

# THE CELL

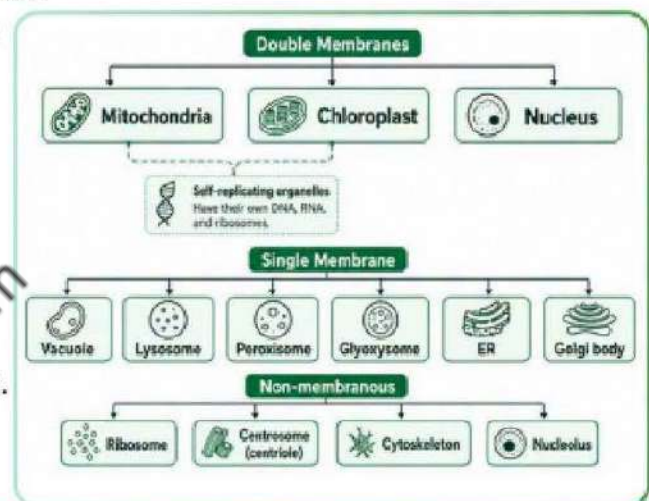


## 10.0 INTRODUCTION TO THE CELL

- Cell is the **structural and functional unit of life**.
- It is the **smallest unit capable of performing all vital life activities**.
- Cells are **basic building blocks** of multicellular organisms.
- Organisms may be:
  - **Unicellular**: made of a single cell, e.g. **Amoeba, Paramecium, Euglena**
  - **Multicellular**: made of many cells, e.g. **plants and animals**
- Cells occur in **different shapes and sizes** according to the functions they perform.
- A typical cell consists of **three basic components**:
  - **Plasma membrane**
  - **Cytoplasm** containing cell organelles
  - **Nucleus** containing chromatin / nuclear material
- In **plant cells**, a **cell wall** is present outside the plasma membrane.
- The living content of a eukaryotic cell is called **protoplasm**.
- Protoplasm consists of:
  - **Nucleus and Cytoplasm**

### BTB

- Most diseases are caused by malfunctioning of cells.
- The adult human body contains more than **37 trillion cells**.



## 10.1 ENDOPLASMIC RETICULUM

- The term *endoplasmic* means **within the cytoplasm**.
- It is a **tube-like lipoprotein network** extending through the cytoplasm.
- It is made up of:

Form / Component	Description
<b>Tubules</b>	• <b>Tube-like structures</b>
<b>Vesicles</b>	• <b>Rounded or spherical structures</b>
<b>Cisternae</b>	• <b>Flattened sac-like compartments</b>

- It is usually **continuous with the nuclear envelope** on one side.
- It **extend toward the plasma membrane** on the other side.
- The ER membrane encloses an **internal cavity** called the **ER lumen** or **cisternal space**.
  - This internal space is separated from the cytoplasm by the **ER membrane**.
- **Both RER and SER** are present in most cells but their ratio varies *according to function*.

### BTB

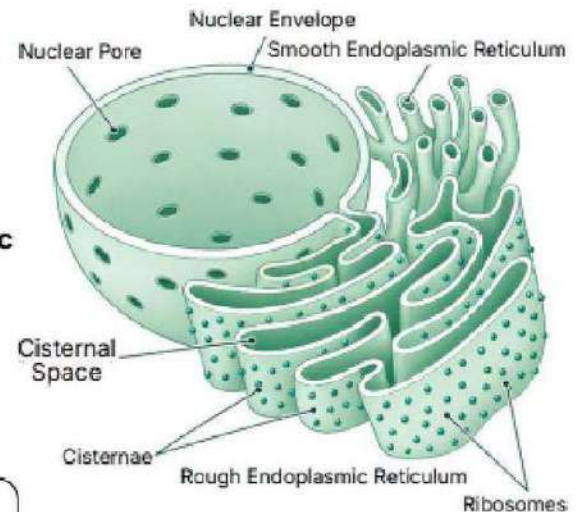
#### Components of ER:

- **Cisternae**: long, *flattened*, usually *unbranched membrane-bound sacs*, often arranged in *stacks*.
- **Tubules**: *irregular*, often branched membrane-bound tubes
  - They may be **free** or **connected with cisternae**
- **Vesicles**: small **oval membrane-bounded structures**.

Types of ER:

Feature	Rough ER (RER)	Smooth ER (SER)
<b>Ribosomes</b>	• Present on <b>outer/cytoplasmic</b> surface	• <b>Absent</b>
<b>Appearance</b>	• <b>Rough</b> under electron microscope	• <b>Smooth</b> under electron microscope
<b>Main structure</b>	• Mainly <b>flattened cisternae</b> and <b>vesicles</b>	• Mainly <b>tubules</b>
<b>Stability</b>	• <b>More stable</b> structure	• <b>Less stable</b> structure
<b>Main occurrence</b>	<ul style="list-style-type: none"> <li>• It is abundant in protein-synthesizing and secretory cells such as:                             <ul style="list-style-type: none"> <li>◦ <b>Liver</b></li> <li>◦ <b>Pancreas</b></li> <li>◦ <b>Goblet cells</b></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• It is abundant in cells involved in:                             <ul style="list-style-type: none"> <li>◦ <b>Lipid metabolism</b> → adipose cells</li> <li>◦ <b>Glycogen metabolism</b> → liver cells, muscle cells</li> <li>◦ <b>Steroid synthesis</b> → interstitial cells, steroid-secreting cells</li> <li>◦ <b>Detoxification</b> → liver cells</li> <li>◦ <b>Calcium storage and release</b> → muscle cells</li> </ul> </li> </ul>
<b>Main role</b>	• Protein synthesis ( <b>Translation</b> ) and <b>membrane formation</b>	• <b>Lipid/steroid</b> synthesis, <b>detoxification</b> , <b>Ca<sup>2+</sup> storage</b> , <b>impulse transmission</b> in muscle and nerve cells
<b>Products</b>	• <b>Secretory</b> proteins, <b>membrane</b> proteins	• <b>Oils, phospholipids, cholesterol, steroids</b>

- RER serves as a **supporting platform for ribosomes**.
- RER with many ribosomes attached to parallel cisternae is called **ergastoplasm**.
  - In nerve cells, ergastoplasm is called **Nissl's bodies**.
- RER is mostly present **outside the nuclear membrane**.
- In skeletal and cardiac muscle, SER is modified into **sarcoplasmic reticulum**, which stores **Ca<sup>2+</sup>** in its lumen.
  - It also helps in **release of Ca<sup>2+</sup>** when required.
- SER makes lipids from **fatty acids and glycerol absorbed in the gut** and passes them to Golgi bodies for export.



FTB

- **Secretory proteins** leave RER in vesicles budding from a specialized region called **transitional ER**.
- Vesicles moving from one part of the cell to another are called **transport vesicles**.
- RER also acts as a **membrane factory** by adding membrane **proteins** and **phospholipids** to *its own membrane*.
- This membrane is later transferred to other parts of the **endomembrane system**.

Mentri Insight

- **Flow of secretions:** Ribosomes on RER → ER lumen / channels → Transitional ER → Transport vesicles → Golgi apparatus → Secretion / final destination
- **ER is the largest** internal membrane system.

