# Biology for Engineers

**Presented by**

Dr. Narinder Singh Punn,

Assistant Professor,

Dept. of CSE,

ABV-IIITM Gwalior

विश्वजीवनामृतं ज्ञानम्

# OUTLINE

- Biology and Engineering
- Why study biology?
- Science vs Engineering
- Eye vs Camera
- Bird vs Aircraft

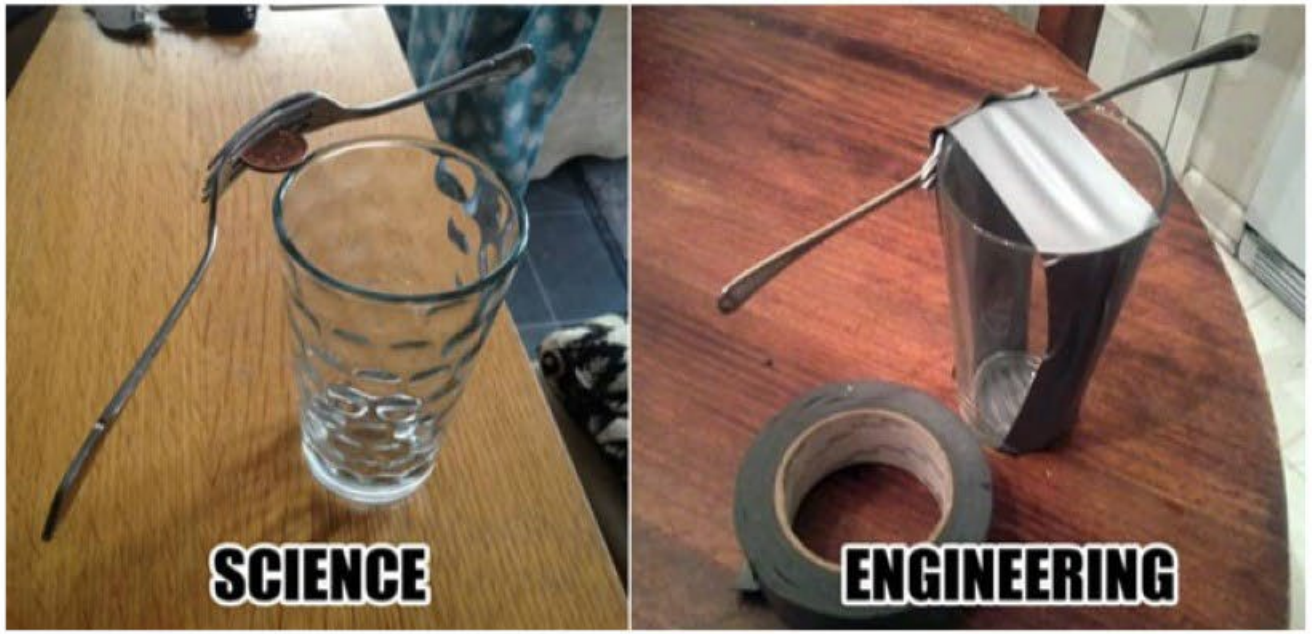
# BIOLOGY & ENGG.

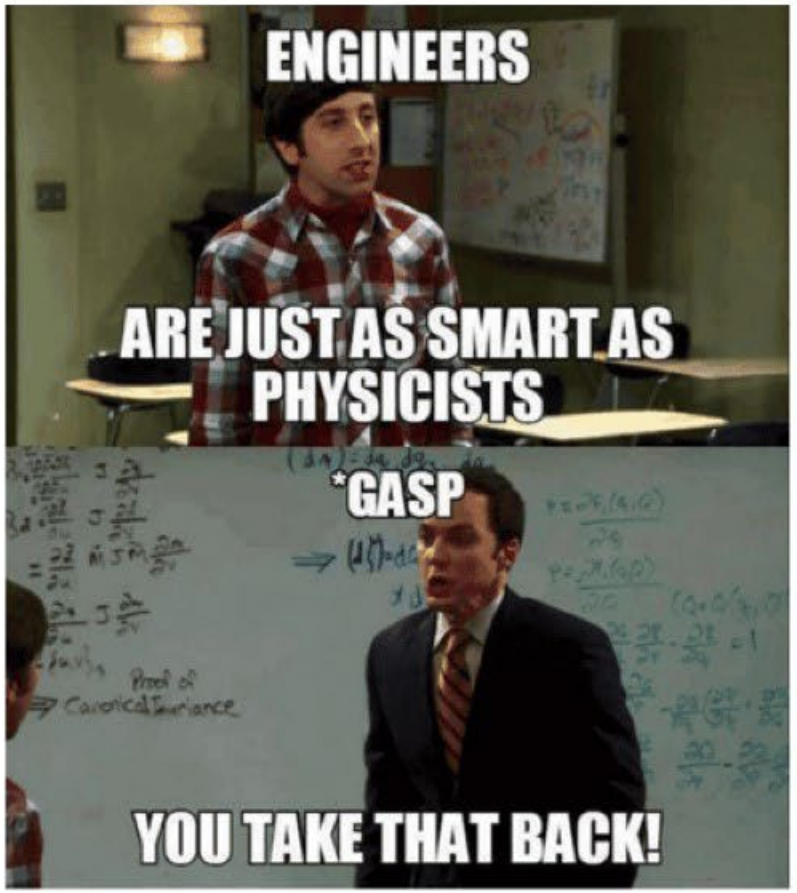
- Bios (Life) and Logos (Study)
- Biology is the study of
  - all living things called organisms (e.g. plants, bacteria, protist, animals, etc.)
  - structure and cellular organisation and functioning of living things.
  - life processes of living things such as respiration, growth, development, reproduction.
  - interaction of living things with one another and with their environment.

# WHY STUDY BIOLOGY?

- To find solutions to the challenges:
  - Historical: bird flight => airplanes
- Sustainability:
  - Biology has sustainable methods
  - Life forms have evolved and co-existed in harmony with nature for millions of years.
- Well being:
  - by understanding - cell, its processes, system as a whole.

# SCIENCE VS ENGINEERING



# SCIENCE VS ENGINEERING

- Science:
  - Study of arranged facts logically explained.
- Engineering:
  - Practical knowledge to design.

- Science:
  - Collection of knowledge and validated systems.
- Engineering:
  - Utilization of these systems and knowledge to create devices and structures.

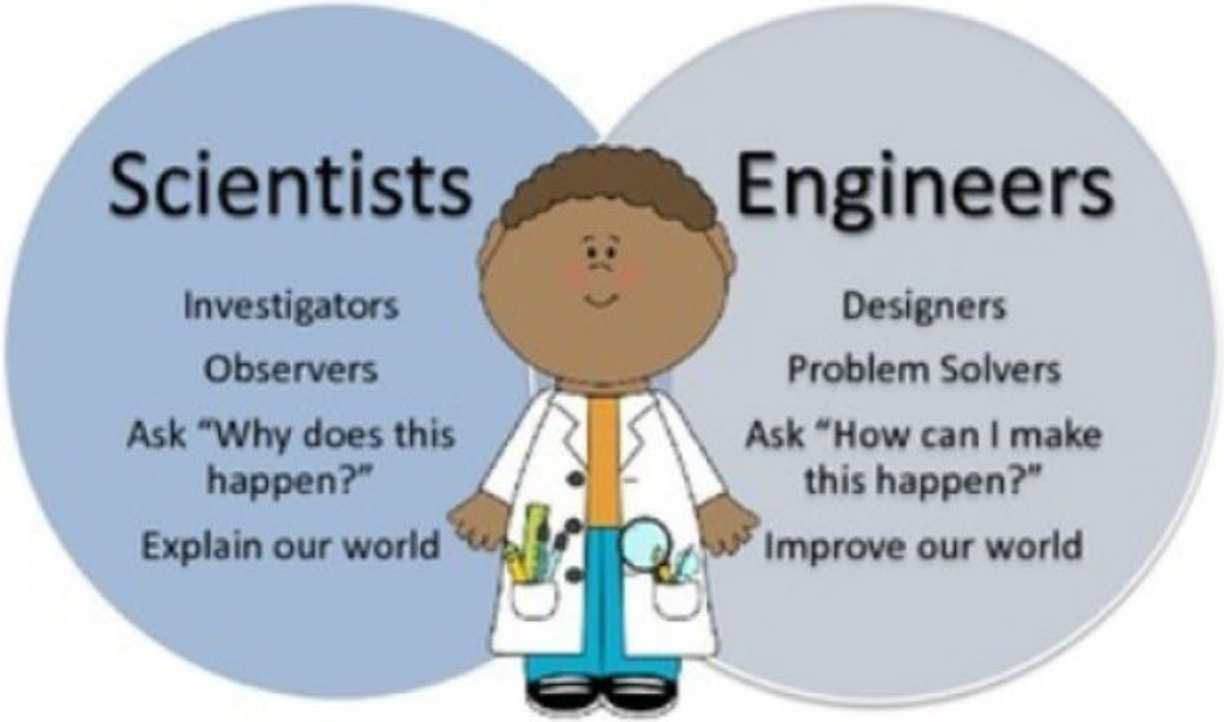
# SCIENCE VS ENGINEERING

"ENGINEERS SOLVE PRACTICAL PROBLEMS, SCIENTIST SOLVE THEORETICAL PROBLEMS"

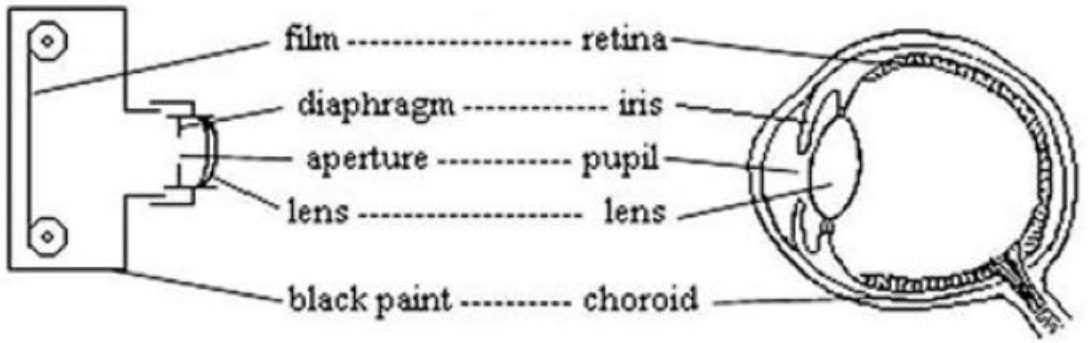
***"Science is about knowing, Engineering is about doing"***

- *Henry Petroski*

# SCIENCE VS ENGINEERING

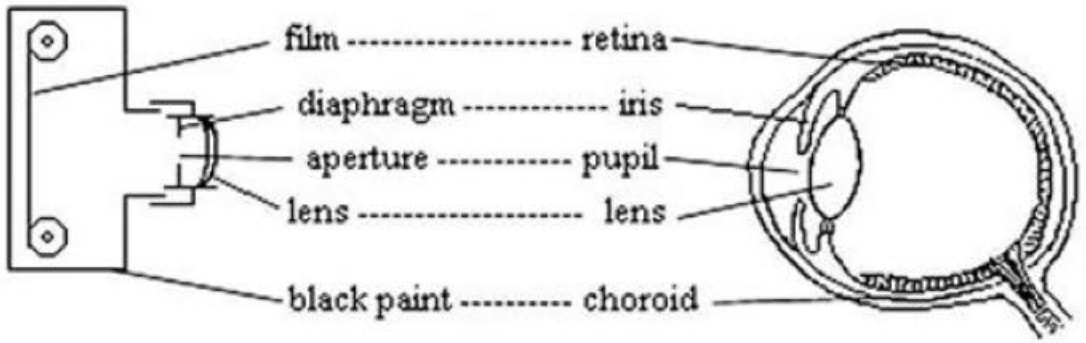


# EYE VS CAMERA



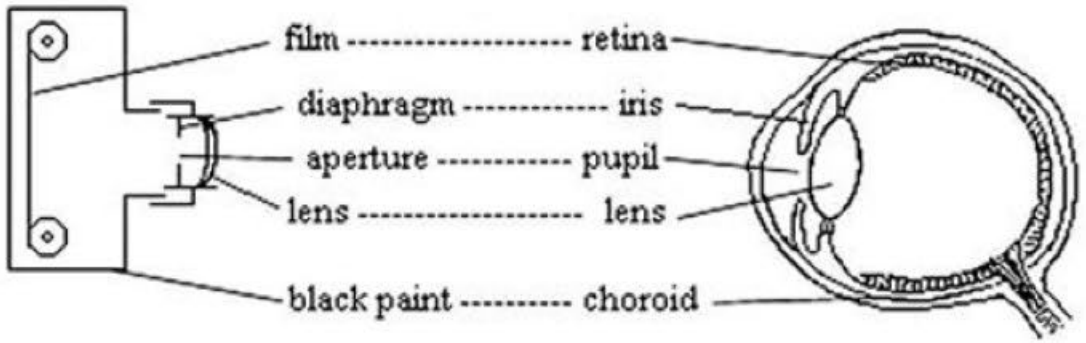

- Film:
  - Detects and records the light which is focused onto it.
  - Can be a photographic film or CCD (Charged-Coupled Device) in case of digital cameras.
- Retina:
  - Detects light and converts it into electrical impulses which are sent to brain.

# EYE VS CAMERA



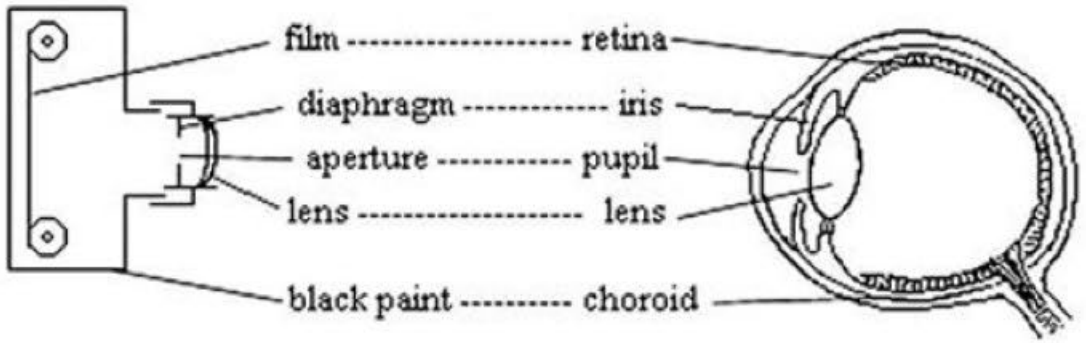

- Diaphragm:
  - Allows the user to adjust the amount of light.
- Iris:
  - Controls the size of pupil.

# EYE VS CAMERA



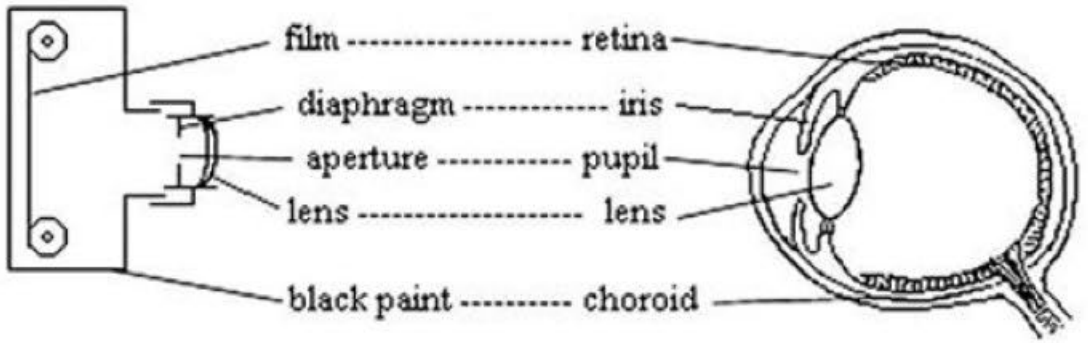

- Aperture:
  - Allows the light to enter.
- Pupil:
  - It allows the light to enter in the eyes.

# EYE VS CAMERA



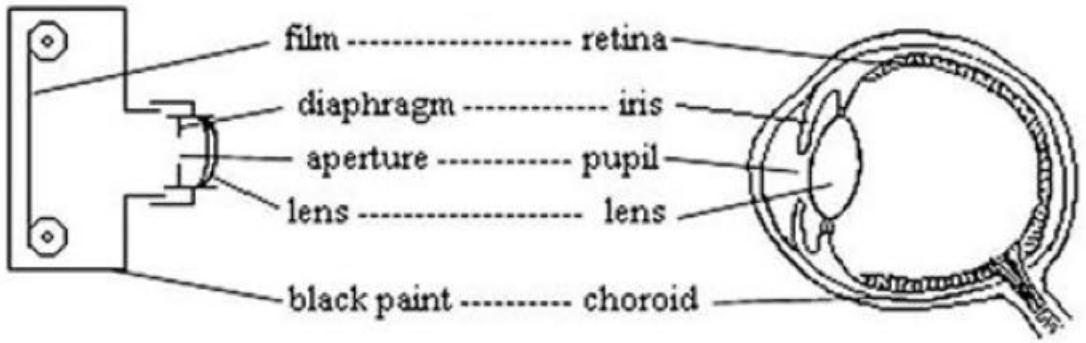

- Lens (Camera):
  - To focus light onto photosensitive surface.
- Lens (Human eye):
  - Focuses light onto retina.

# EYE VS CAMERA




- Black Paint:
  - Absorb excessive light to prevent multiple images formation.
- Choroid:
  - Absorb excessive light to prevent multiple images formation.

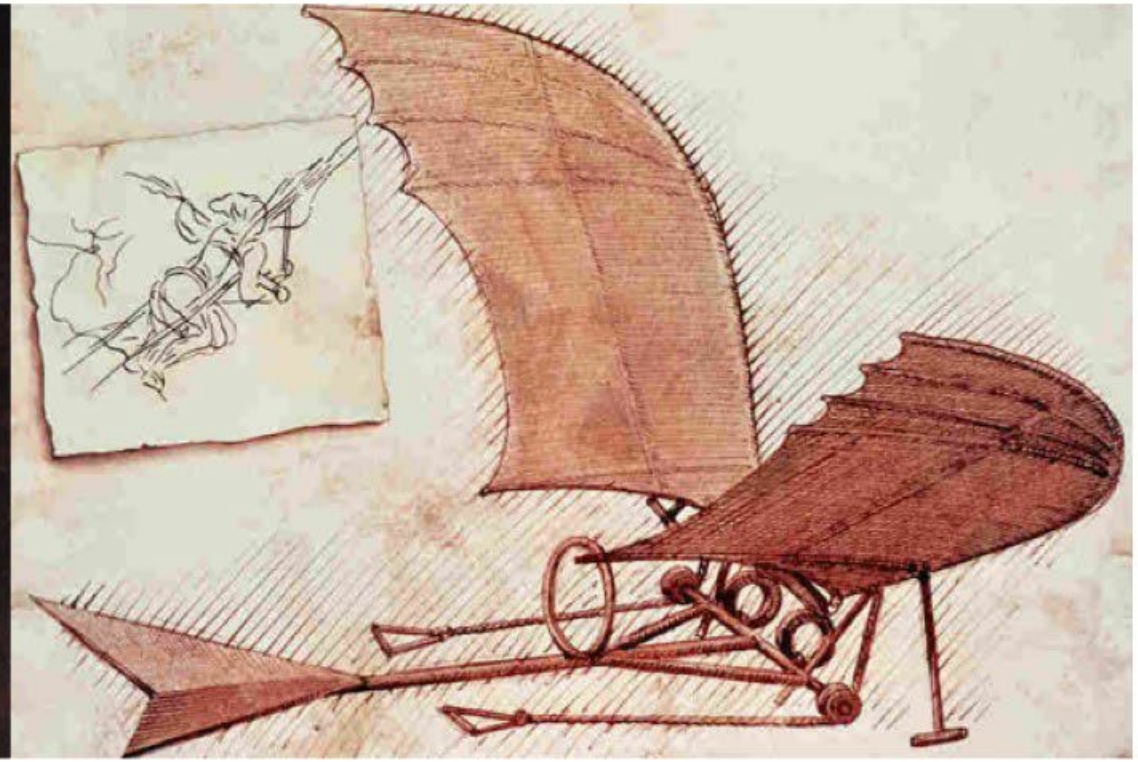
# EYE VS CAMERA




- Focusing screen:
  - To focus on nearer or farthest objects.
- Ciliary muscles:
  - Adjust the shape of lens by adjusting ligaments.

