Johns Hopkins Engineering

Molecular Biology

The Eukaryotic Cell – Plasma Membrane, Organelles, and the Endosymbiont Theory

JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Outline

- The Eukaryotic Cell
  - Plasma membrane
  - Nucleus
  - Organelles
  - The Endosymbiont Theory

Eukaryotic Cells

- A typical eukaryotic cell has: a *plasma membrane*, a *nucleus*, *membrane bounded organelles* and the *cytosol* supported by a *cytoskeleton*

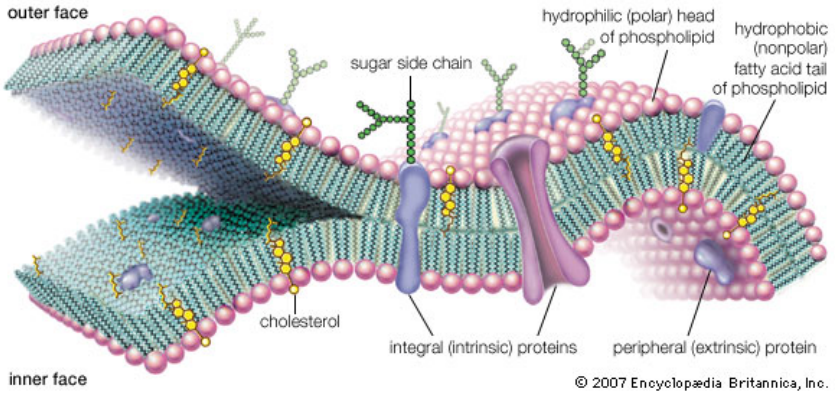
- In addition, bacterial, plant, and fungal cells have a rigid cell wall, surrounded by an *extracellular matrix* composed of proteins and polysaccharides
    - Lipopolysaccharide (LPS)
    - Peptidoglycan
    - Cellulose

The Plasma Membrane Defines Cell Boundaries and Retains Contents

- The plasma membrane surrounds every cell
- It ensures that the cells contents are retained
- It consists of lipids, including phospholipids and proteins, and is organized into two layers

REVIEW:

- Each phospholipid molecule consists of two hydrophobic “tails” and a hydrophilic “head” and is therefore an *amphipathic molecule*
- The **lipid bilayer** is formed when the hydrophilic heads face outward and the tails face inward
- Membrane proteins are also amphipathic, some, with polysaccharides attached to them, are called *glycoproteins*



Roles of plasma membrane proteins

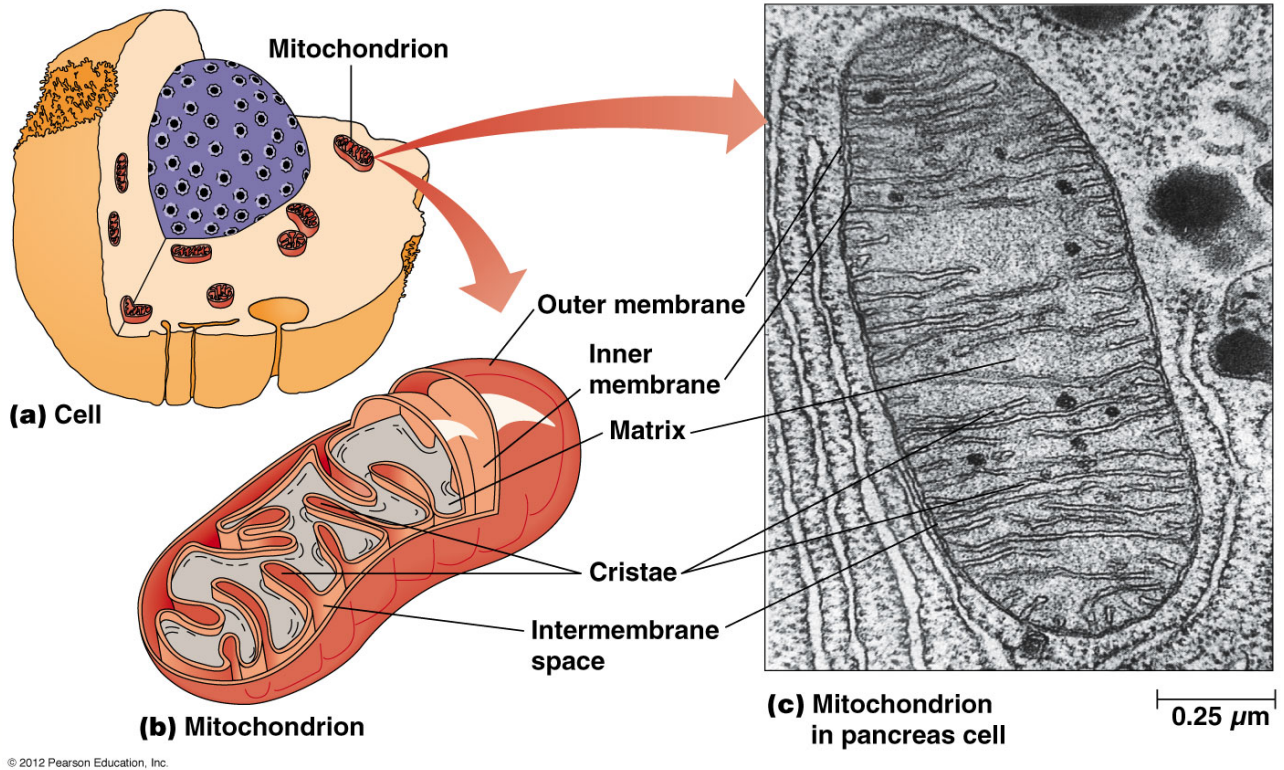
- *Enzymes* catalyze reactions associated with the membranes, such as cell wall synthesis
- Others serve as *anchors* for structural components of the cytoskeleton
- *Transport proteins* move substances across the membrane
- *Receptors* for external signals trigger processes within the cell

