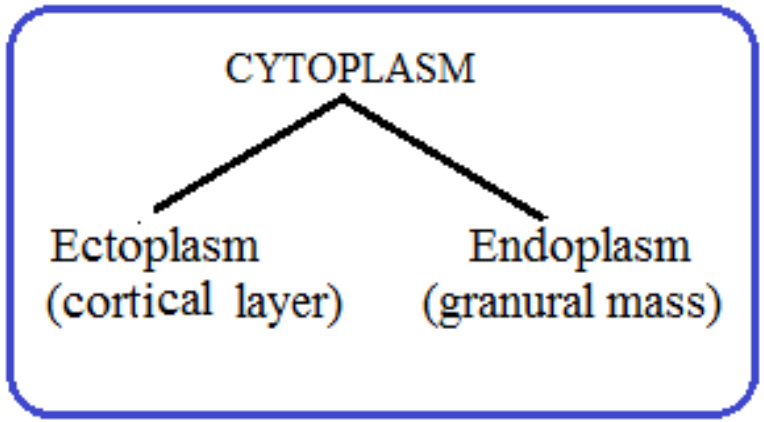
Cytoplasm

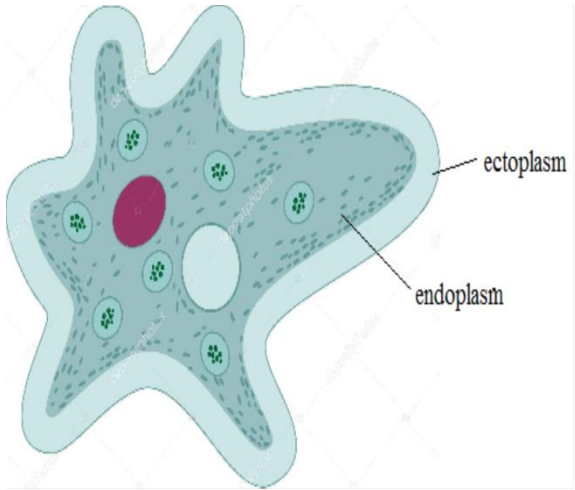
- Cytoplasm is all of the material within a cell, enclosed by the cell membrane, except for the cell nucleus. The main components of the cytoplasm are cytosol – a gel-like substance, the organelles – the cell's internal sub-structures, and various cytoplasmic inclusions.



Cytoplasm

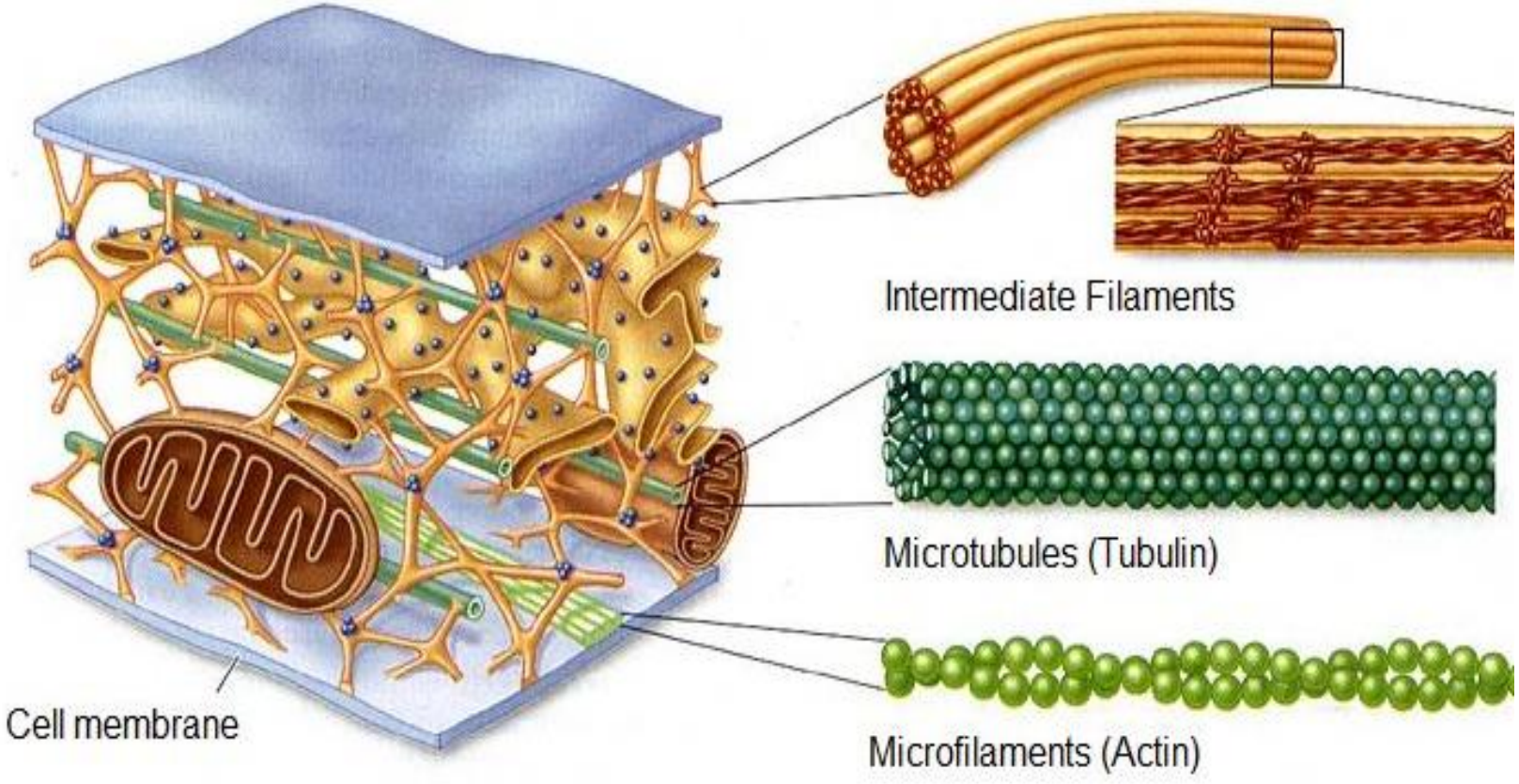
- The central, granular mass in the cytoplasm is the endoplasm while the surrounding lucid layer is known as the cell cortex or the ectoplasm. Cortical layer of cytoplasm, which lies in close contact with the plasma membrane, has a number of features. The main component of the cortical layer is a network of actin filaments.





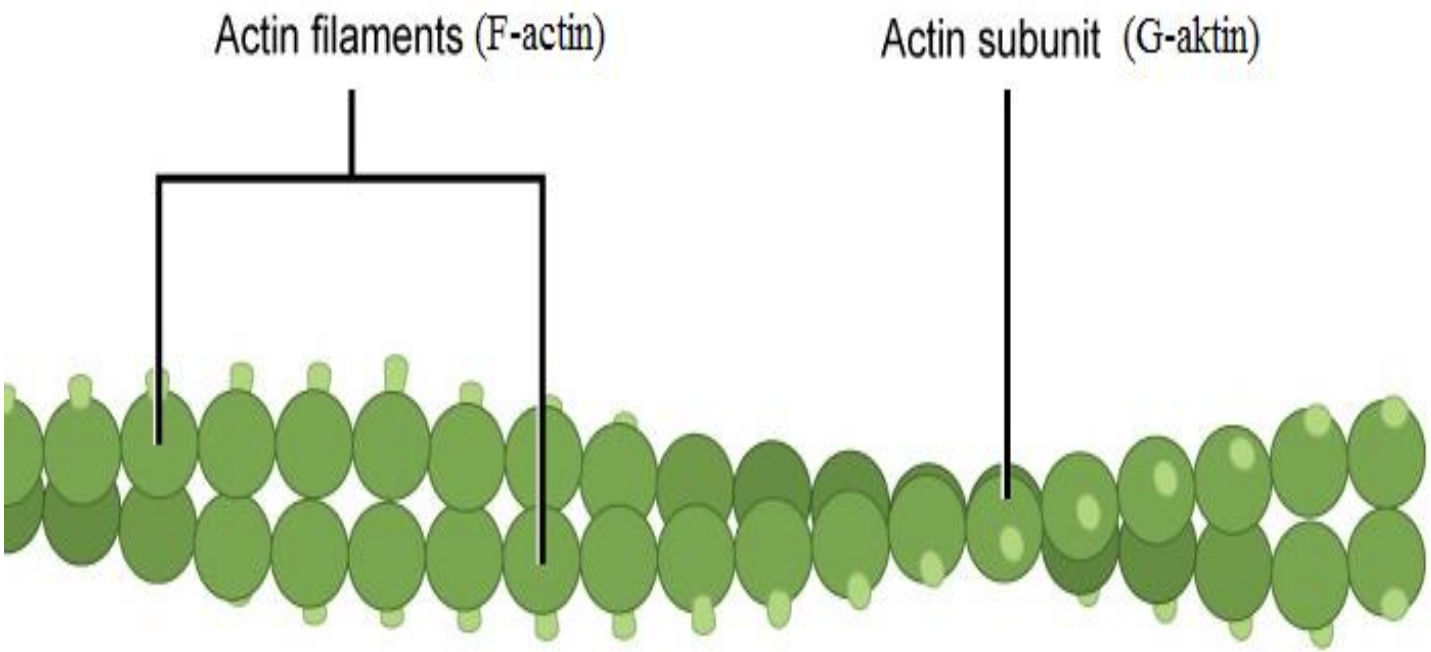
The Cytoskeleton

- There are three types of fibers within the cytoskeleton: microfilaments, intermediate filaments, and microtubules.



Microfilaments

- Microfilaments or actin filaments are thin, flexible fibers about 6-7 nm in diameter and up to several micrometres in length.

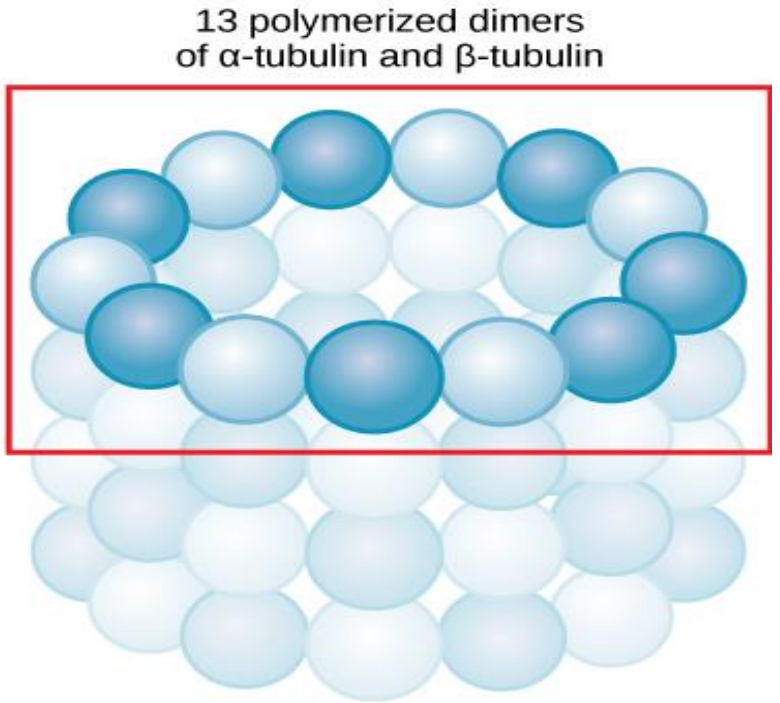


Intermediate filaments

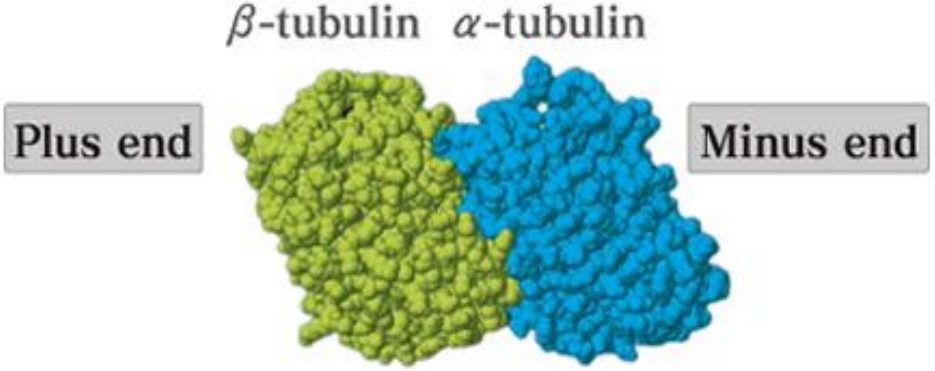
- Intermediate filaments are made of several strands of fibrous proteins that are wound together. These elements of the cytoskeleton get their name from the fact that their diameter, 8-10 nm. Intermediate filaments have no role in cell movement. They maintain the shape of the cell, and anchor the nucleus and other organelles in place.

