Compartmentalization of the Cell

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Objectives

By the end of this session the student should be able to:

1. Identify the different organelles of the cell and name their functions
2. Explain why eukaryotic cells are divided into compartments
3. Account for the particular distribution of organelles in different cell types
4. Distinguish between biological agents that can invade cells: viruses, viroids and prions
5. Give examples of approximate dimensions of biological structures in micrometers and nanometers

Recommended Reading

"The World of the Cell" Becker WM, Kleinsmith LJ, Hardin J

- Chapter 1: The World of the cell: An overview of structure and function:
  - Cell theory;
  - The emergence of modern cell biology;
- Chapter 4: Cells and Organelles

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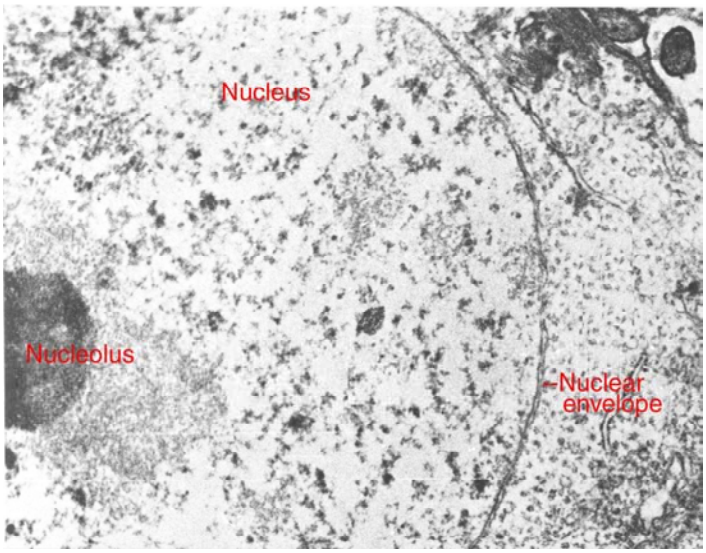
The cell is divided into several compartments enclosed by unit membrane.
Each compartment has a specific structure and function

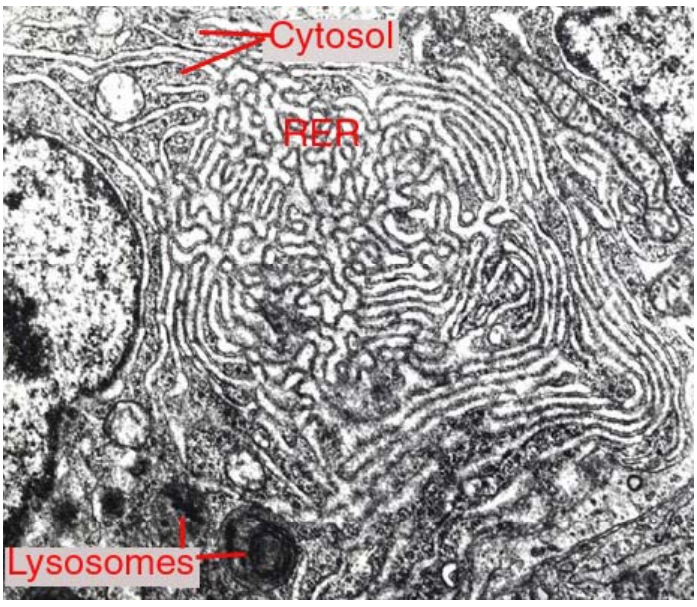


Nuclear compartment (Nucleus)

- Contains dense, fibrillar chromatin
- Function: Genetic replication and transcription
- The nucleolus is a specialized part of the nucleus

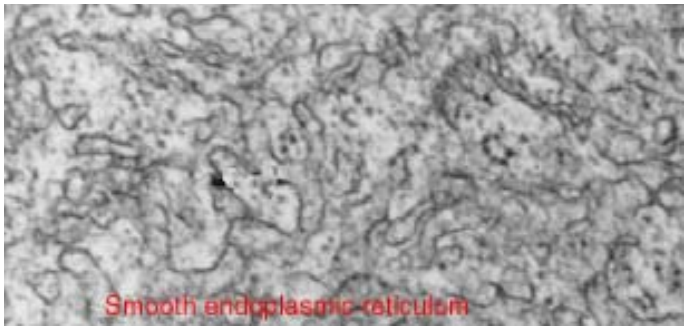
Nuclear envelope compartment

- Encloses the nucleus;
- Consists of two unit membranes enclosing a space
  - Function:
  - Regulates passage of substances between nucleus and cytoplasm;
  - The outer membrane is similar to RER and synthesizes proteins



