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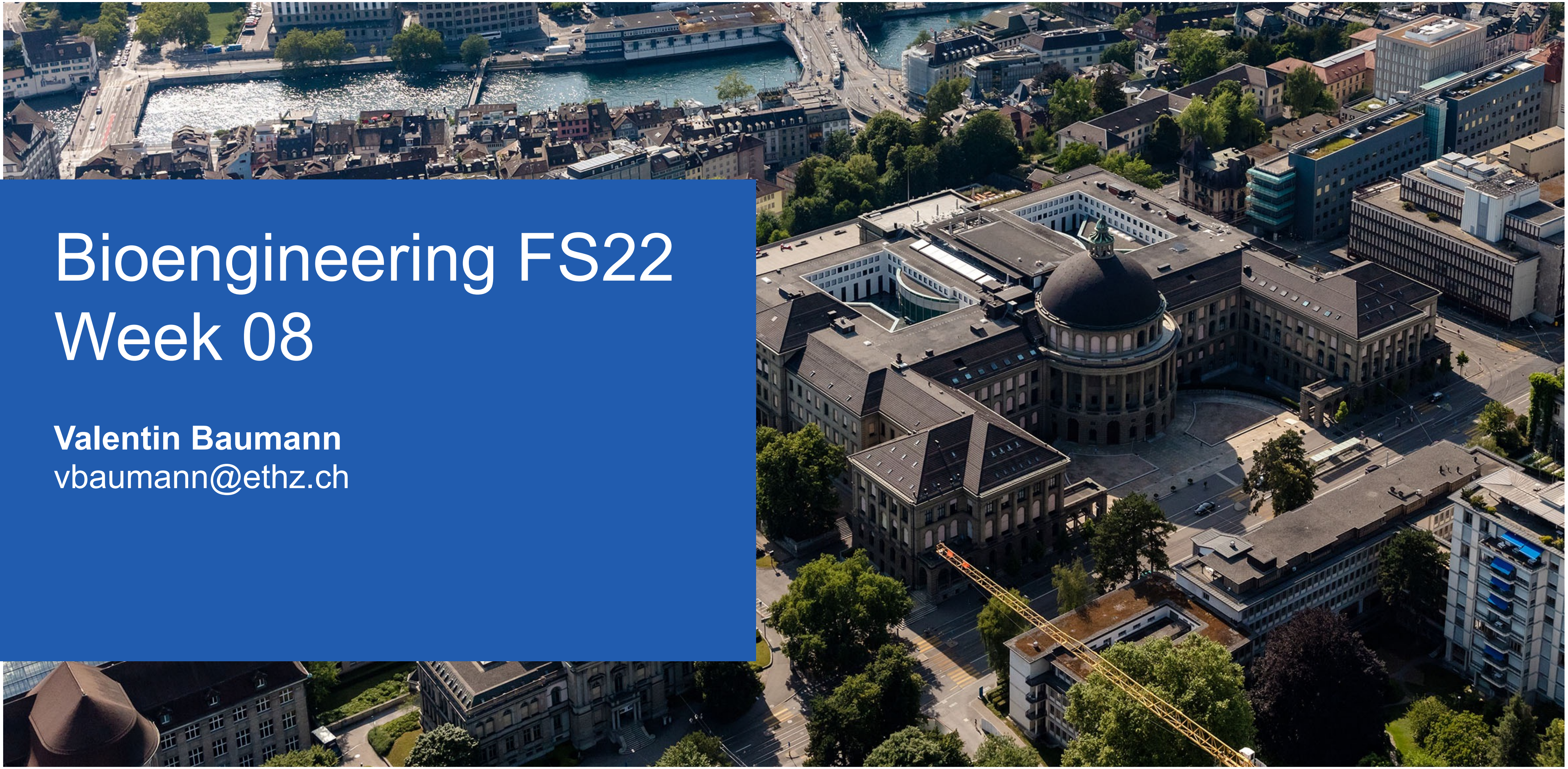