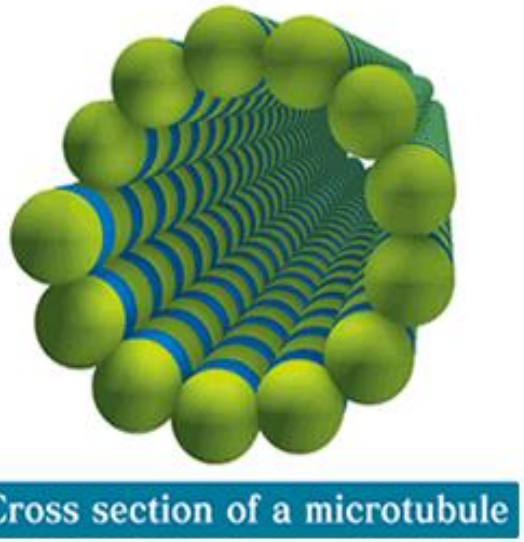
Microtubules

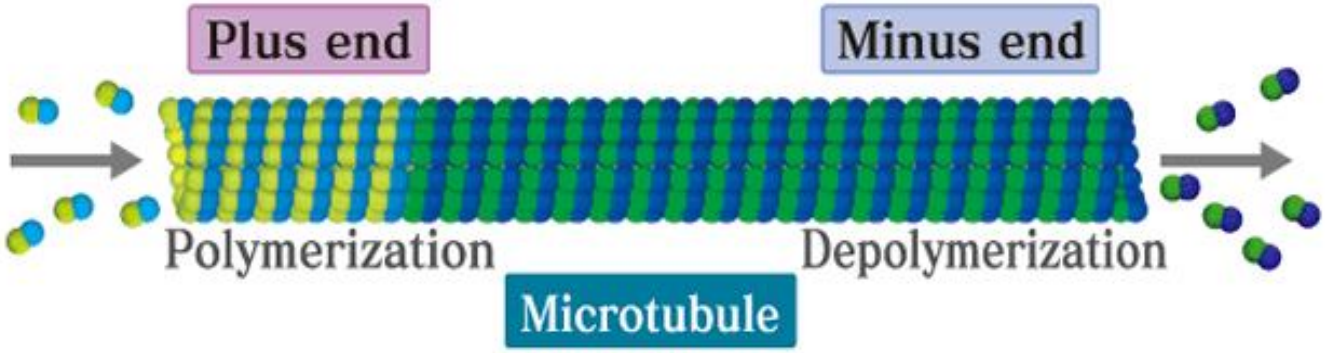
- Microtubules are the largest component of the cytoskeleton and are found throughout the cytoplasm. These polymers are made up of globular protein subunits called α-tubulin and β-tubulin.



Formation of microtubule



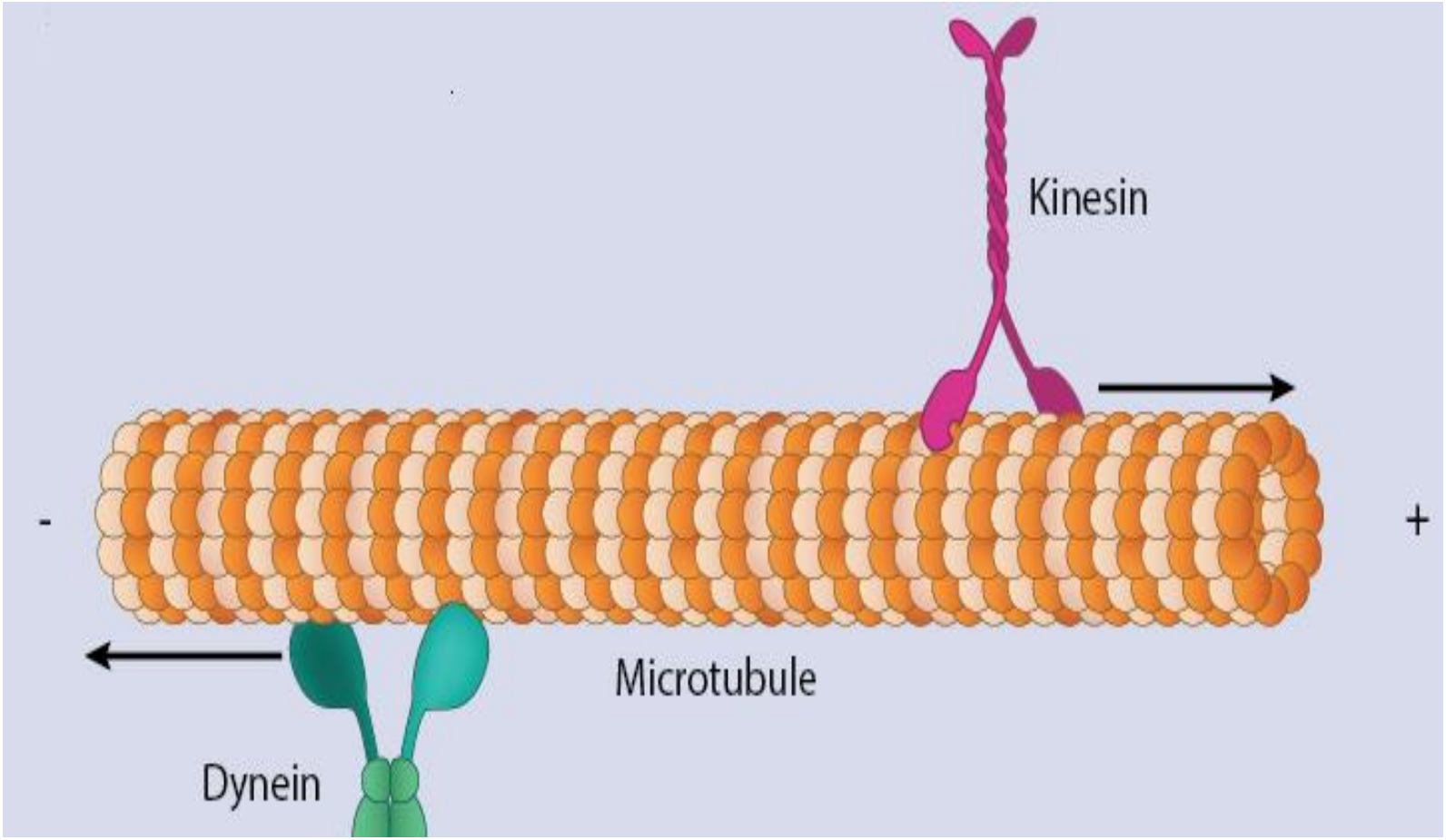




Organelle transport via microtubules: kinesins and dyneins

- **Dyneins** bind to microtubules and move or "walk" from the plus "(+)" end of the cytoskeletal microtubule filament to the minus "(-)" end of the filament, which is usually oriented towards the cell center.
- **Kinesins,** like cytoplasmic dyneins are motor-protein complexes that "walk" from the "(-)" end of the microtubule to the "(+)" end with the hydrolysis of ATP. In most cells, this entails transporting cargo from the center of the cell towards the periphery (the opposite direction to dyneins).

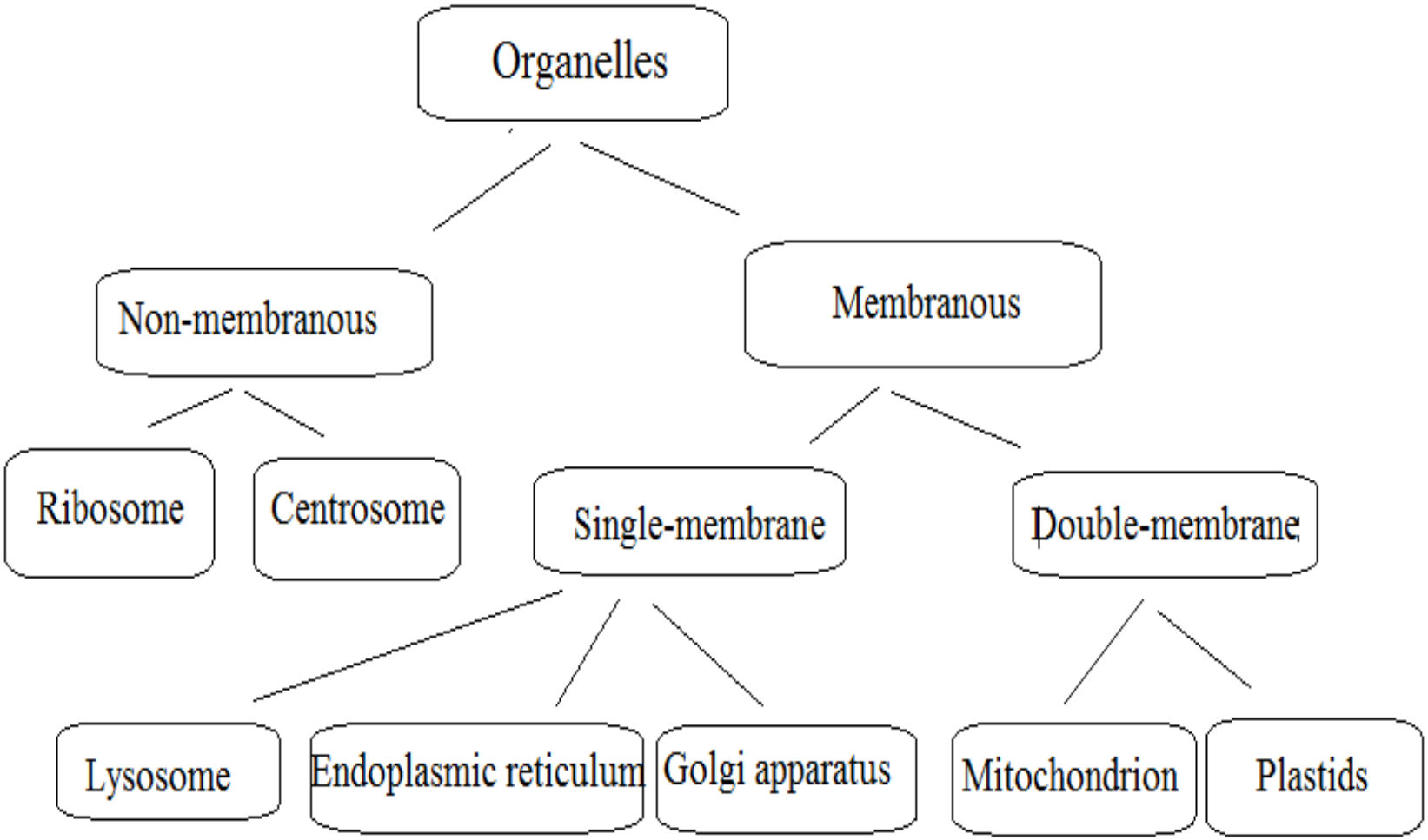
Organelle transport via microtubules: kinesins and dyneins