Rough Endoplasmic Reticulum (RER) compartment

- consists of membrane-bound flat, interconnecting sacs or cisternae with ribosomes on the cytoplasmic surface and enclosing a lumen
- Function: Protein synthesis for export or lysosomes



Smooth Endoplasmic Reticulum (SER) compartment

- Consists of irregular, branched, smooth-surfaced tubules
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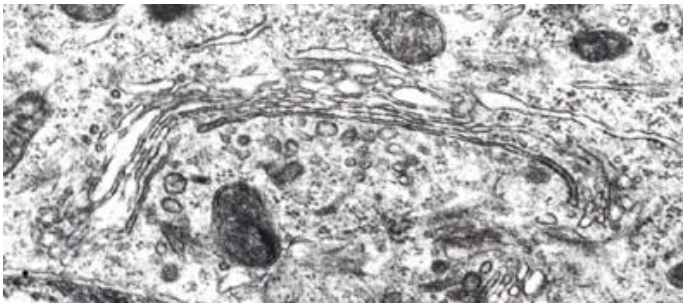
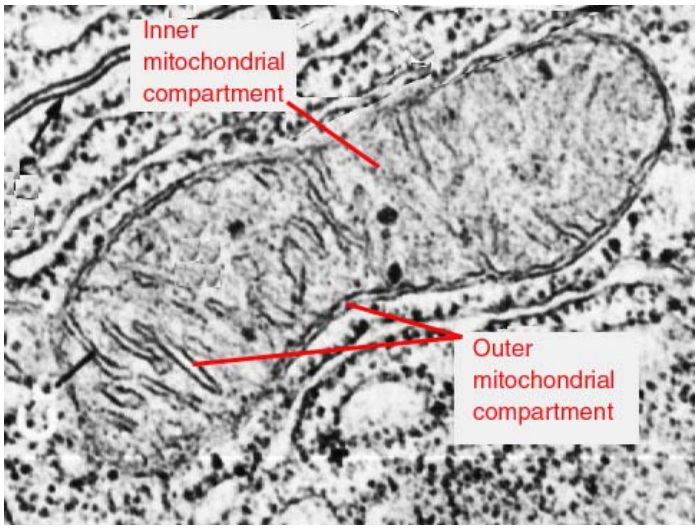
Functions: - Lipid and carbohydrate synthesis;
- Detoxification of drugs (in liver cells);
- Store for Ca^{2+} (in skeletal muscle cells)



Golgi complex compartment - a combination of flat membrane-bound sacs and round vesicles

Function: - Assembly and packing of molecules



Mitochondria consist of two compartments:

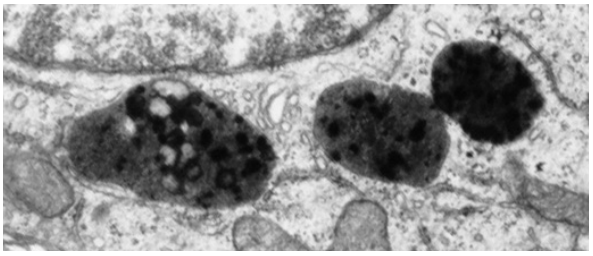
- Inner mitochondrial compartment - enclosed by the inner membrane, which is thrown into folds or cristae

Function: Oxidative respiration and energy production as ATP

- Outer mitochondrial compartment - between inner and outer membranes

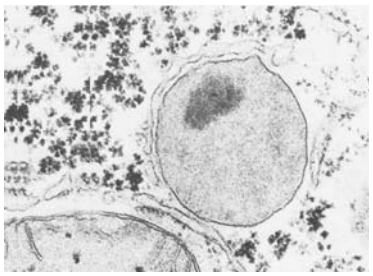
Function: Contains protons (H^+ ions) to drive oxidative phosphorylation

Lysosomes



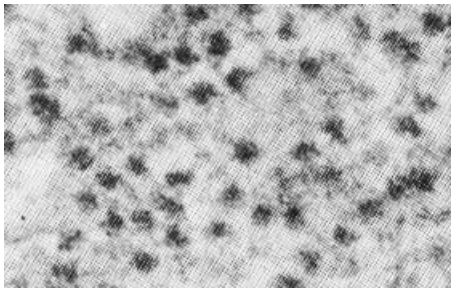
- membrane-bound spherical or irregular with electron-dense, heterogeneous contents
Function: - Breakdown of organelles and ingested particles by action of hydrolytic enzymes