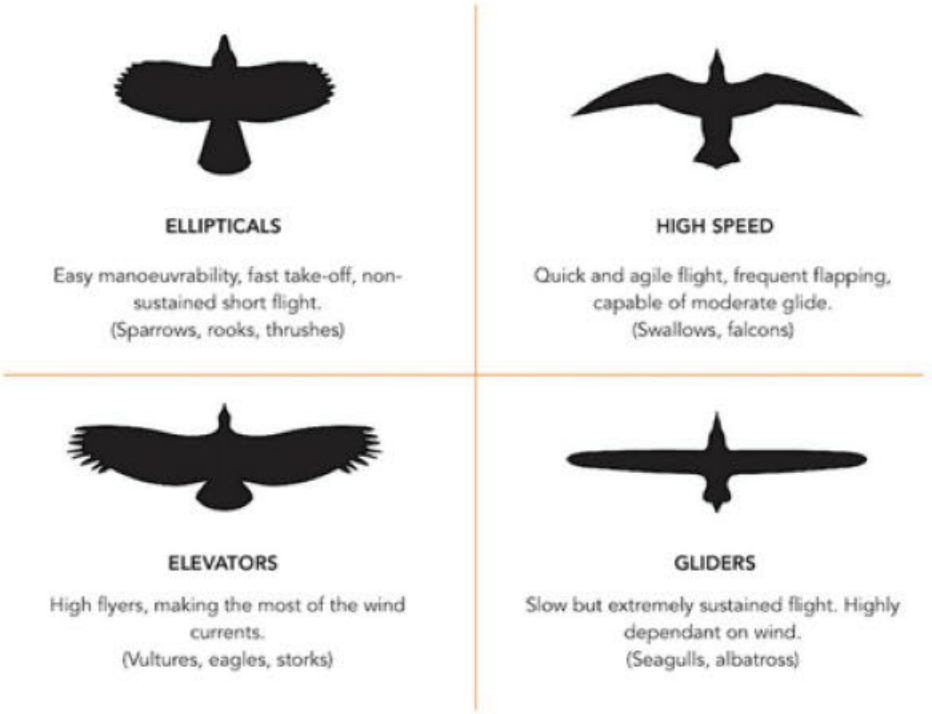
# BIRD VS AIRCRAFT

In 1799, Sir George Cayley, a British Engineer and Inventor, devised the first modern concept of an aeroplane based on lift, inspired by the gliding flight of vultures.



# BIRD VS AIRCRAFT

Gliding like a vulture, reaching the speed of a hawk or suspending like an albatross. Each type of bird has developed its specific wing anatomy adapted to its habitat.



**ELLIPTICALS**

Easy manoeuvrability, fast take-off, non-sustained short flight.
(Sparrows, rooks, thrushes)

**HIGH SPEED**

Quick and agile flight, frequent flapping, capable of moderate glide.
(Swallows, falcons)

**ELEVATORS**

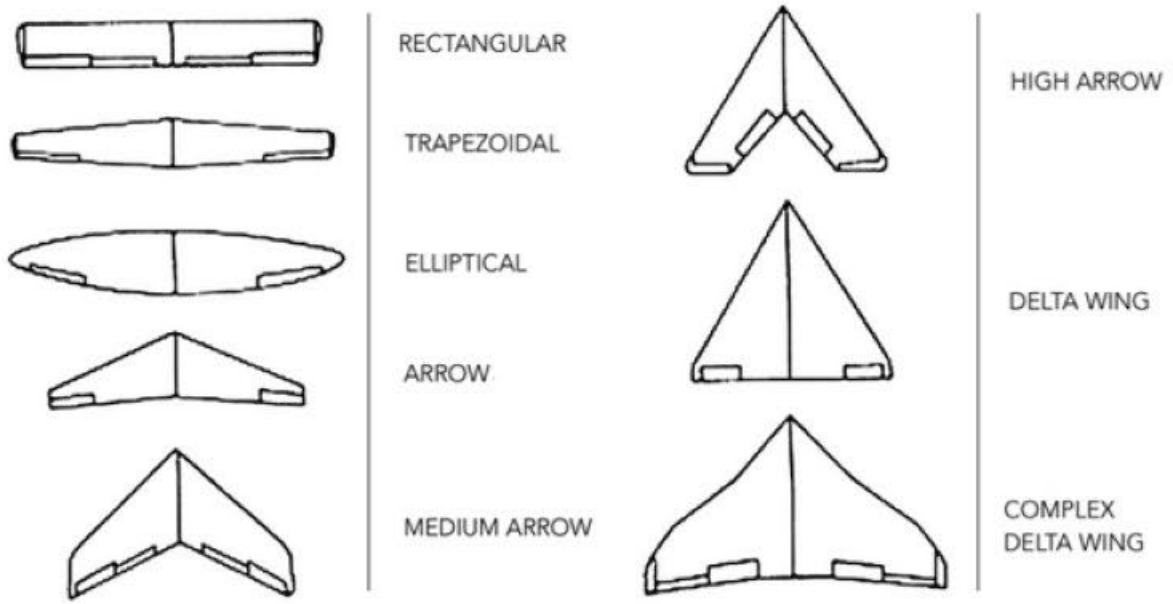
High flyers, making the most of the wind currents.
(Vultures, eagles, storks)

**GLIDERS**

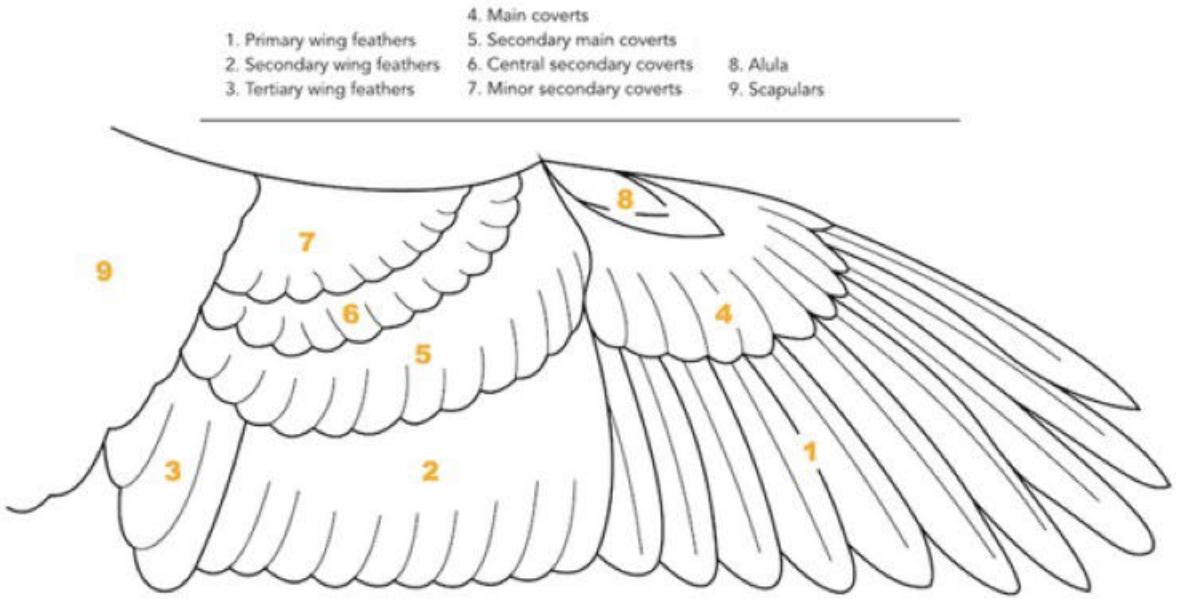
Slow but extremely sustained flight. Highly dependant on wind.
(Seagulls, albatross)

# BIRD VS AIRCRAFT

The design of aircraft includes different types of wings designed for an activity or to favour a specific type of flight

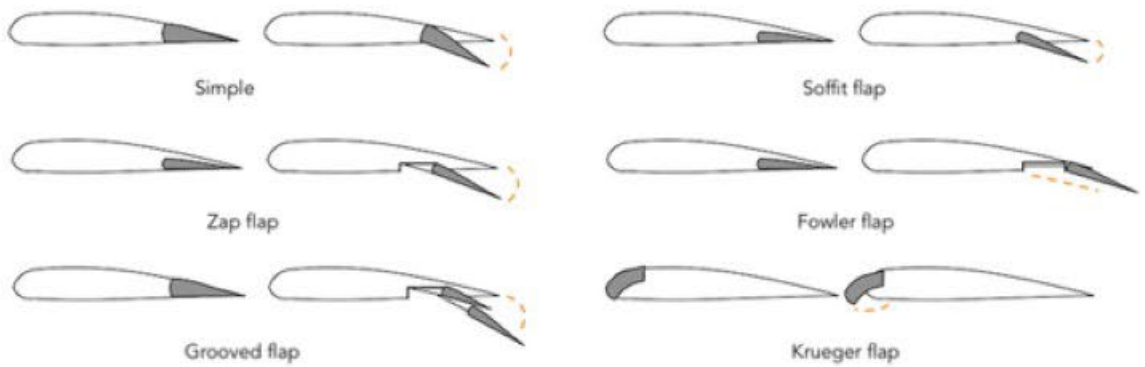


# BIRD VS AIRCRAFT




- **Alulas:** Increase the lift index at low speeds and reduce turbulence.
- **Wing feathers:** Generate the necessary lift to take off and control the speed on landing.
- **Coverts:** Direct air flow under the wings creating an aerodynamic profile.
- **Scapulars:** Cover and protect the joint between the wing and the body in scapulars (shoulder blades).

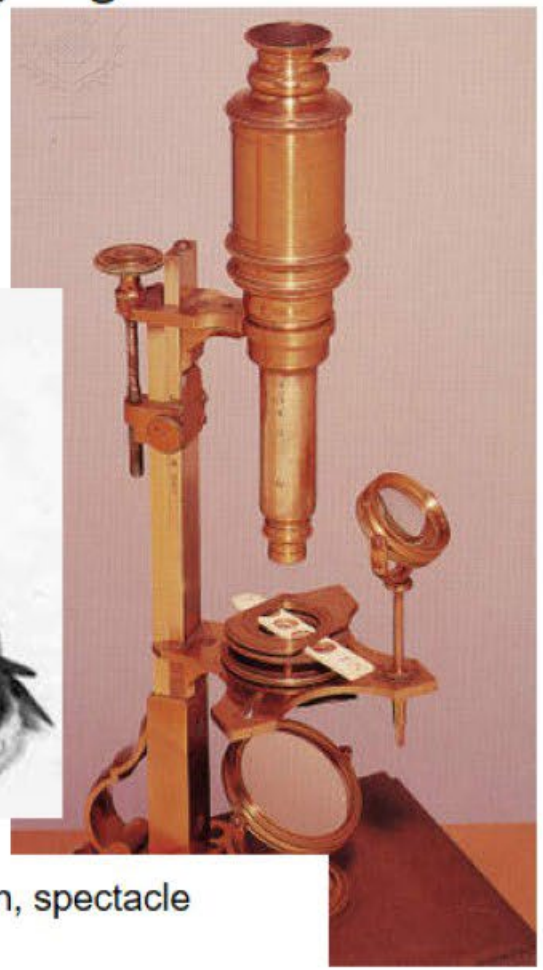
# BIRD VS AIRCRAFT




- As feathers, **flaps** are in charge of varying the angle, shape and the surface of the aircraft wings to increase lift at low speeds.

# CELL

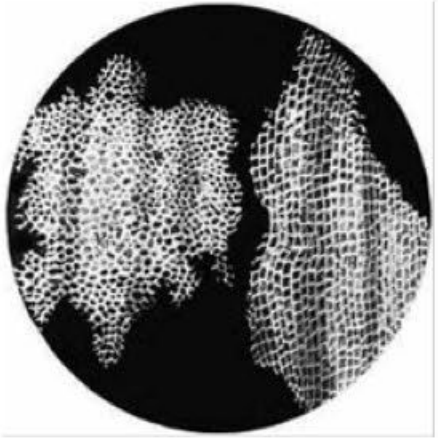
- Living organisms: Microscopic or macroscopic



Zacharias Jansen, spectacle maker, in 1590

Hans Lippershey, a Dutch lensmaker, in 1608

# CELL



The timeline of

## CELL DISCOVERY

**Cell**: The basic structural, functional and biological unit of all known organisms.

**1665**

Robert Hooke an English botanist, discovered cell in cork slice, the term cell was derived from Latin word (cella = a little room). He explained his observations in a book, namely, Micrographia. He found the rigid cell walls of dead cells.

**1674**

Antonie van Leeuwenhoek, a Dutch draper and also he was the father of Microbiology. He observed free-living cells in pond water.

**1831**

Robert Brown, Scottish botanist, discovered the nucleus.

**1839**

Purkinje coined the term protoplasm (the cytoplasm and nucleus of a cell) for the fluid substance of the cell.

**1838 & 1839**

The cell theory was proposed by Matthias Schleiden and Theodore Schwann.
The cell theory denotes, that all the plants and animals are consist of cells and that the cell is the basic unit of life.

**1955**

The cell theory was also further explained by Rudolf Virchow by suggesting that all cells arise from pre-existing cell.

**Note**

Theodore Schwann, a British Zoologist, was first to observe cells have a thin outer layer witch we now call as Plasma membrane.

**Note**

This concept of cell arising from pre-existing cell was started by Virchow as "Omnis cellula e cellula".

**1940**

Vladimir Zworykin invented the electronmicroscope witch
enables to see the complex structure of the cell.

# CELL

## Classical cell theory (Mathias Schleiden and Theodore Schwann)

- All organisms are made up of cells.
- Cells are the basic units of life.
- Cells comes from pre-existing cells that have multiplied spontaneously.

# CELL

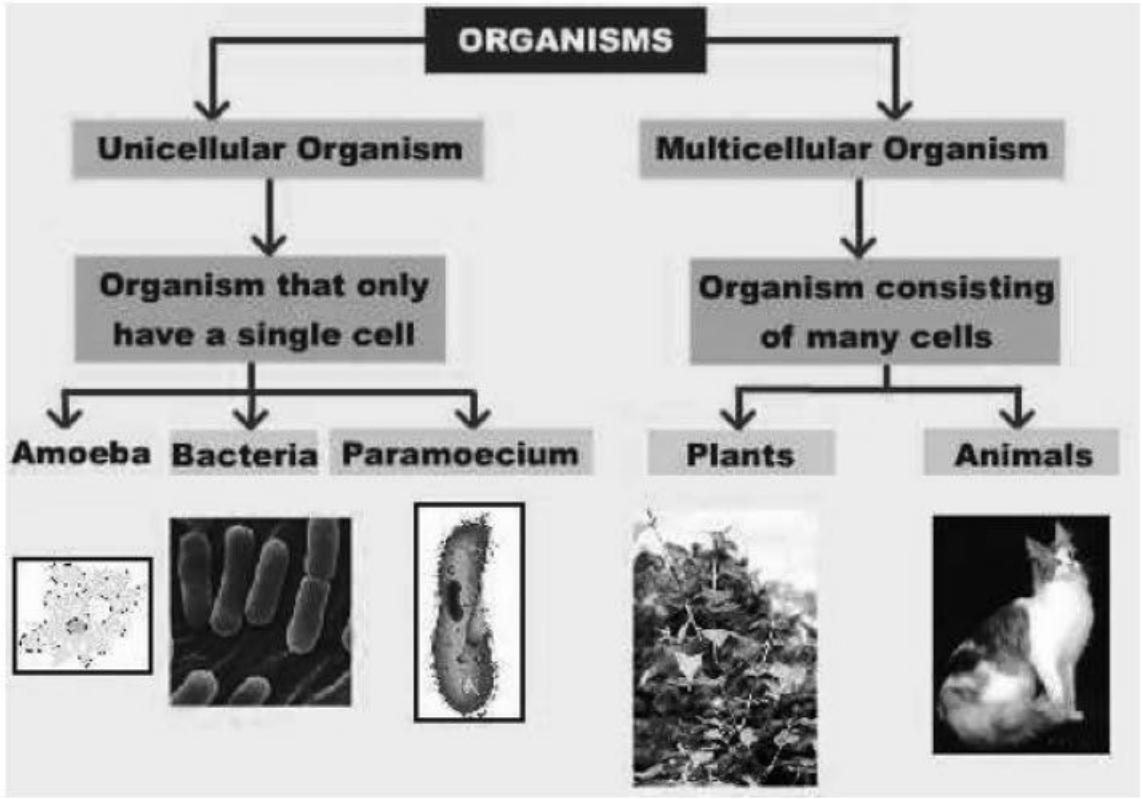
## Classical cell theory (Mathias Schleiden and Theodore Schwann)

- All organisms are made up of cells.
- Cells are the basic units of life.
- Cells comes from pre-existing cells that have multiplied spontaneously.

## Modern cell theory (Rudolph Virchow)

- During cell division, genetic material will pass on to the newly formed cells.
- The cells of an organism within a similar species will not differ structurally and chemically.
- Energy flows occurs within the cells.

# CLASSIFICATION



# CLASSIFICATION

## CELLULARITY

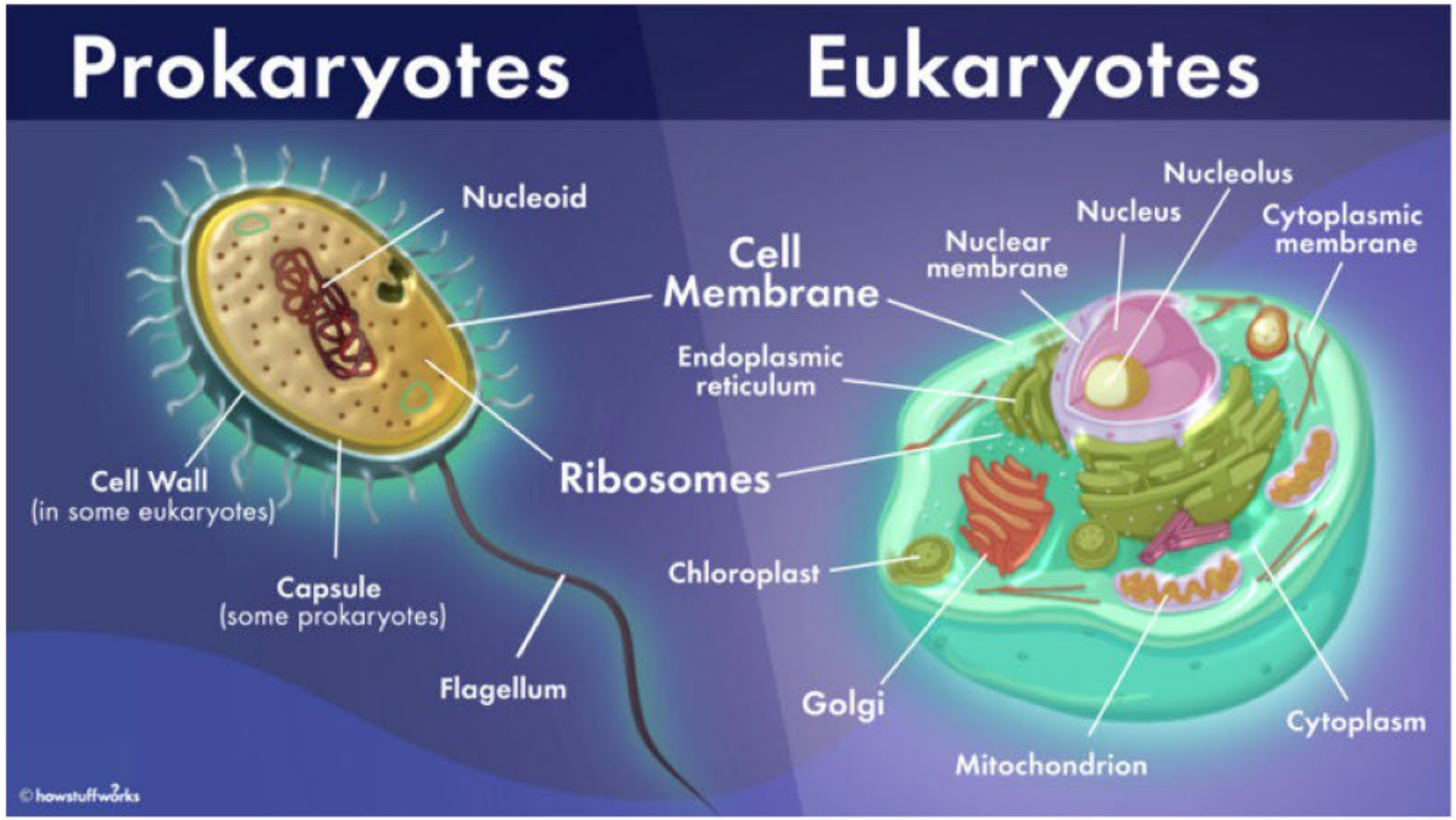
| | Unicellular | Multi-cellular |
|---|---|---|
| **Number of cells** | Single cell in body | More than one cell in body |
| **Cell membrane** | No membrane bound organelles | Membrane bound organelles |
| **Functioning** | All job in one cell | Division of labour for cells |
| **Exposure** | Cell body is exposed to environment | Only outer cells are exposed |
| **Cell Size** | 5 - 10 micrometers | 10 -100 micrometers |
| **Injury** | Injury in cell may cause death to organism | If injury in cell, it will be replaced by new cell and organism doesn't die |
| **Life Span** | Shorter | Longer |
| **Example** | Amoeba, Euglena, Paramecium, etc. | Animals, Plants, Fugi, etc. |