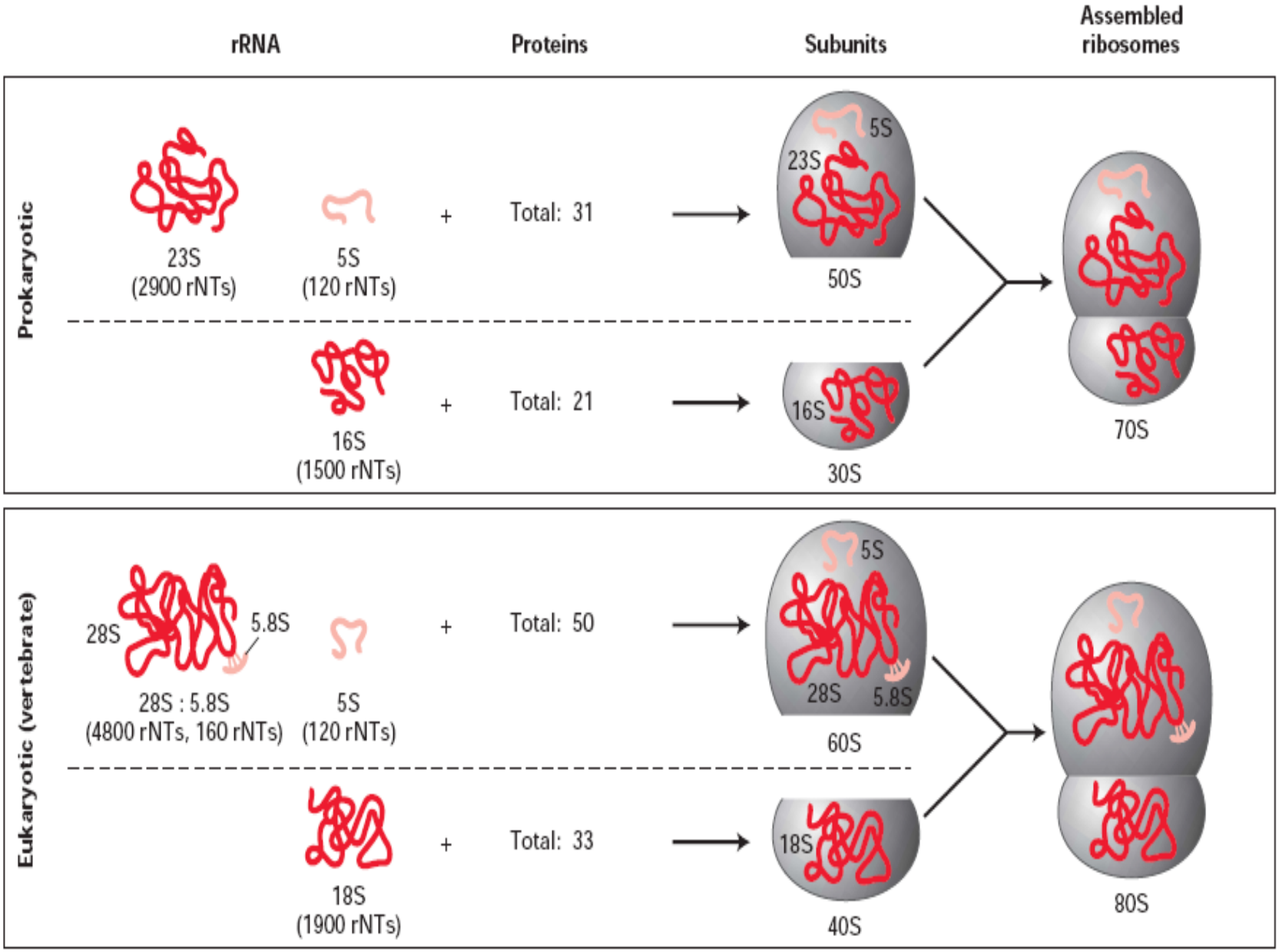
Organelles of cell

- An organelle is a specialized subunit within a cell that has a specific function. **Non-membranous** organelles are not surrounded by a membrane such as *Ribosomes* and *Centrosome*.
- **Membranous** organelles are surrounded by a membrane such as *Endoplasmic reticulum, Golgi apparatus, Lysosomes, Mitochondria and Plastids*.

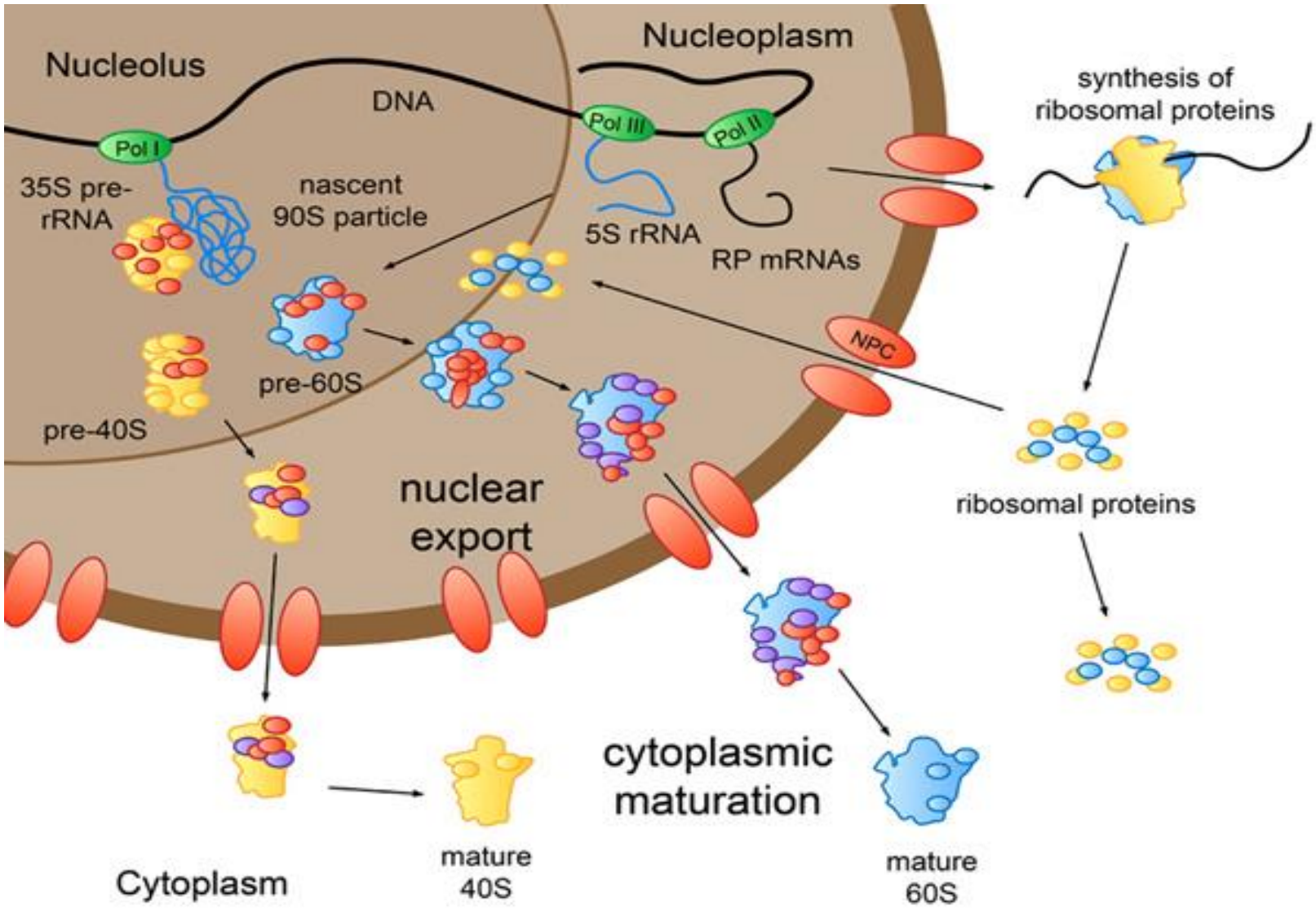
Organelles of cell



Ribosome


rRNA
Proteins
Subunits
Assembled ribosomes
Prokaryotic
23S
(2900 rNTs)
5S
(120 rNTs)
+
Total: 31
5S
23S
50S
16S
(1500 rNTs)
+
Total: 21
16S
30S
70S
Eukaryotic (vertebrate)
28S
5.8S
28S : 5.8S
(4800 rNTs, 160 rNTs)
5S
(120 rNTs)
+
Total: 50
5S
28S
5.8S
60S
18S
(1900 rNTs)
+
Total: 33
18S
40S
80S

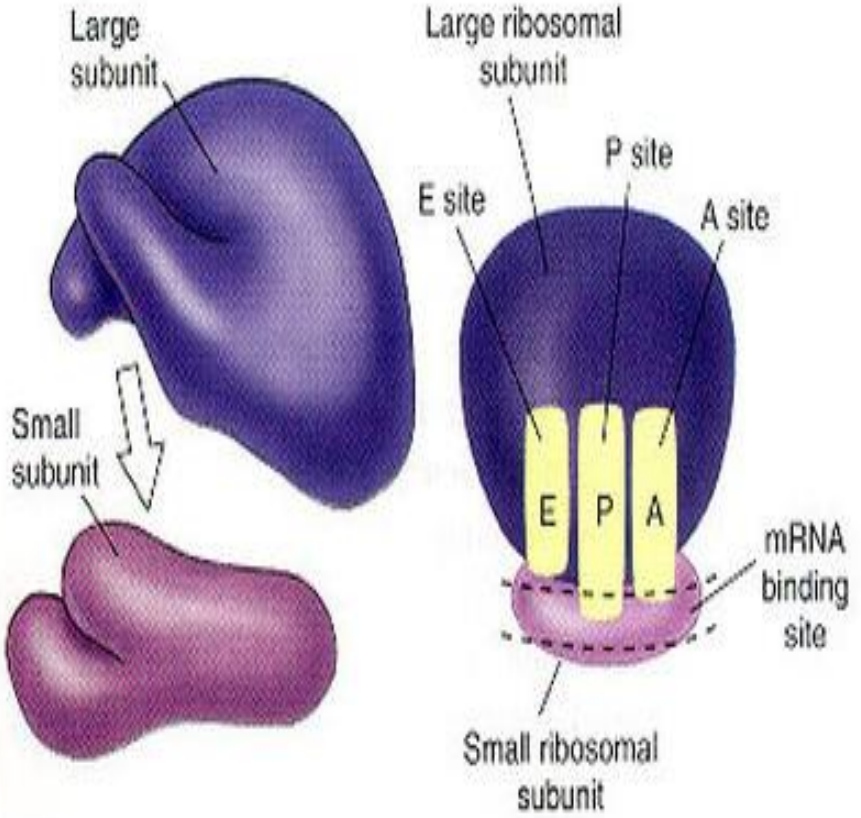
Formation of ribosome



Ribosome Subunits

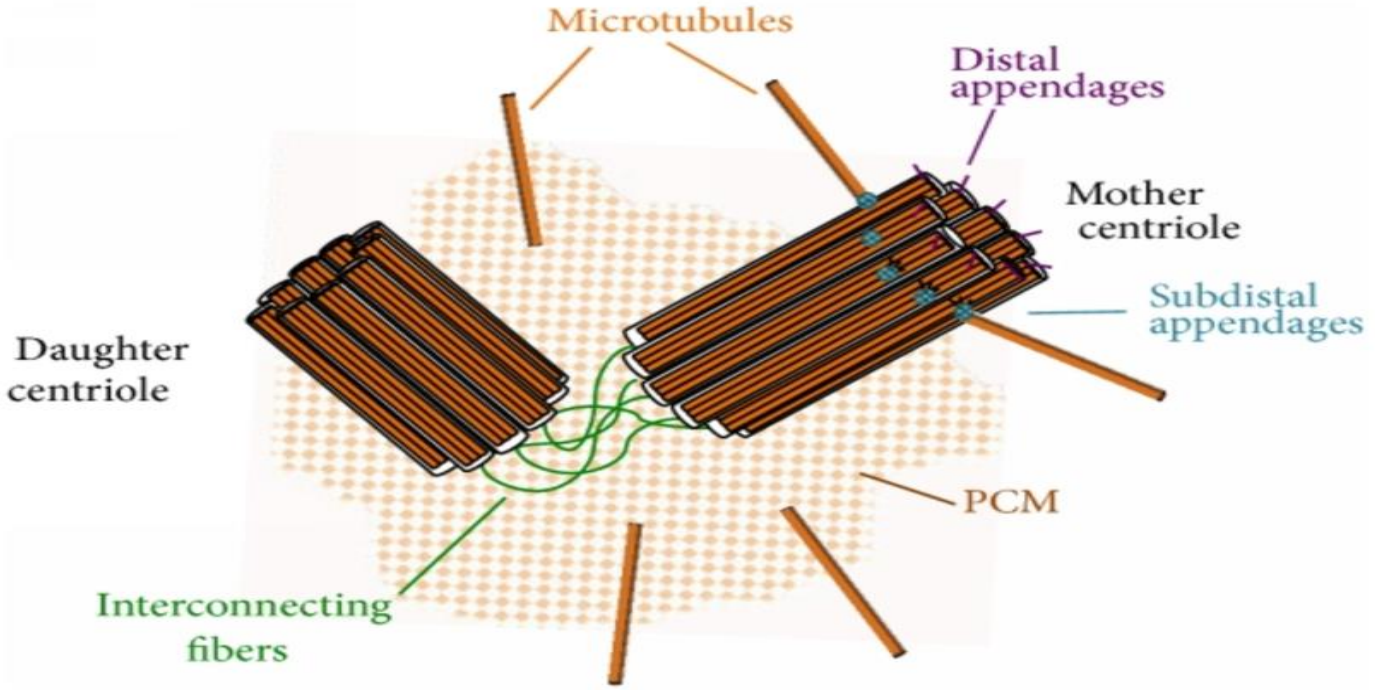
The smaller subunit fits into a depression on the surface of the larger one. The A, P, and E sites on the ribosome play key roles in protein synthesis.