Functions of Endoplasmic Reticulum:

Function	ER Type	Details
<b>Mechanical support</b>	Both	<ul style="list-style-type: none"> <li>• Forms <b>internal supporting framework</b></li> <li>• Helps maintain <b>cell shape</b></li> <li>• Works with <b>microfilaments and microtubules</b></li> </ul>
<b>Protein synthesis</b>	RER	<ul style="list-style-type: none"> <li>• Ribosomes attached to outer surface <b>synthesize proteins</b></li> </ul>
<b>Protein handling</b>	RER	<ul style="list-style-type: none"> <li>• Proteins may be <b>stored</b> in cytoplasm, sent to Golgi, incorporated into membranes, or exported out of the cell</li> </ul>
<b>Lipid synthesis</b>	SER	<ul style="list-style-type: none"> <li>• <b>Synthesizes</b> lipids, oils, phospholipids, and cholesterol</li> </ul>
<b>Steroid synthesis</b>	SER	<ul style="list-style-type: none"> <li>• Forms <b>sex hormones</b>, adrenal <b>steroid hormones</b>, <b>corticosteroids</b>, <b>testosterone</b>, and <b>estrogen</b></li> </ul>
<b>Detoxification</b>	SER	<ul style="list-style-type: none"> <li>• <b>Detoxifies</b> drugs, poisons, pollutants, steroids, and other toxins, especially in liver cells</li> </ul>
<b>Calcium storage and release</b>	SER	<ul style="list-style-type: none"> <li>• Sarcoplasmic reticulum <b>stores and releases Ca<sup>2+</sup></b></li> </ul>
<b>Formation of membranous organelles</b>	Both	<ul style="list-style-type: none"> <li>• All membranous organelles <b>except</b> mitochondria and chloroplasts are formed by ER.                             <ul style="list-style-type: none"> <li>◦ <b>RER</b> contributes membrane <b>proteins</b>, <b>SER</b> contributes membrane <b>lipids</b>.</li> </ul> </li> </ul>
<b>Golgi formation</b>	SER	<ul style="list-style-type: none"> <li>• SER buds off to form Golgi apparatus</li> </ul>
<b>Nuclear membrane formation</b>	Both	<ul style="list-style-type: none"> <li>• During <i>cell division</i></li> <li>• Fragmented ER and nuclear membrane elements reassemble around chromosomes to form <b>nuclear membrane</b>.</li> </ul>
<b>Enzymatic activities</b>	Both	<ul style="list-style-type: none"> <li>• Contains <b>enzymes</b> such as <i>sucrase</i>, <i>glucose-6-phosphatase</i>, and <i>NAD diphosphatase</i></li> </ul>
<b>Surface for metabolism</b>	Mainly SER	<ul style="list-style-type: none"> <li>• Provides a <b>large membrane surface</b> for many metabolic reactions</li> </ul>
<b>Intracellular transport</b>	Both	<ul style="list-style-type: none"> <li>• Forms <b>conducting and connecting system</b> for import, export, and intracellular circulation of substances.</li> </ul>
<b>Connection within cell</b>	Both	<ul style="list-style-type: none"> <li>• Helps connect nuclear material with plasma membrane because it extends from nucleus to plasma membrane.</li> </ul>

10.2

GOLGI COMPLEX

- Golgi apparatus was discovered by **Camillo Golgi** in 1898.
- It is found in **virtually all eukaryotic cells**.
- It is also called **Golgi apparatus, Golgi bodies, Golgosome, or Golgi complex**.
- In plants, Golgi units are called **dictyosomes**.

Structure:

- The **Golgi apparatus** consists of stacks of **flattened, membrane-bound sacs** called **cisternae**.
- Golgi membranes are **smooth** and **lack ribosomes**.
- The flattened cisternae are usually arranged **parallel to one another** and form the **central stack** of the Golgi body.
- Each Golgi unit is generally **disc-shaped** and consists of:

Part	Description
<b>Central cisternae</b>	• Stacked flattened sacs
<b>Peripheral tubules</b>	• Interconnecting tubular network around the stack
<b>Golgian / secretory vesicles</b>	• Vesicles associated with the Golgi complex

- The internal space of each Golgi cisterna is called the **lumen**.

Polarity of Golgi Apparatus:

- Golgi apparatus has two distinct faces:
  - **Cis face / Forming face / Proximal face**
  - **Trans face / Maturing face / Distal face**

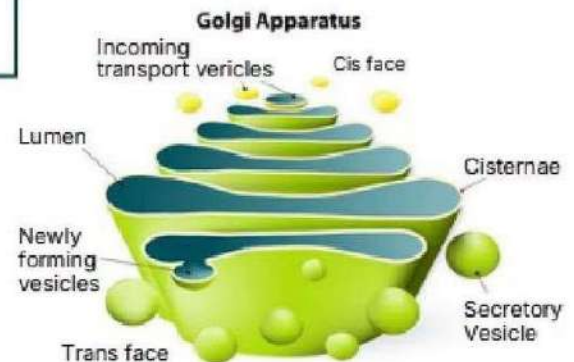
Feature	Cis Face	Trans Face
<b>Other names</b>	• Forming or proximal face	• Maturing or distal face
<b>Shape</b>	• <b>Convex</b>	• <b>Concave</b>
<b>Position</b>	• Near <b>nucleus</b>	• <b>Towards plasma membrane</b>
<b>Main role</b>	• Receives <b>ER-derived vesicles</b>	• Buds off <b>secretory / transport vesicles</b>
<b>Nature</b>	• <b>Receiving side:</b> Incoming transport vesicles fuse with the cis face to form <i>new cisternae</i> .	• <b>Shipping side:</b> The cisternae break up from again into new vesicles e.g <i>secretory / transport vesicles</i> .

KTB

- Each dictyosome is formed of **bundles of curved and flattened cisternae**, associated tubules, and secretory vesicles.

Mentri Insight

- The Golgi stack is described as a series of cisternae **moving from the outer (cis) face towards the inner (trans) face**.



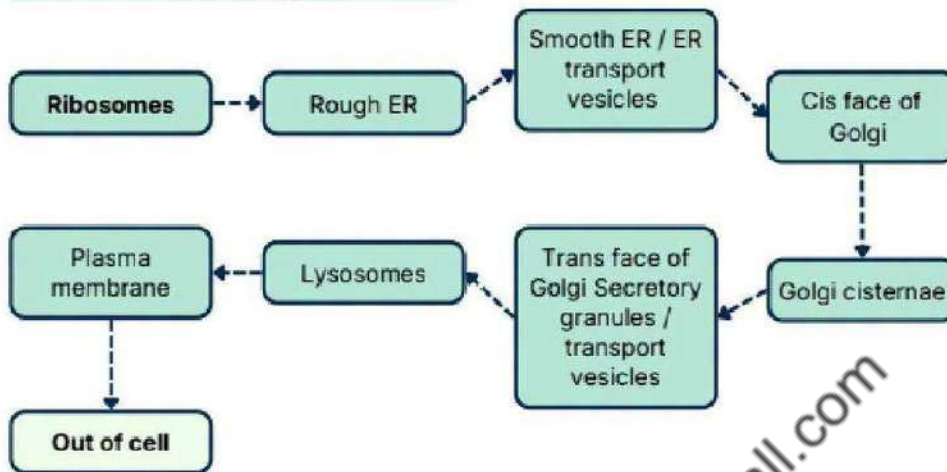
BTB

- In most animals, Golgi stack usually contains **3–7 cisternae**.
- However, in some lower organisms, the number may be as high as **30**.
- Golgi sacs contain **proteins, carbohydrates, glycoproteins, and specific enzymes**.