Peroxisomes



– small, regular, membrane-bound spherical with electron-dense and crystalline contents
Function: Degradation of peroxides / oxidation of fatty acids

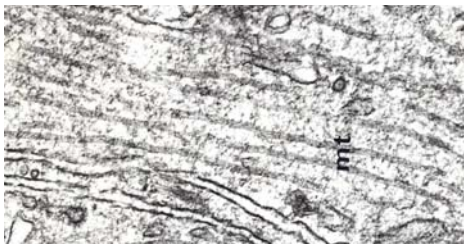
The cell also contains other organelles that are not membrane-bound and have specific functions



Ribosomes

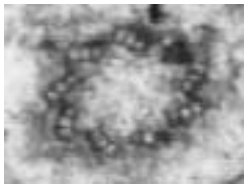
- small spherical particles free in cytosol or attached to RER
Function: - Protein synthesis

Actin filaments – thin filaments 7 nm diameter
Function: - Cell movement
Intermediate filaments – 8-10 nm diameter
Function: -Form the supportive cytoskeleton



Microtubules – long tubular strands 25 nm diameter

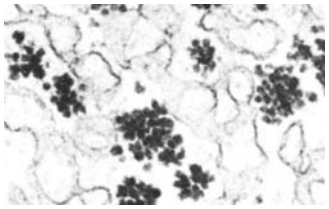
Function: - Transport of organelles within the cell



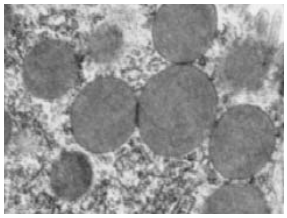
Centrioles – composite of microtubules

Organize formation of microtubules

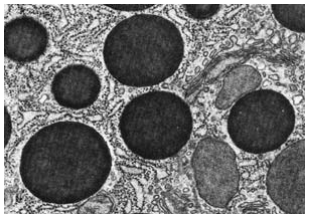
The cell may also contain inclusions – structures that serve as stores



Glycogen granules



Lipid droplets



Secretion granules

Vacuoles

Are all cells divided into compartments?

Prokaryotes (bacteria) consist of only one compartment containing all the enzymes required for basic functions.

Eukaryotes (cells that have a nucleus) are divided into compartments, the most prominent of which is the nucleus.

Why are eukaryotic cells divided into compartments?

- Each compartment performs different functions
- Each compartment has a greater surface area
- Many enzymes within a compartment are attached to its walls
- Cells can become specialized – increase specific compartments for a specific function
- Cells can become large e.g. muscle cells

Variation in cell size – some examples

Viruses	1 µm
Bacteria	1-5 µm
Sperm cell	3µm diameter; 60µm long
Red blood cell	7 µm
White blood cells	12-15 µm
Hepatocyte	20-30 µm
Mature oocyte	140 µm
Skeletal muscle	10-100 µm diameter; 1 – 30 cm long
Nerve cells	4 – 150 µm diameter; 10 µm-1 metre long

Cell specialization

Most cells are specialized to perform one particular function. The predominant organelles they contain are the ones that are necessary for performing that specific function.

The following are some examples of specialized cells and the main organelles they contain

Muscle cell – specialized for movement

- Numerous actin filaments & mitochondria

Neuron – cell specialized for conduction and communication with other cells;

