Organelles and Functions

Nucleus

- Houses genetic material
- Nuclear envelope with pores
- Nucleolus: rRNA synthesis
- Chromatin organization

Endoplasmic Reticulum

- Rough ER: protein synthesis
- Smooth ER: lipid synthesis
- Calcium storage
- Detoxification

Mitochondria

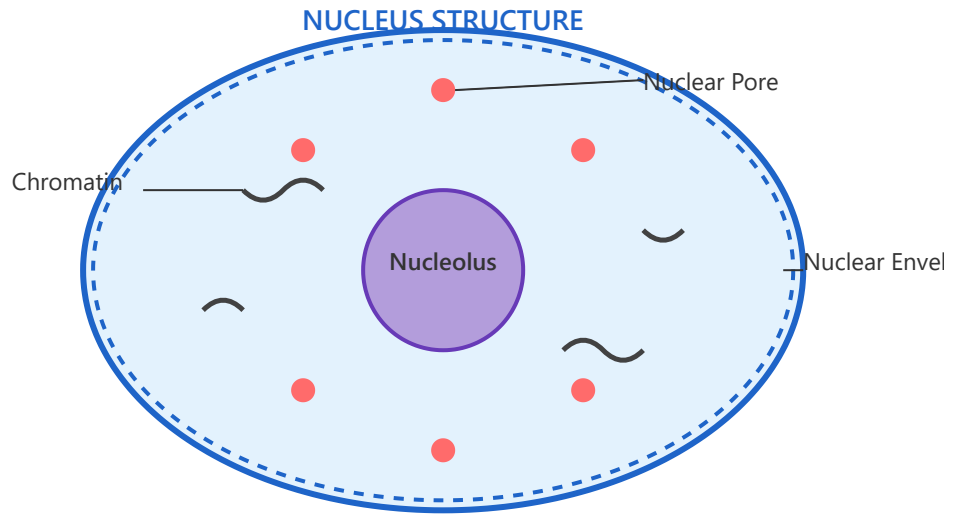
- ATP production (powerhouse)
- Double membrane
- Own DNA and ribosomes
- Apoptosis regulation

Golgi Apparatus

- Protein modification
- Glycosylation
- Protein sorting and packaging
- Vesicle formation

Detailed Organelle Information

1. Nucleus - The Command Center



The nucleus is the largest and most prominent organelle in eukaryotic cells, typically measuring 5-10 micrometers in diameter. It serves as the control center of the cell, housing the genetic blueprint encoded in DNA. The nucleus is enclosed by a double-layered nuclear envelope, which is perforated by nuclear pores that regulate the transport of molecules between the nucleus and cytoplasm. Inside the nucleus, DNA is organized with histone proteins into chromatin, which condenses into chromosomes during cell division. The nucleolus, a distinct region within the nucleus, is responsible for ribosomal RNA (rRNA) synthesis and ribosome assembly.

Key Functions & Features:

→ **Genetic Information Storage:** Contains all cellular DNA organized into chromosomes, preserving hereditary information and controlling gene expression.