# CLASSIFICATION

| | Prokaryotes | Eukaryotes |
|---|---|---|
| **Number of cells** | Unicellular | Multicellular |
| **Cell wall** | Cell wall present (Peptidoglycan) | Only present in plants (Cellulose) |
| **Nucleus** | No nucleus (Nucleoid) | Proper nucelus |
| **DNA** | Circular double strand DNA | Linear double strand DNA |
| **Membrane** | Absence of membrane bound organelles | Presence of membrane bound organelles |
| **Cell division** | Binary fission, conjugation, transformation, transduction | Mitosis |
| **Ribosome** | 70s Ribosome | 80s Ribosome |
| **Example** | Bacteria, Archaea, etc. | Animals, Plants, etc. |

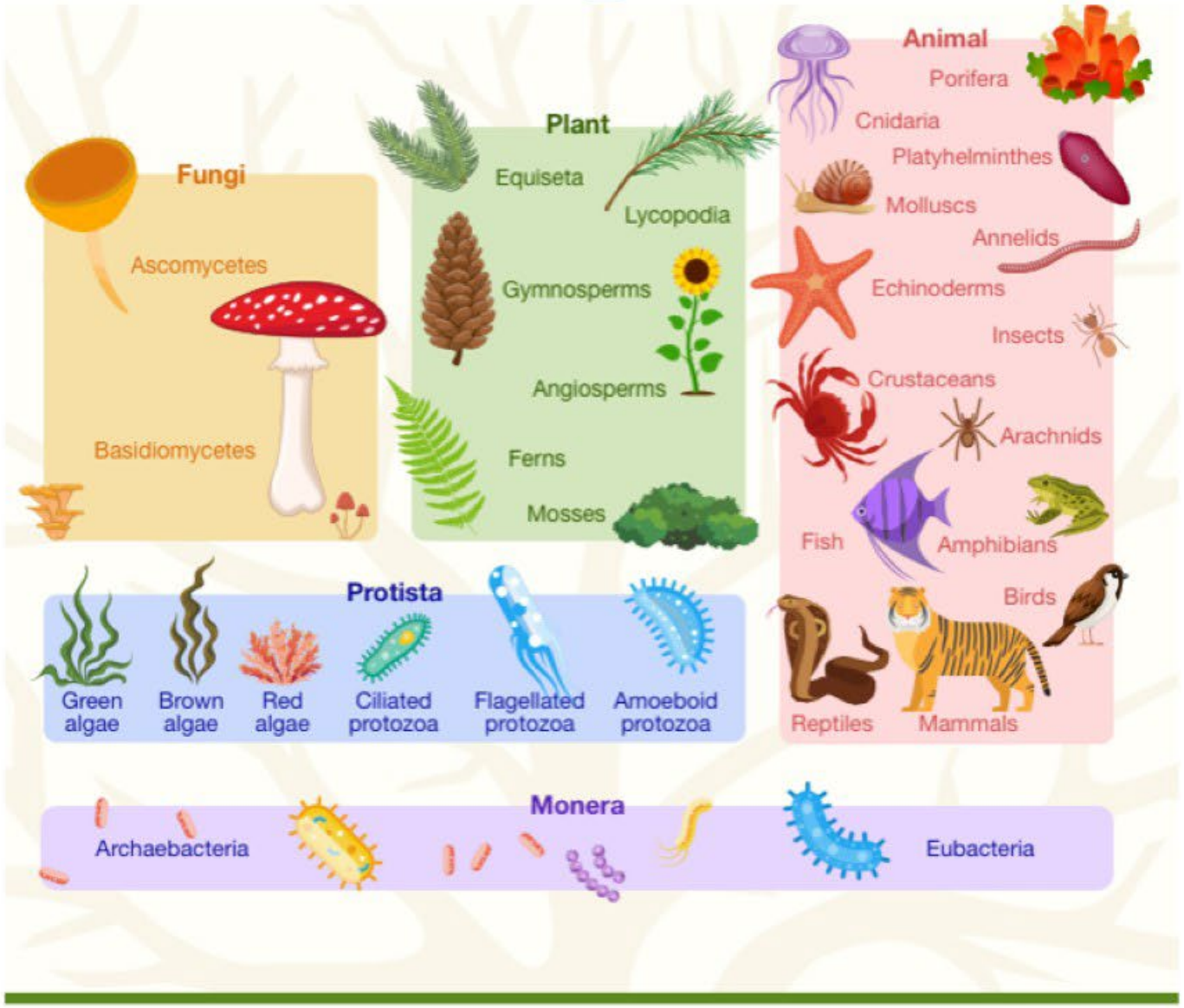
# CLASSIFICATION

## Ultra Structure



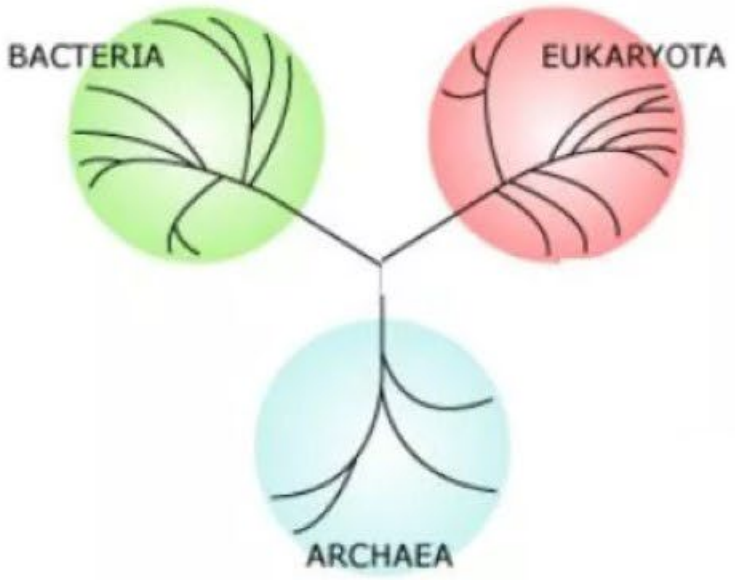
# CLASSIFICATION

- Five Kingdoms of Life:

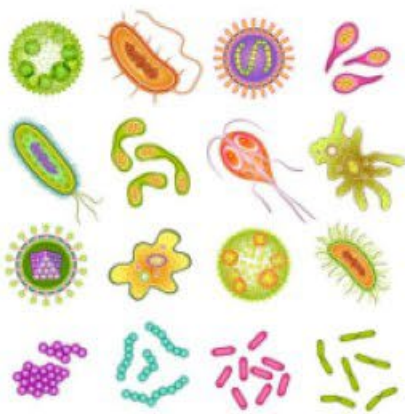


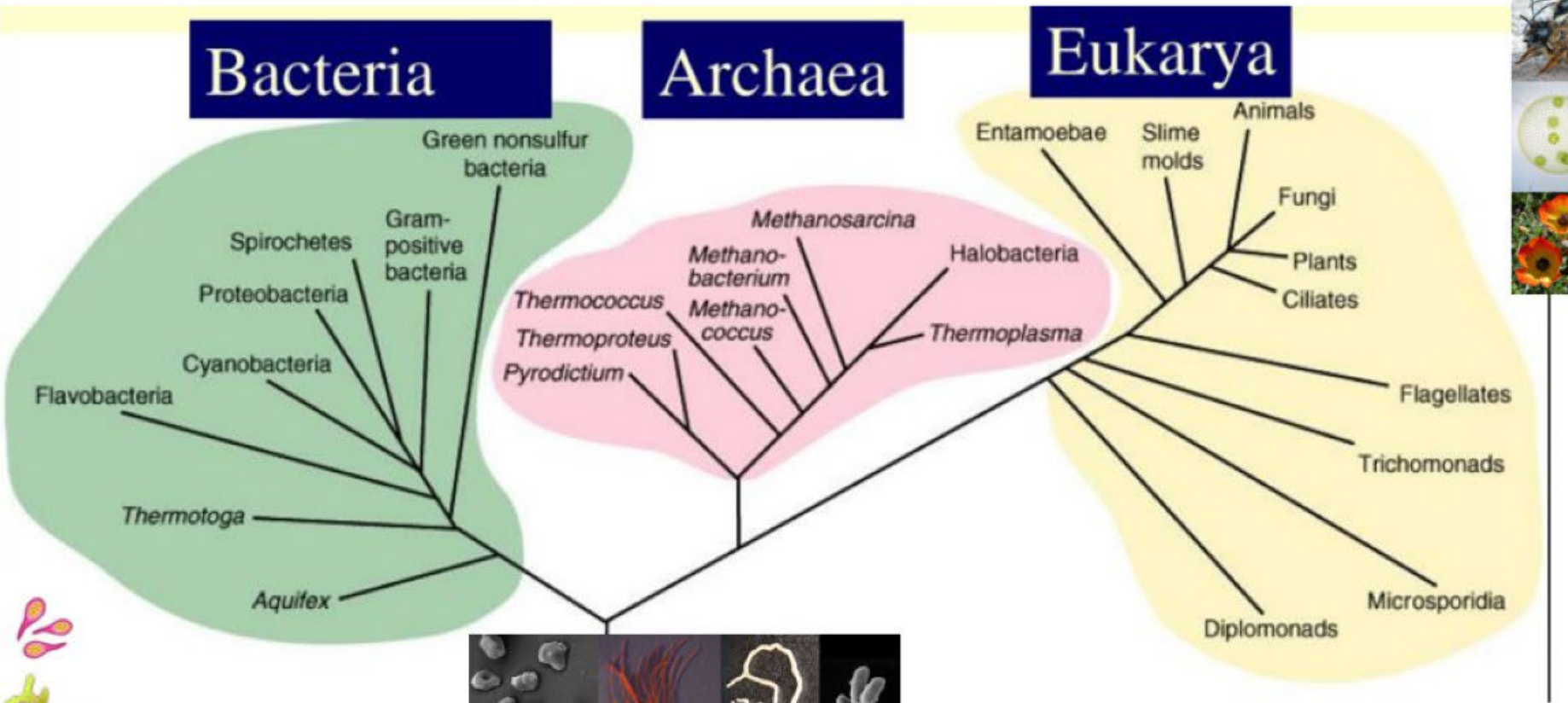
# CLASSIFICATION

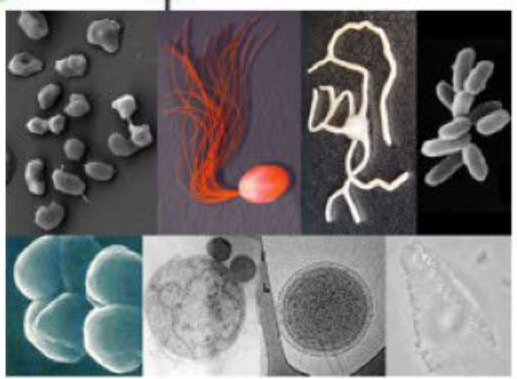
- Three Kingdoms of Life (Carl Woese 1990):



# CLASSIFICATION





# WHY SEPARATE CLASSIFICATION FOR ARCHAEA

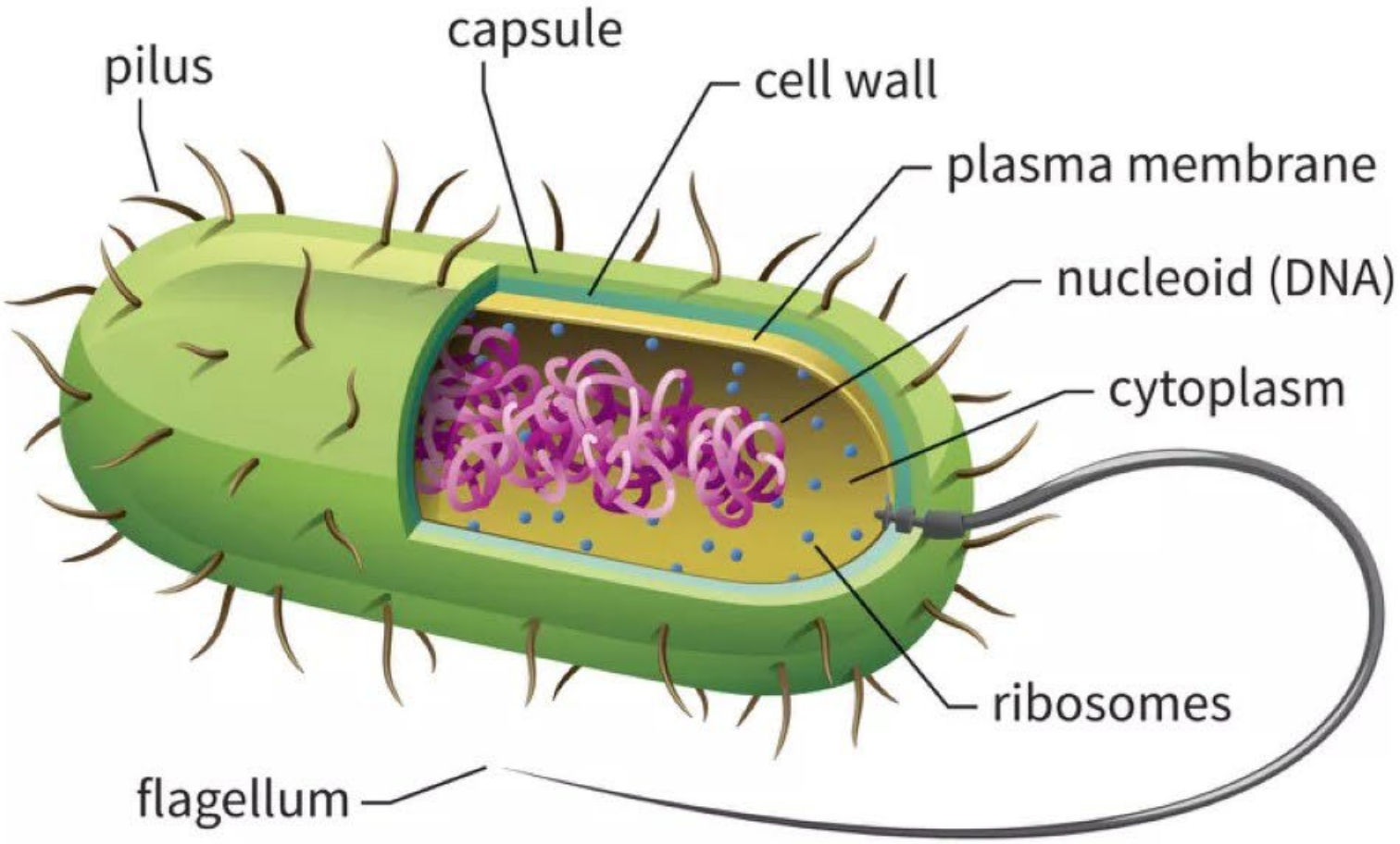
- Archaea is single celled organisms.
- Genes are similar to both bacteria and eukaryotes.
- Very similar to bacteria in appearance.
- Prokaryotic organisms (just like bacteria).
- Do not have membrane bound nucleus and organelles.
- Similar shape and size as bacteria.
- Reproduce by binary fission.
- Have one circular chromosome.
- Use flagella to move in environment.

# WHY SEPARATE CLASSIFICATION FOR ARCHAEA

- Different:
  - cell wall composition from bacteria.
  - membrane composition from bacteria and eukaryotes.
  - rRNA type from bacteria and eukaryotes.

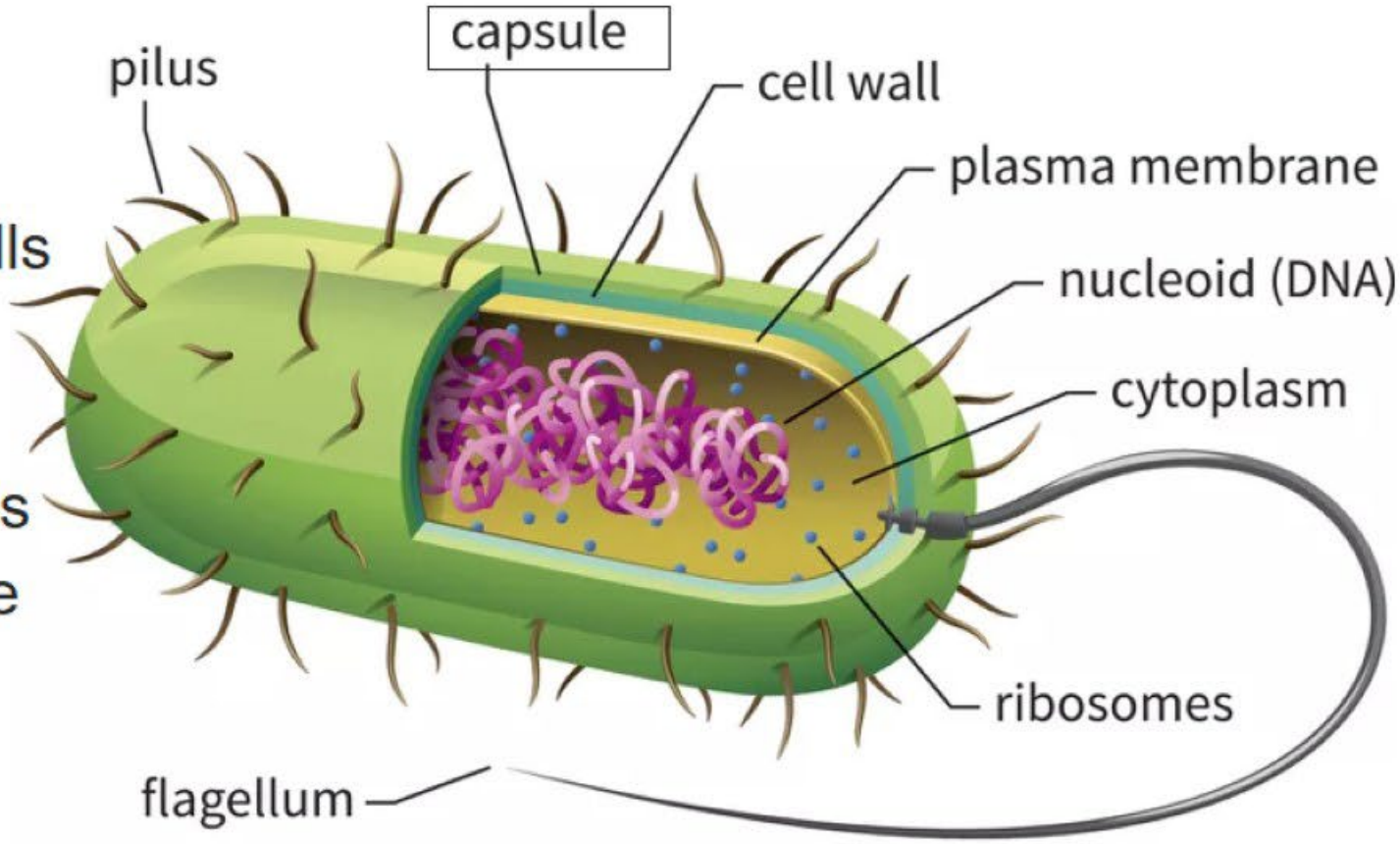
- Hence, Archaea is separate kingdom
- Live under extreme conditions e.g. within hydrothermal vents, acidic springs, and under Arctic ice.