- A ribosome has an mRNA binding site and three tRNA binding sites.
- The tRNA binding sites are A, P, E:
  - A: aminoacyl-tRNA
  - P: peptidyl-tRNA
  - E: exit

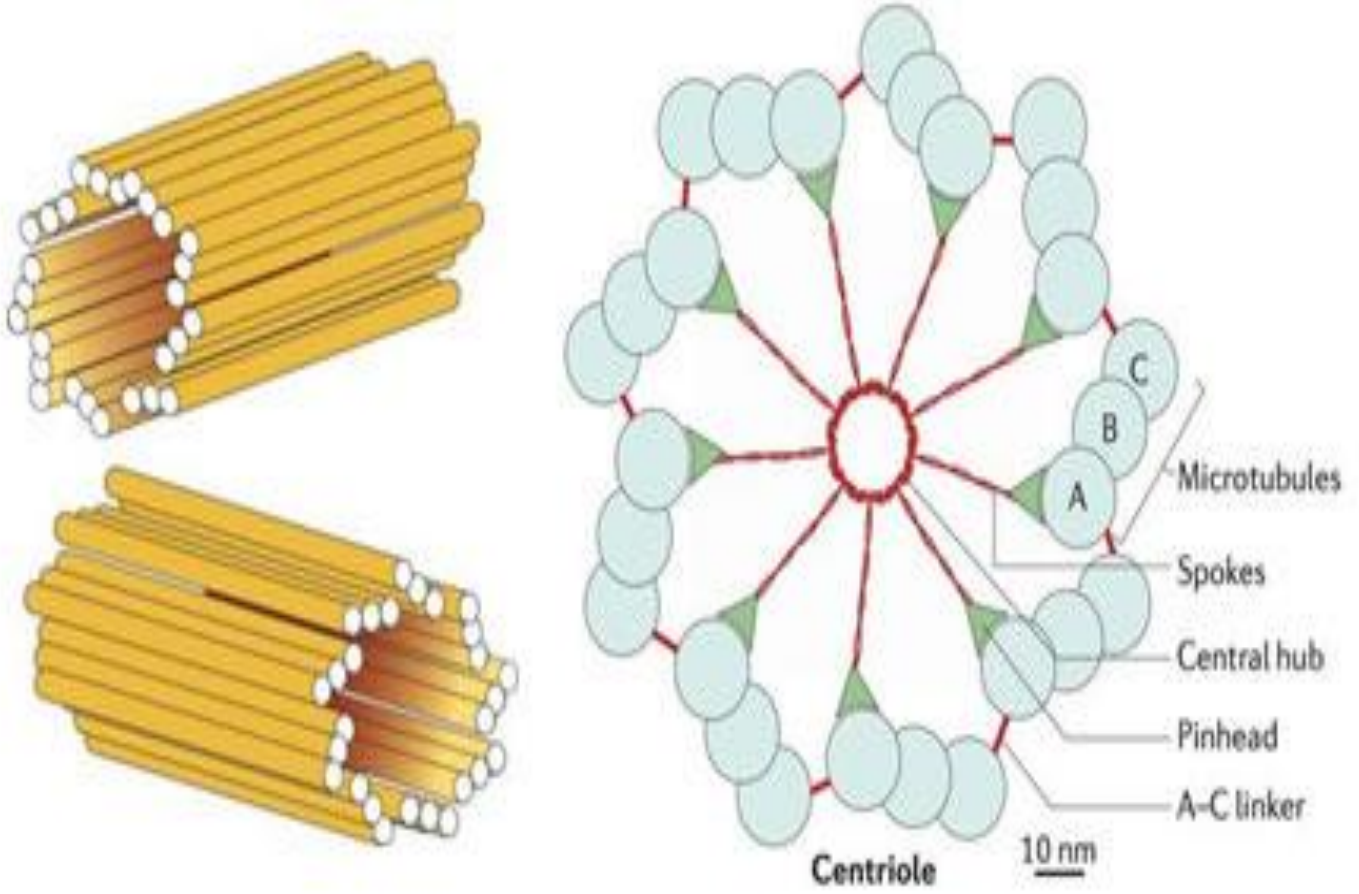


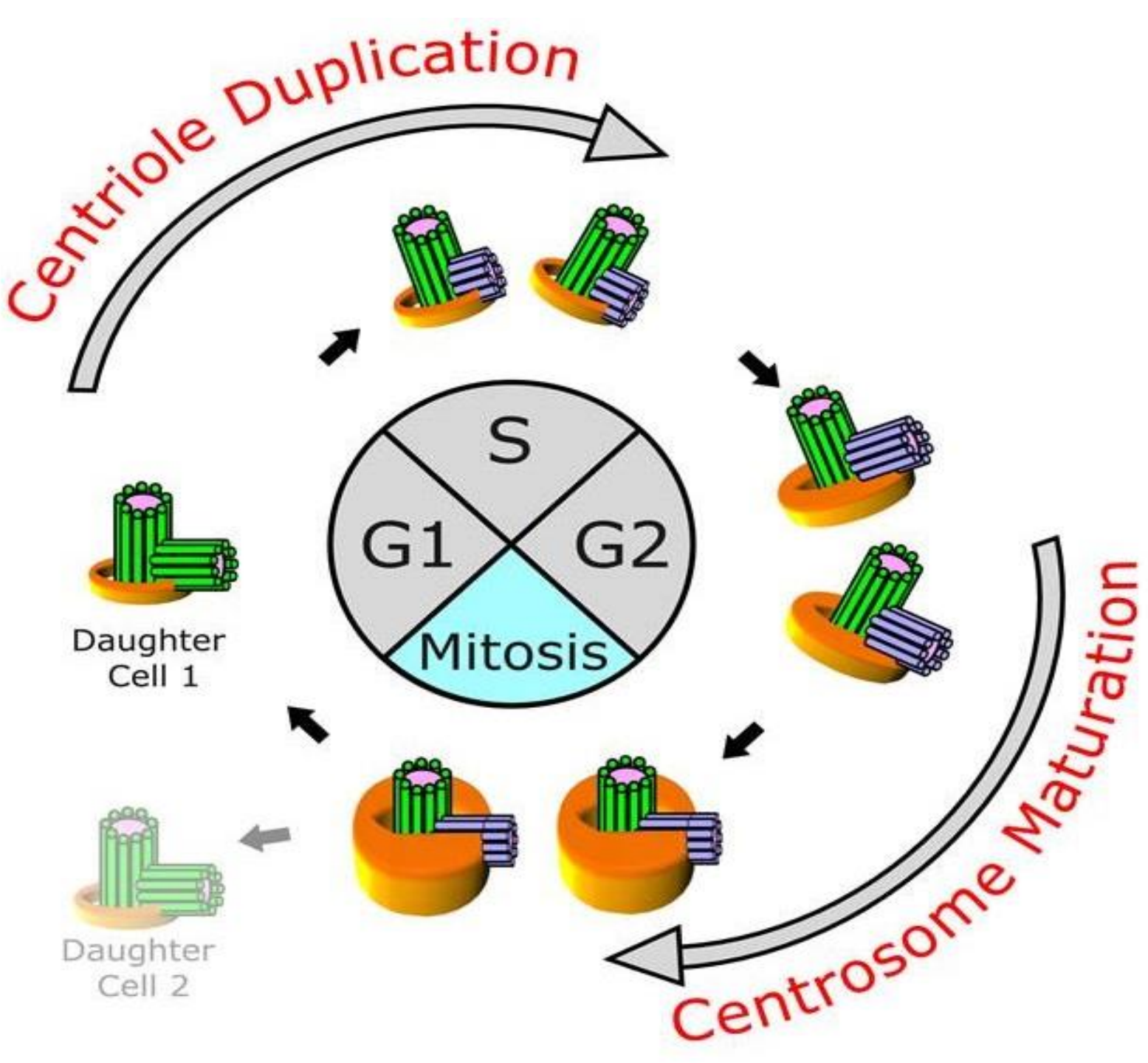
Centrosome

- The centrosome is a cellular organelle that is composed of two centrioles surrounded by pericentriolar matrix.