Bioengineering FS22
Week 08

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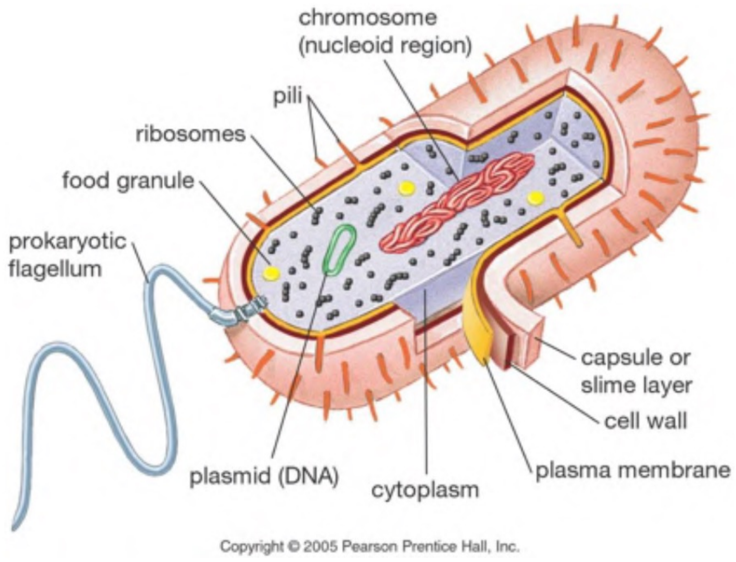
Agenda today

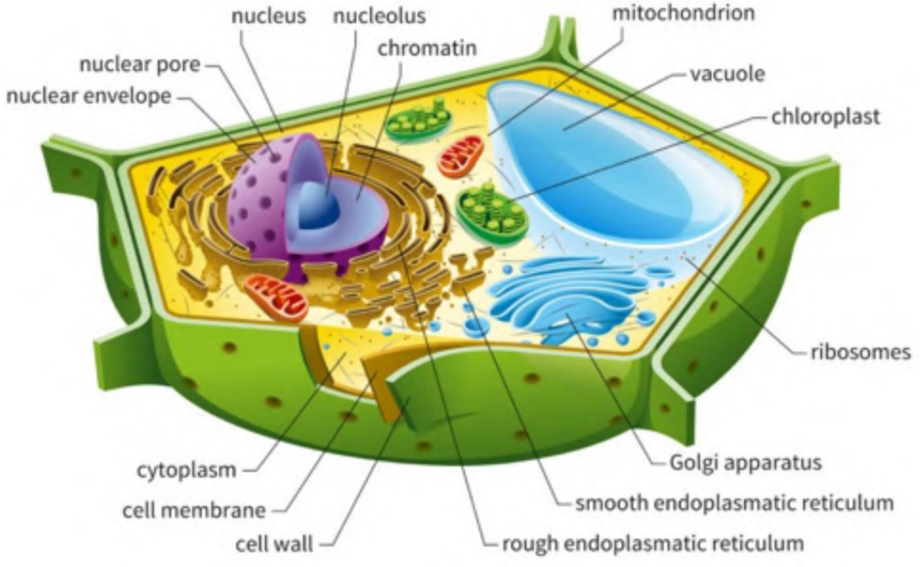
1. Structure of cells
    1. Types of cells
    2. Organelles
        1. Cytoplasm
        2. Nucleus
        3. Ribosomes, Mitochondria, Chloroplasts, Peroxisomes
        4. Endomembrane system
        5. Cytoskeleton
    3. Cellular surface