# STRUCTURE OF PROKARYOTIC CELL



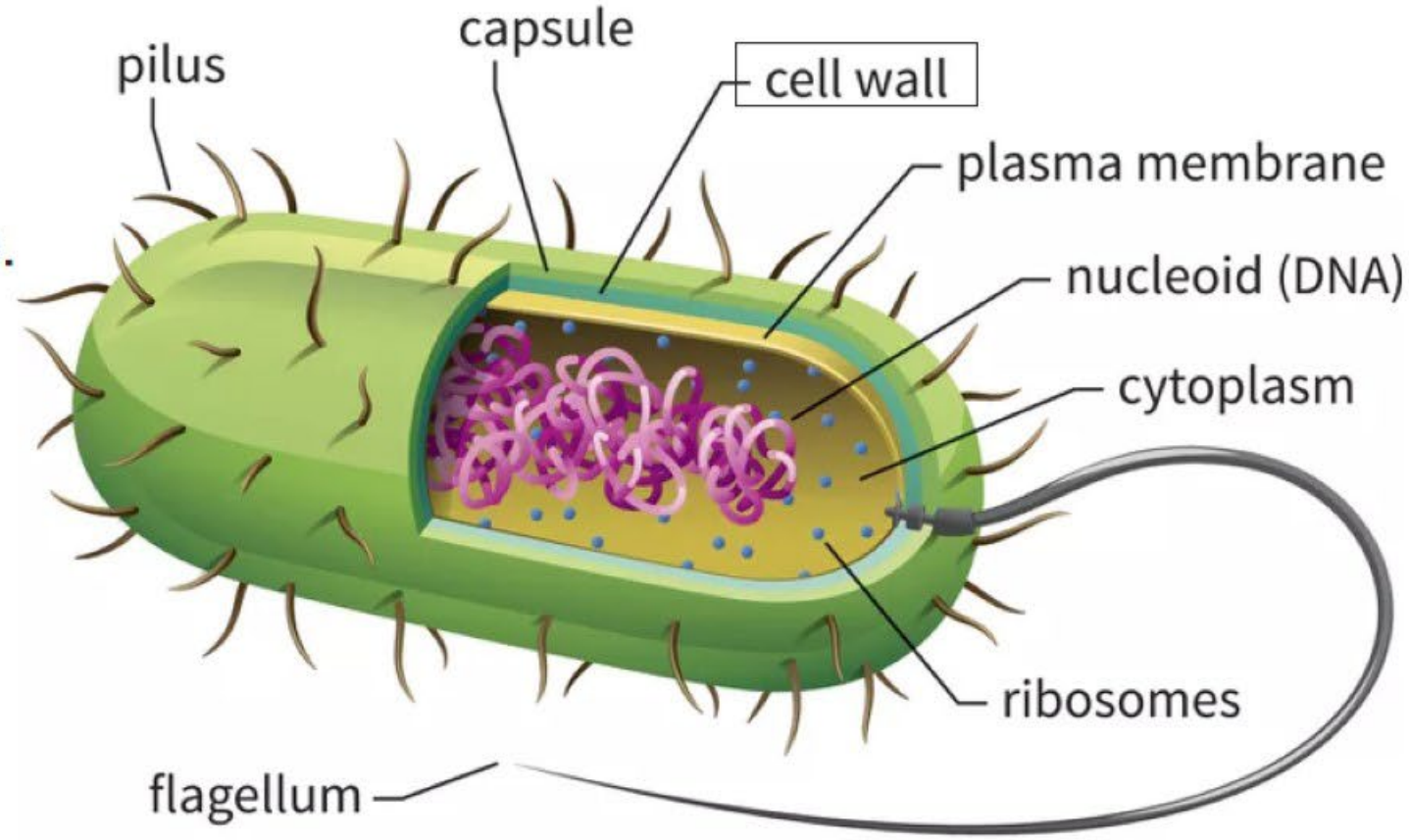
# STRUCTURE OF PROKARYOTIC CELL

- **Capsule:**
  - Found in some bacterial cells
  - Composed of polypeptide
  - Protects the cell when it is engulfed by other organisms
  - Assists in retaining moisture
  - Helps the cell adhere to surfaces and nutrients.



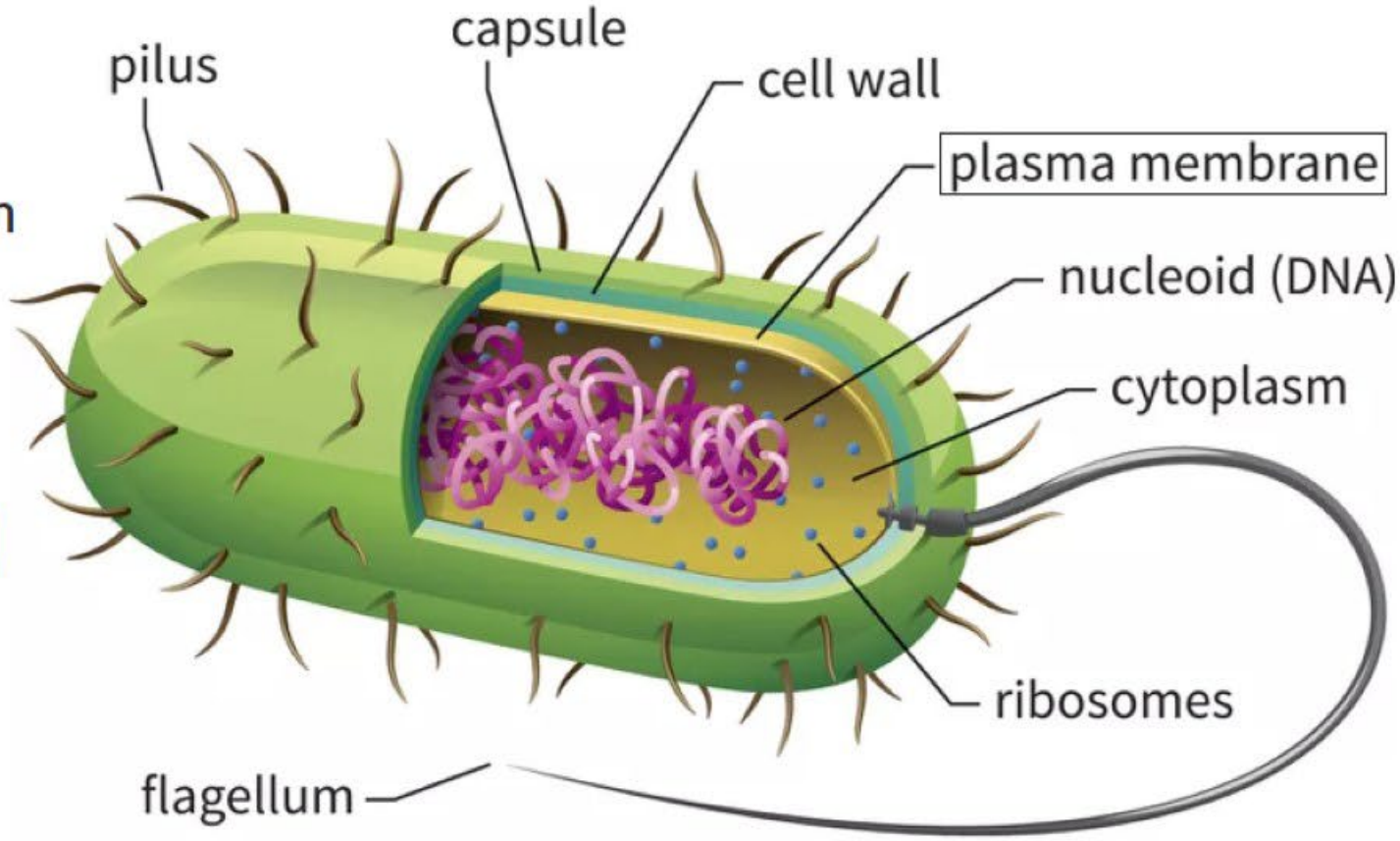
# STRUCTURE OF PROKARYOTIC CELL

- **Cell Wall:**
  - Tougher and rigid structure.
  - Made up of Peptidoglycan.
  - Provides the shape and protects the internal organelles of the cell.
  - Present between capsule and cell membrane.



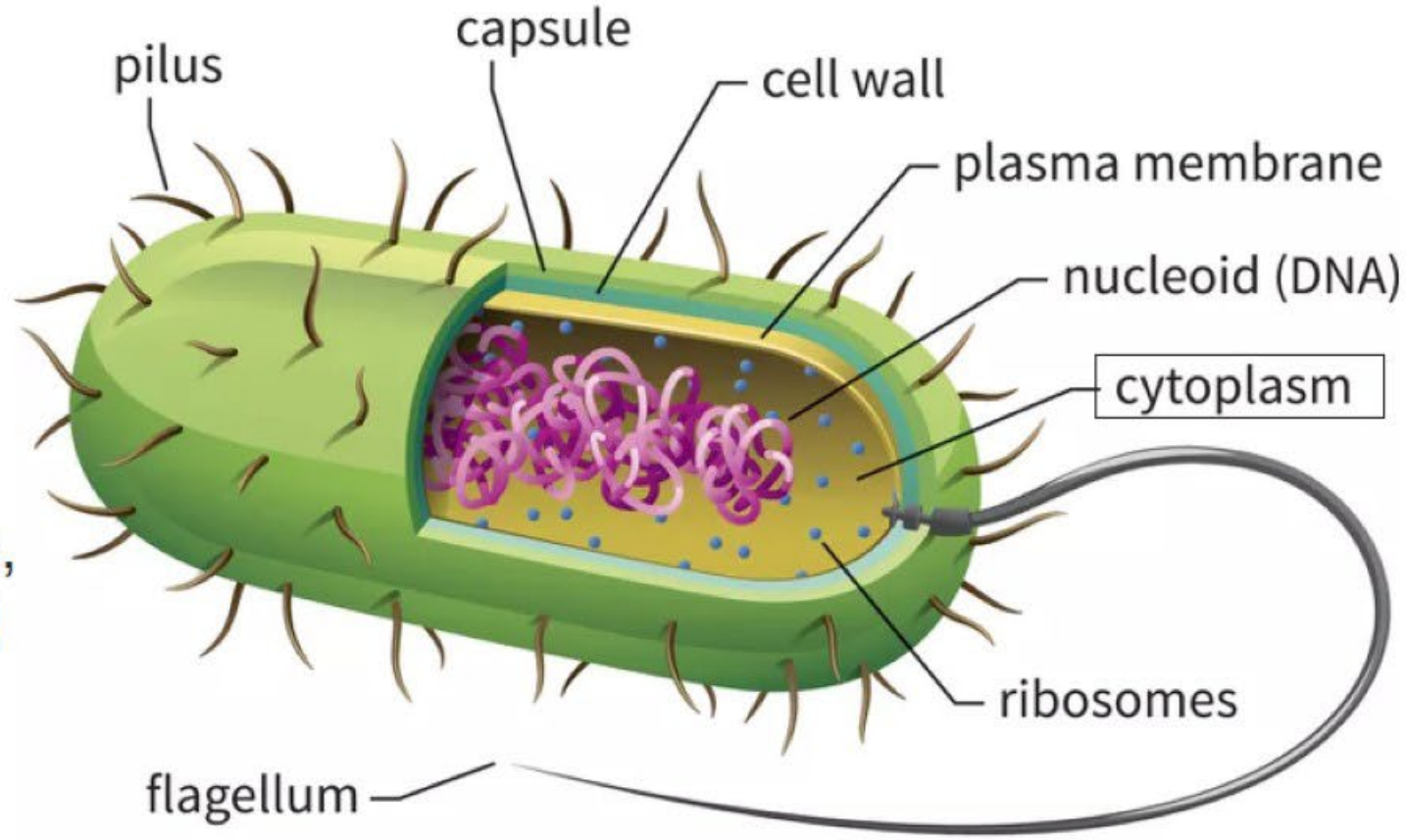
# STRUCTURE OF PROKARYOTIC CELL

- **Cell Membrane:**
  - Surrounds the cell's cytoplasm and regulates the flow of substances in and out of the cell.
  - It acts as a permeable membrane and separates cell from its environment.
  - 5 - 10 nm thickness
  - Helps in the secretion of proteins and elimination of waste products.
  - Plasma membrane



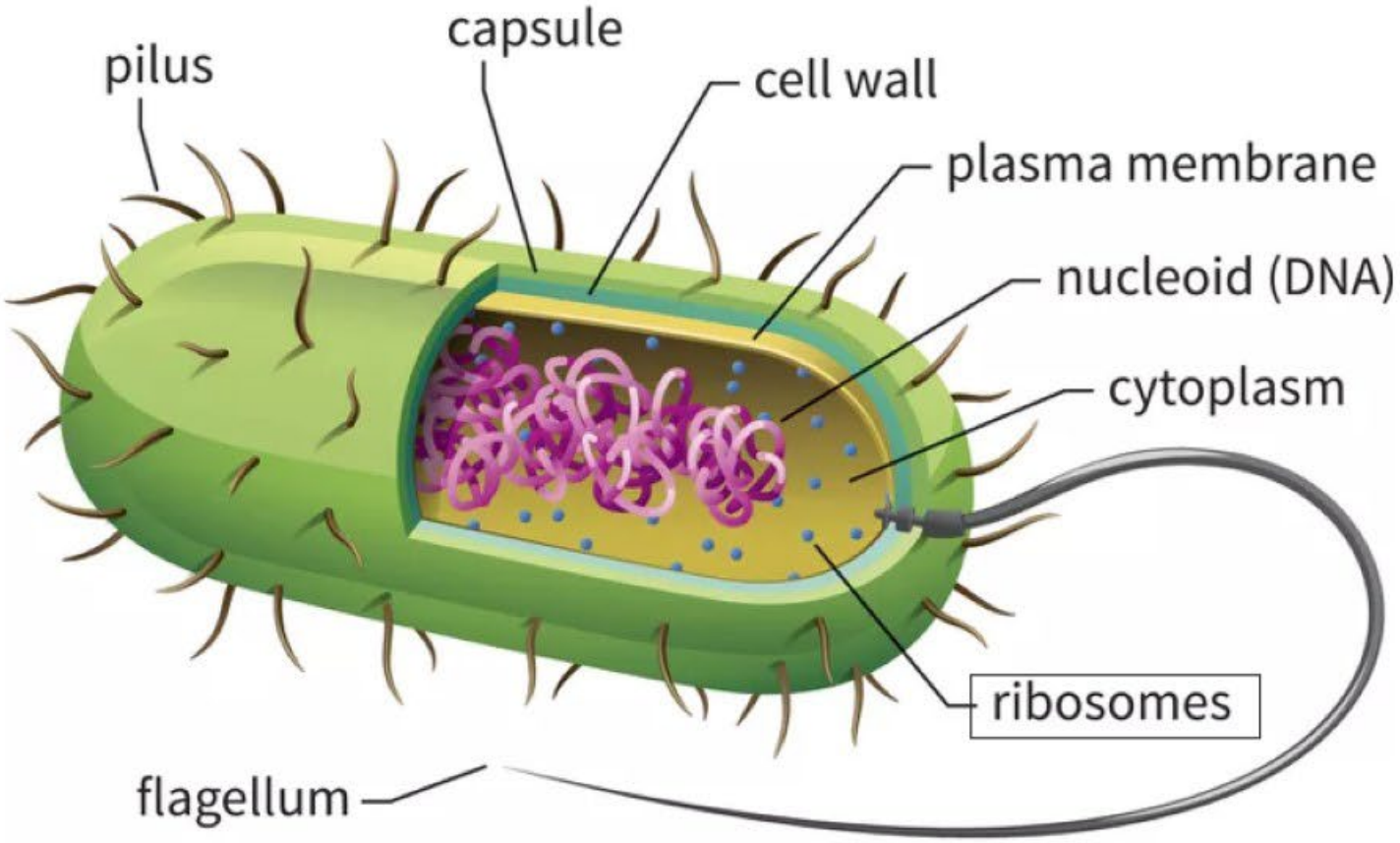
# STRUCTURE OF PROKARYOTIC CELL

- **Cytoplasm:**
  - Present between cell membrane and nucleoid.
  - Gel-like substance composed mainly of water that also contains enzymes, salts, cell components, and various organic molecules.
  - Acts store house for different materials in an organism to sustain life.



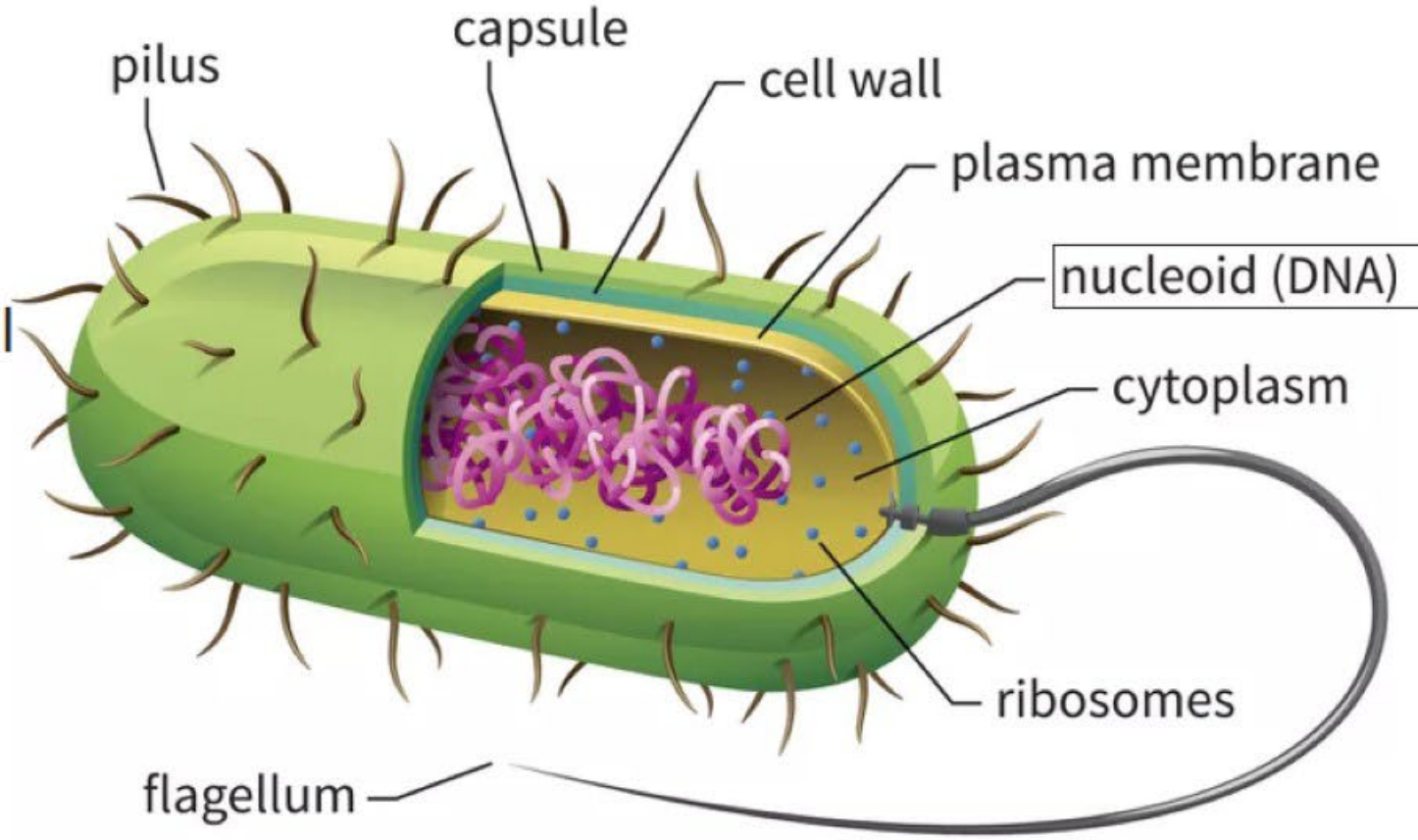
# STRUCTURE OF PROKARYOTIC CELL

- **Ribosomes:**
  - Comprises both RNA and proteins.
  - Responsible for protein production in the cell.