**Association with Endoplasmic Reticulum:**

- Golgi apparatus is functionally closely related to the **endoplasmic reticulum (ER)**.
- New cisternae are continuously formed by fusion of vesicles derived from **SER**
- These vesicles are probably produced by **budding of SER**.
- **Highlighted contradiction:** PTB/FTB/STB emphasize derivation of vesicles from **SER**, whereas KTB mentions vesicles pinched off from **RER**.

**Flow of Secretory Product:**



**KTB**

- Vesicles and tubules pinched off from **RER** also flow, converge, and fuse with the **forming face** to form new cisternae.

**BTB**

- Golgi apparatus acts as a major **collection and dispatch station** for protein products received from ER, therefore it is called the **post office of the cell**.
- It is involved in formation of **acrosome** during **spermiogenesis**.
- It also contributes to formation of **vitelline membrane of egg**.

**01**

**FUNCTIONS OF GOLGI APPARATUS**

**1. Modification of Proteins and Lipids:**

- Golgi apparatus:
  - **modifies proteins and lipids** received from ER
  - sometimes **stored** them
  - and then **sent** them to their **destinations**
- Its most important function is **processing of cell secretions**.
- Its secretory products are mainly **proteins**.

**2. Collection, Packaging, and Secretion:**

- Golgi performs **collection, packaging, processing, storage, and export** of cellular secretions.
- Secretions are products formed within the cell on **ribosomes**.
- Golgi converts secretions into **finished products** and packs them inside a **membrane** before export.
- Proteins or enzymes that have to be transported **out of the cell** pass through the **Golgi apparatus**.
  - *Those proteins never enter/touch cytoplasm.*
- At the **maturing face**, **secretory granules / transport vesicles** are pinched off for transport.

**Mentr Insight**

- Golgi is involved in formation of **conjugated molecules** such as:
- **Glycoproteins** (Carbohydrate + Proteins)
  - **Glycolipids** (Carbohydrated + Lipids)
  - **Lipoproteins** (Lipids + Proteins)

**Mentr Insight**

- Golgi apparatus is especially abundant in **secretory cells** and prominent in **glandular cells**.
- Example: In mammals, Golgi helps in formation of **pancreatic secretory granules** containing digestive enzymes.
- It is poorly developed in **muscle cells**.

### 3. Formation of Vesicles:

- Golgi apparatus produces many types of **vesicles**.
- Vesicles bud off mainly from the **trans / maturing face**.
- These vesicles may:
  - carry **secretory products**
  - transport substances **within the cell**
  - **fuse** with plasma membrane
  - form certain **organelles**

### 5. Synthesis of Polysaccharides:

- In some cases, Golgi synthesizes **polysaccharides from simple sugars**.
- These polysaccharides may then combine with proteins and lipids to form **conjugated molecules**.

### 6. Formation of Lysosomes and Related Organelles:

- Golgi apparatus forms **primary lysosomes**.
- It also gives rise to:
  - **Lysosomes**
  - **Peroxisomes**
  - **Glyoxysomes**

### 7. Role in Plant Cell Wall and Cell Plate Formation:

- In plant cells, Golgi helps in formation of the **new cell wall**.
- It forms vesicles containing **cell wall-synthesizing materials**.
- Golgi also contributes to formation of **cell plate**.

### 8. Addition to Plasma Membrane:

- Secretory vesicles produced by Golgi may fuse with the **plasma membrane**.
- In this way, Golgi secretory vesicles help in **adding surface area to plasma membrane**.

#### BTB

### 4. Storage Role:

- Golgi apparatus helps in **storage of secretory products**.
- Proteins synthesized by ribosomes pass to ER and may be **stored in Golgi apparatus** before further transport.

#### STB

- Many **polysaccharides** secreted by cells are Golgi products.
- **Cellulose** and **chitin** associated with formation of **cell wall** and **cell plate** are described as Golgi products.

#### FTB

- During cytokinesis, these Golgi vesicles collect at the **cell equator**, fuse, and form a structure called **phragmoplast**.
- Later, the **new cell wall** is derived from this structure.

## 02

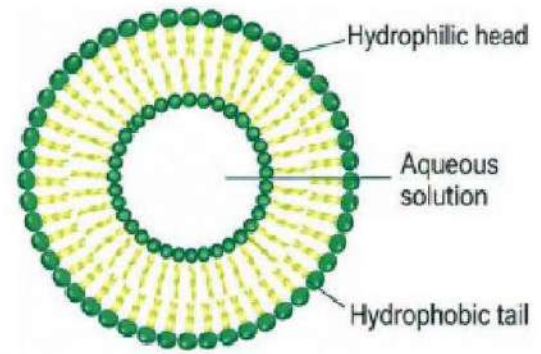
## VESICLES

- **Vesicles** are small **membrane-enclosed sacs** present in cells.
  - A vesicle consists of fluid enclosed by a **lipid bilayer**.
- Because vesicles are made of phospholipids, they can **bud off** from one membrane and **fuse** with another membranous structure.
- Many vesicles are formed in the **Golgi complex** and **endoplasmic reticulum**.
- Vesicles may also originate from **plasma membrane by endocytosis**.

#### Mentr Insight

- The word **vesicle** is derived from Latin **vesicula**, meaning **small bladder**.
- Examples of vesicles include:
  - **Secretory vesicles**
  - **Transport vesicles**
  - **Synaptic vesicles**
  - **Lysosomes**

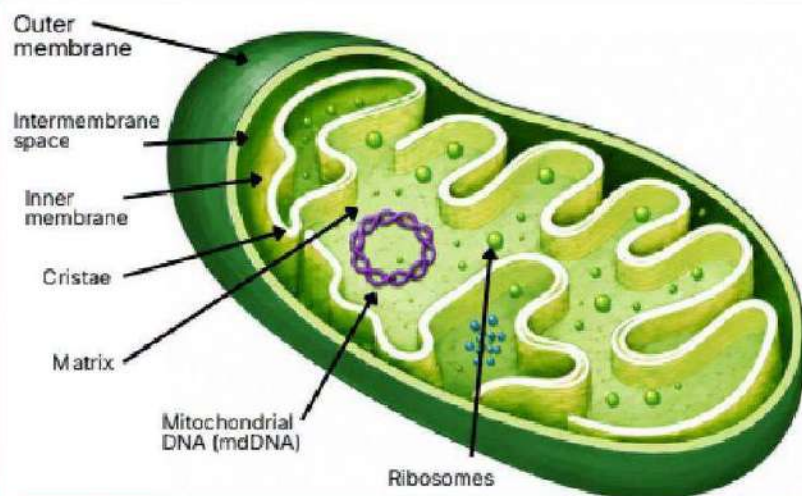
- Vesicles are found in **bacteria, Archaea, plants, and animals.**
- Main functions of vesicles include:
  - transport of substances **within the cell**
  - transport of substances **from one cell to another**
  - **enzyme storage**
  - participation in **metabolism**
  - **buoyancy control**
  - acting as **chemical reaction chambers**
- The first step in vesicular transport is **formation of vesicle by budding from membrane.**