Basics in biology – cell types

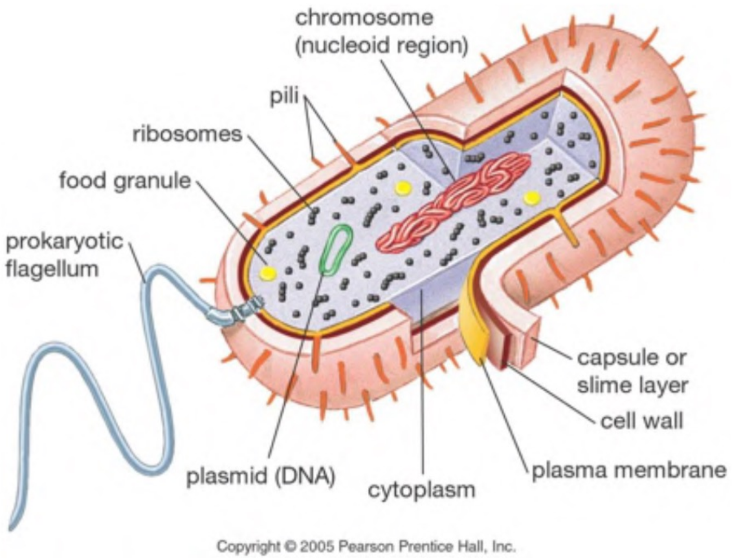
Prokaryote



Eukaryote



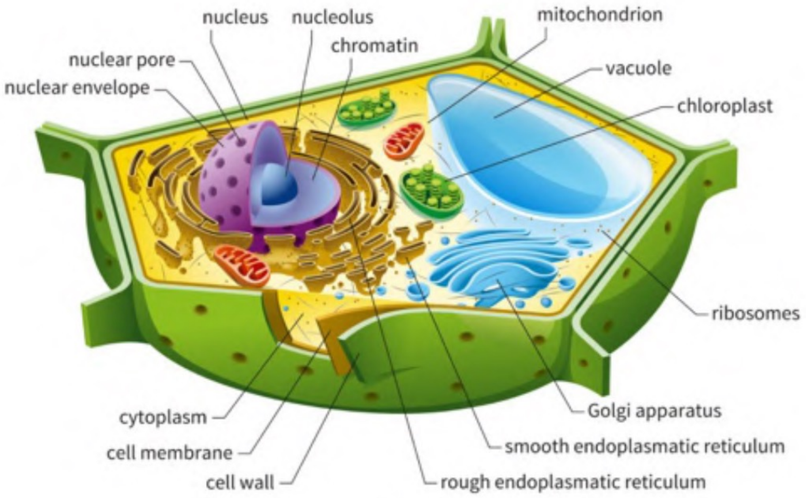
Basics in biology - Prokaryotes



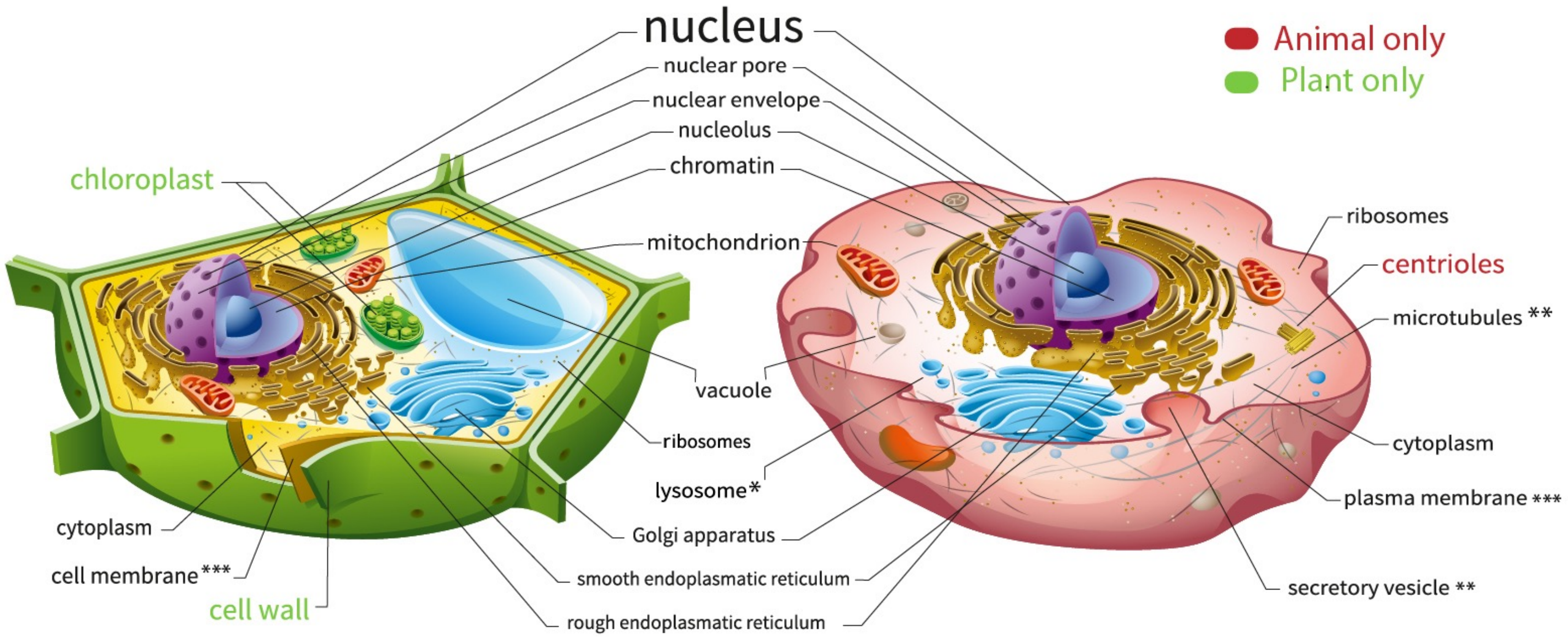
- They do not have any internal structures and no membranes.
- The DNA is not contained in any way and «floats» in the cytoplasm.
- Since there are no compartments, all cellular processes happen in the same place.
- Prokaryotes consist of:
    - *Capsula*
    - *Flagellum and Pili (used for moving and attaching)*
  - *Cell wall*
  - *Plasma membrane*
  - *Cytoplasm*
    - *Ribosomes (only type of organelle)*
    - *DNA (Plasmid) found in the nucleoid*
    - *Food particles for energy generation*