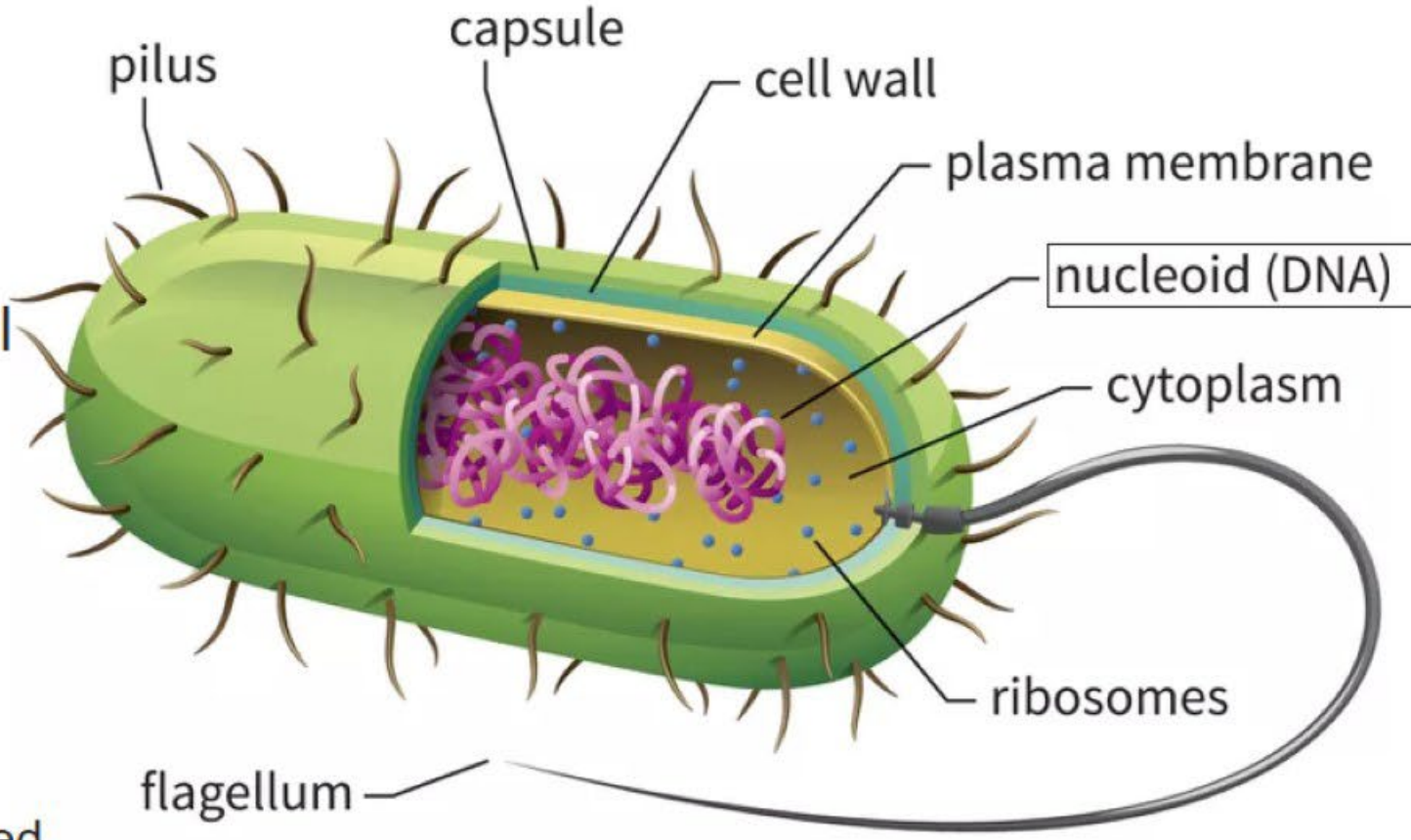
# STRUCTURE OF PROKARYOTIC CELL

- **Nucleoid Region:**
  - Area of the cytoplasm that contains the single bacterial DNA molecule.
  - Circular DNA double stranded.
  - Plays vital role in cell division.



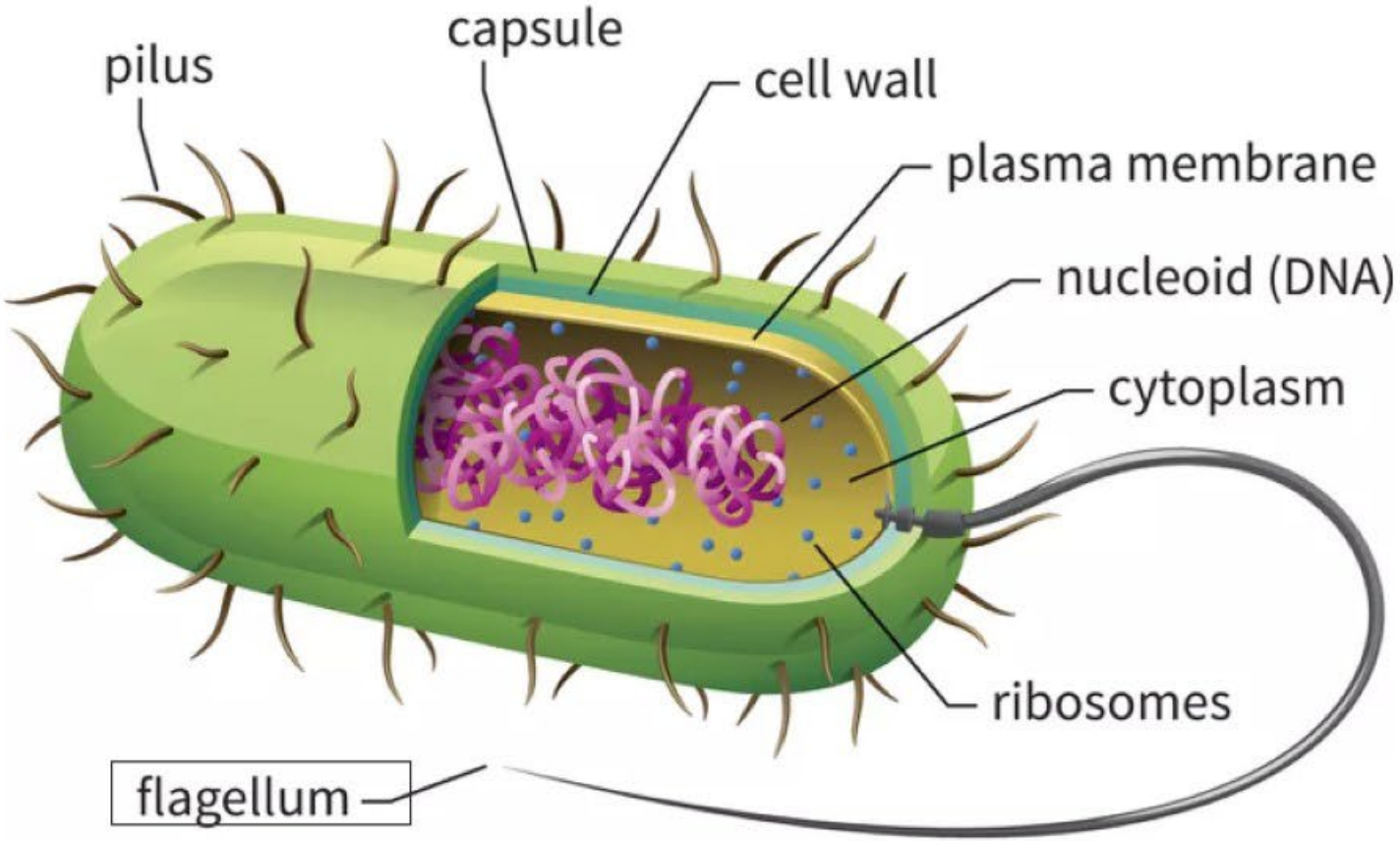
# STRUCTURE OF PROKARYOTIC CELL

- **Nucleoid Region:**
  - Area of the cytoplasm that contains the single bacterial DNA molecule.
  - Circular DNA double stranded.
  - Plays vital role in cell division.
- *Chromosomes:* made of DNA and stored in nucleus, which contains instructions for traits and characteristics.



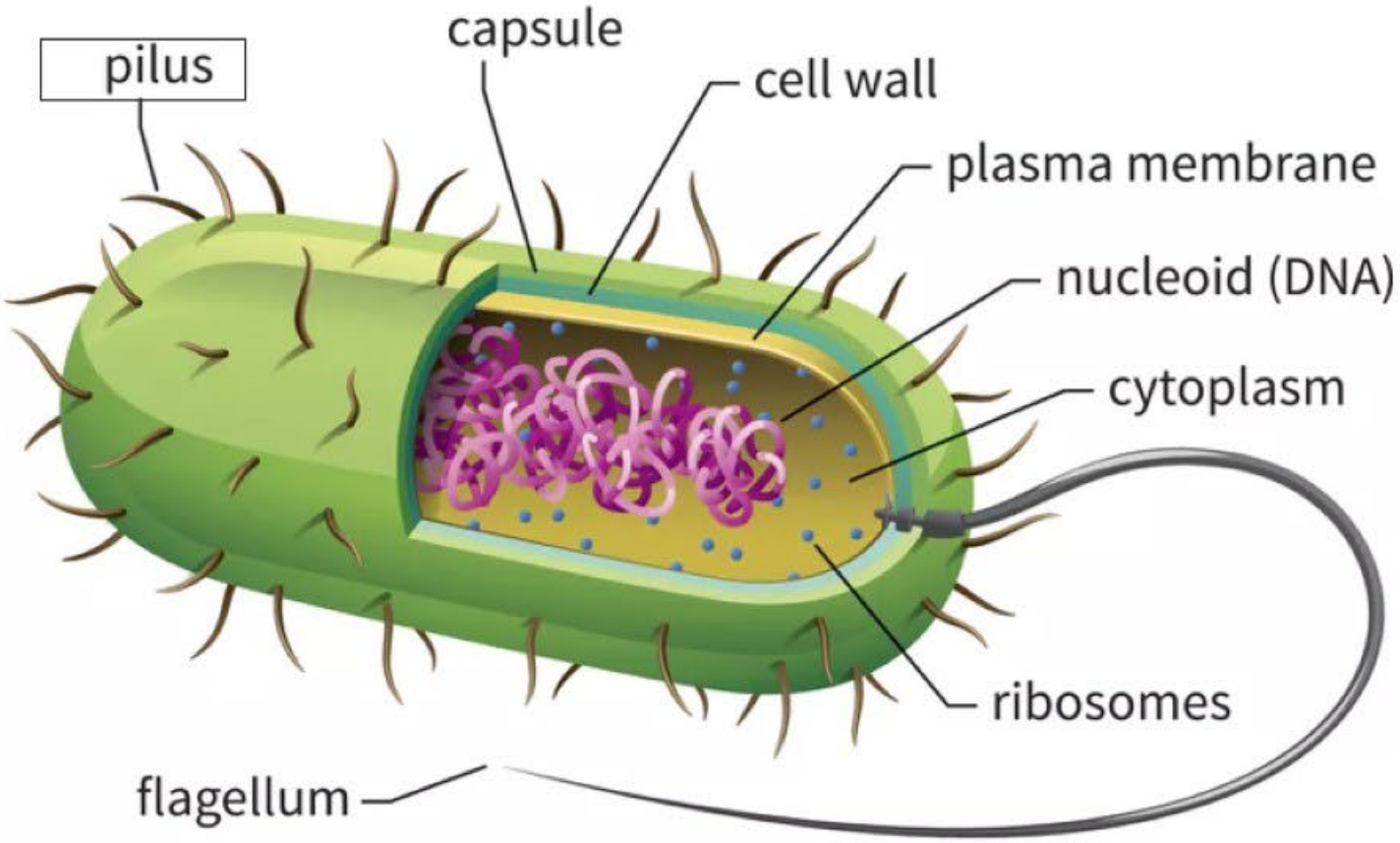
# STRUCTURE OF PROKARYOTIC CELL

- **Flagellum:**
  - long, whip-like protrusions that aid in cellular locomotion (swimming, gliding, rotation, etc.).
  - 19-20 nm in diameter

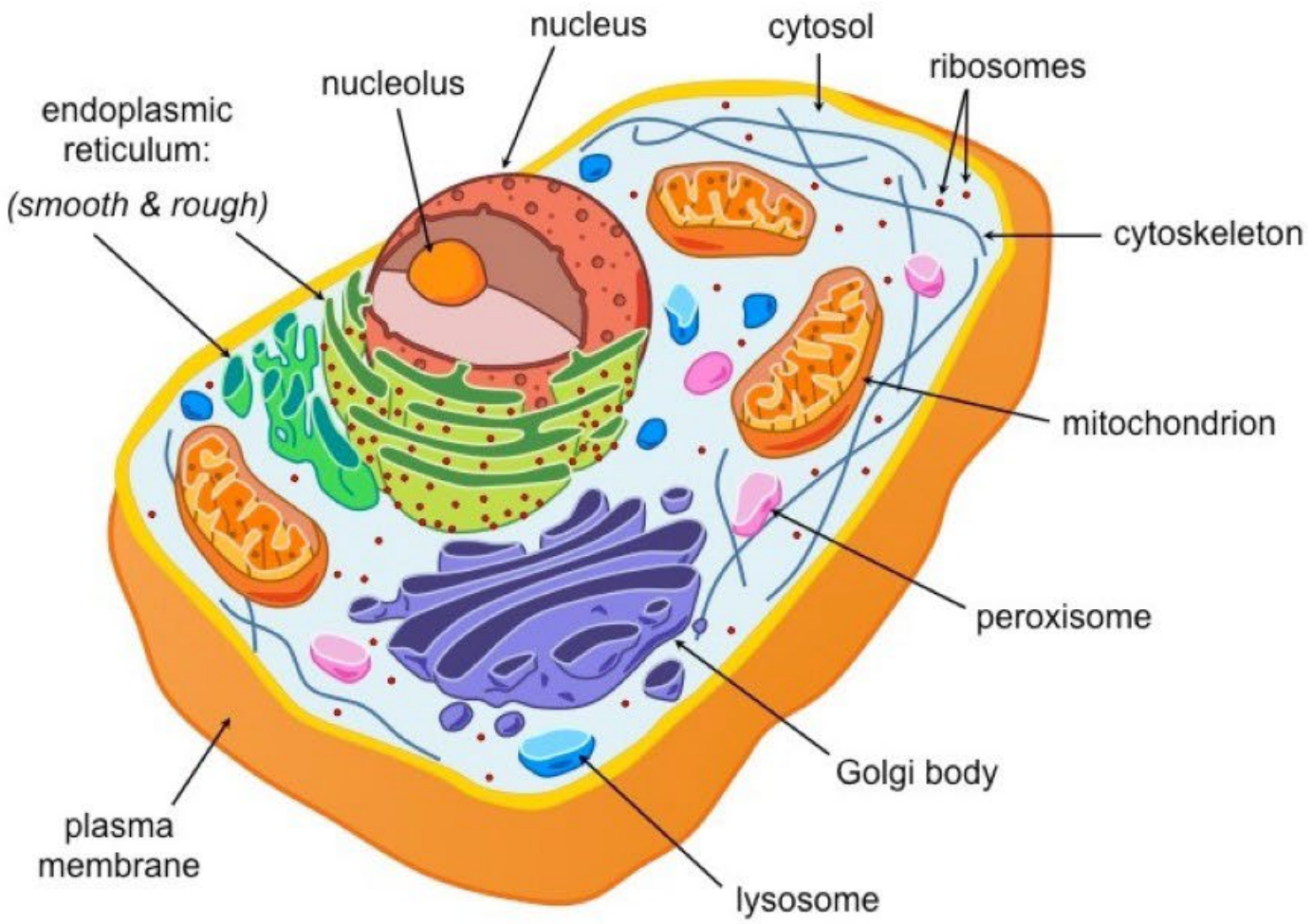


# STRUCTURE OF PROKARYOTIC CELL

- **Pili (Pilus singular):**
  - Hair-like structures on the surface of the cell that attach to other bacterial cells.
  - Contains protein complex called pilin.
  - Shorter pili is called fimbriae help bacteria attach to surfaces.

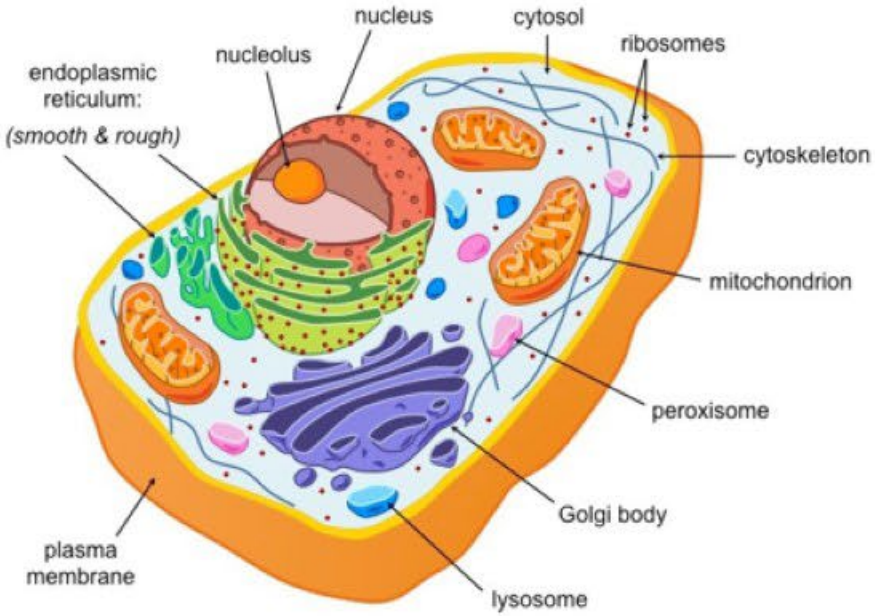


# STRUCTURE OF EUKARYOTIC CELL



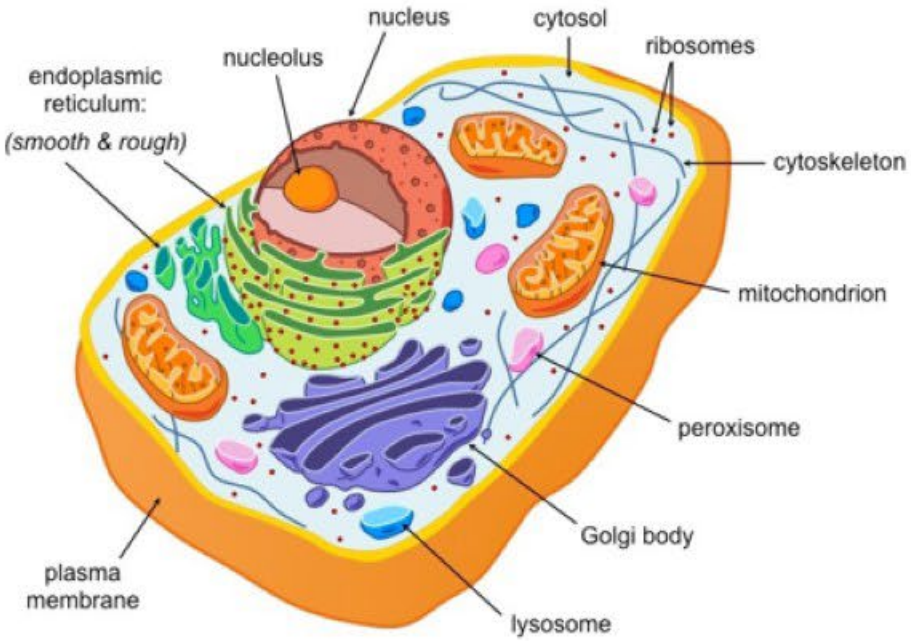
# STRUCTURE OF EUKARYOTIC CELL

- **Plasma Membrane:**
  - Semi permeable.
  - Lipid bilayer through which extracellular substances (e.g.. nutrients, water) enter the cell and waste substances or secretions exit the cell.
  - Protects and separate from external environment.
  - Passage of substances may require expenditure of energy (active transport) or may be passive (diffusion).



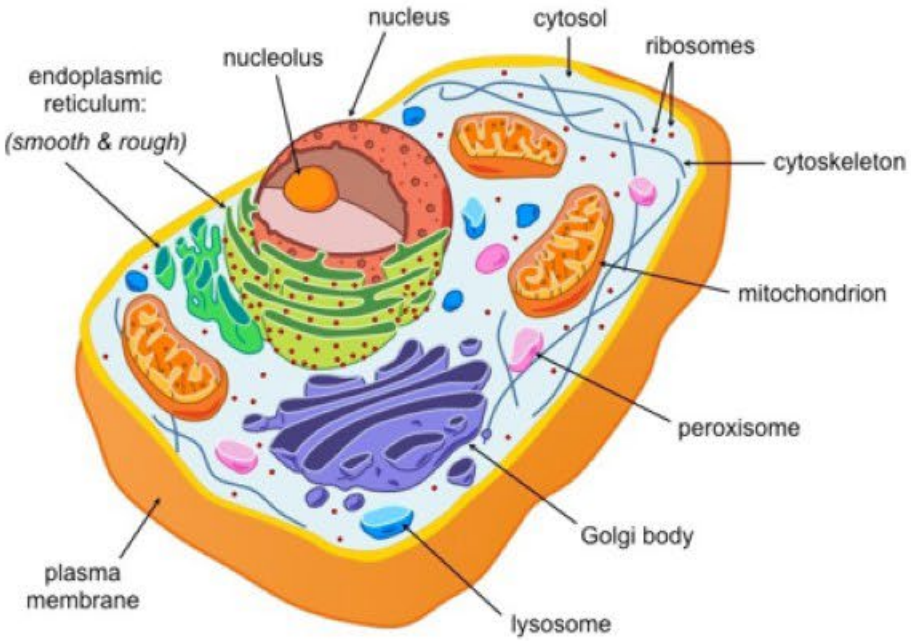
# STRUCTURE OF EUKARYOTIC CELL

- **Nucleus:**
  - Master control of cellular functions via its genetic material (DNA).
  - *Nuclear Envelope:* Double layered of Phospho lipid bilayer. membrane controlling the movement of materials between the nucleus and Cytoplasm. Contains pores that communicate with the ER.