## 10.3

## MITOCHONDRIA

- The word mitochondria is derived from Greek:
  - **mitos** = thread
  - **chondrion / khondrion** = granule or small grain
- Mitochondria are **double membrane-bound organelles** present in the cytoplasm of **almost all eukaryotic cells.**
- They are called the **power house of the cell** because they are the main site of **aerobic respiration** and **ATP production.**
- In shape, they may appear **granular, vesicular, rod-like, filamentous, thread-like, spherical, elongated, or bean-shaped.**
  - Under a compound microscope, they may appear as **vesicles, rods, or filaments.**
- Their **number varies widely** from a few to thousands per cell, depending on the **physiological and metabolic activity** of the cell.
- **Highly active cells**, such as muscle cells, contain **more mitochondria.**



### Mentri Insight

- Alternate names for mitochondrion are **Power house of the cell, Chondriosome, ATP mill, Cell furnace, Storage batteries of the cell, Cell within cell.**

### KTB

- Mitochondria were first seen as granules in muscle cells in **1850**
- Mitochondria may be **absent in some highly specialized cells**, such as **mature RBCs.**

### STB

- Mitochondria are also called **chondriosome.**
- In living cells, mitochondria are often **in constant motion.**

### FTB

- Excess mitochondria may be digested by **lysosomes.**
- Mitochondria and chloroplasts, if carefully fractionated, can survive for some time in an **artificial medium.**

### BTB

- Animal cells contain **more mitochondria** than plant cells.
- **All mitochondria** in a cell collectively form **chondriome.**
- Term **mitochondria** was given by **C. Benda** in **1898.**
- **Altman (1890)** called them **bioblasts.**

01

SIZE & STRUCTURE OF MITOCHONDRIA

- Mitochondria are microscopic organelles with variable size.
  - **BTB**: diameter 0.2-1.0  $\mu\text{m}$ ; length 1-4.1  $\mu\text{m}$ .
  - **STB**: diameter 0.5-1.0  $\mu\text{m}$ ; length about 10  $\mu\text{m}$ .
- Each mitochondrion is bounded by **two membranes**:
  - **Outer membrane**
  - **Inner membrane**
- Both membranes are composed of **lipids and proteins**.
- Mitochondrial membranes are **similar in structure / chemical nature to the cell membrane**.

**Outer Membrane:**

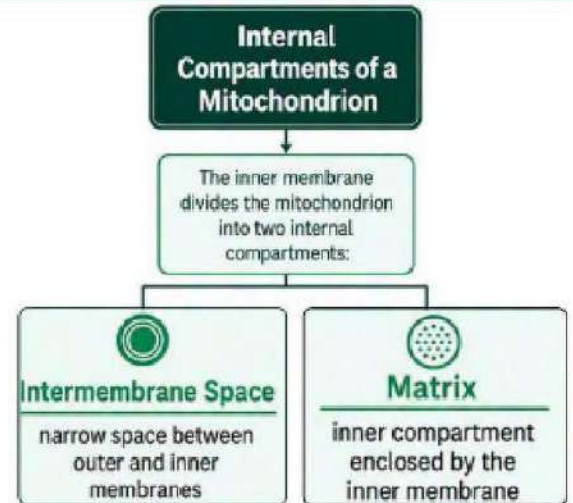
- The **outer membrane is smooth**.
- It contains **porins**, which make it relatively **permeable**.
- Porins allow free passage of various molecules into the **intermembrane space**.

**Inner Membrane:**

- The **inner membrane is selectively permeable**.
- It is folded inward to form **cristae**.
- **Cristae increases surface area** for metabolic reactions and ATP production.
- A **crista is made of lipoprotein membrane** containing:
  - **Respiratory enzymes**
  - **F<sub>0</sub>/ F<sub>1</sub> particles**

**Mitochondrial Matrix:**

- The **matrix** is a jelly-like or fluid-like region enclosed by the inner membrane.
- It contains:
  - **Oxidative enzymes**
  - **Coenzymes**
  - **Organic and inorganic salts**
  - **Proteins**
  - **All types of RNA**
  - **70S ribosomes**
  - **Small circular double-stranded DNA**
- The matrix contains enzymes for:
  - **Krebs cycle**
  - **Fatty acid metabolism**
  - Other steps of **aerobic respiration**
- Matrix enzymes and respiratory molecules help metabolize:
  - **Carbohydrates, Fats and Amino acids**



**BTB**

- If the outer membrane is removed, the remaining structure is called a **mitoplast**.

**STB**

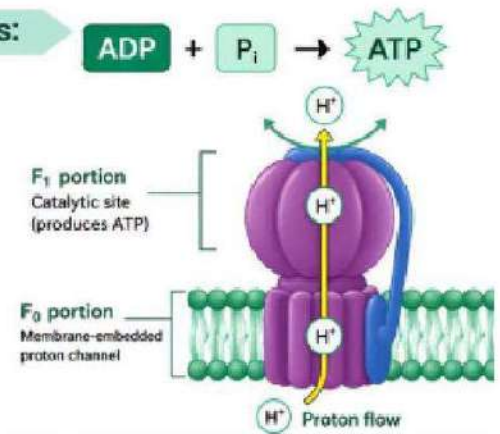
- Cristae may appear as **irregular, incomplete partitions**.
- The inner membrane also contains:
  - **ETC components**
  - **Cytochromes**
  - **NAD- and FAD-related respiratory complexes**

**BTB**

- Mitochondrial DNA is about **1% of the total DNA of the cell**.

**F<sub>0</sub>-F<sub>1</sub> Particles / F<sub>1</sub> Particles / Elementary Particles / Oxysomes:**

- Small knob-like or pinhead particles are present on the **inner membrane / cristae**.
- These particles contain **ATP synthase / ATP synthetase / ATPase complex**.
- They are directly involved in the **synthesis of ATP**.
- In special preparations, when the inner mitochondrial membrane is ruptured, **F<sub>1</sub> particles project outward / come out on the surface**.



**02 FUNCTIONS OF MITOCHONDRIA**

- Mitochondria are the **main site of aerobic respiration**.
- They are the centers of **oxidative metabolism** and **ATP production (ADP is regenerated into ATP)**.
- They oxidize **carbohydrates, fats and amino acids** to release energy.
- Energy extracted from organic food is converted into **ATP**.
- ATP produced in mitochondria supplies energy for various **cellular activities**.
- Mitochondria are involved in:
  - **Krebs cycle**
  - **Electron transport chain**
  - **Fatty acid metabolism**

**BTB**

- Mitochondria also help in **vitellogenesis (yolk formation) in oocyte**

**STB**

- During aerobic respiration, carbohydrates, lipids, and proteins are metabolized into **CO<sub>2</sub> and H<sub>2</sub>O**, releasing energy stored as **ATP**.

