

Cell organization

When the electron microscope was introduced in the early 1950s it revealed a new world for cell biologists. It was then possible to study the intracellular structures and their interrelationship.

Eukaryotes

Humans consist of around 200 different cell types. These cells are different in size and shape and have various functions.

The **red blood cell** is an example of a small cell. It is 7-9um in diameter. The shape varies since the cell must be able to enter the very narrow capillaries during oxygen delivery.

The cell body of the **nerve cell** can be 80-100 um in diameter while the axon can be a meter long.

The cellular content varies and depends on the function of the cell.

Example: the liver cell that is responsible for massive protein synthesis has often 2 nuclei.

Despite above described differences is the DNA content in all cells in one individual always identical.

Which organelles do we find in a Cell

Nucleus

Nucleolus

Cytoskeleton

Ribosomes

Endoplasmic reticulum ER

Golgi body

Mitochondria

Peroxisomes

Lysosomes

The **Plasma membrane** surrounds the organelles and keeps them together.

It create an intracellular environment and establish the resting potential - negative intra cellular milieu -20- -100 mV

It consists of Phospholipids - 2 fatty acids attached to a glycerol molecule

Proteins

Carbohydrates

and is often refereed to as a **Fluid mosaic model**

Phospholipids are Amphipathic. They consist of a hydrophilic head and hydrophobic tails.

In this Fluid mosaic model is the phospholipids arranged in a Bi-layer with the polar hydrophilic ends exposed to the outside and the hydrophobic side chains are embedded in the interior of the membrane.

The plasma membrane of the red blood cell consists of

52% protein

40% lipids

8% carbohydrates

The proteins can be localized to one side of the membrane or go through the two layers and be exposed both to the in and out side of the membrane.

Damages to the plasma membrane can result in cell death.

Cytoskeleton

The cytoskeleton fill up the cell and is important for the cell shape, cellular movements, contraction of striated muscle cells or cardiac cells but also for intra cellular transport, the formation of the mitotic spindle and the following cell division.

Three different structures make up the cytoskeleton

Microtubules 24nm

Intermediate filaments 10nm

Microfilaments 7nm

Common for these structures are that they are insoluble globular or fibrous proteins.

Microfilaments are built up by actin.

G-actin is the globular form of actin- monomeric form. This g-actin is arranged into strings (compare with pearls on a string). A string of g-actin is called f-actin (fibrous actin). Two strings of f-actin are twisted around each other and form a filament.

In the muscle cell - actin together with myosin form the contractile system responsible for muscle contraction.

Microtubules are built up by tubulin.

Tubulin is a heterodimer consisting of α - and β - tubulin.

These dimers are arranged in tubular structures with a diameter of 10 nm and a central hole.

The microtubules can be arranged in different ways and form in these way different structures.

In cilia found on the respiratory epithelial cells in the airways, and transport dust from the lungs, are the microtubules "fused" and form together with associated proteins (nexin and dynein) a very specific structure.

There are a number of **intermediate filaments**. The name derives from their intermediate size 10 nm.

Examples are Vimentin in fibroblasts,
 Keratin in keratinized epidermal cells
 Fibrillary acidic protein in glial cells

Nucleus 1 or multiple **nuclei**

Most cells contain one nucleus but there are exceptions such as striated muscle cells, liver cells and cells lining the urinary bladder.

The nucleus is surrounded by a nuclear envelope. The nuclear envelope belongs to the cytoplasmic membrane system, and is an extension of ER. The side exposed to the cytoplasm can carry ribosomes.

The **nuclear envelope** contains pores that allow exchange between the nucleus and the cytoplasm. These pores are 50-80 nm in diameter. In the red blood cell consists 5-15 % of the nuclear envelope of pores. The pore is not an open hole that permits unregulated exchange between the cytoplasm and nucleus. Instead, it is gated by an octameric structure referred to as annuli.

Pore-complex=pore and annuli.

Number of pores reflects the transcriptional activity of the cells.

DNA and Histons are found in the nucleus

DNA is a double stranded structure built up by many millions of nucleotides. DNA is about 172 cm long.

The DNA is packed in a very specific, well-arranged way.

DNA is twisted around proteins named Histons. There are 5 different types of Histons.

Heterochromatin condensed DNA and genetically inactive.

Euchromatin genetically active regions of the DNA

Facultative heterochromatin DNA condensed only in certain cell types or at special stages during development.

Nucleolus (nucleoli pl) Regions in the nucleus that appears more condensed. RNA and the mRNA synthesis of protein necessary for the ribosomes build up the nucleolus. A cell can contain a single or multiple nucleoli. This depends on transcription demand.

Cell organelles

Ribosomes

Protein synthesis place take place in this organelle. The ribosome consists of 2 subunits made up by RNA – rRNA and protein (30 – 40) different proteins. It is nearly equal amounts of protein and RNA. **Size** The organelle is 23 nm in diameter. The molecular size is $4.5 \cdot 10^6$ Daltons.

The ribosome can be free in the cytoplasm or bound to the Endoplasmic reticulum (ER)
Ribosomes are also present in the mitochondria and chloroplasts.