The Nucleus is the Information Center of the Eukaryotic Cell

- The most prominent structure in the eukaryotic cell is the **nucleus**
- It contains the DNA and is surrounded by the **nuclear envelope**, composed of inner and outer membranes
  - Eukaryotic DNA is condensed into chromosomes; the number of chromosomes in the nucleus is a species-specific characteristic
- The nuclear envelope has numerous openings called *pores*, each of which is a transport channel, lined with a *nuclear pore complex*

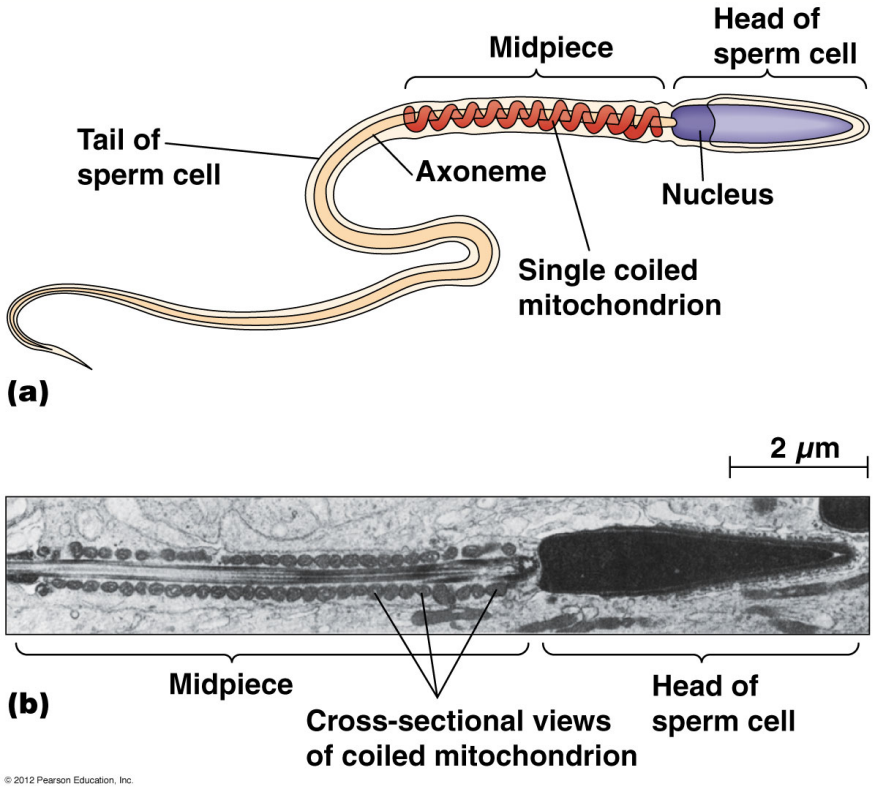
The Mitochondrion

- **Mitochondria**, found in all eukaryotic cells, are the site of aerobic respiration
- They are comparable in size to bacteria
- Most eukaryotic cells contain hundreds of mitochondria
- *Similar to bacterial cells*
  - Mitochondria contain small circular molecules of DNA
  - The mitochondrial chromosome encodes some RNAs and proteins needed for mitochondrial function
  - They also have their own ribosomes, to carry out protein synthesis