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**03 UNIQUE CHARACTERISTICS**

**Semi-Autonomous Nature:**

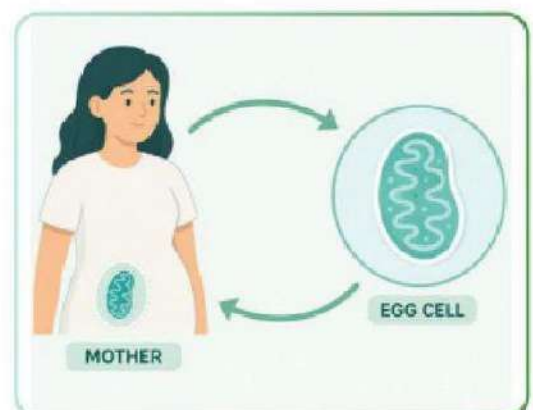
- Mitochondria are **semi-autonomous organelles**. (like Chloroplasts)
- They possess their own:
  - **DNA, RNA and 70S ribosomes**
- Therefore, they have their own **genetic system**.
- They can synthesize **some of their own proteins / enzymes** required for metabolic functions.
- They are **self-replicating organelles** and divide by **fission**.

**Mitochondrial Inheritance:**

- In animals, mitochondria are inherited entirely from the **mother**.
- This is because mitochondria are present in the **ovum**, whereas the part of sperm that enters the egg does not contribute mitochondria.
- Therefore, mitochondrial lineage can be traced through the **maternal line**.

**FTB**

- The number of mitochondria **doubles before cell division**.



**Endosymbiotic Significance:**

- Mitochondria show similarities with bacteria because they have:
  - **Circular DNA**
  - **All types of RNA**
  - **70S ribosomes**
  - **Self-replication**
  - Their own partial metabolic machinery
- Therefore, mitochondria are described as:
  - **cell within cell**
  - **organism within organism**

**Mentr Insight**

The **endosymbiotic theory** states that:

- Early ancestors of eukaryotic cells engulfed **independent prokaryotic organisms**
- These later formed a **symbiotic relationship** with the host cell
- Eventually they became **mitochondria**

**10.4**

**NUCLEUS AND CHROMOSOMES**

- Nucleus is a **double membrane-bound organelle** of **eukaryotic cells**.
- It was reported by **Robert Brown in 1831 (1838 in KTB)**.
- It was discovered because of its **prominent appearance** i.e, **slightly darker than the surrounding cytoplasm**.
- It acts as the **control center** of the cell because it regulates:
  - cellular metabolism
  - growth
  - heredity
  - overall cell activities
- It contains **genetic information** in the form of **DNA arranged into chromosomes**.
- In most cells, nucleus is visible during **interphase (non-dividing stage)**.
- During cell division:
  - the typical nuclear organization becomes **indistinct**
  - chromatin condenses into **chromosomes**

**BTB**

- Nucleus is described as a **self-replicating organelle** and arises from a **pre-existing nucleus**.
- **Robert Brown** first observed nucleus in **orchid cells**.

**Mentr Insight**

Nucleus is also called as:

- **Heart of cell**
- **Brain of cell**
- **Control centre of cell**
- **Information centre of cell**

**01**

**SHAPE, SIZE, NUMBER AND POSITION OF NUCLEI**

- Nucleus is usually:
  - **spherical**
  - **oval**
  - **elongated**
  - **irregular**
  - **lobed** in some cells
- It is typically about **10 µm in diameter**.
- In **animal cells**, nucleus generally occupies the **central position**.
- In **plant cells**, nucleus is usually pushed towards the **periphery** because of the **large central vacuole**.

**FTB**

- **Exception of location of nucleus:** In some animal cells such as **muscle fibre cells**, nucleus is not centrally placed.

**Mentr Insight**

- **Mature RBCs** are **anucleated** (so **lack DNA**) while **immature RBCs** (erythroblast) have **nucleus**.

Number of Nuclei:

Condition	Term	Example / note
Cell with one nucleus	• Mononucleate	• Most cells
Cell with two nuclei	• Binucleate / Dikaryotic	• Paramecium is dikaryotic
Cell with many nuclei	• Multinucleate / Coenocytic	• Muscle fibres, Opalina
Cell with no nucleus	• Anucleated	• <b>Mature mammalian RBCs, mature phloem sieve tube elements</b>

02

COMPONENTS OF NUCLEUS

A typical *interphase nucleus* consists of:

- Nuclear envelope
- Nucleoplasm
- Nucleolus
- Chromatin / chromosomes

Nuclear Envelope:

- Nuclear envelope, also called **nuclear membrane**:
  - is a **double membrane covering** around the nucleus.
  - forms the **boundary of the nucleus** and separates nuclear contents from cytoplasm.
- The two membranes are separated by a **fluid-filled perinuclear space**.
- Nuclear envelope is composed of:
  - **lipid bilayer**
  - **proteins**
- The **outer nuclear membrane**:
  - is continuous at places with the **endoplasmic reticulum**
  - may bear **ribosomes** on its outer surface
- The **inner nuclear membrane** encloses the nuclear contents.
- At certain points, both membranes fuse to form **nuclear pores**.
- Nuclear pores regulate the **exchange of materials** between nucleus and cytoplasm.
- Nuclear pores are formed by specialized transport proteins called **nucleoporins**.
- Through nuclear pores, the following materials may move:
  - **RNA, ribosomal subunits & proteins, DNA polymerase**
  - proteins, carbohydrates, signaling molecules, lipids, ions
    - Small molecules may pass by **simple diffusion**.
    - Larger molecules require **specific signal sequences** and regulated transport through pore complexes.
- The number of nuclear pores is **variable**.

BTB

- Perinuclear space is about **10–50 nm** wide.

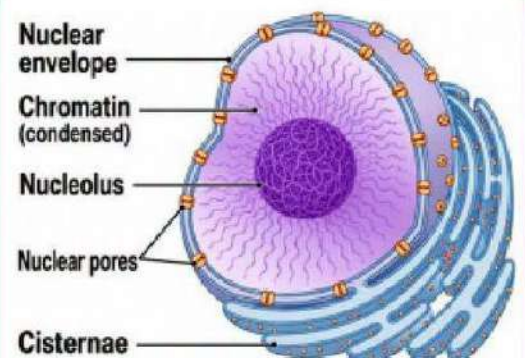
PTB

- Undifferentiated cells such as **egg cells** may have about **30,000 pores per nucleus**.

Mentri Insight

Highlighted contradiction:

- PTB states very few nuclear pores in erythrocytes, but as you know mature mammalian erythrocytes are **anucleate**, so this wording is biologically inconsistent for mature RBCs. But this can be true for the **immature RBCs**.