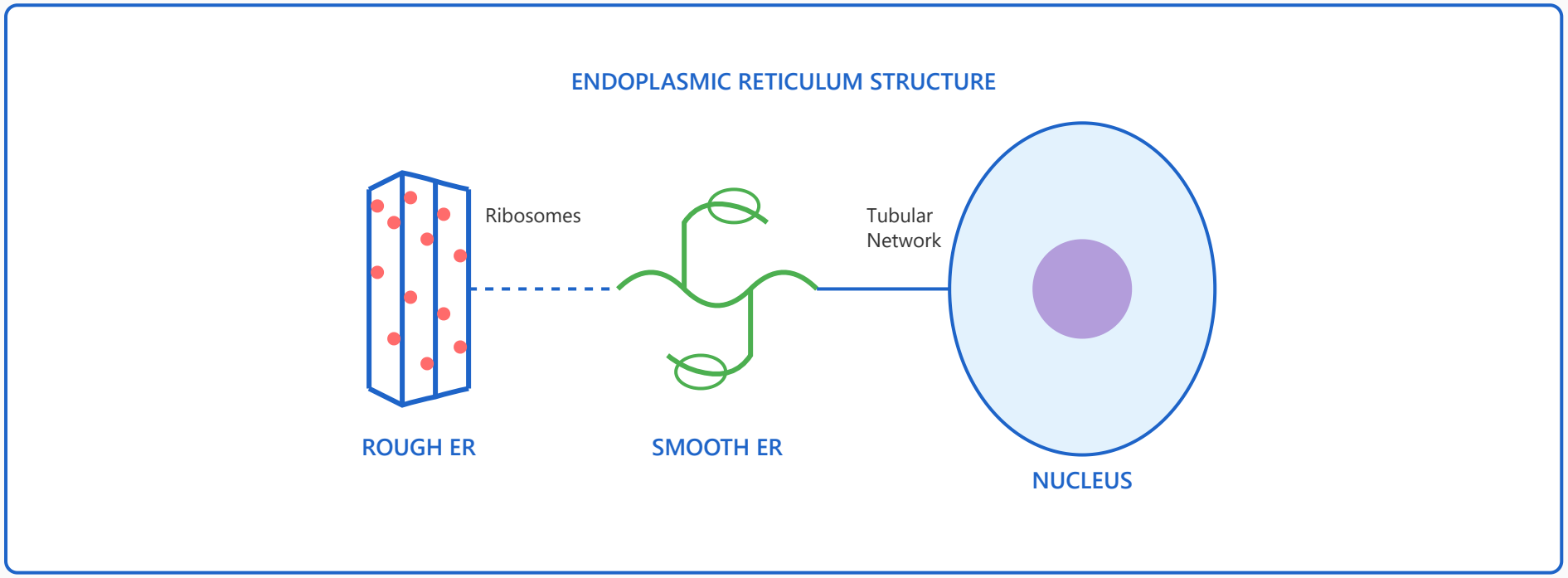
→ **Nuclear Pore Complexes:** Approximately 3,000-4,000 pores allow selective transport of proteins, RNA, and other molecules while maintaining nuclear integrity.

→ **Gene Transcription:** DNA is transcribed into messenger RNA (mRNA), which then exits through nuclear pores for protein synthesis.

→ **Ribosome Production:** The nucleolus assembles ribosomal subunits that are exported to the cytoplasm for protein synthesis.

→ **Cell Division Control:** Coordinates DNA replication and mitosis, ensuring accurate genetic transmission to daughter cells.

2. Endoplasmic Reticulum - The Manufacturing Network



The endoplasmic reticulum (ER) is an extensive network of interconnected membranous tubules and flattened sacs called cisternae, extending from the nuclear envelope throughout the cytoplasm. It exists in two distinct forms with specialized functions. The rough endoplasmic reticulum (RER) is studded with ribosomes on its cytoplasmic surface, giving it a "rough" appearance under electron microscopy. The RER is primarily involved in the synthesis and modification of proteins destined for secretion, membrane insertion, or specific organelles. The smooth endoplasmic reticulum (SER) lacks ribosomes and has a tubular structure. It plays crucial roles in lipid and steroid hormone synthesis, carbohydrate metabolism, calcium storage, and detoxification of drugs and harmful substances.

Key Functions & Features:

→ **Protein Synthesis (RER):** Ribosomes on the RER translate mRNA into proteins, which enter the ER lumen for folding and modification.

→ **Lipid Synthesis (SER):** Produces phospholipids and cholesterol for membrane synthesis, and synthesizes steroid hormones in specialized cells.