Mitochondrial function

- Oxidation of sugars and other fuel molecules in mitochondria extracts energy from food and stores it as *ATP* (*adenosine triphosphate*)
- Most molecules for mitochondrial function are localized on the **cristae** (infoldings of the inner mitochondrial membrane) or the **matrix** (fluid that fills the inside of the mitochondrion)
- Number and location of mitochondria varies among cells according to their role in that cell type
  - Tissues with high demand for ATP have many mitochondria, located within the cell at the site of greatest energy needs (e.g., sperm and muscle cells)
- We inherit mitochondrial DNA (mtDNA) only from our mothers
  - Useful tool for tracing maternal lineage



https://www.youtube.com/watch?v=kS5qREISS-Q

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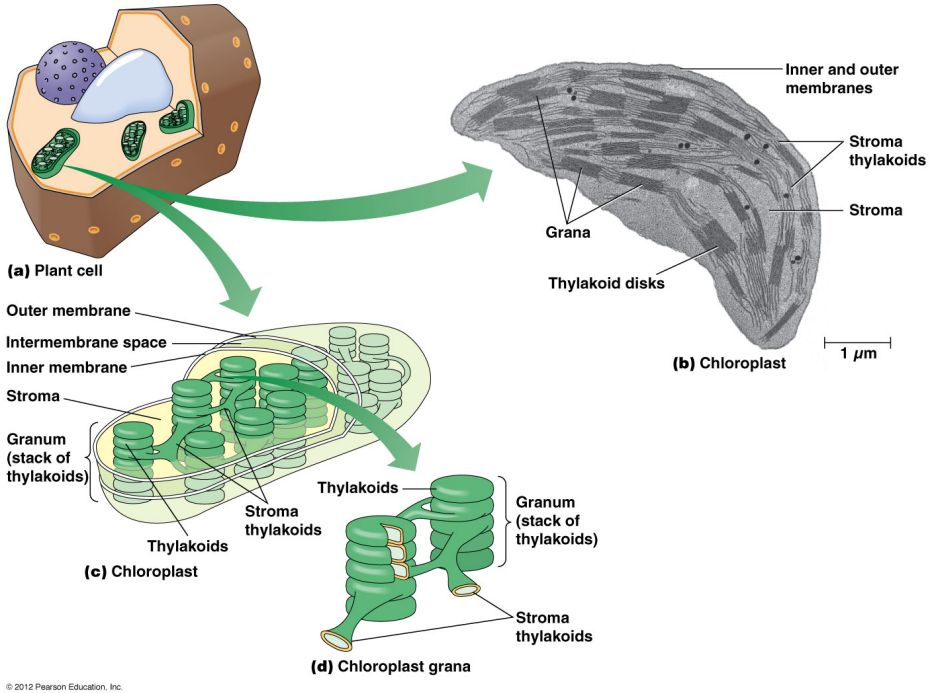
The Chloroplast

- The chloroplast is the site of photosynthesis in plants and algae
- They are large, and can be quite numerous
- They are surrounded both inner and outer membranes
- Like mitochondria, chloroplasts contain their own ribosomes, and a small circular DNA molecule that encodes some RNAs and proteins needed in the chloroplast