### Nucleoplasm:

- Nucleoplasm is the **semi-fluid ground substance** of the nucleus.
- It is also called:
  - **karyoplasm | karyolymph | nuclear matrix**
- It is a **transparent colloidal solution** filling the nucleus.
- Nucleoplasm contains:
  - water, proteins, enzymes, free nucleotides
  - organic and inorganic salts, mineral ions
  - histone proteins, non-histone proteins
- Important **enzymes** present in nucleoplasm include:
  - **DNA polymerase**
  - **RNA polymerase**
- Nucleoplasm differs slightly in composition from cytoplasm.
- Functions of nucleoplasm:
  - **provides matrix** for suspension of **chromatin**
  - **stores enzymes** required for nuclear activities
  - stores raw materials for **DNA replication**
  - stores materials needed for **RNA synthesis**
  - serves as medium for metabolic activities inside nucleus

### Nucleolus:

- Nucleolus is a **dense, darkly stained, spherical, non-membranous structure** present in the nucleus.
- It is *not separated* from nucleoplasm by any membrane.
- A nucleus may contain **one or more nucleoli**.
- The number of nucleoli varies in different cell types.
- Nucleolus is prominent during **interphase**.
- It disappears during **cell division** and reappears afterwards.
- Nucleolus is the site of:
  - **rRNA synthesis & storage**
  - **ribosome assembly**
- Ribosomal subunits formed in the nucleolus move to cytoplasm through **nuclear pores**.
- Therefore, nucleolus is called the **ribosome factory** of the cell.
- Nucleolus has two main regions:
  - **Peripheral granular region** : precursors of ribosomal subunits
  - **Central fibrillar region**: contains **rRNA, rDNA, large molecular weight RNA**

### Chromatin network / nuclear reticulum:

- Chromatin is a **network of fine thread-like structures** present in the nucleus of non-dividing cells.
- Chromatin consists of:
  - **DNA | Histone proteins | Non-histone proteins**
  - small amount of **RNA**

### BTB

- Enzymes present in nucleoplasm include:
  - **ATPase**
  - **Endonucleases**
- Important **ions** include:
  - **Mg<sup>2+</sup>**
  - **Ca<sup>2+</sup>**

### Mentr Insight

- During cell division, chromosomes attach to spindle fibers **through kinetochores**, not **directly** to the centromere.

### BTB

- **Nucleolus** is associated with a chromosomal region called the **nucleolar organizer region (NOR)**.
- Chemical composition of nucleolus is:
  - **85% proteins**
  - **10% RNA**
  - **5% DNA**

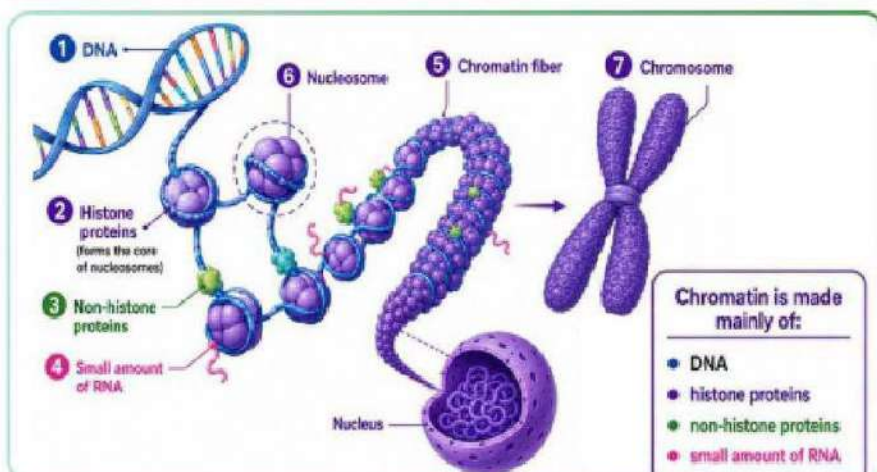
Euchromatin	Heterochromatin
• <b>Loosely</b> packed chromatin	• <b>Tightly</b> packed chromatin
• <b>Lightly</b> stained	• <b>Darkly</b> stained
• Transcriptionally active	• Mostly transcriptionally inactive
• Present more toward inner nucleus	• Present near nuclear membrane, centromeres, and telomeres

- Chromatin is embedded in nucleoplasm.
- Chromatin carries the **genetic information** of the cell.
- During cell division, chromatin:
  - condenses, coils, shortens.
  - becomes visible as **chromosome**.

**Chromosome and its structure:**

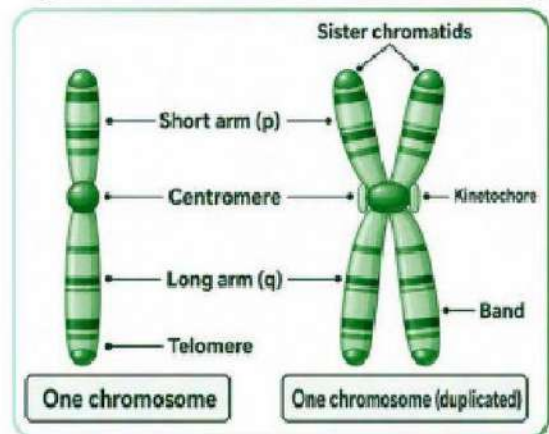
- Chromosomes are the **highly condensed form of chromatin**.
- They are visible only during **cell division**.
- After condensation, chromosomes become thick enough to be seen under a **light / compound microscope**.
- They stain deeply with **basic dyes**.
- Chromosomes contain the **genes**, which are units of heredity.
- Chromosomes transfer hereditary information from one generation to the next.
- The gene position on chromosome is called its **locus** (Plural **loci**).
- At the beginning of cell division, each chromosome consists of **two genetically identical sister chromatids**.
- Each chromatid is an exact replica of the other.
- Sister chromatids are joined together at the **centromere**.
- Centromere is the **primary constriction** of chromosome.
- Under the compound microscope, chromosome appears to consist of:
  - **Arms**
  - **Centromere**
- The part of chromosome extending from centromere to the end is called an **arm**.
- Around the centromere is a **disc-like protein** structure called **kinetochore**.
- Kinetochores are present on **opposite sides of the centromere**.
- Spindle fibres attach to chromosome at the **kinetochore** during cell division.
- Ends of chromosomes are called **telomeres**.

**Packaging of Genetic Material:**



**BTB**

- Chromosomes are best studied at **metaphase**, when they are shortest and most condensed.
- Each chromatid consists of a **single long DNA** molecule associated with:
  - Histone proteins (Basic)
  - Non-histone proteins
  - Small amount of RNA
- Chromosomes are covered by a thin proteinaceous sheath called **pellicle**.



