Faculty of Medicine – Department of Medicine – Cytology Course – First Year of Medicine – Academic Year 2025/2026 – Academic Coordinator of the Cytology Module: Prof.W.AYAD

GENERAL ORGANIZATION OF THE CELL

I – Introduction

All living organisms are composed of cells, the elementary units of organization of living matter. The first scientist to propose the term "cell" was the Englishman Robert Hooke in 1665, to designate the units that make up living matter. Unicellular or multicellular organisms are made up of cells that share a similar basic metabolism. Cellular specialization, however, is accompanied by variations of the "typical cell," which leads to a diversity of cell shapes and specific metabolic pathways, adapted to diverse modes and environments of life.

II – Classification

Currently, the living world is divided into three major domains: **Eukaryotes, Eubacteria, and Archaea.**

A – Eukaryotes

The eukaryotic cell essentially contains:

- **A nucleus:** containing, in the form of DNA, the information necessary for maintaining species characteristics and for the synthesis of specific proteins. Within the nucleoplasm, it contains chromatin and the nucleolus, and is separated from the other cellular components by the nuclear envelope. This envelope has two membranes: the outer membrane in contact with the cytoplasm, and the inner membrane separated from the chromatin by the lamina. A perinuclear space separates these two membranes. Nuclear pores within the envelope allow both endogenous and exogenous substances to transit between the nucleus and the cytoplasm in both directions.
- **A plasma membrane:** a lipid bilayer associated with transmembrane and peripheral proteins. It is covered by the cell coat. The main role of the plasma membrane is to maintain the integrity of the cell. Its outer surface interacts with the extracellular environment, while its inner surface faces the intracellular medium. These two surfaces do not have the same structure or functions, a phenomenon known as **membrane asymmetry**. The plasma membrane contains receptors and may present microvilli and intercellular junctions.
- **A cytoskeleton:** composed of microtubules, microfilaments, and intermediate filaments.
- **An endomembrane system:** including the endoplasmic reticulum (ER), the Golgi apparatus, and lysosomes, which communicate via vesicles formed by budding from their membranes.
  - The endoplasmic reticulum is a network of interconnected cavities bounded by a membrane. It may bear ribosomes, forming rough endoplasmic reticulum (RER), or be devoid of them, forming smooth endoplasmic reticulum (SER).
  - The RER, participates in the synthesis of proteins destined for secretion and most membrane proteins. Free ribosomes translate mRNA into proteins destined for the cytosol or for organelles such as peroxisomes and mitochondria.
  - The SER is involved in lipid synthesis.
  - The Golgi apparatus consists of a stack of flattened sacs (dictyosomes) associated with vesicles. It modifies, sorts, packages, and distributes the products synthesized by the ER. It is involved in glycosylation and is the main distributor of newly synthesized membranes.

- Lysosomes are membrane-bound organelles containing hydrolases capable of degrading most endogenous and exogenous molecules.

- **Mitochondria:** bounded by a double membrane. The outer membrane is highly permeable, while the inner membrane, less permeable, presents invaginations called **cristae**, which extend into the mitochondrial matrix. The cristae contain the respiratory chain and the ATP-synthesizing machinery, whose hydrolysis releases part of the energy required for cellular function. The matrix contains mitochondrial DNA and the components necessary for protein synthesis.

B – Eubacteria

Eubacteria constitute a highly diverse group of unicellular microscopic organisms, with variable shapes but sharing a general plan of organization and several structural features. In general, the bacterial cell is surrounded by a resistant cell wall (a complex of lipids, polysaccharides, and polypeptides). It is bounded by a plasma membrane composed of a lipid bilayer containing integral proteins. The bacterial chromosome (nucleoid) is arranged as a closed-loop filament occupying the center of the cell. It is not separated from the cytoplasm by an envelope. The cytoplasm is rich in proteins and contains ribosomes.

Eubacteria may also possess:

- a capsule of polysaccharidic nature,
- inclusions (glycogen, lipids, etc.), which serve as storage reserves,
- surface appendages such as pili and flagella.

C – Archaea

Archaea, formerly called archaebacteria, are unicellular microorganisms. They are very similar to eubacteria in terms of morphology and metabolism. With a size range similar to eubacteria (0.1–15 µm), archaea have a single circular chromosome, divide by binary fission, and often possess proteinaceous flagella for motility. Depending on the species, they may occur as coccoid, clustered, rod-shaped, or filamentous forms.

At the molecular level, archaea are much closer to eukaryotes than to eubacteria. For instance, many of their proteins—particularly those involved in information processing such as DNA replication, repair, and transcription—are far more similar to eukaryotic proteins than to bacterial ones. In numerous cases, archaea and eukaryotes share proteins absent from eubacteria.

However, archaea also possess unique characteristics distinguishing them from both other domains. Their rRNA differs from that of both bacteria and eukaryotes. Their envelopes do not contain peptidoglycan (present in most eubacteria) but are generally composed of a protein layer covering the plasma membrane. Moreover, archaeal phospholipids are entirely different: they are isoprenoid ethers (derived from a long-chain alcohol) rather than fatty acid esters as in eubacteria and eukaryotes.

Archaea are notable for the diversity and originality of the habitats they occupy. Some are well known for their ability to thrive in extreme conditions (anaerobic, high salinity, high temperature, or extreme depth) and colonize environments such as marshes, deep-sea hydrothermal vents, saline waters, and acidic hot springs. Nevertheless, many archaea live in more common and varied habitats such as soils, lakes, oceans, or even within the intestines and lungs of mammals.

III – Viruses

Viruses are pathogenic agents that cannot reproduce outside a host cell. They are obligate parasites. Lacking cytoplasm and a true nucleus, they consist of nucleic acid (DNA or RNA) associated with proteins.

There are DNA viruses (e.g., hepatitis B virus) and RNA viruses (e.g., HIV, SARS-CoV-2/Covid-19).
Viruses require a host cell in order to replicate. Each virus possesses surface proteins capable of binding to specific components of the host cell membrane. Viruses lack their own metabolism and have no intrinsic capacity to produce proteins encoded by their RNA or DNA genome. Instead, they hijack the host cell machinery to synthesize their proteins and replicate their genome.
The replication cycle involves entry into a host cell, diversion of the host's equipment to replicate viral genetic material and synthesize viral proteins and assembly of new viral particles, and release of virions either by cell lysis (rupture) or exocytosis.
Some viruses are also capable of integrating into the host genome. In such cases, viral DNA replicates at the same pace as the host DNA into which it has integrated. Under the influence of various factors, they may exit this latent cycle through excision from the host genome. The viruses thereby enter the lytic cycle, regaining the capacity for active replication before being released from the cell.