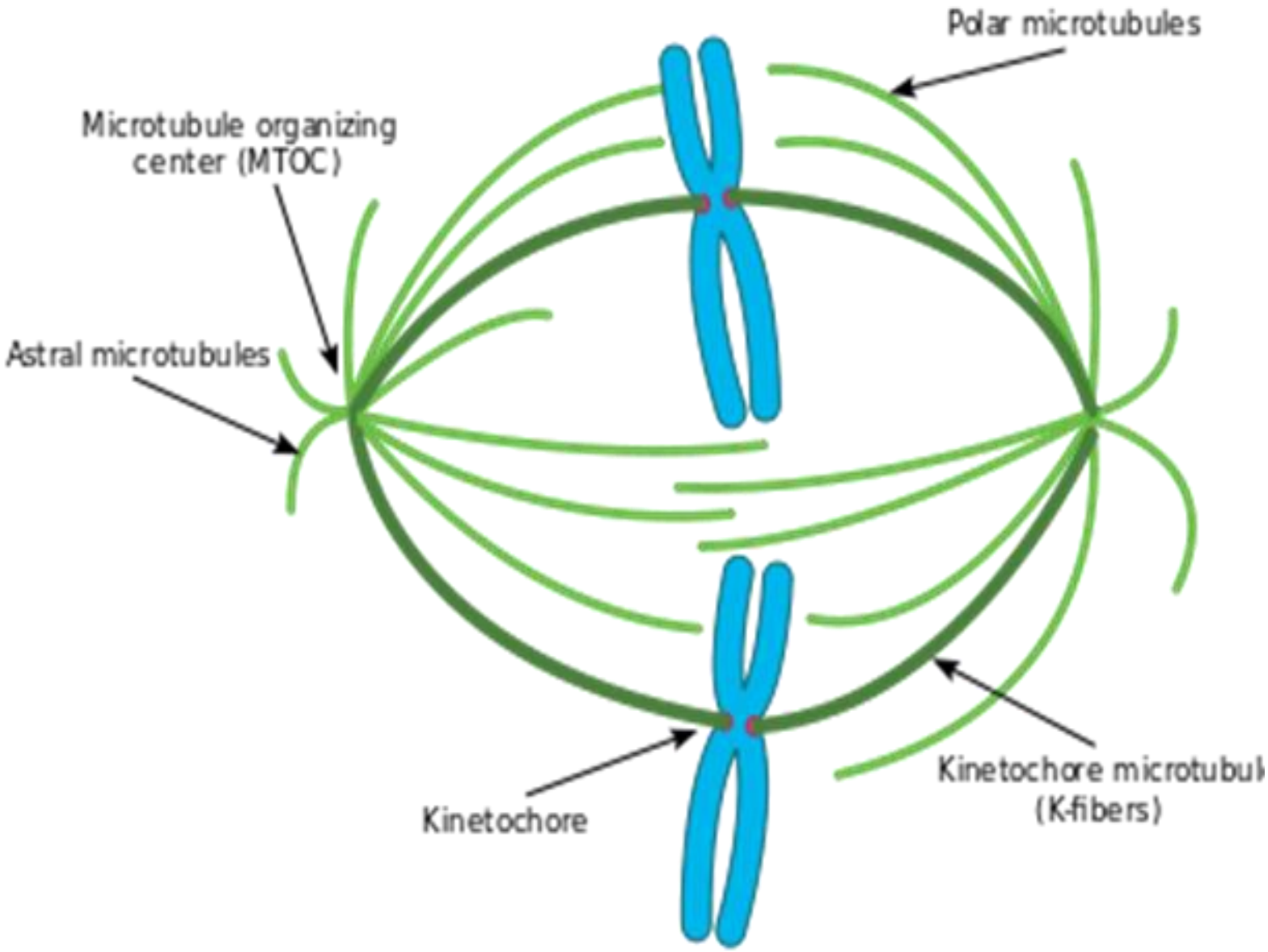


Structure of centriole

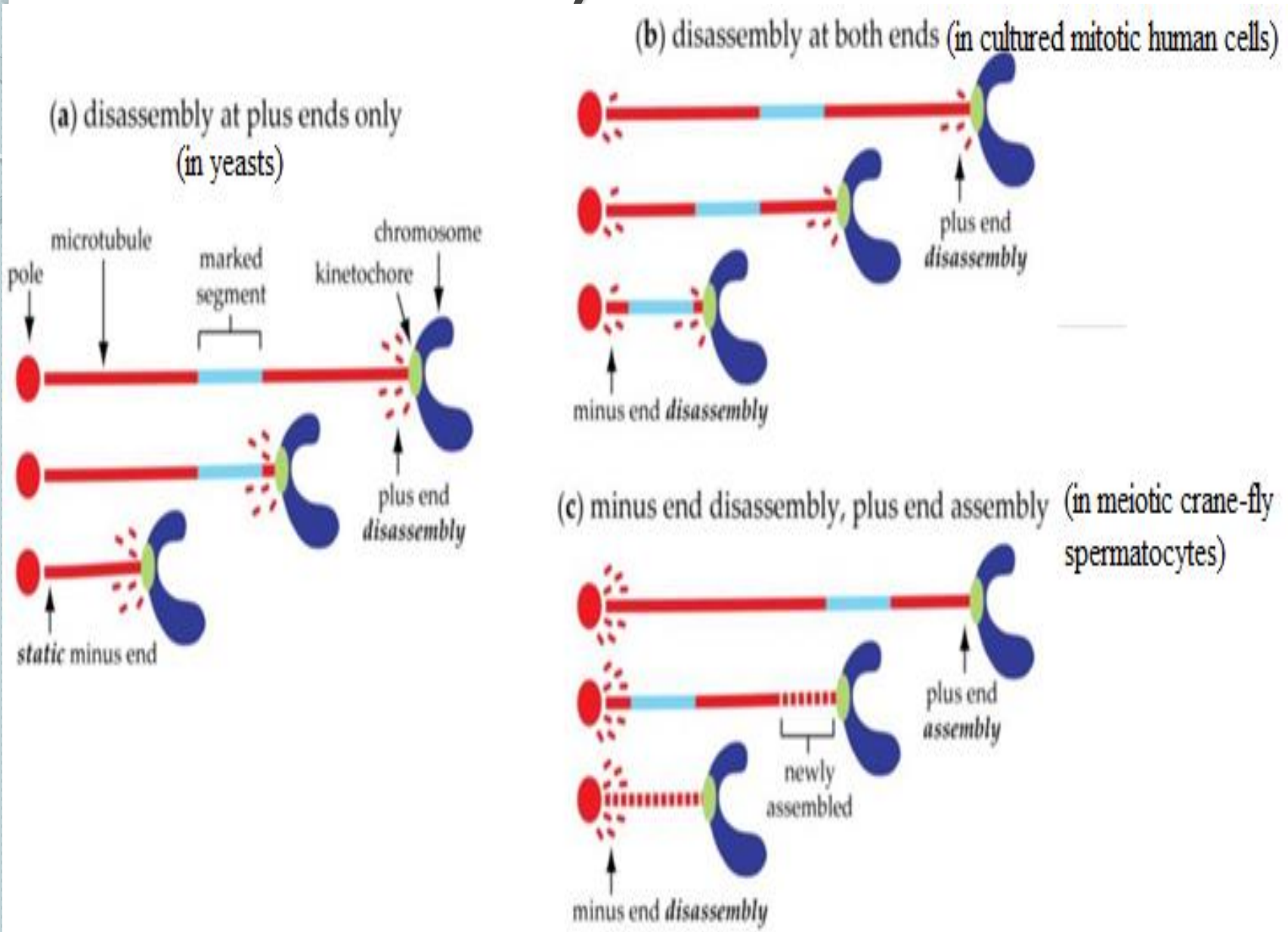



Centriole Duplication
S
G1
G2
Mitosis
Daughter Cell 1
Daughter Cell 2
Centrosome Maturation

Spindle structure

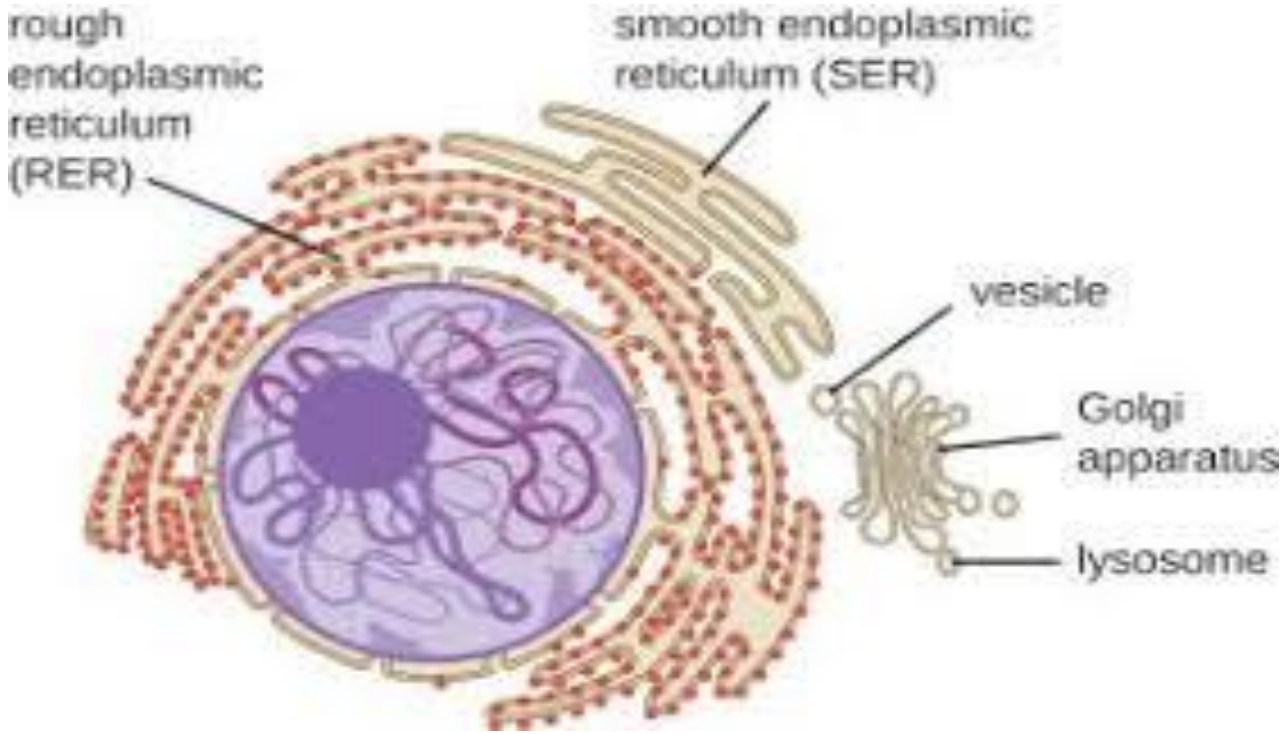


Disassembly of microtubules



Endoplasmic reticulum

The endoplasmic reticulum (ER) is single-membrane organelle found in eukaryotic cells that forms an interconnected network of flattened, membrane-enclosed sacs or tube-like structures known as cisternae.



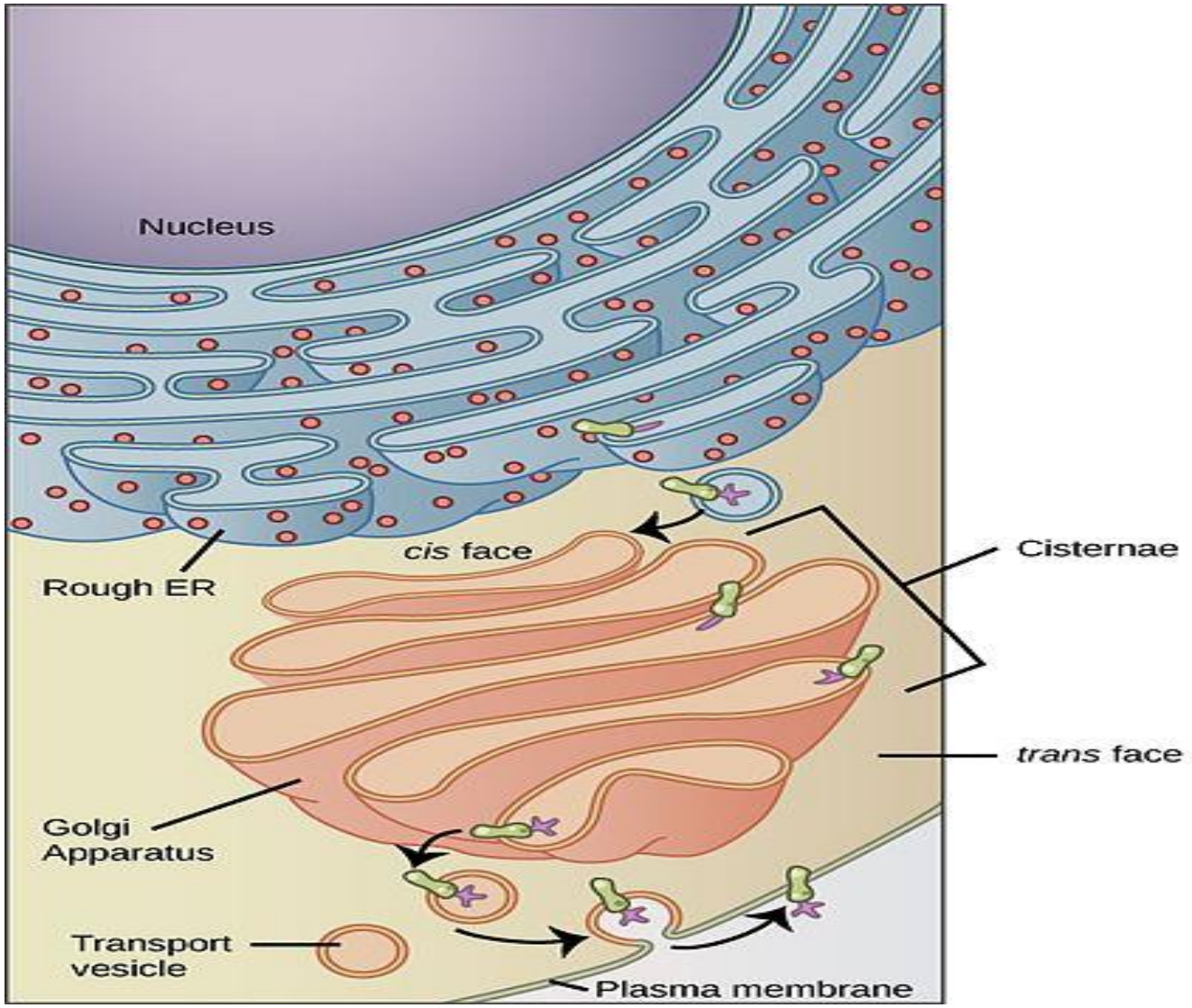
Endoplasmic reticulum

- There are two types of ER: rough endoplasmic reticulum and smooth endoplasmic reticulum. The outer (cytosolic) face of the rough endoplasmic reticulum is studded with ribosomes that are the sites of protein synthesis. The smooth endoplasmic reticulum lacks ribosomes and functions in lipid synthesis but not metabolism, the production of steroid hormones, and detoxification.

Golgi apparatus

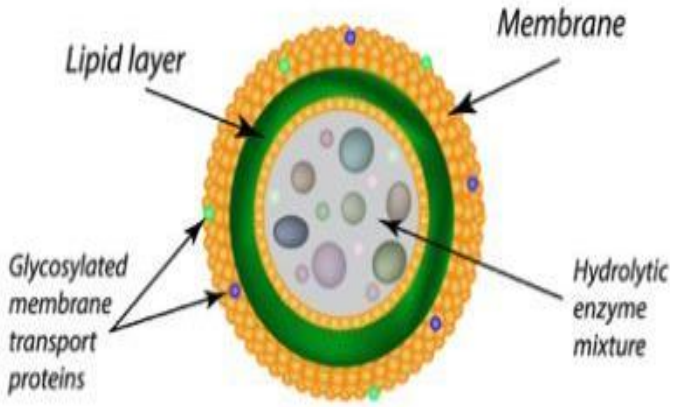
- Golgi apparatus is membrane-bound organelle of eukaryotic cells that is made up of a series of flattened, stacked pouches called cisternae.
- The apparatus has two primary compartments, known generally as “cis” (cisternae nearest the endoplasmic reticulum) and “trans” (cisternae farthest from the endoplasmic reticulum).

Golgi apparatus



Lysosome

- A lysosome is a membrane-bound organelle found in many animal cells. Lysosomes are known to contain more than 60 different enzymes, and have more than 50 membrane proteins.