**Mentri Insight**

- A **nucleosome** is a bead-like structure made of DNA wrapped around histone proteins.
- About **147 base** pairs of DNA wrap around **one histone core**.
- **Histones are basic, positively charged proteins, rich in lysine and arginine.**
- **H2A, H2B, H3, H4** : Core histones; form the histone octamer around which DNA wraps.
- **H1**: Linker histone, do not form nucleosome complex

**Mentr Insight**

- Chromosomes were first observed by the German embryologist **Walther Fleming** in 1882, when he was examining the rapidly dividing cells of **salamander** larvae.
- Since their discovery, chromosomes have been found in the cells of **all eukaryotes**.
- Their number however **varies** from species to species.
- Each of the 46 chromosomes in humans contains **hundreds** or **thousands** of genes.

**Karyotype:**

- The **particular array of chromosomes** that an individual possesses is called its **karyotype**.
- **Karyotype** is the characteristic chromosome no. of a species.
- Each chromosome can be identified by its:
  - **Size**
  - **Shape**
- Chromosomes number is **definite** and **constant** for each species.
- Normal body cells usually contain the **diploid number (2n)**.
- Gametes contain the **haploid number (n)**.
- Fertilization *restores* the **diploid number**, thereby maintaining species chromosome number.
- Chromosome number does **not necessarily indicate complexity** of organism.

Organism	Chromosome Number
Human	46
Chimpanzee	48
Frog	26
Fruit fly (Drosophila)	8
Onion	16
Potato	48
Garden pea / sweet pea	14
Maize / corn	20
Mucor	2
Ascaris	2
Penicillium (Fungus)	2
Some ferns	more than 500 pairs
Mosquito	6
Sugarcane	80
Honeybee	32
Mouse	40

**Types of Chromosomes:**

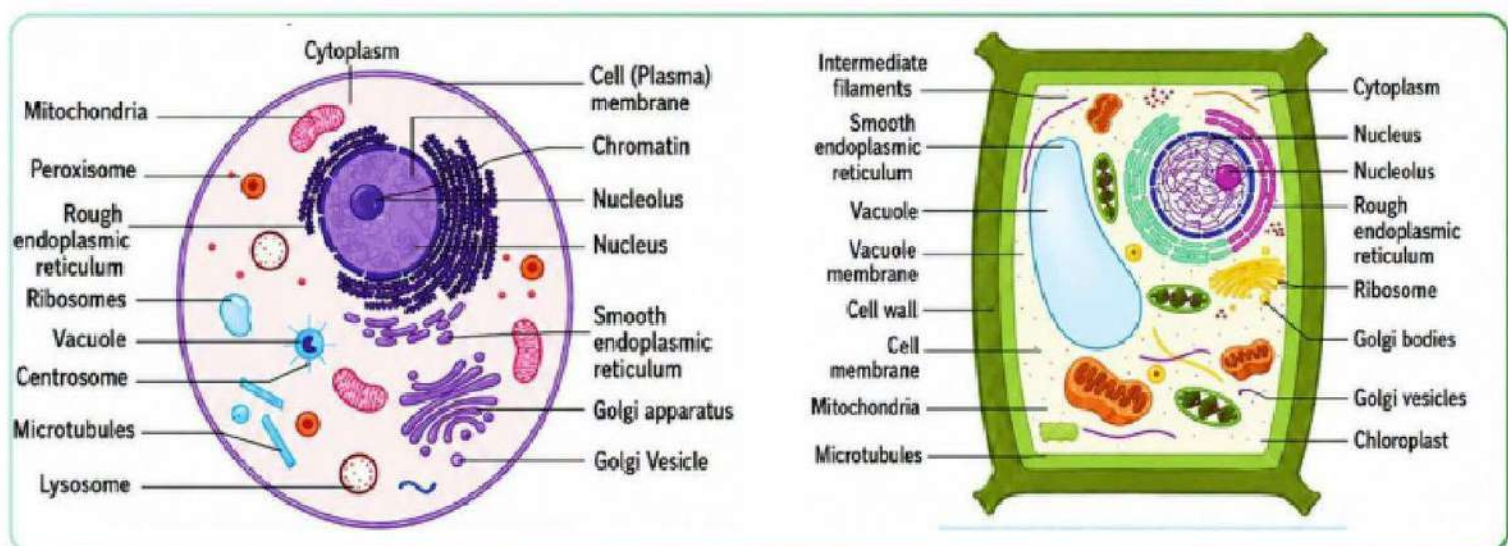
Type	Position of Centromere	Arms
Metacentric	Middle	Equal
Submetacentric	Slightly away from the middle	Slightly unequal
Acrocentric / Subtelocentric	Near one end	One very short, one very long
Telocentric (not present in humans)	Terminal	Effectively one arm

**10.5**

**ANIMAL VS PLANT CELL**

Feature / Structure	Animal Cell	Plant Cell
Cell boundary	Plasma membrane present	Plasma membrane present
Cell wall	<b>Absent</b>	Present
Nucleus	Present	Present
Nuclear envelope	Present	Present

Feature / Structure	Animal Cell	Plant Cell
Nuclear pores / pore	Present	Present
Nucleolus	Present	Present
Nucleoplasm	Present	Present
Chromatin	Present	Present
Cytoplasm	Present	Present
Endoplasmic reticulum	Present	Present
Ribosomes	Present	Present
Golgi apparatus	Present	Present
Mitochondrion / mitochondria	Present	Present
Peroxisome	Present	Present
Glyoxysomes	<b>Absent</b>	Present
Lysosome	Present	<b>Absent</b>
Centriole	Present	<b>Absent</b>
Centrosome	Present	Present
Secretory vesicles	Present	Absent
Cytoskeleton	Present	Present
Microtubules	Present	Present
Microfilaments	Present	Present
Flagellum	Present	<b>Absent</b>
Chloroplast	<b>Absent</b>	Present
Vacuole	Present	Present
Central vacuole	<b>Absent</b>	Present