Endoplasmic reticulum It is a tube system with a Cytoplasmic and a luminal face.

Two types of ER exist- with and without ribosomes
rough ER - rER and smooth ER - sER

rER is well differentiated in cells with active protein synthesis intended for secretion.

In the lumen of rER is numerous of proteins present. These proteins are used for processing and folding of synthesized proteins.

sER participates in the **glucogenolysis**.

This is new production of glucose from glycogen.

Detoxification p450 system

Lipid synthesis

A special form of ER is the **sarcoplasmic reticulum** in the striated muscle fiber. It facilitates the muscle contraction.

Golgi apparatus is a continuation of ER.

The **Trans golgi network** consists of vesicular structures and can be divided into **3 different structures**

Flat sacs

Vesicles 60 nm or tubules

Larger vesicles

In ER and Golgi starts the posttranslational processing and modification of the proteins.

The formation of **Disulfide bond** occur in the lumen of ER

Glycosylation of proteins. Proteins or lipids can contain carbohydrates glycoproteins or glycosphingolipids.

Glycoproteins The coupling of carbohydrates to protein can occur in 2 different ways **O or N coupling**.

O-linked carbohydrates – binding to serine threonine and hydroxyl lysine. Use O in OH group. Take place in the golgi.

N-linked carbohydrates – binding to asparagine. Take place in ER or Golgi.

The sugar monomers are added to the protein one at the time and the responsible enzymes are **Glycosyl-transferases**. These enzymes are membrane bound.

Proteins that are to be subjected to glycosylation contain a specific amino acid sequence that directs the protein to the golgi apparatus.

Converting enzymes.

Many hormones are subjected to posttranslational processing prior to secretion from the cell. This process is necessary for the production of a biological active hormone. The proteins responsible for this is called subtilisine like enzymes.

Secretion of proteins from the cell

mRNA is transported from the nucleus in to the cytoplasm.

Synthesis of proteins in the ribosome.

Removal of the signal peptide from the protein take place in the ER.

Posttranslational modification of the protein in the ER or in the golgi apparatus.

Storage and release from the cell. The release of a protein from the cell can be through the regulated pathway or through the constitutive pathway.

Lysosomes Cleaning machinery of the cell

The lysosome contains a high number of enzymes that can degrade proteins- **proteases**. It is a single membrane organelle and when viewed at high magnification a clear halo region can be observed inside the membrane. This halo consists of carbohydrates and functions as a protection layer against self-degradation.

Primary lysosomes derive from ER and the proteases are produced by the ribosomes. The primary lysosomes mature in the golgi.

The proteases are active at low pH. Therefore, proton pumps are localized to the membrane and pump in H⁺ into the lysosome.

The lysosomes can be divided into

Primary lysosomes and Secondary lysosomes

The secondary lysosome is formed after fusion between the primary lysosome and the material that should be degraded.

The secondary lysosomes can be divided into

Heterophagosome consists of material engulfed by pinocytosis or fagocytosis.

Autophagic vacuole degradation and removal of cellular organelles. Such as mitochondrion or endocrine granules.

Residual body. Reminisces after incomplete degradation.

Lysosomes are important for degradation of various materials but also during shedding and remodeling of tissue during **development**. **Acrosome** on the head of the sperm is a giant lysosome and necessary for the penetration of the egg.

Mitochondrion (Mitochondria pl) the power station of the cell.

They multiply by fission and divide between the newly formed cells during mitosis. 100-1600 mitochondrion in a single liver cell. Number depends on energy requirement.

Contain DNA mtDNA. This DNA is circular and code for all mitochondrial rRNA. Ribosomes are also present in the mitochondria but the ribosome proteins are imported from the cell cytosol.

Symbiont hypothesis Mitochondria and chloroplasts derives from bacteria

The mitochondrion consists of 2 membranes 6 nm thick and 6.8 nm spacing between the outer and inner membrane. The inner membrane does also form the crista.
 Inside the inner membrane is the mitochondrial matrix.

All biological processes demand energy

A covalent binding contain 3000 calories
 1 mole of glucose 180 gram correspond to 686000 calories

Energy is stored in ATP
 Adenosine and 3 phosphate groups. In each of the binding between the phosphates can store 7300 calories. This is an efficient way to store high amount of energy in a small place.

We use **Glucose** as fuel **glycolysis**. The glycolysis takes place in the cytosol.

Glucose is converted to pyruvate

Aerobic 2 molecules of acetyl CoA these enters the mitochondrion and the Krebs cycle.

Krebs cycle take place in the matrix of the mitochondrion

The oxidative phosphorylation ATP production by phosphorylation of ADP using the energy provided by electron transport

36 ATP/glucose molecules.

40 % the chemical energy will be stored in ATP while the rest will be lost heat

Peroxisomes

It is a single membrane containing organelle. It derives from ER and contains enzymes important for production and degradation of peroxides. It participates in degradation of proteins and fatty acids. During this process is peroxides formed and these substances are dangerous for the cell and the peroxisome contains the enzyme catalase that can degrade H_2O_2 .