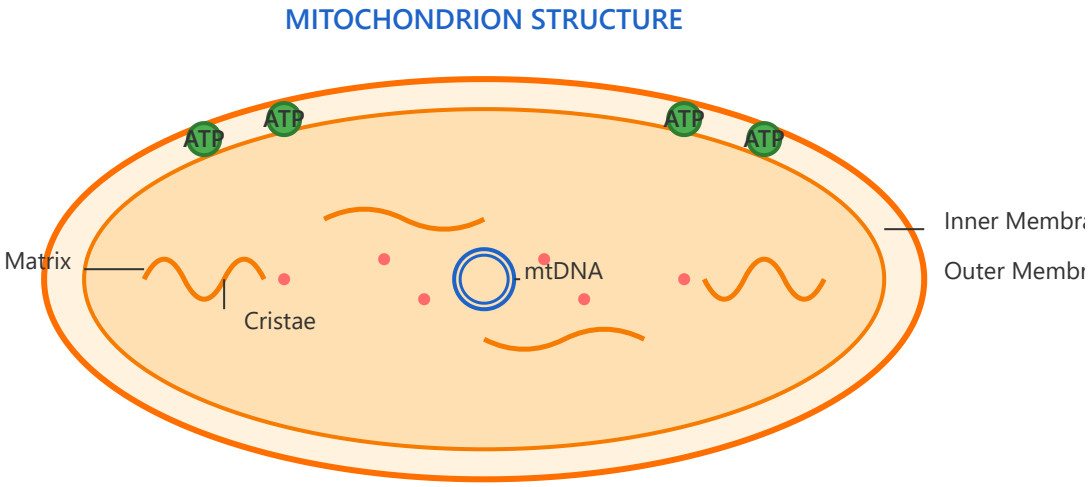
→ **Calcium Storage:** The SER stores calcium ions and releases them to trigger various cellular processes including muscle contraction.

→ **Detoxification:** Liver cells' SER contains enzymes that detoxify drugs, alcohol, and metabolic waste products through hydroxylation reactions.

→ **Quality Control:** The ER monitors protein folding and degrades misfolded proteins through ER-associated degradation (ERAD).

→ **Membrane Continuity:** The ER is continuous with the nuclear envelope and can produce vesicles that bud off to transport materials to the Golgi apparatus.

3. Mitochondria - The Cellular Powerhouse



Mitochondria are dynamic, double-membrane-bound organelles that serve as the primary site of cellular energy production through aerobic respiration. Each mitochondrion is enclosed by an outer membrane and an inner membrane, with the inner membrane folding extensively to form cristae, which dramatically increase the surface area for energy-producing reactions. The space enclosed by the inner membrane is called the matrix, containing enzymes for the citric acid cycle, mitochondrial DNA (mtDNA), and mitochondrial ribosomes. Remarkably, mitochondria possess their own circular DNA and can reproduce independently through binary fission, supporting the endosymbiotic theory that they originated from ancient bacterial ancestors. A typical cell may contain hundreds to thousands of mitochondria, with higher numbers in energy-demanding tissues like muscle and nerve cells.

Key Functions & Features:

→ **ATP Production:** Generates approximately 32-34 ATP molecules per glucose molecule through oxidative phosphorylation, providing over 90% of cellular energy.

→ **Electron Transport Chain:** Located on the inner membrane cristae, this system pumps protons to create an electrochemical gradient that drives ATP synthesis.

→ **Citric Acid Cycle:** The matrix contains enzymes that break down pyruvate and fatty acids, producing electron carriers (NADH and FADH2) for the electron transport chain.