## 10.6

## PROKARYOTIC VS EUKARYOTIC CELLS

Feature	Prokaryotic Cell	Eukaryotic Cell
Meaning of term	<ul style="list-style-type: none"> <li>• <b>Pro</b> = first/early, <b>karyon</b> = nucleus</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Eu</b> = true/proper, <b>karyon</b> = nucleus</li> </ul>
General organization	<ul style="list-style-type: none"> <li>• Simpler cell organization</li> </ul>	<ul style="list-style-type: none"> <li>• More complex cell organization</li> </ul>
Nucleus	<ul style="list-style-type: none"> <li>• True nucleus <b>absent</b></li> </ul>	<ul style="list-style-type: none"> <li>• True nucleus <b>present</b></li> </ul>
Position of genetic material	<ul style="list-style-type: none"> <li>• Present in cytoplasmic region called the <b>nucleoid</b></li> </ul>	<ul style="list-style-type: none"> <li>• Present inside the <b>nucleus</b></li> </ul>
DNA / chromosomes	<ul style="list-style-type: none"> <li>• Usually <b>one circular, double-stranded DNA chromosome</b></li> </ul>	<ul style="list-style-type: none"> <li>• Usually many <b>linear chromosomes</b></li> </ul>
Number of DNA molecules	<ul style="list-style-type: none"> <li>• Usually <b>one main chromosome</b>; plasmids may also be present</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Many DNA molecules/chromosomes</b> present</li> </ul>
Appearance during cell division	<ul style="list-style-type: none"> <li>• DNA <b>does not form</b> typical visible mitotic <b>chromosomes</b></li> </ul>	<ul style="list-style-type: none"> <li>• DNA condenses into <b>visible chromosomes</b> during cell division</li> </ul>
Histone proteins	<ul style="list-style-type: none"> <li>• Bacteria usually <b>lack true histones</b>; <b>archaea</b> may have histone-like proteins</li> </ul>	<ul style="list-style-type: none"> <li>• Histones <b>present</b> with DNA</li> </ul>
Composition of chromosomes	<ul style="list-style-type: none"> <li>• Mainly DNA, with associated proteins</li> </ul>	<ul style="list-style-type: none"> <li>• <b>DNA + histone proteins + some RNA</b></li> </ul>
Plasmids	<ul style="list-style-type: none"> <li>• <b>Common</b>; small circular extra-chromosomal DNA rings</li> </ul>	<ul style="list-style-type: none"> <li>• Generally <b>absent</b></li> <li>• Present in some <b>yeasts</b>.</li> </ul>
Transposons ( <i>Jumping genes</i> )	<ul style="list-style-type: none"> <li>• <b>Present</b> in many prokaryotes</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Present</b> in eukaryotes too</li> </ul>
Membrane-bound organelles	<ul style="list-style-type: none"> <li>• Absent</li> </ul>	<ul style="list-style-type: none"> <li>• Present; e.g., nucleus, mitochondria, ER, Golgi bodies, lysosomes</li> </ul>
Ribosomes	<ul style="list-style-type: none"> <li>• <b>70S</b> (50S + 30S) ribosomes</li> </ul>	<ul style="list-style-type: none"> <li>• <b>80S</b> (60S + 40S) cytoplasmic ribosomes;</li> <li>• Mitochondria and chloroplasts have <b>70S-type ribosomes</b></li> </ul>
Ribosome abundance	<ul style="list-style-type: none"> <li>• <b>Numerous</b>; thousands may occur in actively growing bacteria</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Numerous</b>; present free in cytoplasm and attached to rough ER; number depends on <b>protein synthesis</b> activity</li> </ul>
Reproduction / Cell division	<ul style="list-style-type: none"> <li>• <b>Asexual reproduction</b> by <b>binary fission</b></li> <li>• Genetic exchange may occur by <b>conjugation, transformation, or transduction</b></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Asexual reproduction</b> by <b>mitosis</b>;</li> <li>• <b>sexual reproduction</b> involves <b>meiosis</b> and fertilization</li> </ul>
Body organization	<ul style="list-style-type: none"> <li>• <b>Mostly unicellular</b>; may form colonies or filaments but lack true multicellularity</li> </ul>	<ul style="list-style-type: none"> <li>• Unicellular or multicellular</li> </ul>
Cell wall presence	<ul style="list-style-type: none"> <li>• Usually <b>present</b> in bacteria</li> <li>• <b>Absent</b> in some such as <b>Mycoplasma</b></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Present</b> in plants, algae, and fungi; absent in animal cells</li> </ul>

Feature	Prokaryotic Cell	Eukaryotic Cell
<b>Pili</b>	<ul style="list-style-type: none"> <li>• May be <b>present</b>; made of pilin</li> <li>• Help in attachment and conjugation</li> </ul>	<ul style="list-style-type: none"> <li>• Bacterial-type pili <b>absent</b></li> </ul>
<b>Capsule</b>	<ul style="list-style-type: none"> <li>• May be <b>present</b> in many bacteria</li> <li>• Helps protection and attachment</li> </ul>	<ul style="list-style-type: none"> <li>• Bacterial-type capsule <b>absent</b></li> </ul>
<b>Size</b>	<ul style="list-style-type: none"> <li>• Usually <b>smaller</b>, commonly about <b>0.1–5 μm</b></li> </ul>	<ul style="list-style-type: none"> <li>• Usually <b>larger</b>, commonly about <b>10–100 μm</b>; some cells are much larger</li> </ul>
<b>Cell wall composition</b>	<ul style="list-style-type: none"> <li>• Bacterial wall mainly <b>peptidoglycan/murein</b></li> <li>• Archaeal walls are different and lack true peptidoglycan</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Cellulose</b> in plants/algae</li> <li>• <b>Chitin</b> in fungi</li> </ul>
<b>Cell wall nature</b>	<ul style="list-style-type: none"> <li>• <b>Rigid</b>; gives shape and protection from osmotic bursting</li> </ul>	<ul style="list-style-type: none"> <li>• If present, provides <b>support and protection</b></li> </ul>
<b>Mesosomes</b>	<ul style="list-style-type: none"> <li>• <b>Present</b></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Absent</b></li> </ul>
<b>Plasma membrane sterols</b>	<ul style="list-style-type: none"> <li>• Usually <b>absent</b></li> <li>• Some exceptions exist, and some bacteria have <b>hopanoid-like stabilizers</b></li> </ul>	<ul style="list-style-type: none"> <li>• Usually <b>present</b></li> <li>• Animal membranes contain cholesterol</li> <li>• Fungi contain ergosterol</li> <li>• Plants contain phytosterols</li> </ul>
<b>Respiratory enzymes</b>	<ul style="list-style-type: none"> <li>• <b>Present</b> in <b>plasma membrane or membrane infoldings</b> because mitochondria are absent</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Present</b> mainly in the <b>inner mitochondrial membrane</b> for aerobic respiration</li> </ul>
<b>Locomotory structures</b>	<ul style="list-style-type: none"> <li>• Bacterial flagella are made of <b>flagellin</b> and move by a rotary motor</li> </ul>	<ul style="list-style-type: none"> <li>• Cilia/flagella have <b>microtubules, dynein, and plasma membrane</b> covering</li> </ul>
<b>Examples</b>	<ul style="list-style-type: none"> <li>• Bacteria, including cyanobacteria, and archaea</li> </ul>	<ul style="list-style-type: none"> <li>• Protists, fungi, plants, animals</li> </ul>
<b>Diagram</b>	<p>Diagram of a prokaryotic cell with the following labeled parts:</p> <ul style="list-style-type: none"> <li>Flagella</li> <li>Pili (Fimbriae)</li> <li>Plasmid</li> <li>Nucleoid (DNA)</li> <li>Capsule</li> <li>Cell wall</li> <li>Cell (Plasma) membrane</li> <li>Cytoplasm</li> <li>Ribosome</li> </ul>	<p>Diagram of a eukaryotic cell with the following labeled parts:</p> <ul style="list-style-type: none"> <li>Endoplasmic reticulum (Rough and Smooth)</li> <li>Peroxisome</li> <li>Mitochondria</li> <li>Vacuole</li> <li>Golgi apparatus</li> <li>Intermediate filaments</li> <li>Nuclear envelope</li> <li>Chromatin (DNA)</li> <li>Nucleoplasm</li> <li>Nucleolus</li> <li>Nucleus</li> <li>Microfilament</li> <li>Lysosome</li> <li>Microtubule</li> <li>Cytoplasm</li> <li>Ribosome</li> <li>Cell (Plasma) membrane</li> </ul>