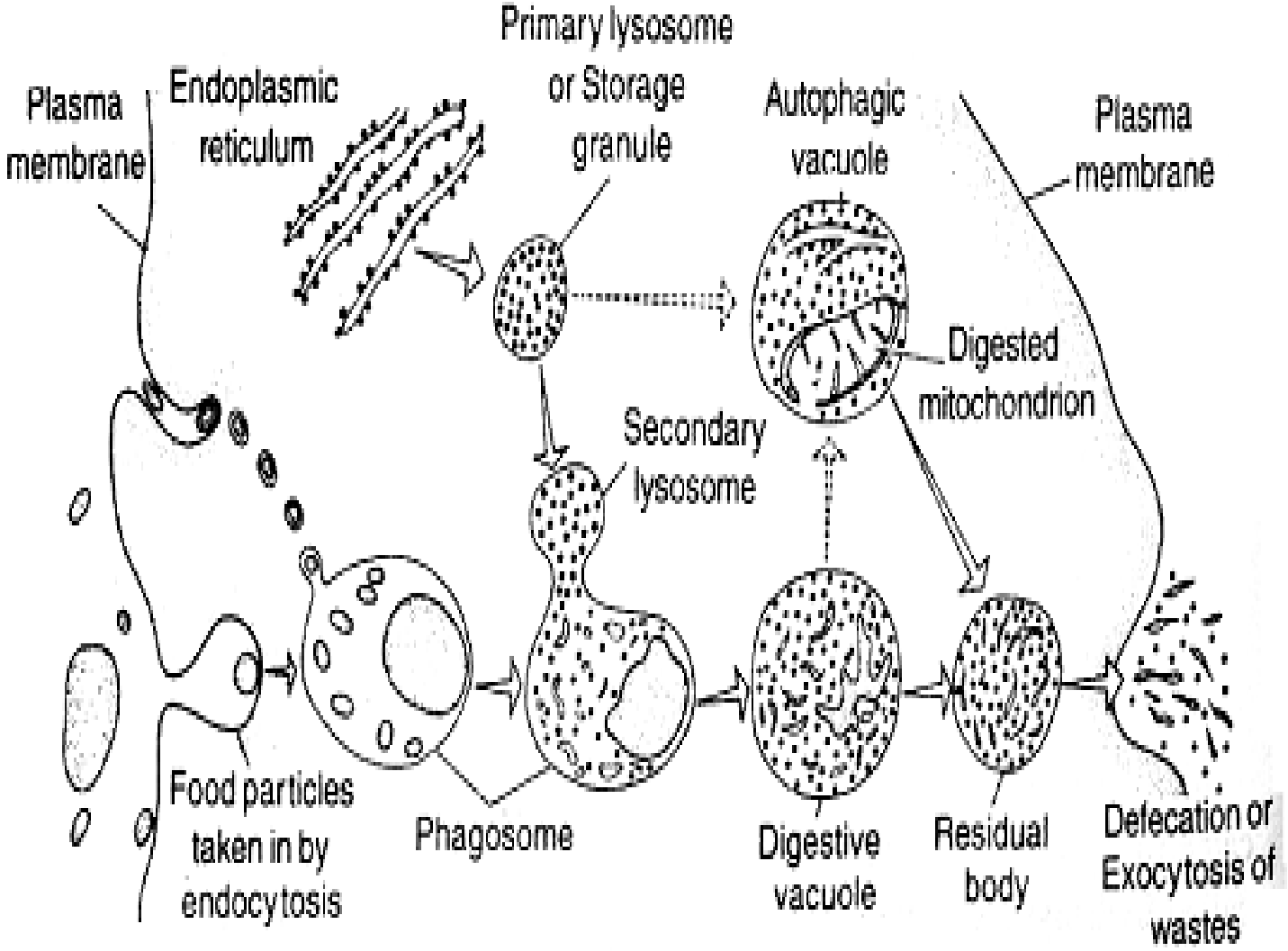


Types of lysosomes

- **Primary lysosomes** - are formed from Golgi apparatus appearing as small vesicles. Although primary lysosomes are popular on Golgi apparatus, they also occur as granulocytes and monocytes. These lysosomes are surrounded by a single phospholipid layer and contain acid hydrolases.
- **Secondary lysosomes** - are formed when primary lysosomes fuse with phagosomes (they are also referred to a endosomes). After digestion of the contents of the secondary lysosome, nutrients diffuse through the lysosomal-limiting membrane and enter the cytosol. Indigestible compounds are retained within the vacuoles, which are now called **residual bodies**.
- lysosomes are also involved in another process referred to as **autophagocytosis**. This process helps in the degradation of various cell components that are either worn out or malfunctioning.

- Autophagy also takes place during starvation. During starvation periods, lysosomes will start hydrolysing organic foods that are stored in cells so as to produce energy.

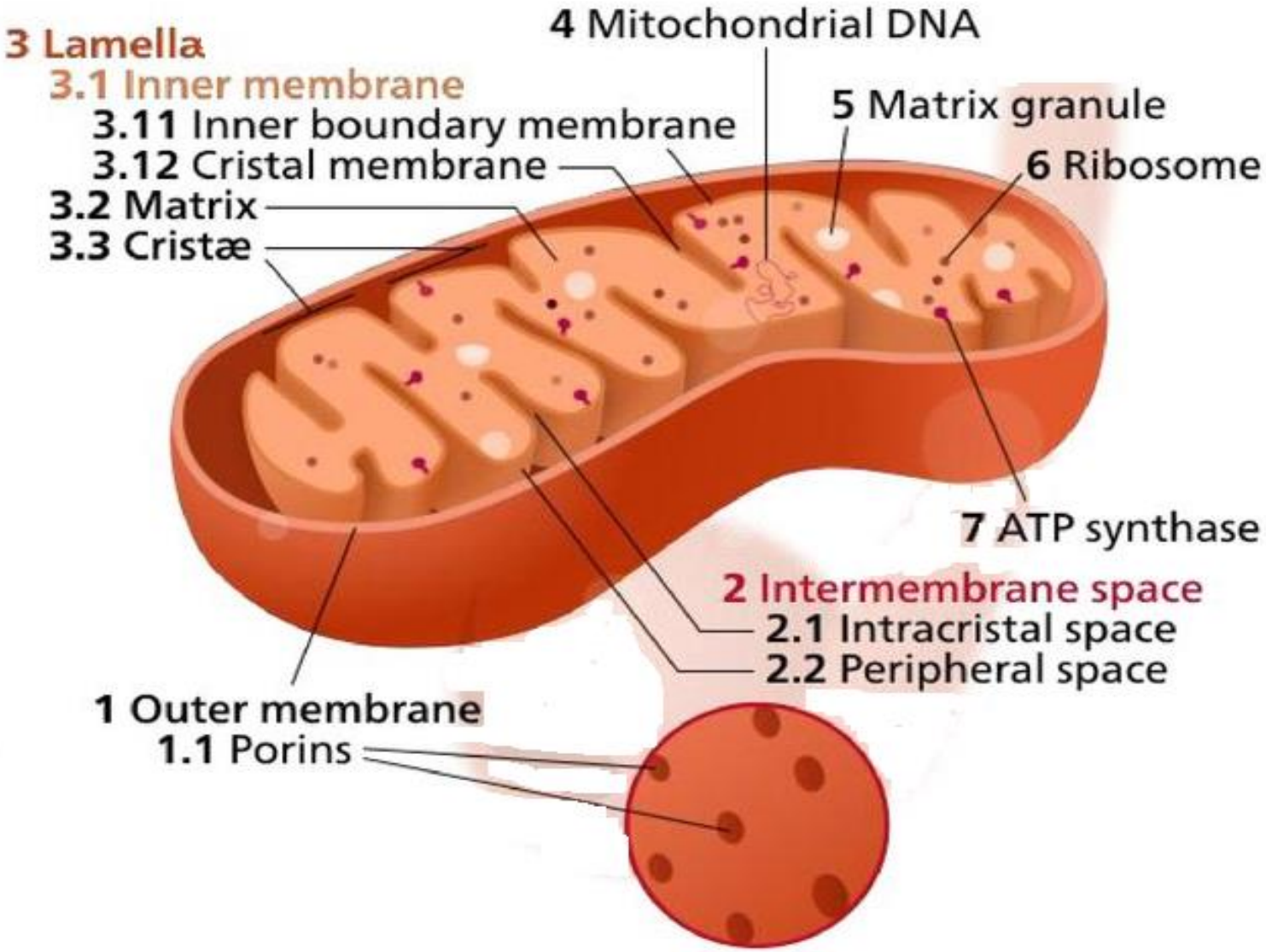
Lysosomes


Primary lysosome
or Storage
granule
Plasma
membrane
Endoplasmic
reticulum
Autophagic
vacuole
Plasma
membrane
Digested
mitochondrion
Secondary
lysosome
Food particles
taken in by
endocytosis
Phagosome
Digestive
vacuole
Residual
body
Defecation or
Exocytosis of
wastes

Mitochondria

- The mitochondrion is a double-membrane-bound organelle found in most eukaryotic organisms. Some cells in some multicellular organisms may, however, lack them (for example, mature mammalian red blood cells).
- Although most of a cell's DNA is contained in the cell nucleus, the mitochondrion has its own independent genome that shows substantial similarity to bacterial genomes.

Mitochondrion



Mitochondrion

- **Outer membrane**: Small molecules can pass freely through the outer membrane. This outer portion includes proteins called porins, which form channels that allow proteins to cross. The outer membrane also hosts a number of enzymes with a wide variety of functions.
- **Intermembrane space**: This is the area between the inner and outer membranes.
- **Inner membrane:** This membrane holds proteins that have several roles. Because there are no porins in the inner membrane, it is impermeable to most molecules. Molecules can only cross the inner membrane in special membrane transporters. The inner membrane is where most ATP is created.
- **Cristae:** These are the folds of the inner membrane. They increase the surface area of the membrane, therefore increasing the space available for chemical reactions.
- **Matrix:** This is the space within the inner membrane. Containing hundreds of enzymes, it is important in the production of ATP. Mitochondrial DNA is housed here.

Function of mitochondria

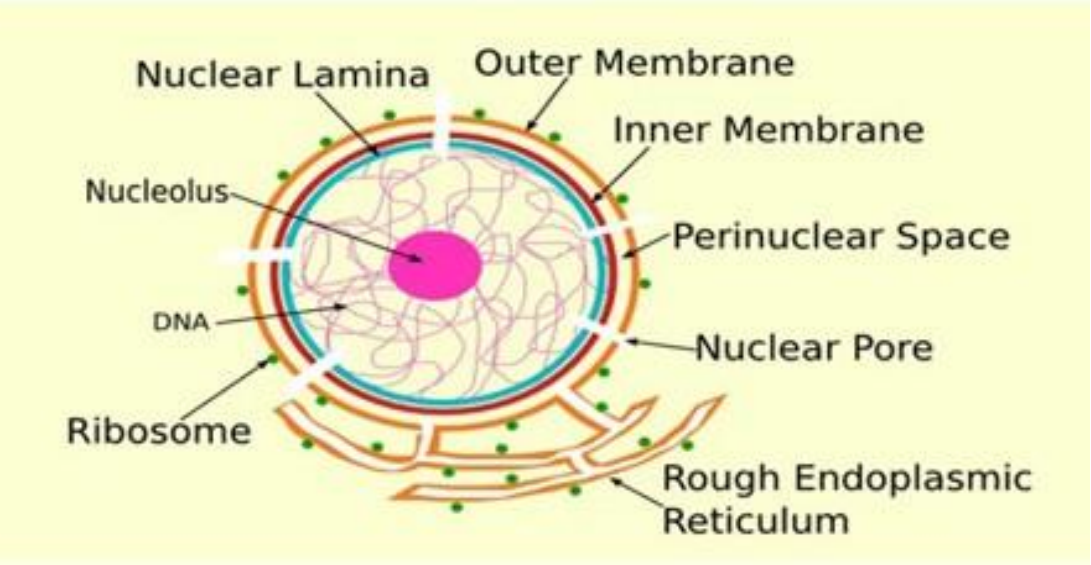
- Producing energy
- Cell death
- Storing calcium
- Heat production

Cell nucleus

- The cell nucleus is bound by a double membrane called the nuclear envelope. This membrane separates the contents of the nucleus from the cytoplasm. Like the cell membrane, the nuclear envelope consists of phospholipids that form a lipid bilayer. The envelope helps to maintain the shape of the nucleus and assists in regulating the flow of molecules into and out of the nucleus through nuclear pores.

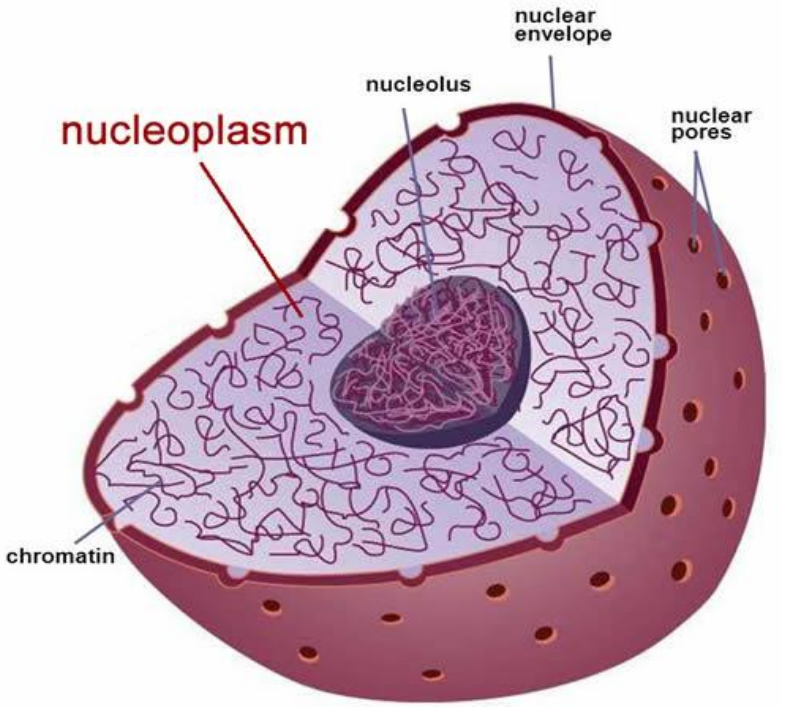
Nuclear lamina

- In animal cells, two networks of intermediate filaments provide the nucleus with mechanical support: The nuclear lamina forms an organized meshwork on the internal face of the envelope, while less organized support is provided on the cytosolic face of the envelope.