The Endosymbiont Theory

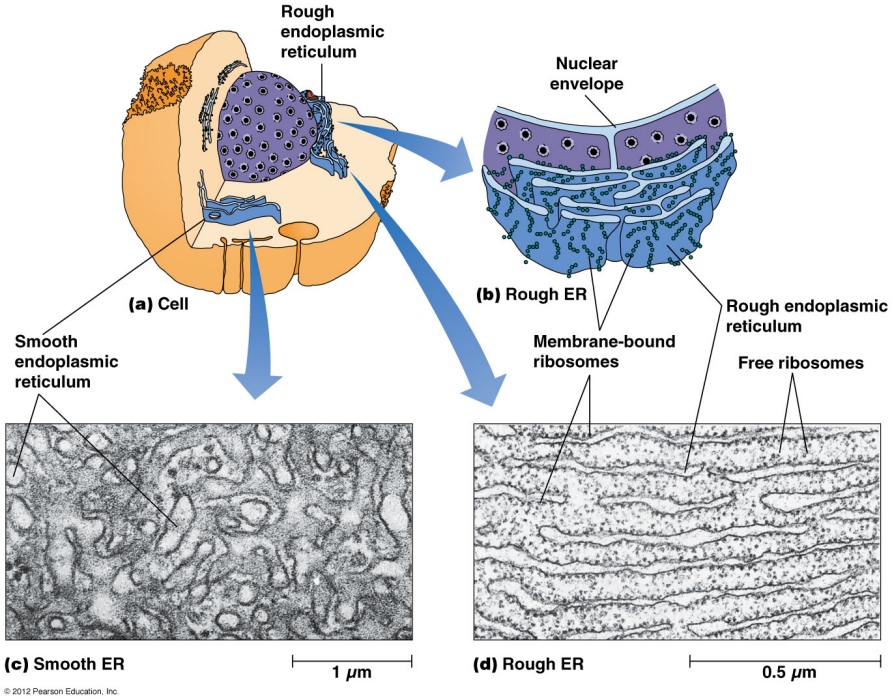
- Both mitochondria and chloroplasts have their own DNA and ribosomes and can produce some of their own proteins
- However, most of the proteins needed in these organelles are encoded by nuclear genes
- Overall there are many similarities between processes in mitochondria and chloroplasts and those in bacteria

Similarities between mitochondria and chloroplasts and bacteria

- All three have circular DNA molecules without associated histones
- rRNA sequences, ribosome size, sensitivities to inhibitors of RNA and protein synthesis and type of protein factors used in protein synthesis are all similar
- Both resemble bacteria in size and shape and are surrounded by double membranes, the inner of which has bacterial-type lipids
- The **endosymbiont theory** suggests that mitochondria and chloroplasts originated from prokaryotes

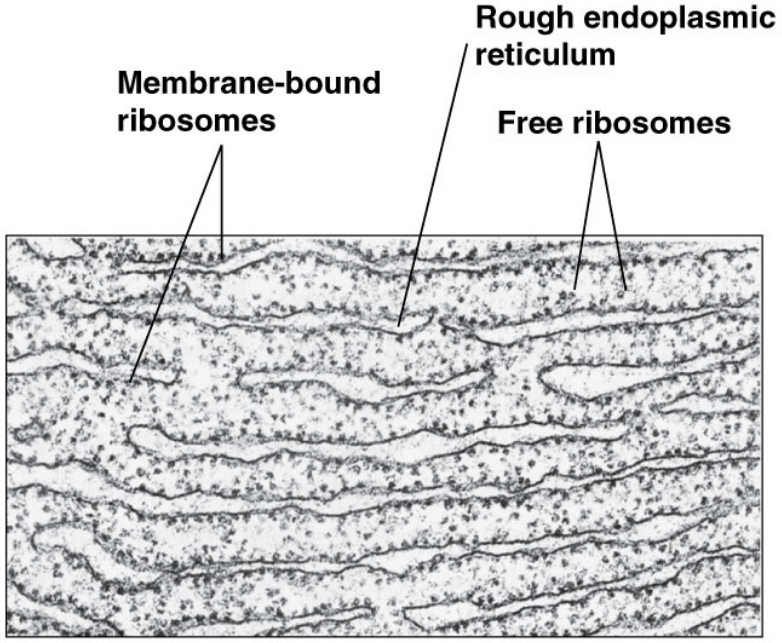
The Endoplasmic Reticulum

- Almost every eukaryotic cell has a network of membranes in the cytoplasm, called the **endoplasmic reticulum (ER)**
- It consists of tubular membranes and flattened sacs called **cisternae**
- The internal space of the ER is called the **lumen**