- Plasma membrane; RER; lysosomes; microfilaments

Fat cell – lipid stores

- Lipid droplet inclusions

Red blood cells – carriage of oxygen

- Cytosol containing haemoglobin

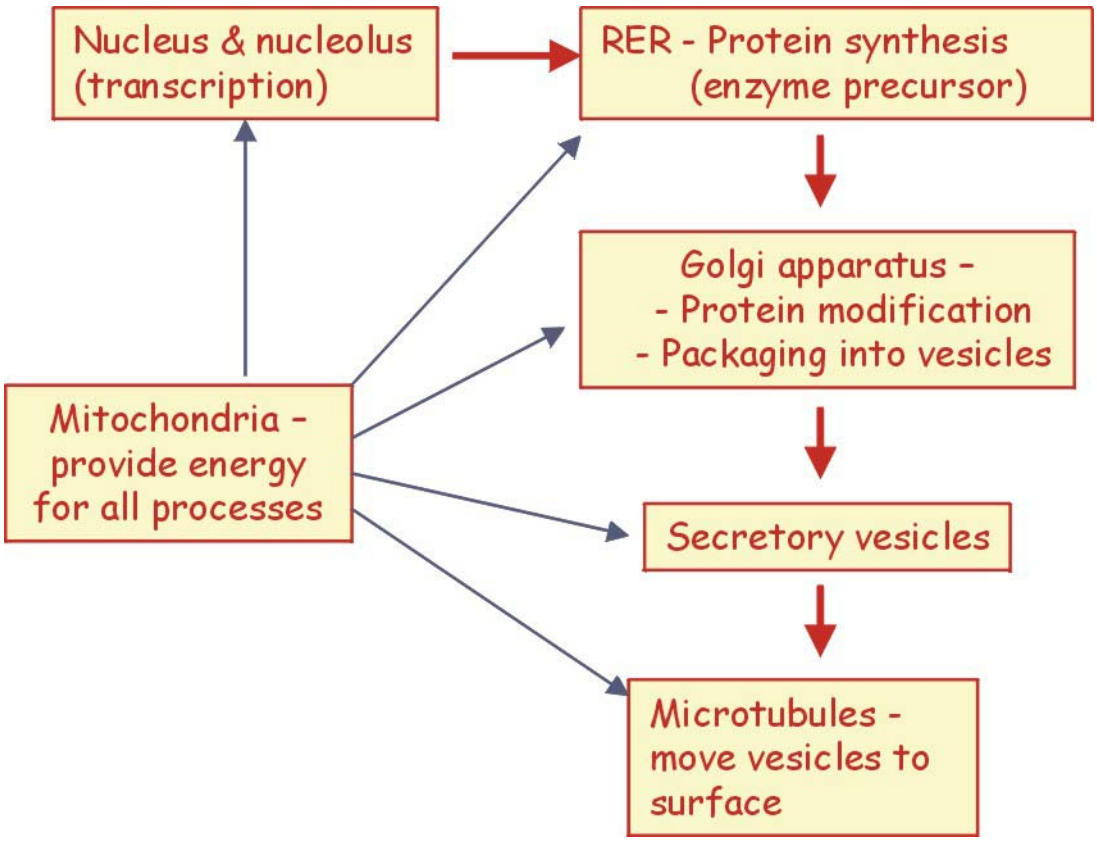
Lymphocyte – a resting cell in transit in the blood

- Scanty organelles

Fibroblast – synthesizes collagen

- RER & Golgi (when active)
- Scanty organelles (when inactive)

The following diagram outlines the main activities in a pancreatic cell that secretes digestive enzymes cell and the organelles involved.



Bacteria

- Prokaryotes – i.e. cells that do not have a nucleus
- Have an outer limiting membrane
- Contain free strands of DNA not enclosed within a membrane
- Perform a variety of functions – synthesis, replication, reproduction, respiration, movement etc.
- Can invade the body and cause damage to the adjacent cells

Viruses

- Structures incapable of independent existence
- Can invade cells and use their organelles to reproduce
- Very small 25 – 300 nm; Vary in shape
- Consist of:
  - External protein coat (capsid)
  - Core containing a molecule of DNA or RNA
  - Few proteins and few genes
- They are important because:
  - They cause disease
  - They are simple to analyse
  - They can be modified and used to carry DNA into cells

Viroids

- Consist of:
  - A small circular molecule of RNA without a capsid
  - A few associated proteins
- Can invade cells and reproduce
- May cause disease in plant cells (they are not known to cause human disease)

Prions

- Consist of:
  - A few proteins (very little is known about them)
- Can invade cells and reproduce
- May cause disease in animals and man
  - Spongiform encephalitis (mad cow disase)
  - Guru – a neurological disorder in cannibals

Applications to medicine

Many diseases and drugs affect specific structures and functions within cells. Here are a few examples:

- Cancer – uncontrolled cell proliferation – deranged cell functions
- Anti cancer drug therapy – to control proliferation and the cell cycle
- Antibiotics – usually interfere with protein synthesis
- Addictive drugs - penetrate unit membranes and readily enter neurons
- Lipoprotein disorders – disorders of peroxisomes
- Genetic disorders – affect many different organelles e.g. nucleus and lysosomes
- Metabolic disorders – may affect the endoplasmic reticulum
- Mitochondrial disorders
- Ageing – affects various organelles

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