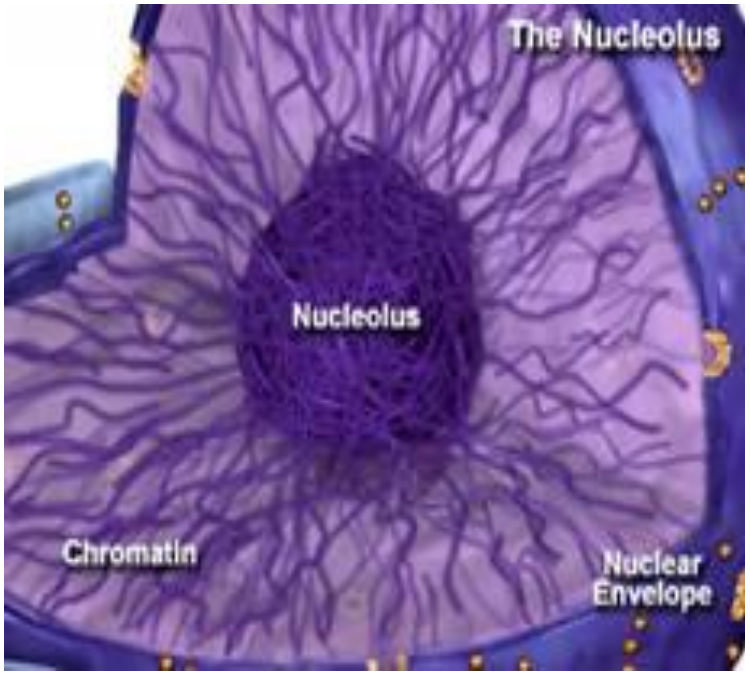
Nucleoplasm

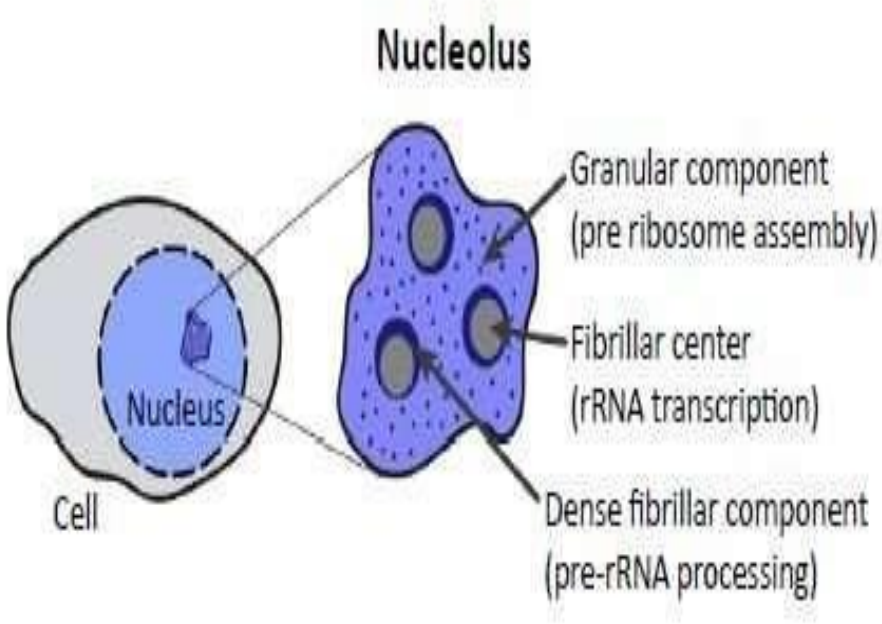
- Nucleoplasm is the gelatinous substance within the nuclear envelope. Also called karyoplasm, this semi-aqueous material is similar to cytoplasm and is composed mainly of water with dissolved salts, enzymes, and organic molecules suspended within.



Nucleolus

- Contained within the nucleus is a dense, membrane-less structure composed of RNA and proteins called the nucleolus. The nucleolus contains nucleolar organizers, which are parts of chromosomes with the genes for ribosome synthesis on them.

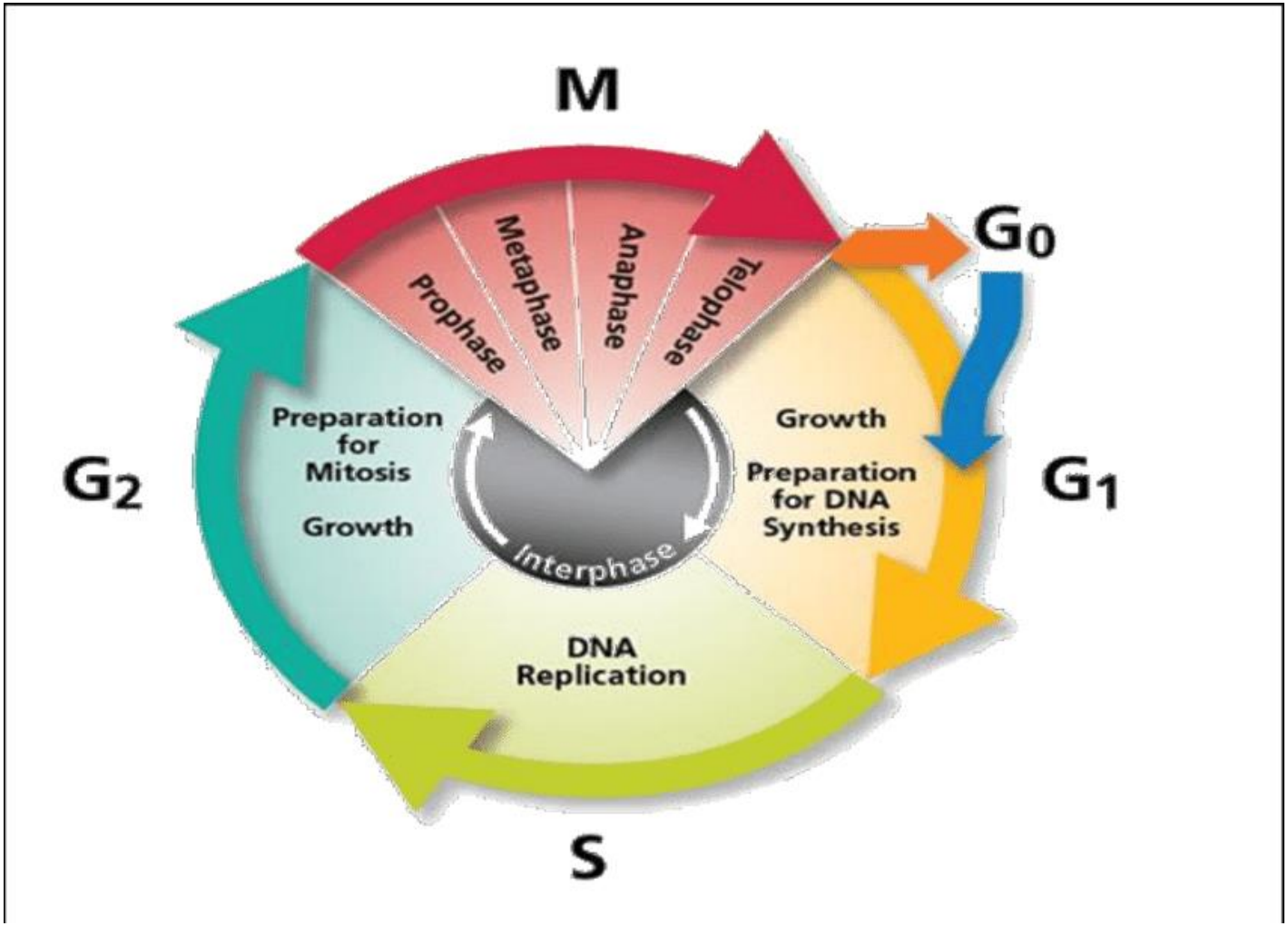




Cell cycle

- The cell cycle is the series of events that take place in a cell leading to duplication of its DNA (DNA replication) and division of cytoplasm and organelles to produce two daughter cells.
- The eukaryotic cell cycle consists of four distinct phases: G1 phase, S phase, G2 phase and M phase (G0 – a phase where the cell has left the cycle and has stopped dividing (some liver, kidney, and stomach cells)).

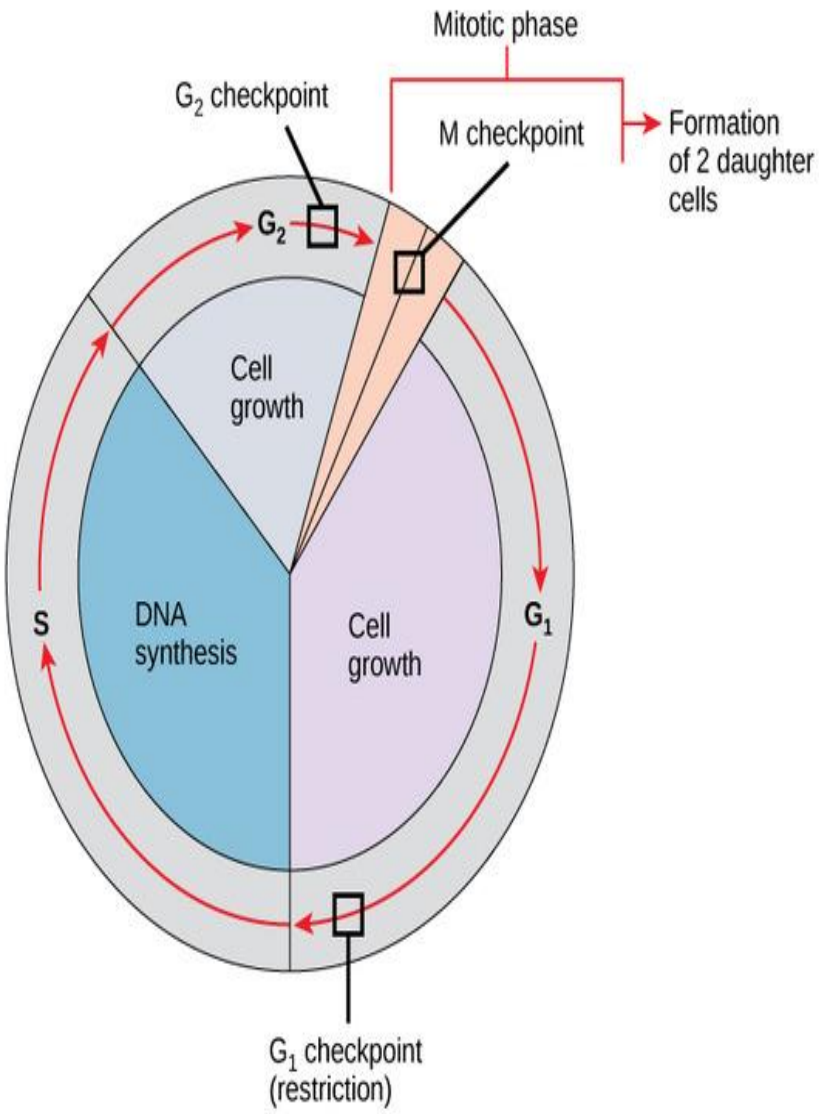
Cell cycle


M
Prophase
Metaphase
Anaphase
Telophase
G0
G1
Growth
Preparation for DNA Synthesis
S
DNA Replication
G2
Preparation for Mitosis
Growth
Interphase

Check points of cell cycle

- Cell cycle checkpoints are control mechanisms in eukaryotic cells which ensure proper division of the cell.
- There are three known checkpoints. These checkpoints occur near the end of G1, at the G2/M transition, and during metaphase.

- The integrity of the DNA is assessed at the G1 checkpoint.
- Proper chromosome duplication is assessed at the G2 checkpoint.
- Attachment of each kinetochore to a spindle fiber is assessed at the M checkpoint.