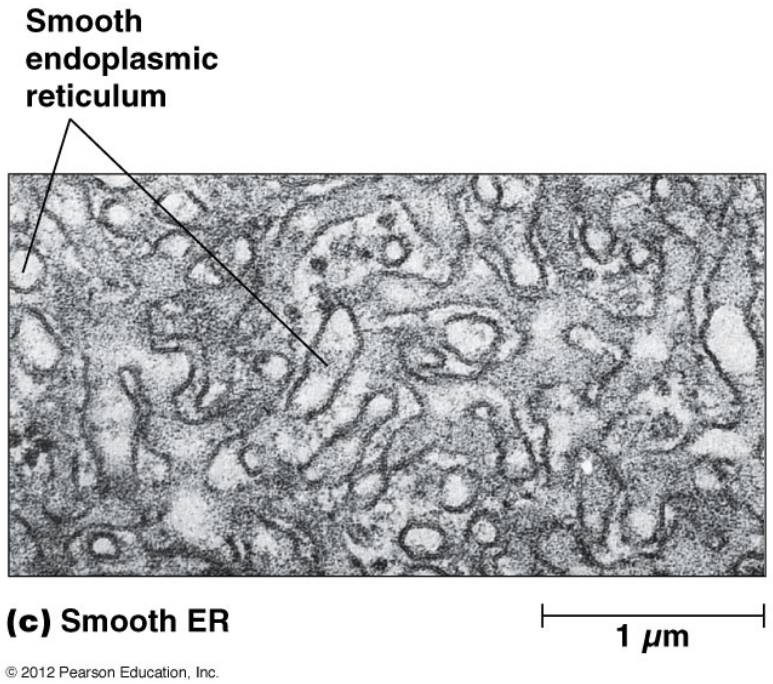
Rough endoplasmic reticulum

- ER can be *rough* or *smooth* in appearance
- **Rough ER** is studded with ribosomes on the cytoplasmic side of the membrane
- These ribosomes synthesize polypeptides that accumulate within the membrane or are transported across it to the lumen
- Free ribosomes are not associated with the ER



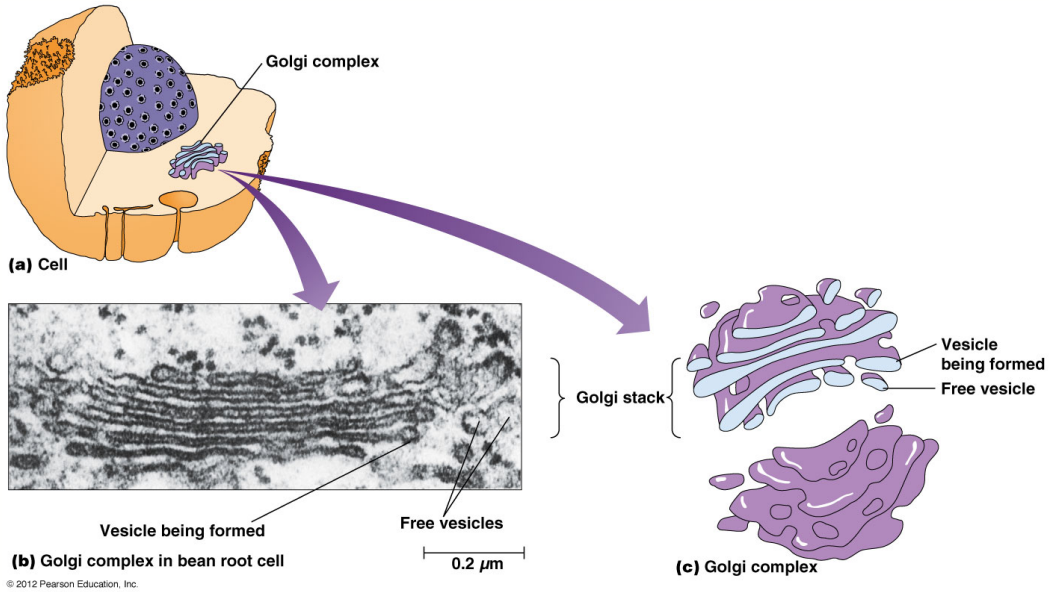
Smooth endoplasmic reticulum

- **Smooth ER** has no role in protein synthesis
- It is involved in the synthesis of *lipids and steroids* such as cholesterol and its derivatives
- Smooth ER is responsible for inactivating and detoxifying potentially harmful substances
- *Sarcoplasmic reticulum* has critical functions in contraction



The Golgi Complex

- The **Golgi complex,** closely related to the ER in proximity and function
- It plays an important role in processing and packaging secretory proteins, and in complex polysaccharide synthesis
- It accepts vesicles that bud off of the ER



The Golgi complex is like a processing station

- The contents of vesicles from the ER are modified and processed in the Golgi complex
- E.g., secretory and membrane proteins are mainly *glycosylated* (the addition of short-chain carbohydrates), a process that begins in the ER and is completed in the Golgi complex
- The processed substances then move to other locations in the cell through vesicles that bud off of the Golgi complex

Summary

Eukaryotic cell

- Basic organization
- Plasma membrane
  - Selectively permeable
  - Associated proteins
- Nucleus and DNA
- Organelles and basic functions
- Endosymbiont theory