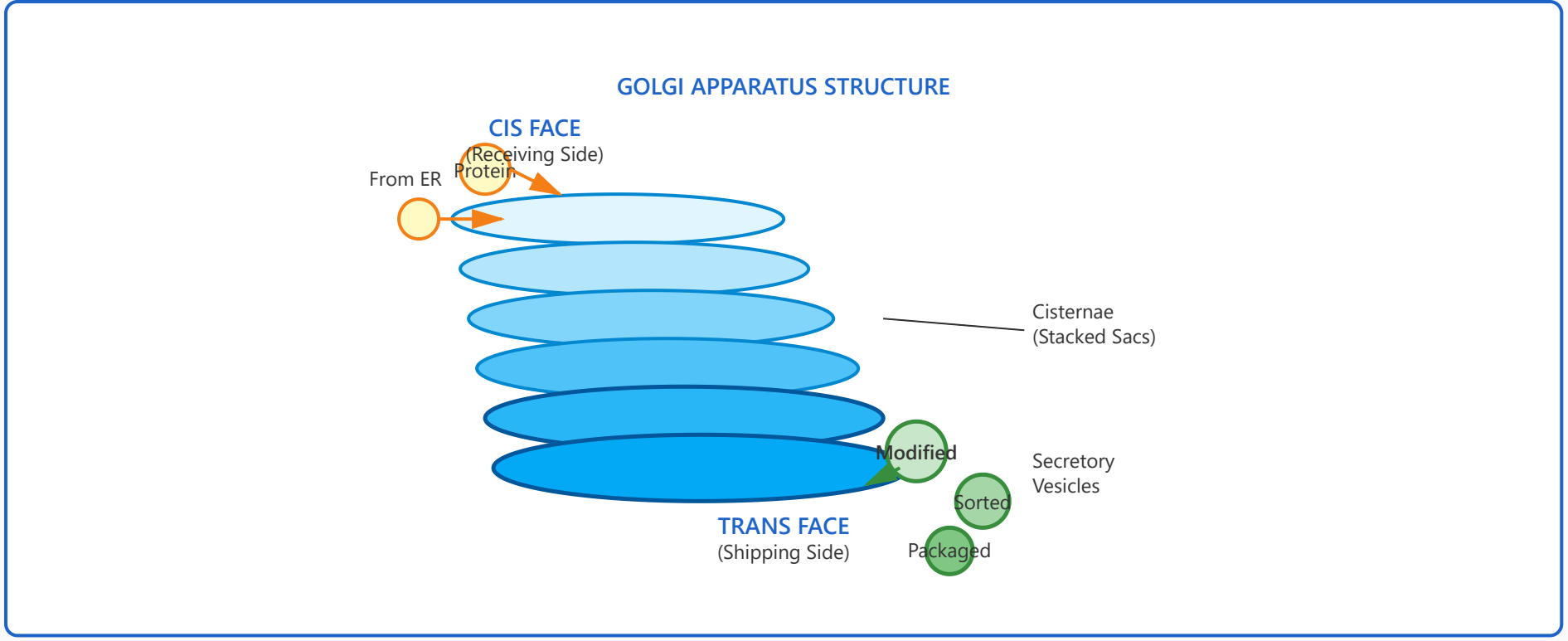
→ **Calcium Regulation:** Mitochondria can rapidly take up and release calcium ions, playing crucial roles in cell signaling and preventing calcium overload.

→ **Apoptosis Control:** Releases cytochrome c and other proteins that trigger programmed cell death when cells are damaged or no longer needed.

→ **Metabolic Functions:** Involved in heme synthesis, steroid synthesis, and regulation of metabolic pathways including fatty acid oxidation.

→ **Maternal Inheritance:** Mitochondrial DNA is inherited exclusively from the mother, making it useful for evolutionary and genetic studies.

4. Golgi Apparatus - The Shipping and Receiving Center



The Golgi apparatus, also known as the Golgi complex or Golgi body, is a membrane-bound organelle consisting of a series of flattened, stacked pouches called cisternae. Typically, a Golgi stack contains 4-6 cisternae, though this number can vary depending on cell type. The Golgi apparatus has distinct structural and functional polarity, with a cis face (receiving side) oriented toward the endoplasmic reticulum and a trans face (shipping side) oriented toward the plasma membrane. The medial cisternae lie between these two faces. Proteins and lipids synthesized in the ER arrive at the cis face in transport vesicles, undergo progressive modification as they move through the Golgi stack, and exit from the trans face in vesicles destined for various cellular locations or secretion outside the cell.

Key Functions & Features:

→ **Protein Modification:** Adds or removes sugar groups (glycosylation), phosphate groups (phosphorylation), and sulfate groups to proteins, creating a molecular "shipping label."

→ **Glycosylation:** Performs complex carbohydrate modifications that are critical for protein stability, folding, and recognition by other molecules.

→ **Protein Sorting:** Acts as the cellular post office, determining whether proteins should go to lysosomes, plasma membrane, or be secreted from the cell.

→ **Vesicle Formation:** Packages modified proteins and lipids into membrane-bound vesicles that bud from the trans face and deliver cargo to specific destinations.

→ **Lipid Processing:** Synthesizes certain complex lipids and modifies lipids received from the ER before distributing them throughout the cell.

→ **Lysosome Formation:** Produces lysosomes by packaging hydrolytic enzymes and adding mannose-6-phosphate tags for proper targeting.

→ **Secretory Pathway:** Essential for constitutive and regulated secretion, releasing proteins like hormones, antibodies, and digestive enzymes outside the cell.