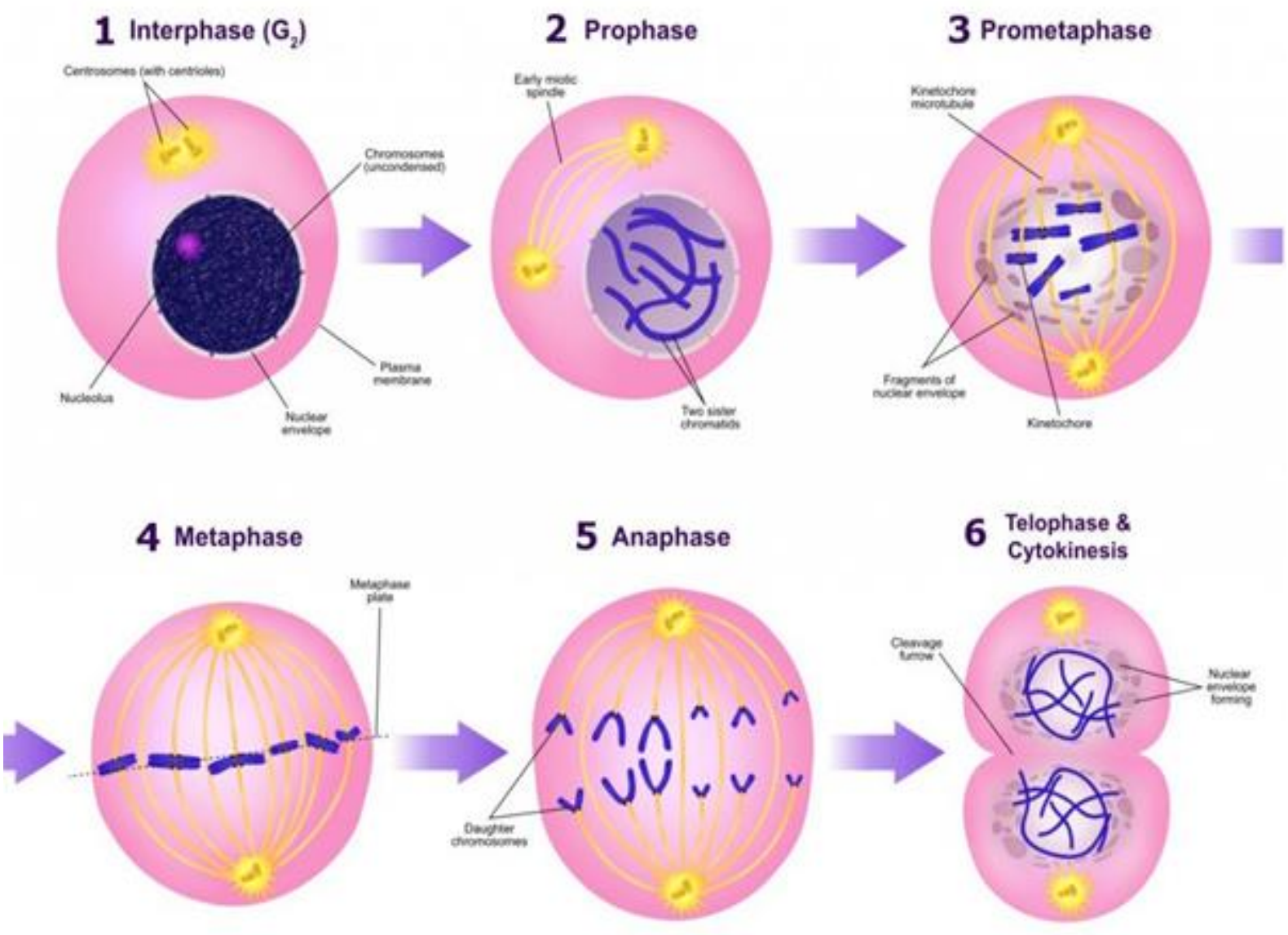
Cell cycle regulation

- The main mechanism of action of the cell cycle checkpoints is through the regulation of the activities of a family of protein kinases known as the **cyclin-dependent kinases** (CDKs), which bind to different classes of regulator proteins known as cyclins, with specific cyclin-CDK complexes being formed and activated at different phases of the cell cycle. Those complexes, in turn, activate different downstream targets to promote or prevent cell cycle progression.

Mitosis

- Mitosis is a part of the cell cycle when replicated chromosomes are separated into two new nuclei. Cell division gives rise to genetically identical cells in which the number of chromosomes is maintained. In general, mitosis (division of the nucleus) is preceded by the S stage of interphase (during which the DNA is replicated) and is often accompanied or followed by cytokinesis, which divides the cytoplasm, organelles and cell membrane into two new cells containing roughly equal shares of these cellular components.

Phases of mitosis



Meiosis

- Meiosis is a special type of cell division that reduces the chromosome number by half, creating four haploid cells, each genetically distinct from the parent cell that gave rise to them. This process occurs in all sexually reproducing single-celled and multicellular eukaryotes, including animals, plants, and fungi.
- Meiosis is divided into meiosis I and meiosis II (meiosis I is referred to as a reductional division, meiosis II is an equational division which analogous to mitosis).

Substages of Prophase I

-Leptotene

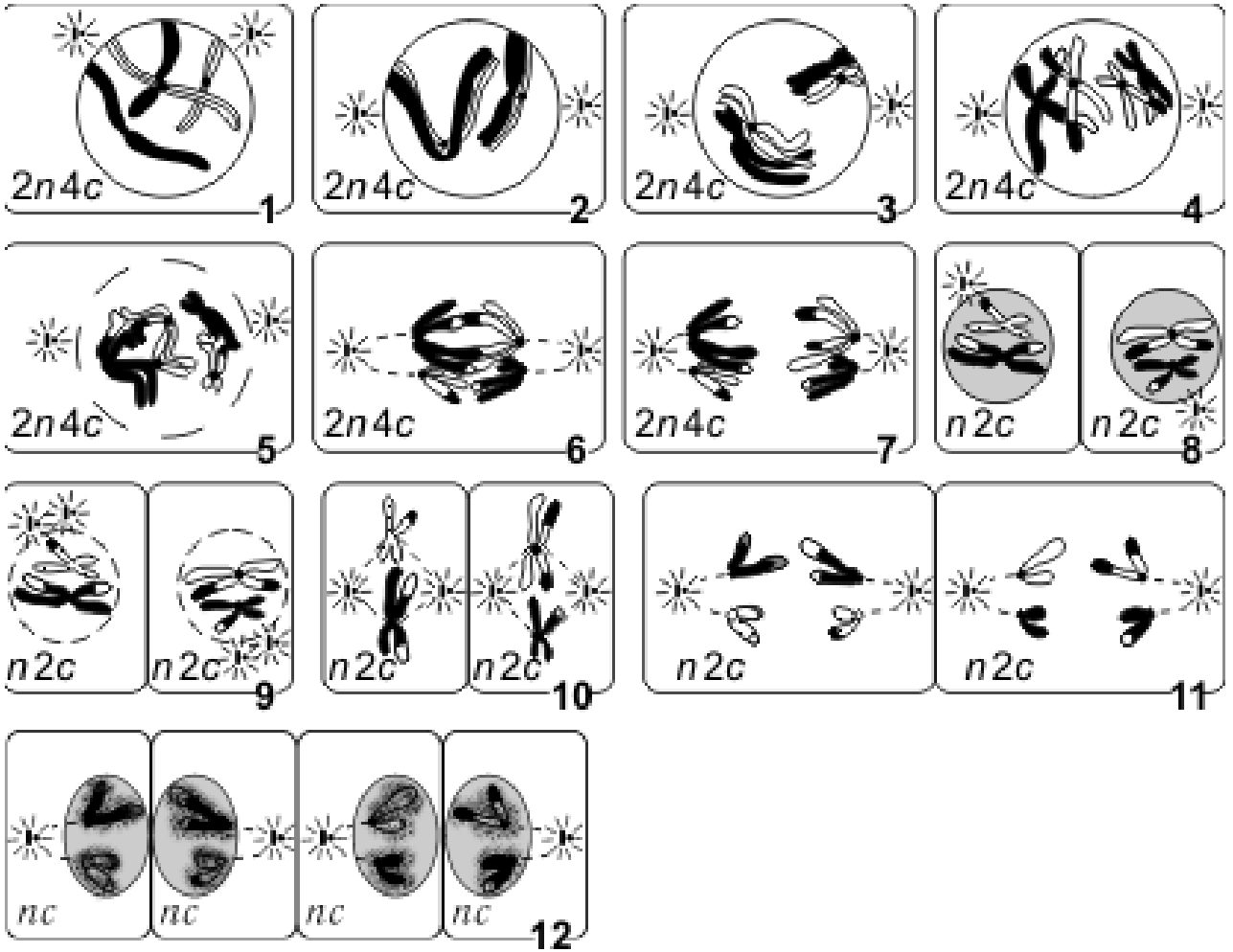
-Zygothene

-Pachytene

-Diplotene

-Diakinesis

Meiosis


2n4c
1
2n4c
2
2n4c
3
2n4c
4
2n4c
5
2n4c
6
2n4c
7
n2c
n2c
8
n2c
n2c
9
n2c
n2c
10
n2c
n2c
11
nc
nc
nc
nc
12

Aging of cell

- In the process of aging:

- cell loses its ability to replicate DNA and is retained in the G1 phase of the cell cycle, then passing into the G0 phase.
- number of organelles and cell volume decreases
- number of lysosomes increases
- pigment and fat inclusions accumulate
- nucleus and cytoplasm vacuolise
- cytoplasm permeability increases.

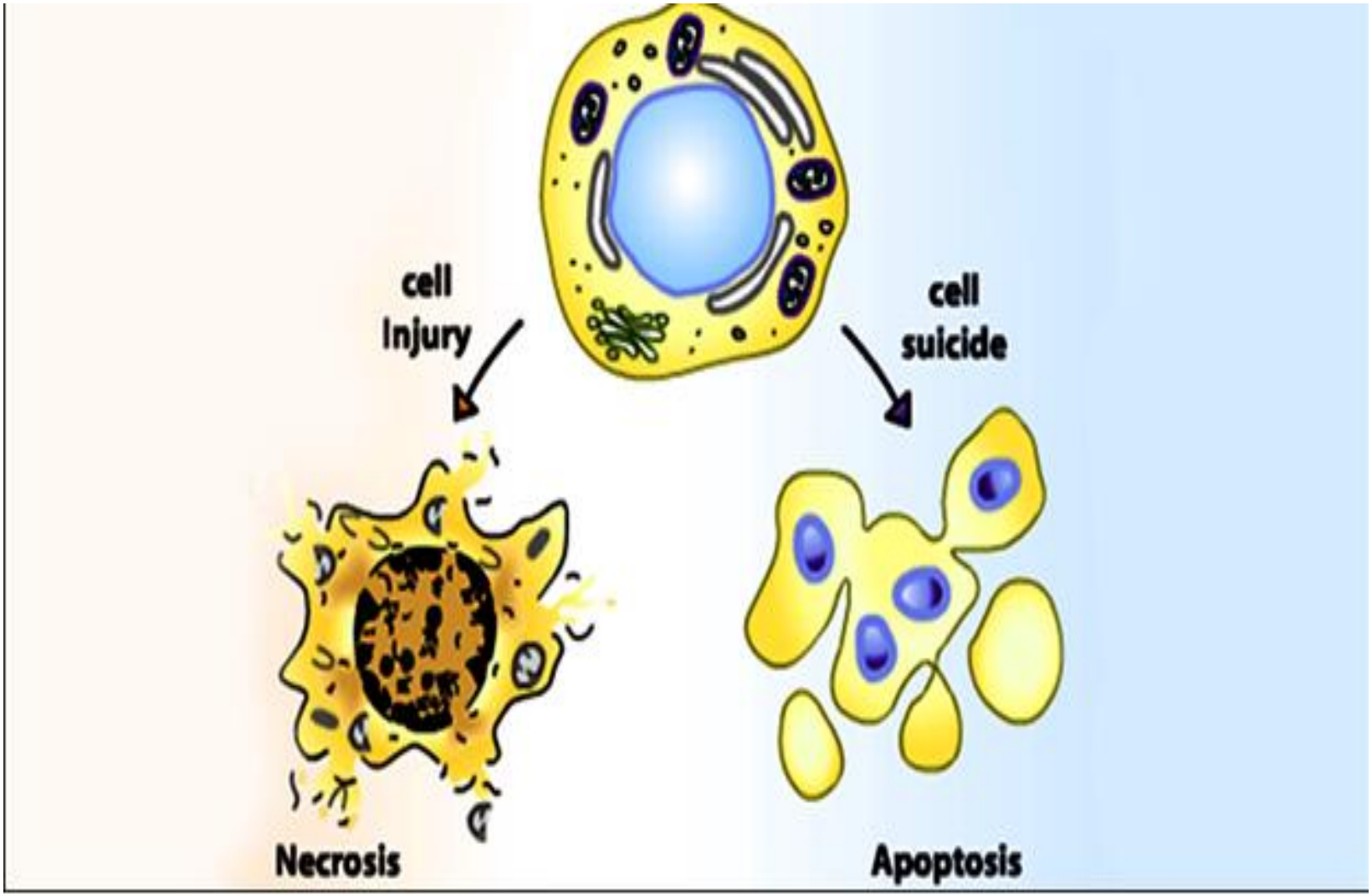
Apoptosis

- Apoptosis is form of programmed cell death. Biochemical events lead to characteristic cell changes (morphology) and death. These changes include cell shrinkage, nuclear fragmentation, chromatin condensation, chromosomal DNA fragmentation, and global mRNA decay.

Necrosis

- Necrosis is a non-physiological process that occurs as a result of infection or injury. Necrosis is caused by factors external to the cell or tissue, such as infection, toxins, or trauma which result in the unregulated digestion of cell components.
- In necrosis, a cell undergoes swelling, followed by uncontrolled rupture of the cell membrane with cell contents being expelled. These cell contents often then go on to cause inflammation in nearby cells.

Apoptosis and Necrosis



Thank you for attention