Basics in biology - Eukaryotes

- Eukaryotes are larger than prokayotes. They are compartimentalised and have visible internal structures.
  - Different cellular processes take place in different compartments/ organelles.
- Eukaryotic DNA is found in the nucleus. The DNA is tightly wound up to form the chromosomes.
- Eukaryotes consist of:
  - *Cell wall*
  - *Plasma membrane*
  - *Cytoplasm*
    - *Golgi-Apparatus*
    - *Mitochondria*
    - *Ribosomes*
    - *Endoplasmatic Reticulum (smooth and rough)*
      - *Smooth: Lipid synthesis*
      - *Rough: Protein synthesis*
    - *Peroxisomes*
    - *Lysosomes*
    - *Endosomes*
    - *Nucleus*
      - *Nuclear envelope*
      - *Chromatin*
      - *Nucleolus*



Basics in biology – Eukaryotes, Plants vs. Animal cells



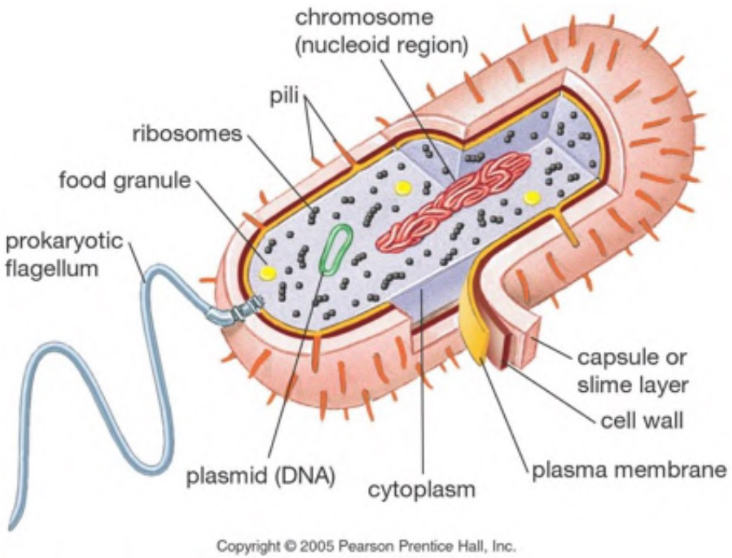
* Plants may have lytic vacuoles, which act like lysosomes in animal cells.