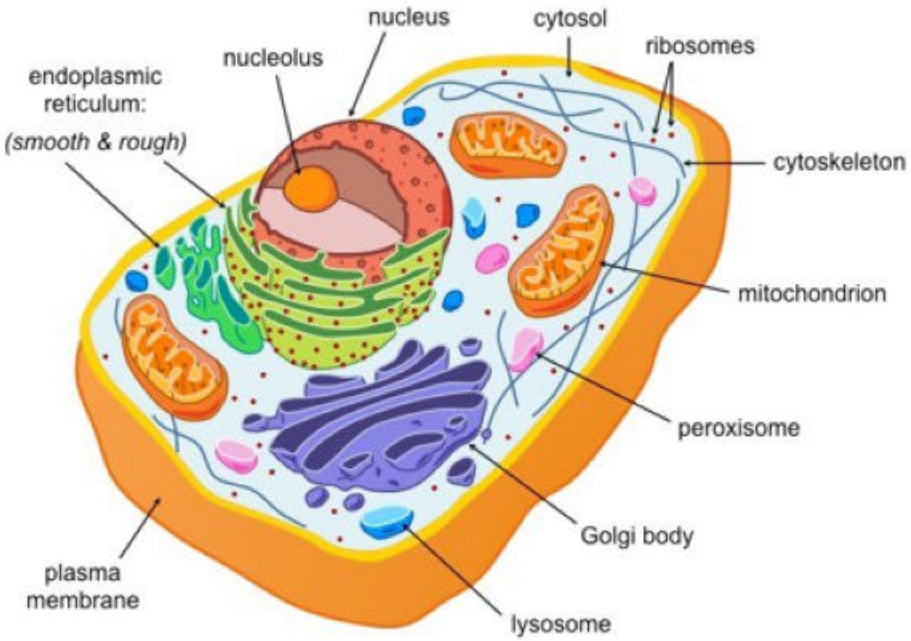
# STRUCTURE OF EUKARYOTIC CELL

- **Nucleus:**
  - *Chromatin:* Composed of proteins and DNA. Determines the sex of the individual. Each cell contains 23 pairs of chromosomes (46 total)
  - *Nucleolus:* Non-membrane bound organelles. Involved in controlling all types of cellular activities.



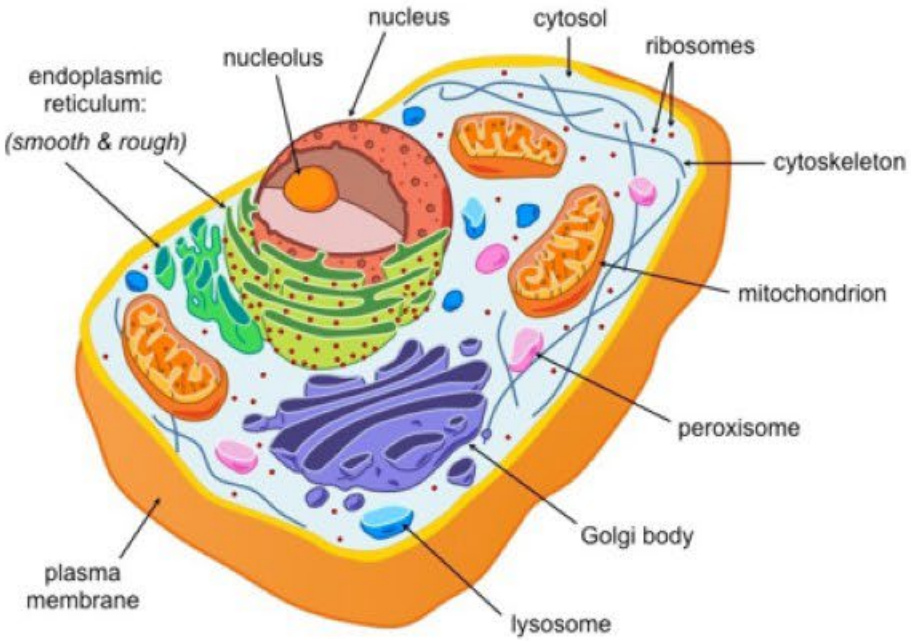
# STRUCTURE OF EUKARYOTIC CELL

- **Nucleus:**
  - *Nucleoplasm:* Nonchromatin components of the nucleus containing materials for building DNA and messenger RNA (mRNA molecules serve as intermediates between nucleus and cytoplasm).



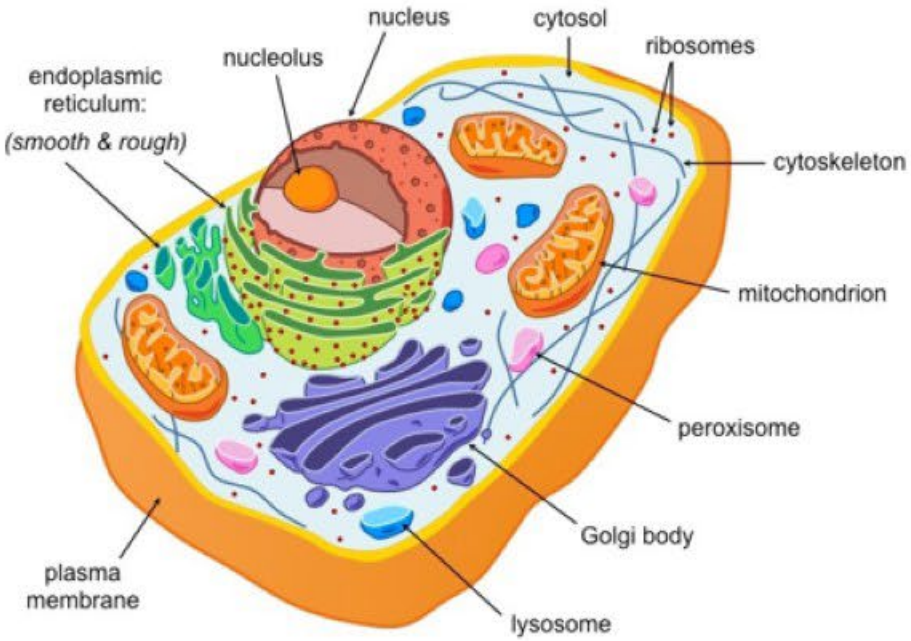
# STRUCTURE OF EUKARYOTIC CELL

- **Ribosomes:**
  - Present in cytoplasm.
  - Responsible for cellular protein synthesis.
  - Consists of three molecular weight classes of ribosomal RNA molecules and about 50 different proteins.



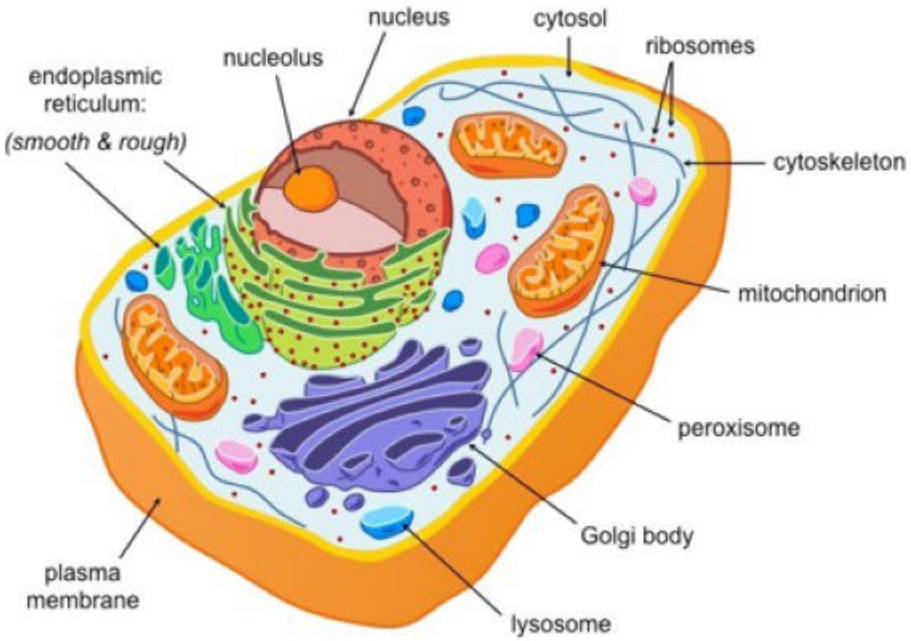
# STRUCTURE OF EUKARYOTIC CELL

- **Lysosome:**
  - Contains digestive enzymes to break down macromolecules.
  - Aid in protecting against other foreign bodies
  - May cause cell destruction if ruptured



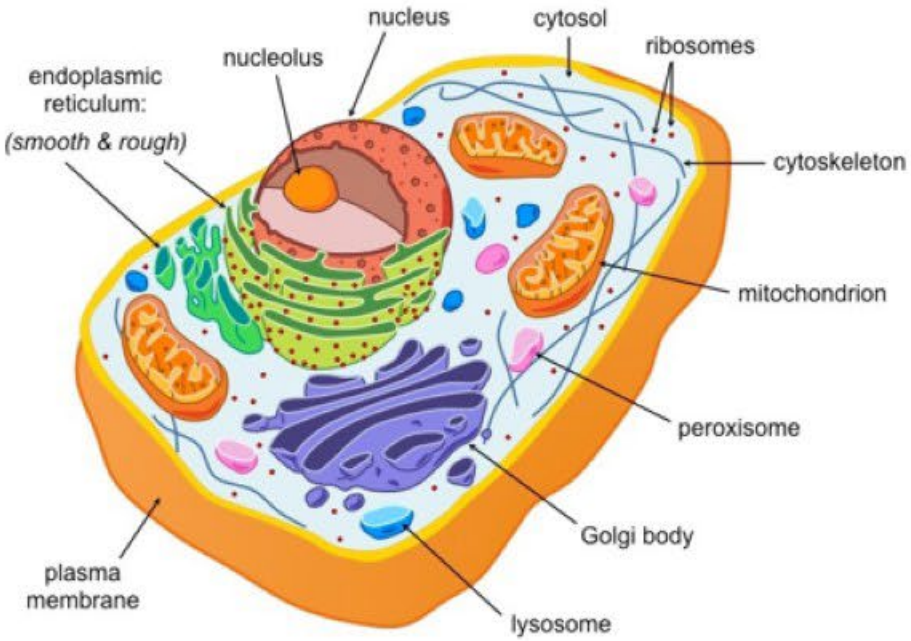
# STRUCTURE OF EUKARYOTIC CELL

- **Mitochondria:**
  - Powerhouse of the cell.
  - Double smooth membrane, present in all eukaryotic cells.
  - Synthesis of ATP and converts glucose to ATP.



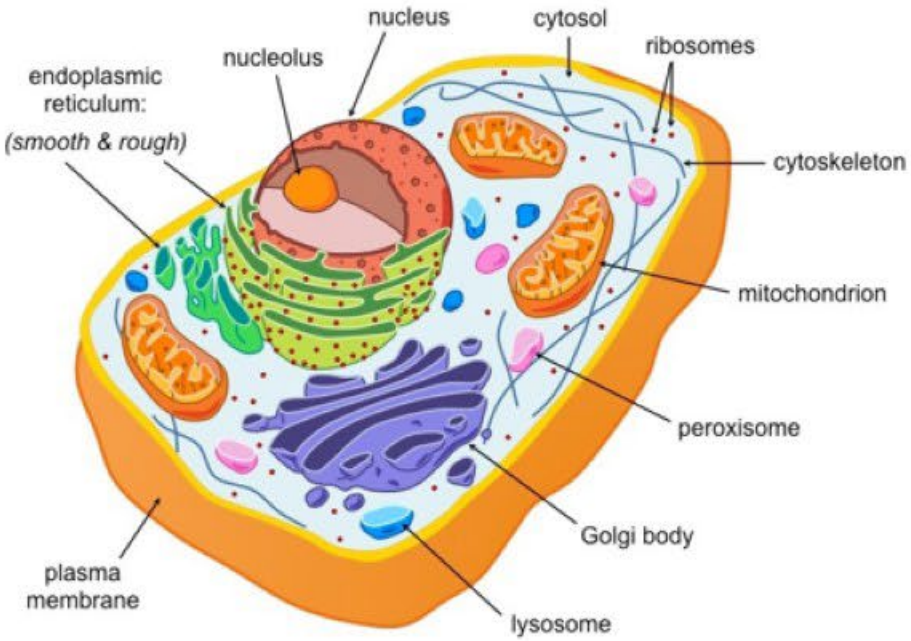
# STRUCTURE OF EUKARYOTIC CELL

- **Golgi bodies:**
  - Flattened membrane used to store the substances made by the cell.
  - Helps in preserving, transporting materials within the cell.
  - Also called post office of a cell.



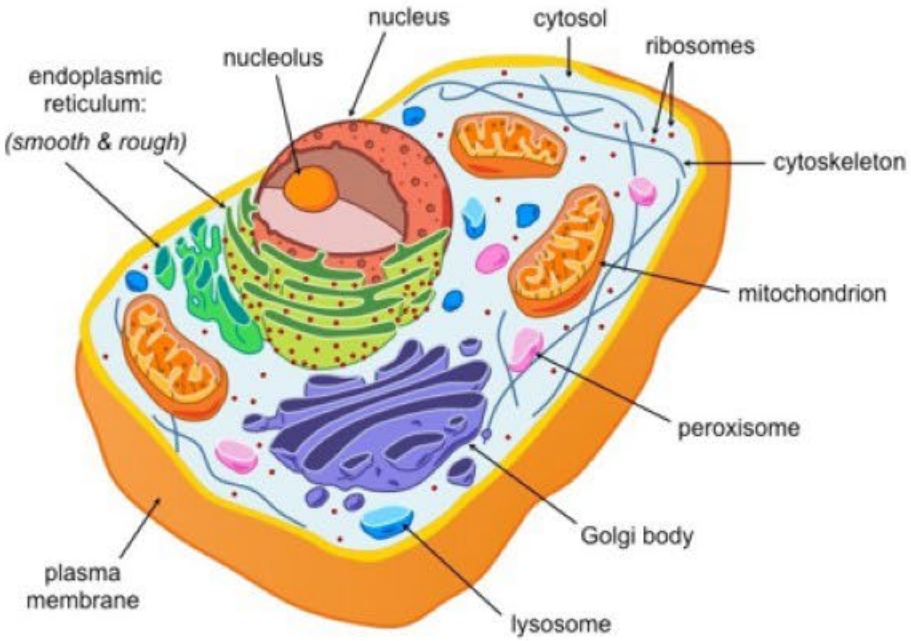
# STRUCTURE OF EUKARYOTIC CELL

- **Endoplasmic reticulum:**
  - Double membrane organelle, which divides cell into compartments.
  - Connected to the nuclear membrane.
  - Vital roles in:
    - Protein synthesis.
    - Biosynthesis of lipids and steroids.
    - Stores and regulates calcium
    - Metabolism of carbohydrates



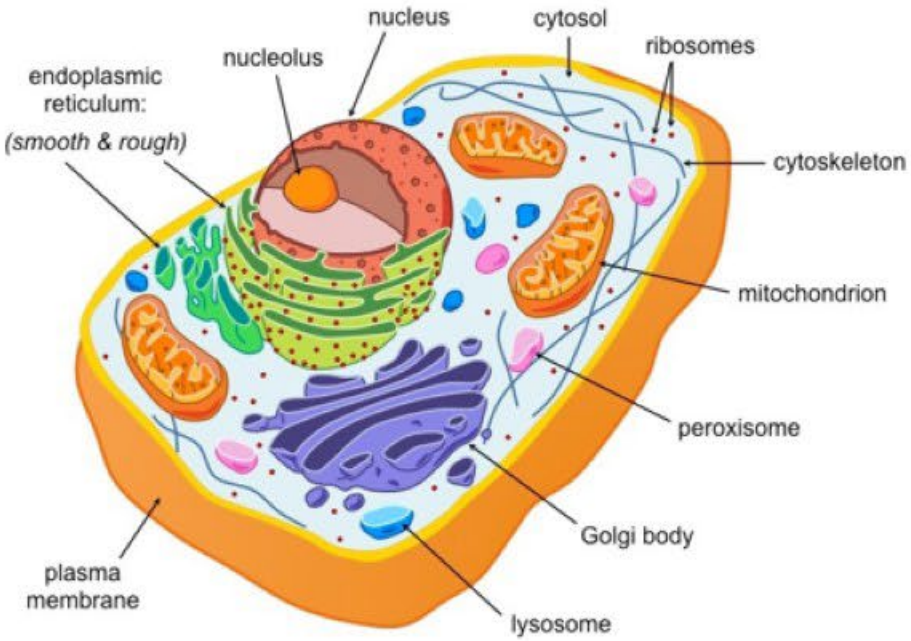
# STRUCTURE OF EUKARYOTIC CELL

- **Vacuole:**
  - Helps in maintaining its shape
  - Stores water, food, waste, etc.

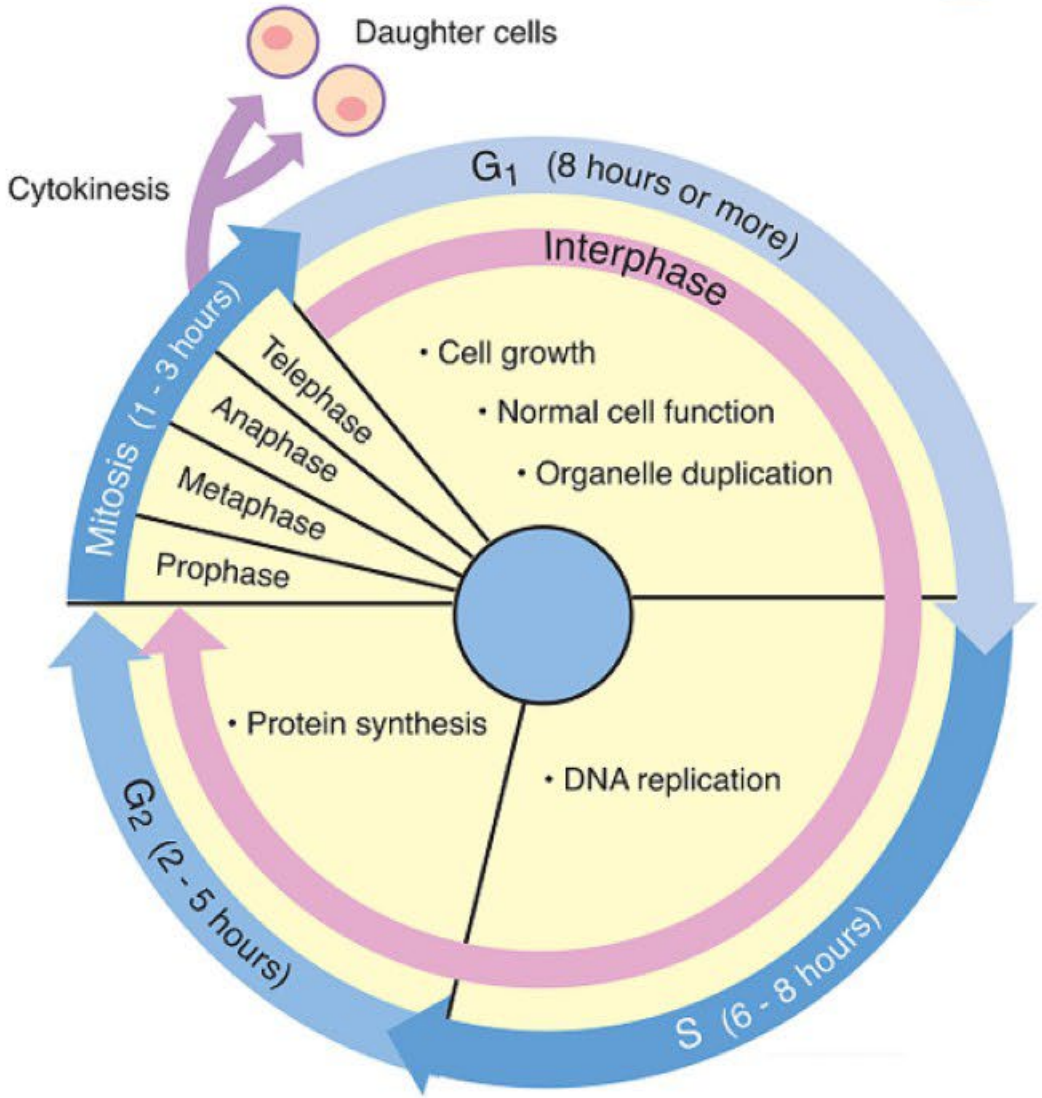


# STRUCTURE OF EUKARYOTIC CELL

- **Cytoskeleton:**
  - Structural Support: Provides cell shape and stability.
  - Cell Movement: Enables cell motion and locomotion.
  - Intracellular Transport: Aids in organelle and cargo movement.
  - Cell Division: Facilitates accurate chromosome segregation.
  - Process Regulation: Regulates signaling, adhesion, and communication.