** Although they're not labelled here, plant cells have microtubules and secretory vesicles, too.

*** Cell membrane and plasma membrane are just different names for the same structure.

Biology basics

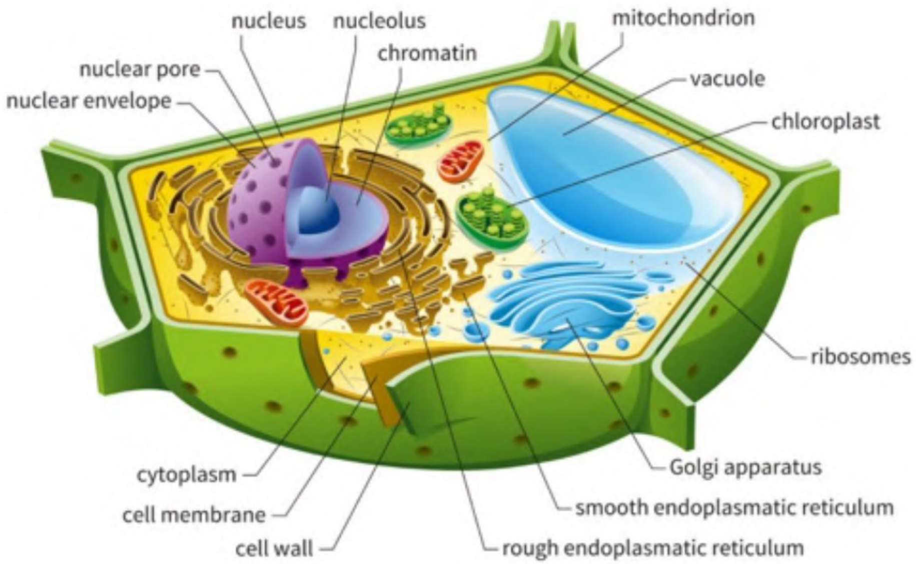
Prokaryotes



Important: Biological processes in prokaryotes and eukaryotes are oftentimes similar, if not the same. Usually the process is first described using the prokaryote as an example. In eukaryotes, the process is usually slightly more complicated but follows the same principle.

The most important structures of cells are listed on the right:

Eukaryotes



Cytoplasm: „liquid“ where all biochemical processes take place

Mitochondrion: generates energy for the cell

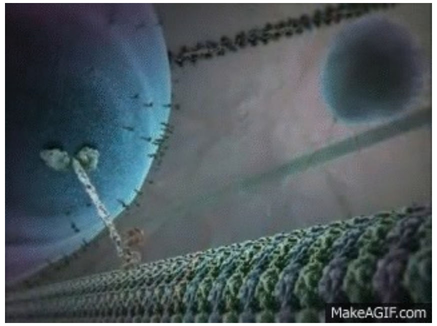
Ribosomes: Translation of mRNA into proteins

Nucleus: contains DNA

Nucleolus: Hotspot for transcribing DNA into mRNA

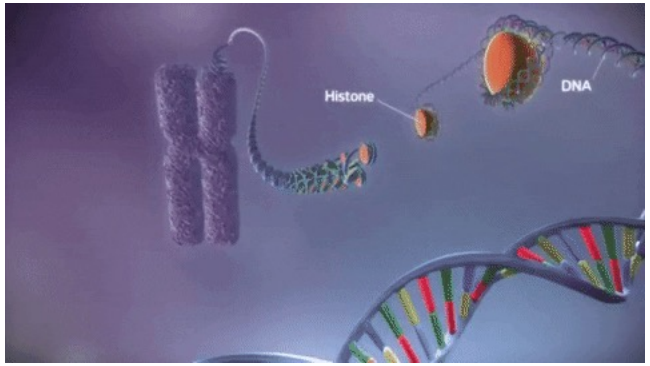
Organelles - Cytoplasm

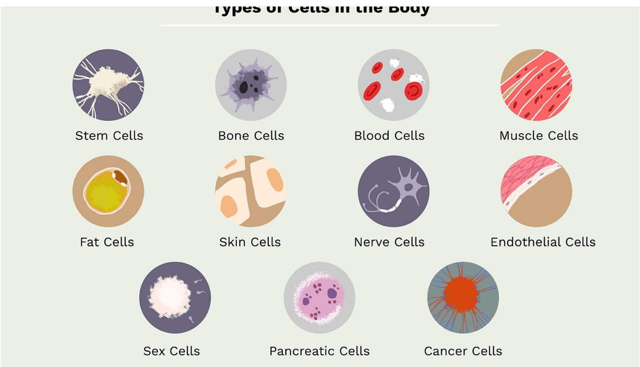
- Gelatinous liquid that fills the cell. It is thme most important component in eukaryotic cells and makes **up more than 50%** of the cell volume.
- Many **essential reactions** take place in the cytoplasm:
  - Protein biosynthesis
  - Glycolysis
  - Gluconeogenesis
- The cytoplasm contains many important **structures** and **macromolecules**:
  - *Endoplasmatic Reticulum*
  - *Golgi Apapratus*
  - *Ribosomes*
  - *Lysosomes*
  - *Mitochondria/ Chloroplasts*
  - *Peroxisomes*
  - *Cytoskeleton*
  - *Macromolecules for protein biosynthesis*
  - *Enzymes*
  - *Inorganic ions*
  - *Water*