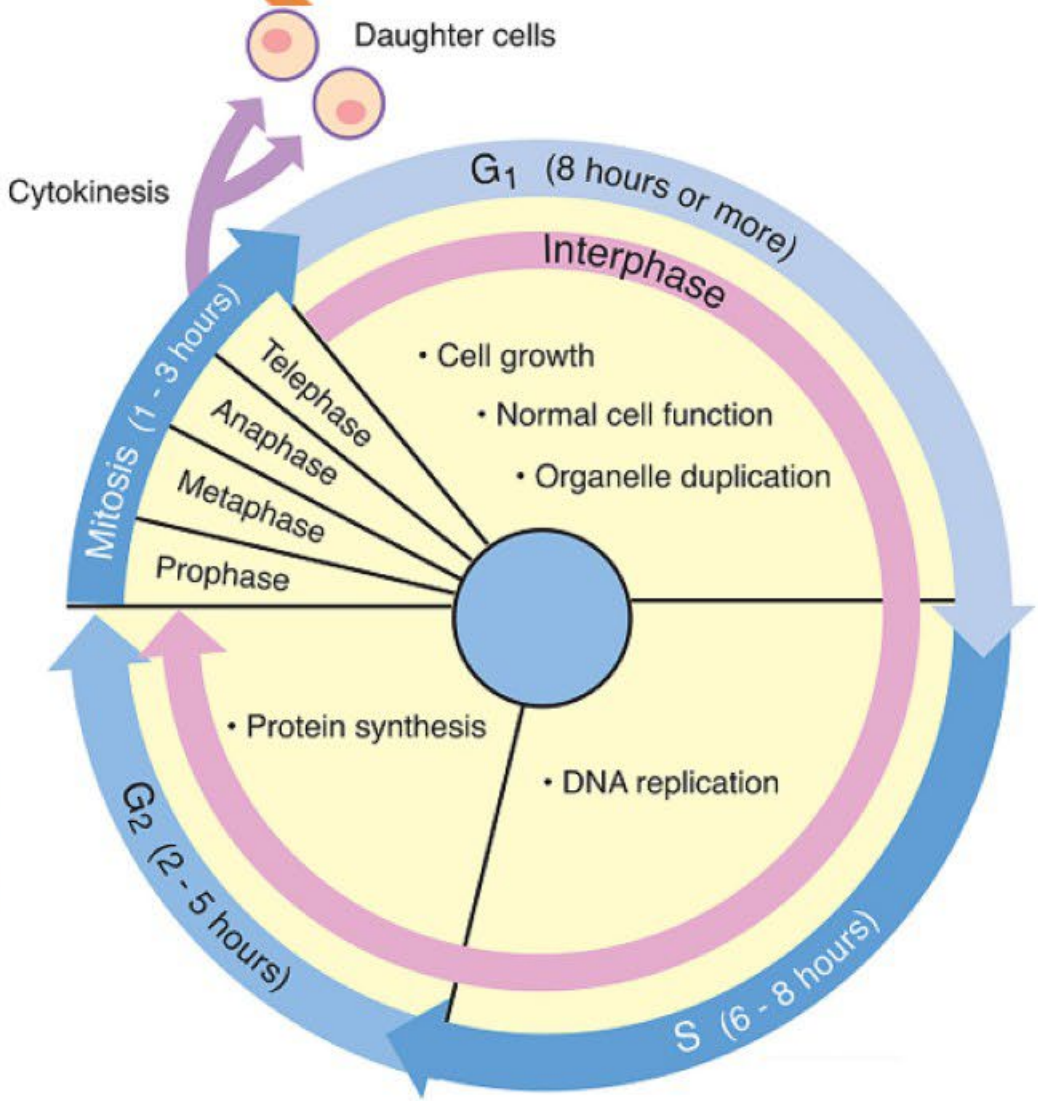


# CELL CYCLE


Daughter cells
Cytokinesis
G1 (8 hours or more)
Interphase
Mitosis (1 - 3 hours)
Telephase
Anaphase
Metaphase
Prophase
• Cell growth
• Normal cell function
• Organelle duplication
• Protein synthesis
• DNA replication
G2 (2 - 5 hours)
S (6 - 8 hours)

# CELL CYCLE

- Responsible for the growth, development, and maintenance of multicellular organisms.
- it represents a repetitive sequence of events, starting with a newly formed cell, progressing through various phases, and ultimately leading to the formation of two new daughter cells.
- Cyclical nature ensures the continuity of life and the replenishment of cells in the body.



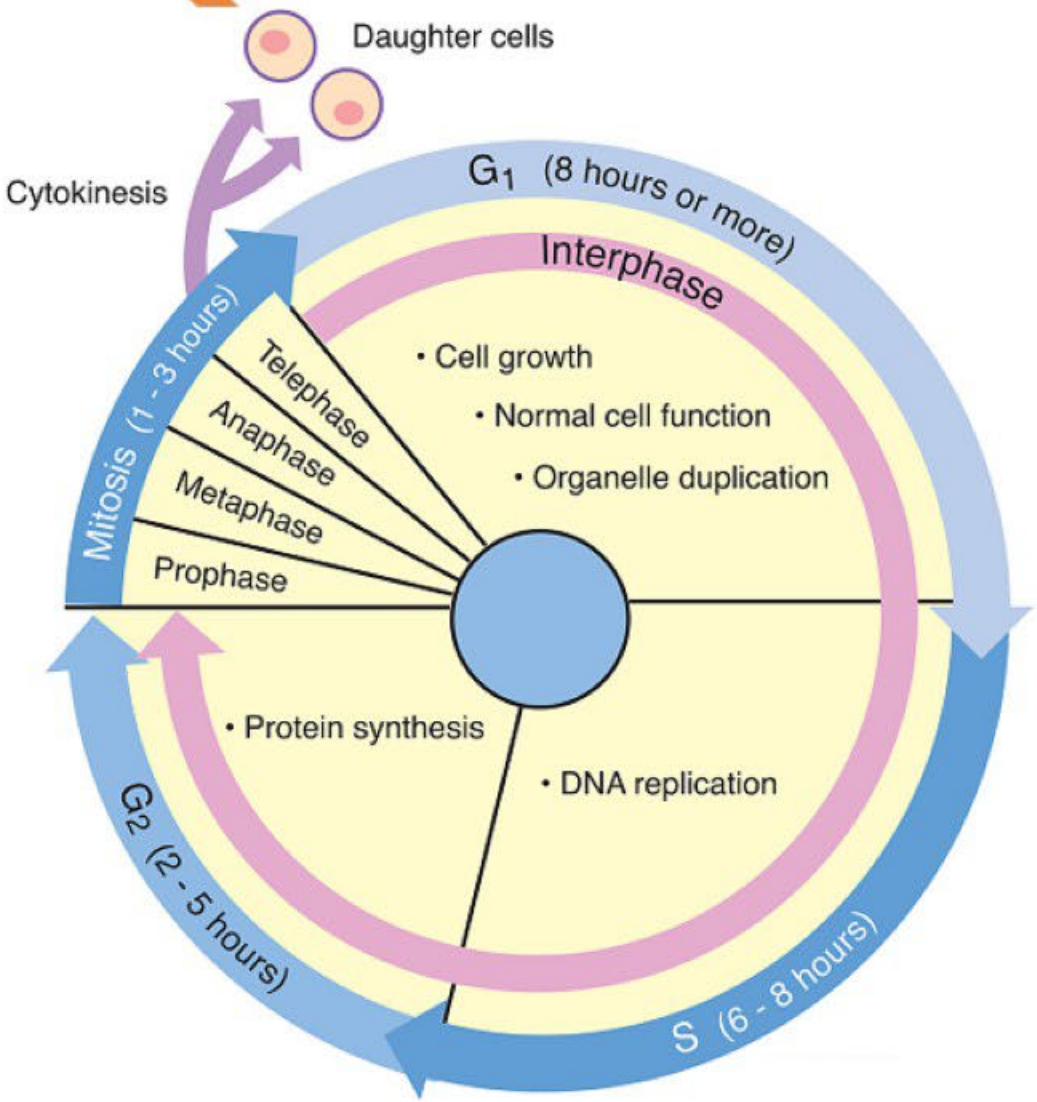
# CELL CYCLE

- **Interphase:**
  - Longest phase of the cell cycle.
  - Subdivided into G1 (gap 1), S (synthesis), and G2 (gap 2) phases.
  - Cell grows, carries out normal functions, and replicates DNA.
- **Mitosis:**
  - Process of dividing the cell's nucleus into two identical nuclei.
  - Phases: prophase, metaphase, anaphase, telophase.
  - Ensures accurate separation of chromosomes.
- **Cytokinesis:**
  - Follows mitosis.
  - Division of cytoplasm and organelles between daughter cells.
  - Completes the cell cycle, leading to the formation of two new daughter cells.

# CELL CYCLE

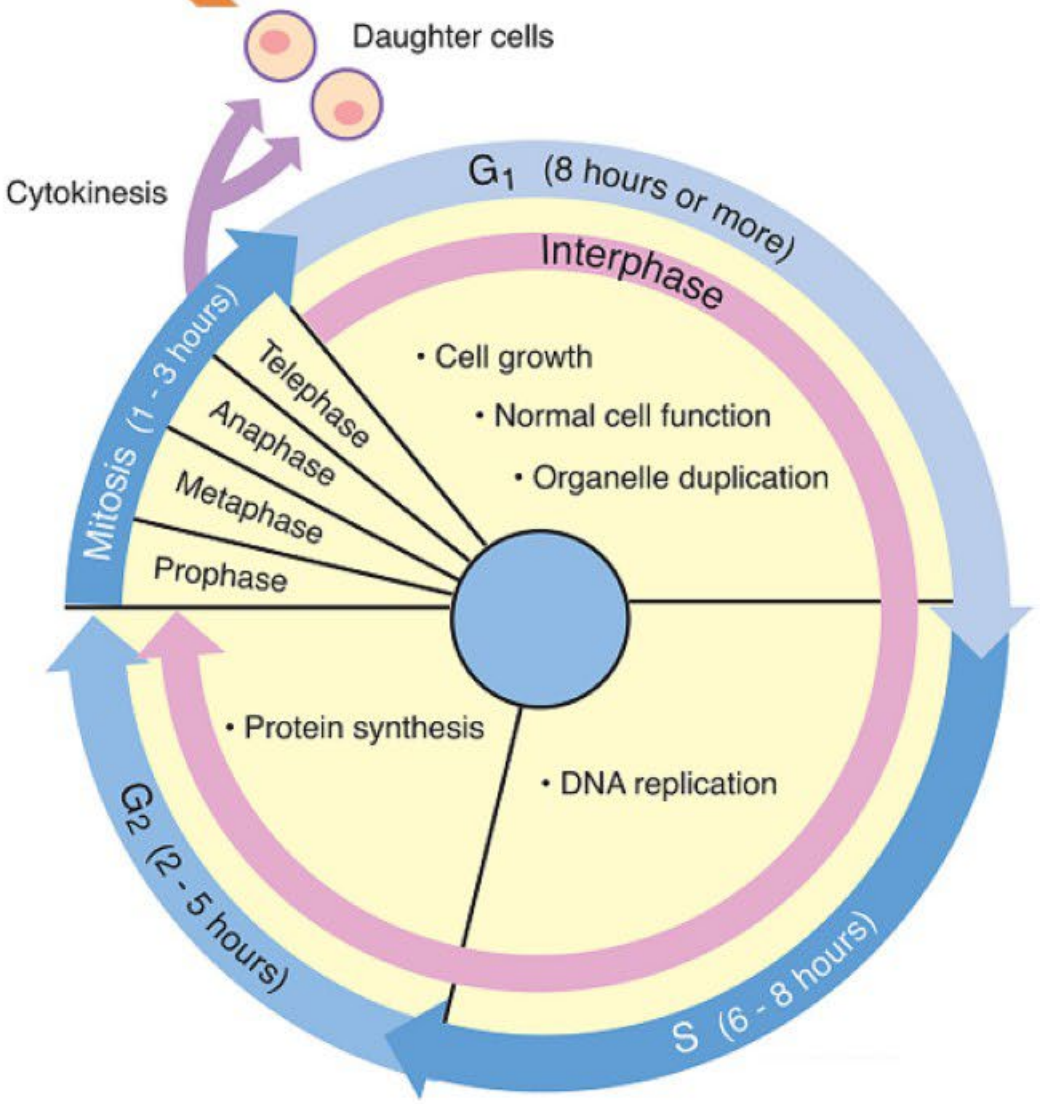
- G0 phase:
  - Cell is predominantly present.
  - Non-dividing phase

*After a cell completes one cell cycle, it can either enter another cycle or exit the cycle temporarily by entering a non-dividing phase called the G0 phase.*



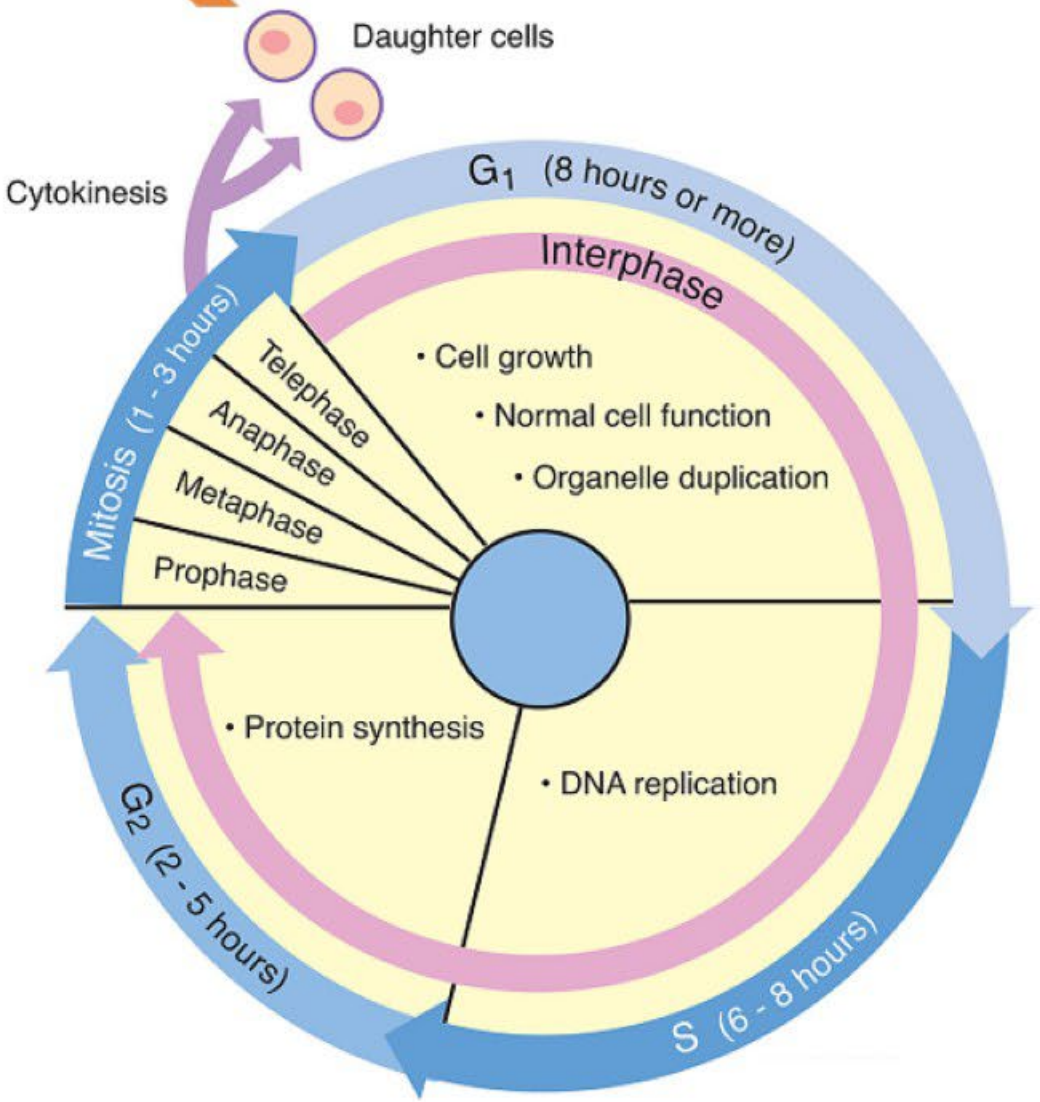
# CELL CYCLE

- G1 phase:
  - also called the first gap phase
  - the cell grows physically larger
  - copies organelles,
  - makes the molecular building blocks



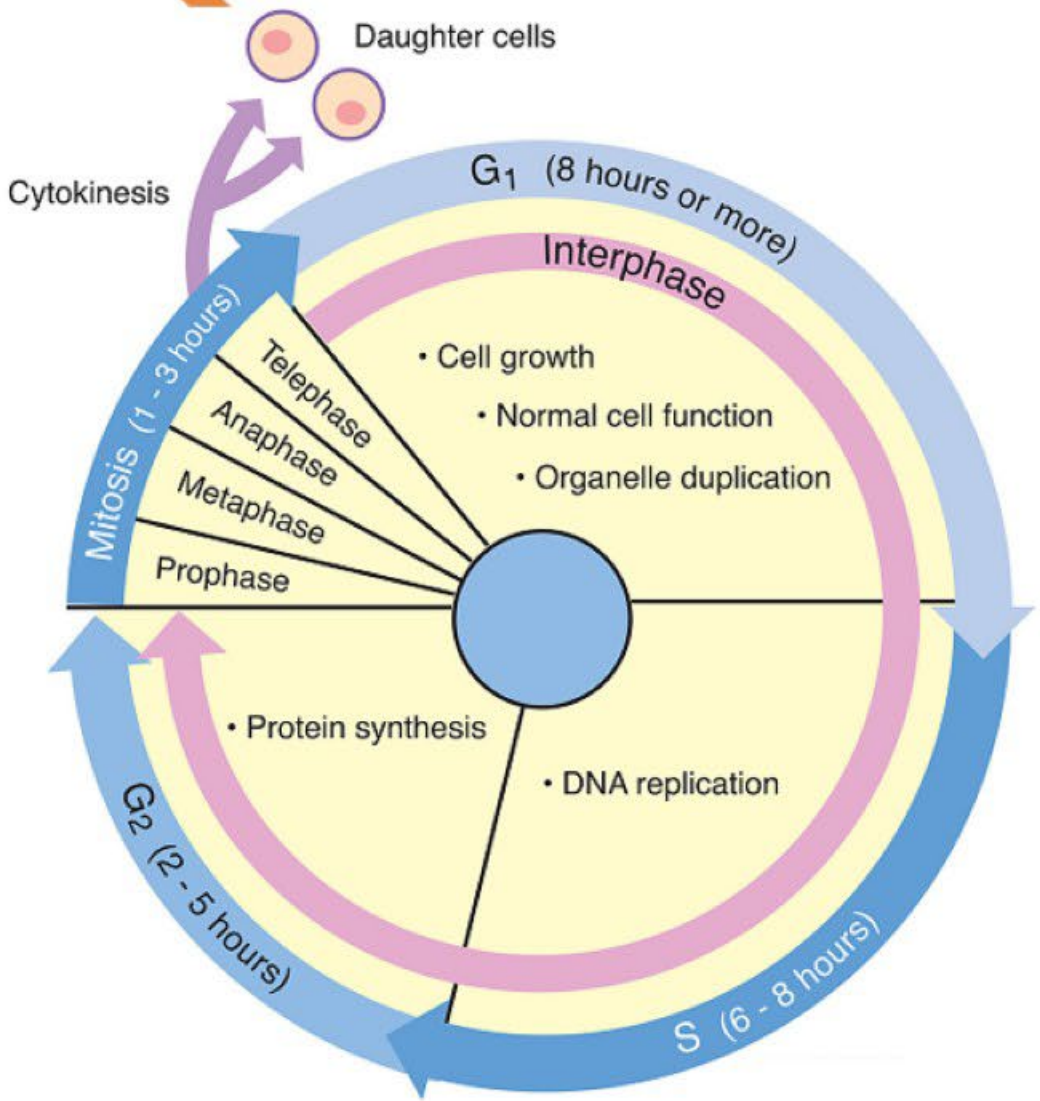
# CELL CYCLE

- S phase:
  - synthesizes a complete copy of the DNA in its nucleus
  - Duplicates a microtubule-organizing structure called the centrosome.
  - centrosomes help separate DNA during M phase.

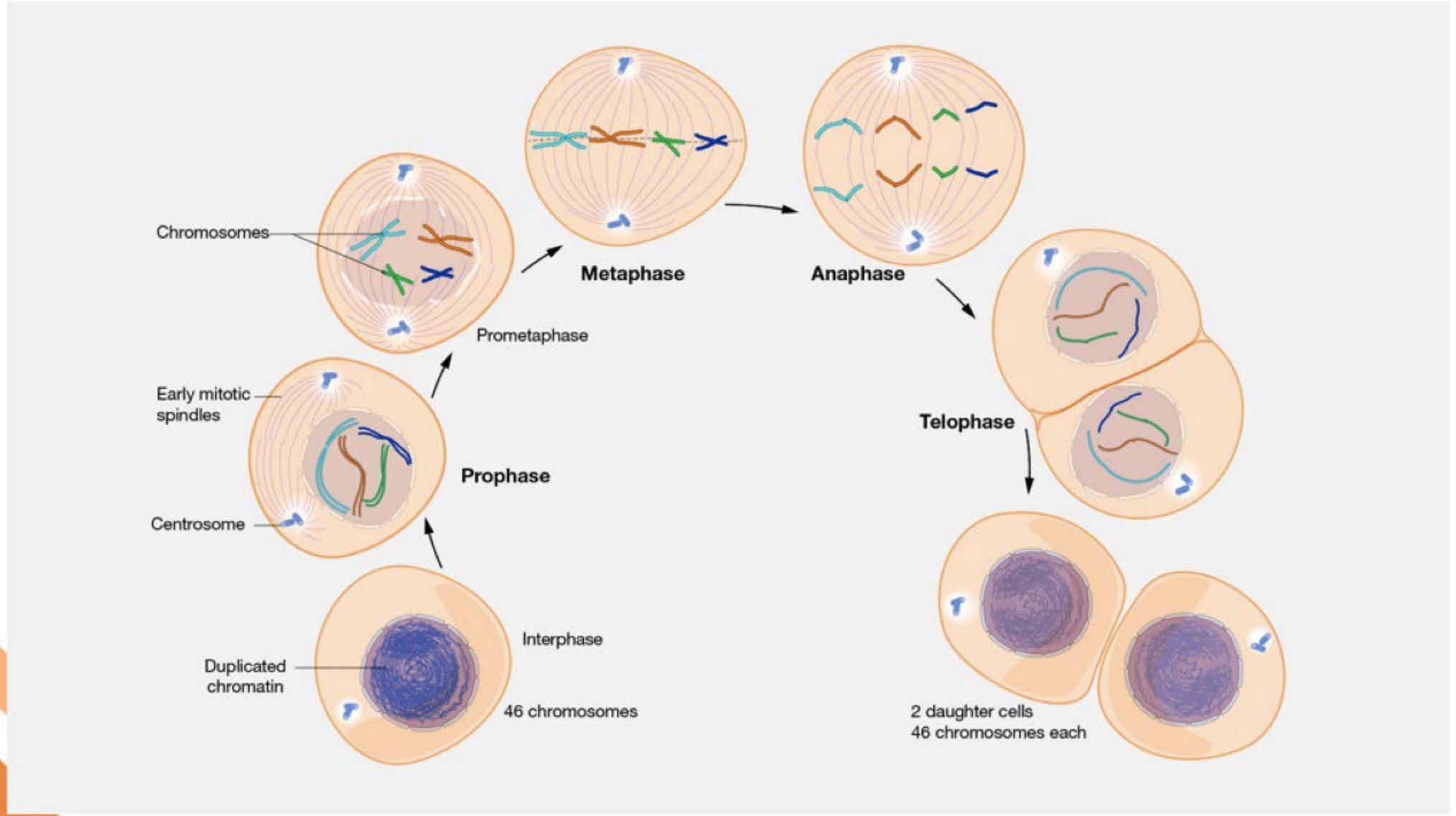


# CELL CYCLE

- G2
  - cell grows more, makes proteins and organelles, and begins to reorganize its contents in preparation for mitosis.

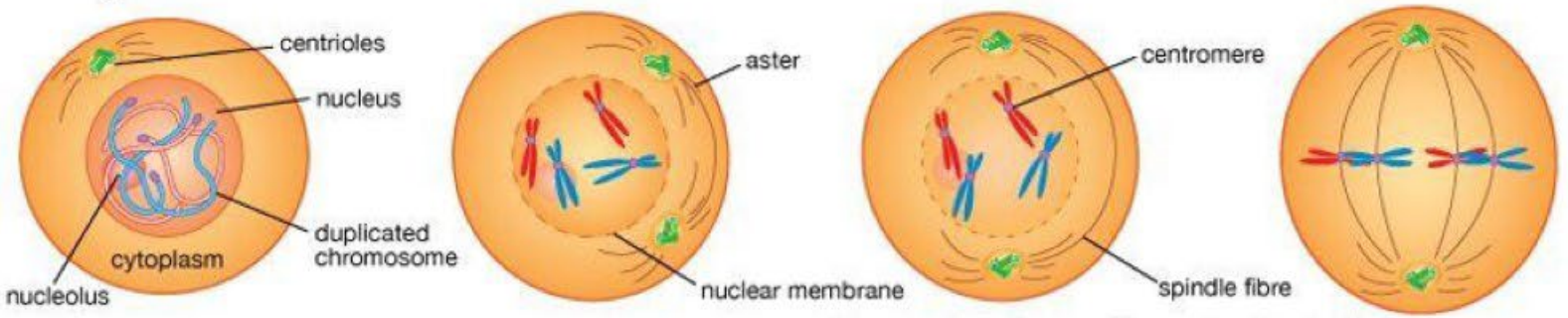


# MITOSIS


Chromosomes
Prometaphase
Metaphase
Anaphase
Telophase
Early mitotic spindles
Prophase
Centrosome
Interphase
Duplicated chromatin
46 chromosomes
2 daughter cells
46 chromosomes each

# MITOSIS

**Mitosis, or somatic cell division**

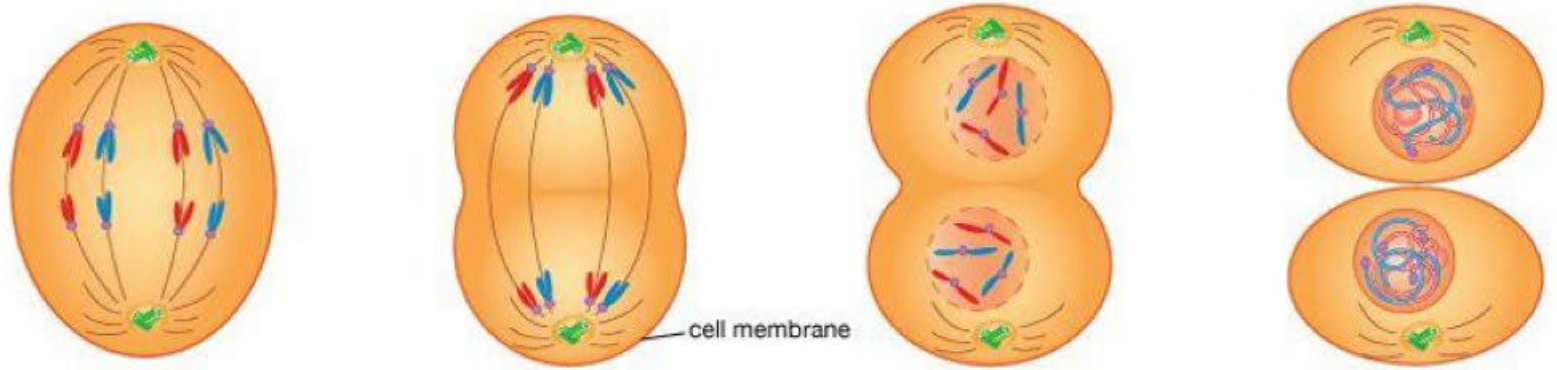



Prior to mitosis, each chromosome makes an exact duplicate of itself. The chromosomes then thicken and coil.

In early prophase the centrioles, which have divided, form asters and move apart. The nuclear membrane begins to disintegrate.

In late prophase the centrioles and asters are at opposite poles. The nucleolus and nuclear membrane have almost completely disappeared.

The doubled chromosomes—their centromeres attached to the spindle fibres—line up at mid-cell in metaphase.




In early anaphase the centromeres split. Half the chromosomes move to one pole, half to the other pole.

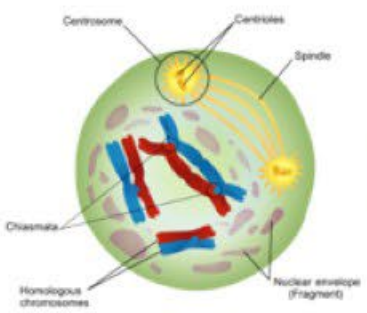
In late anaphase the chromosomes have almost reached their respective poles. The cell membrane begins to pinch at the centre.

The cell membrane completes constriction in telophase. Nuclear membranes form around the separated chromosomes.

At mitosis completion, there are two cells with the same structures and number of chromosomes as the parent cell.

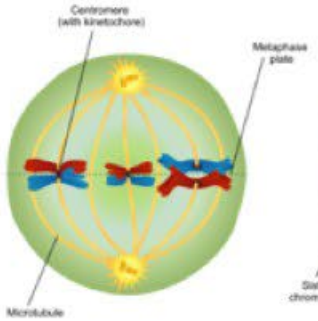
# MEIOSIS

**Prophase I**



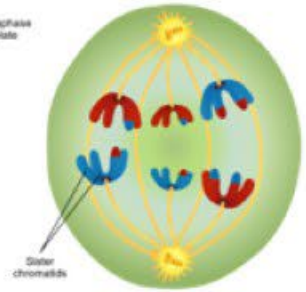

The chromosomes condense, and the nuclear envelope breaks down. Crossing-over occurs.

**Metaphase I**



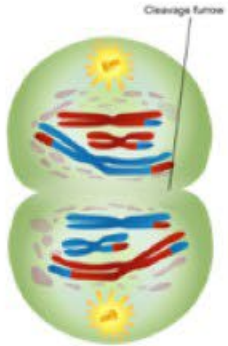

Pairs of homologous chromosomes move to the equator of the cell.

**Anaphase I**



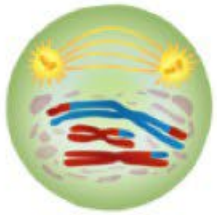

Homologous chromosomes move to the opposite poles of the cell.

**Telophase I & cytokinesis**

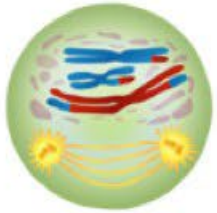



Chromosomes gather at the poles of the cells. The cytoplasm divides.

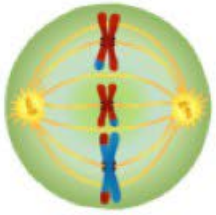
**Prophase II**



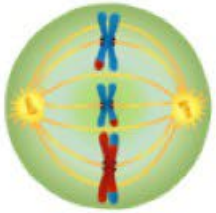
A new spindle forms around the chromosomes.



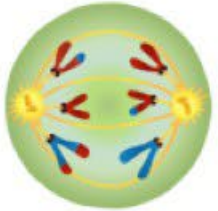
**Metaphase II**



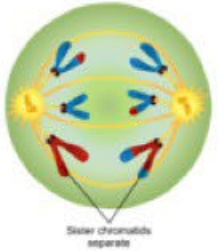
Metaphase II chromosomes line up at the equator.



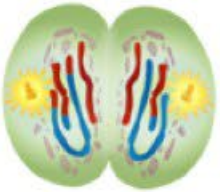
**Anaphase II**



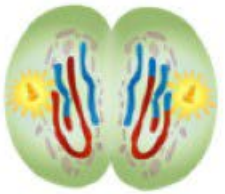
Centromeres divide. Chromatids move to the opposite poles of the cells.



**Telophase II & cytokinesis**

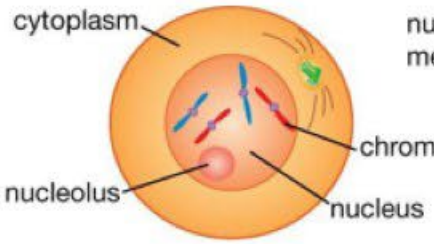


A nuclear envelope forms around each set of chromosomes. The cytoplasm divides.

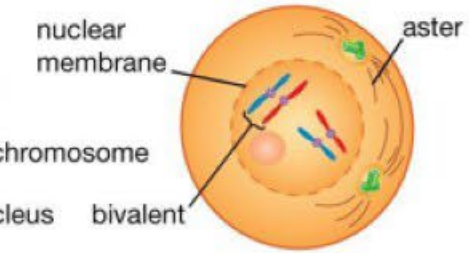


# MEIOSIS

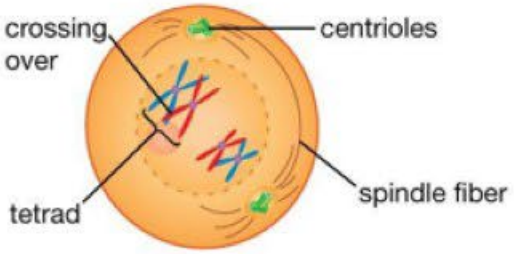
**Meiosis, or sex cell division**



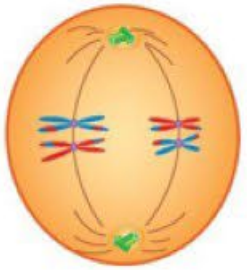

At the onset of meiosis, DNA strands thicken into chromosomes. Homologous, or like, chromosomes begin to approach each other.



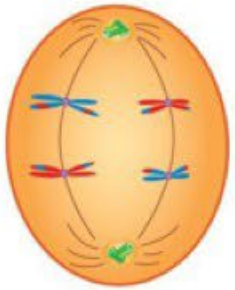

Homologous chromosomes pair to form bivalents. The centrioles divide and move to opposite poles of the cell.



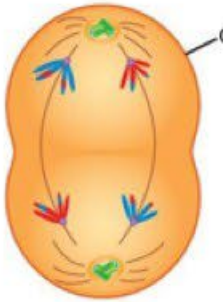

The bivalents duplicate to form tetrads, or four-chromatid groups. The nuclear membrane disintegrates. Crossing over (recombination) occurs.



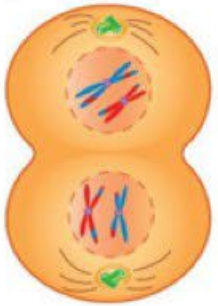
In metaphase I, the tetrads, attached to spindle fibers at their centromeres, line up at mid-cell.



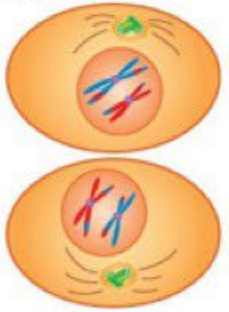
In early anaphase I, the tetrads separate, and the paired chromatids move along the spindle to their respective centrioles.



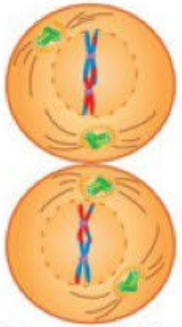

In late anaphase I, the chromatids have almost reached the spindle poles. The cell membrane begins to constrict.



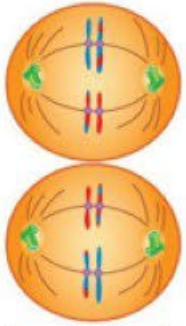
In telophase I, nuclear membranes enclose the separated chromatids. The cell membrane completes its constriction.



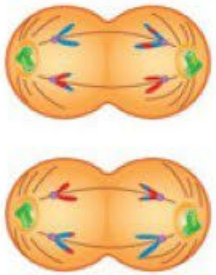
The first meiotic division ends. There are now two cells, each with the same number of chromatids as the parent cell.



Prophase II begins. In the second meiotic division, homologous chromatids do not duplicate but merely separate.



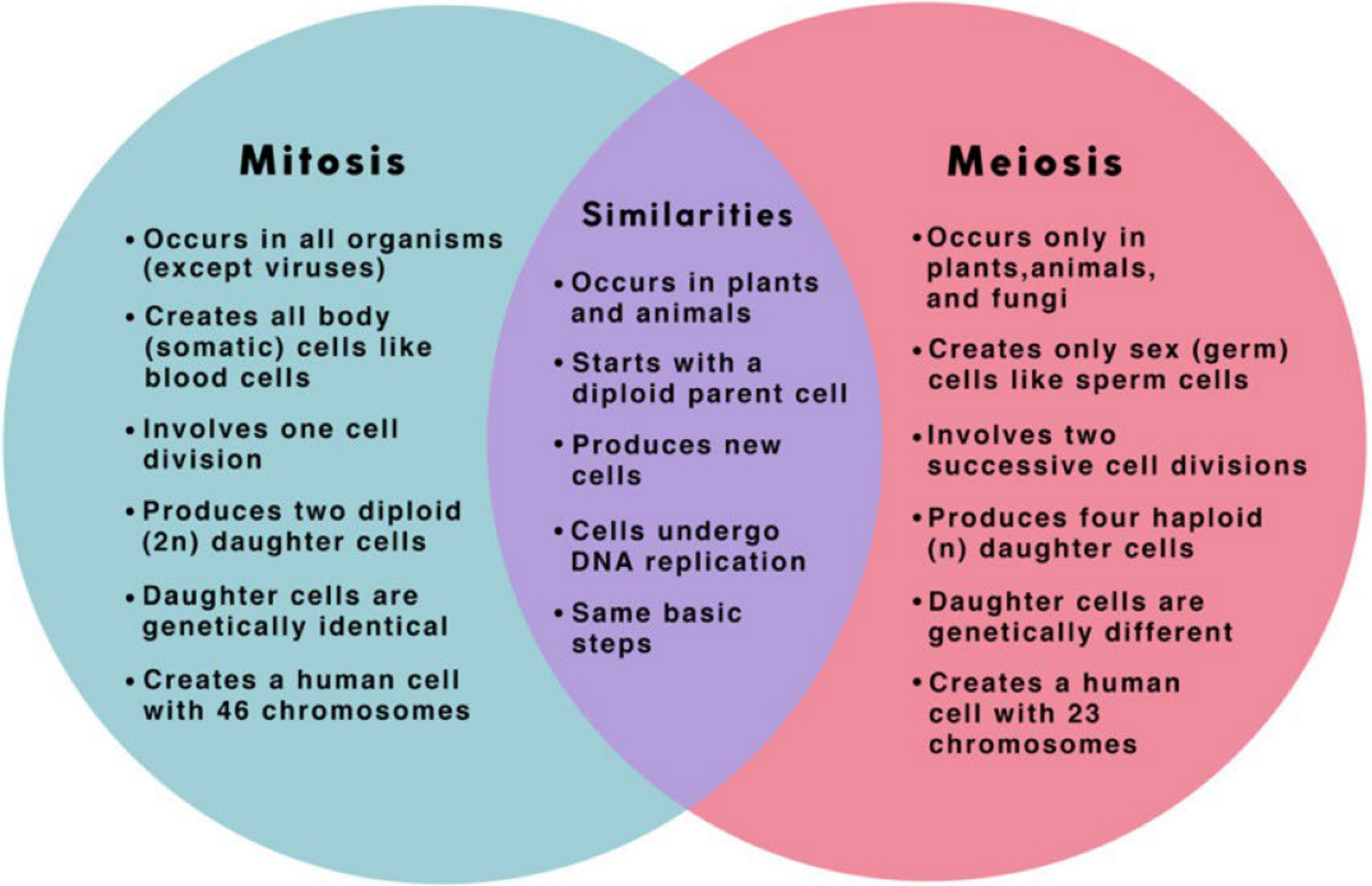
In metaphase II, the chromatids line up at mid-cell. The centrioles and asters are at the poles. A spindle has formed.



In anaphase II, the now-separated chromatids approach their respective poles. The cell membrane begins to constrict.

Telophase II has been completed. There are now four cells, each with half the number of chromosomes of the parent cell.

# MITOSIS VS MEIOSIS



# THANK YOU