Organelles - Nucleus

- The nucleus is the largest organelle in eukaryotic cells. It is surrounded by a double membrane with pores connecting the inner and outer part. The pores are also important for the regulation of the entry and exit of certain macromolecules.
- The most important component of the nucleus is the **DNA**, which is stored in chromosomes. Chromosomes are made out of DNA, which is tightly wound around histones, and is now called chromatin.
  - Heterochromatin: highly condensed and thus inaccesible for RNA polymerase
  - Euchromatin: not as condensed and thus accesible for RNA polymerase
- The DNA contains all the information the cell (and in the bigger picture, the body) needs to survive. All the cells contain the same DNA, but during the development in utero, the cells undergo differentiation processes, where the cell fate is determined. By doing so, different genes are made accessible which then determine the cell type, such as blood cell, bone cell, muscle cell.





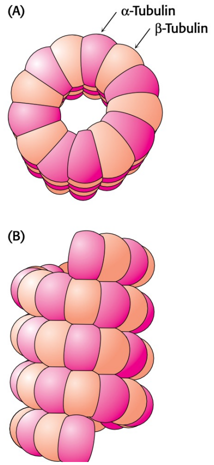
Organelles – Ribosomes, Mitochondria/ Chloroplasts and Peroxisomes

- **Ribosomes**
  - catalyse the translation part of the protein synthesis.
  - consist of two subunits (small and large), which are made out of rRNA. The small and large subunit only assemble in the presence of mRNA.
- **Mitochondria**
  - *The powerhouse of the* cell, most ATP is produced by oxidative phosphorylation.
  - The outer membrane is smooth, while the inner one is stronlgy folded. They have their own DNA.
- **Chloroplasts**
  - Site of photosynthesis in plant cells that contains its own DNA.
  - The stroma contains **thylakoids**, which are stacked into grana. The stroma is enclosed by a double membrane.
- **Peroxisomes**
  - Spherical organelles with granular or crytalline core, surrounded by a single membrane.
  - They comtain enzymes that produce peroxide (H_2O_2) by using oxygen. Peroxide is used to break down fatty acids so that they can be used in the respiratory chain.

Organelles – Endomembrane system

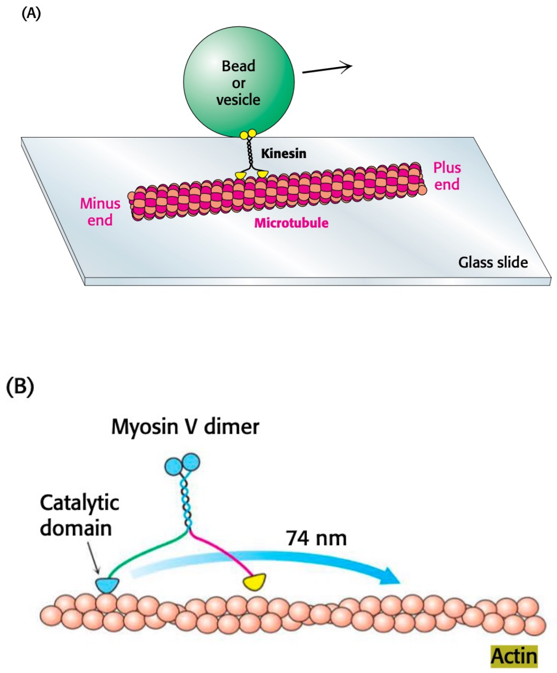
- **Endoplasmatic Reticulum**
  - **Rough ER**: Lies adjacent to the nucleus and has membrane bound ribosomes on the cytosolic part of the membrane. The rER is the site of protein biosynthesis, the proteins are folded and modified after translation. They either remain as membrane bound proteins in the rER or reach the golgi apparatus through vesicles and are then transported further.
  - **Smooth ER**: lies further away from the nucleus and has no membrane-bound ribosomes. It has a more “tube-like” structure and contains enzymes that catalyse the lipid synthesis
- **Golgi Apparatus**
  - Complex system of flattened and stacked membrane. Here proteins mature further and are sorted & packed into vesicles/ lysosomes and then transported to their final destination.
- **Lysosomes**
  - Used for enzymatic degradation of macromolecules and organelles. They have a high concentration of lysozymes.
- **Vacuoles and Vesicles**
  - “Droplets” of membrane enclosed space in the cytoplasm.
  - Used for transport, as a pump and in plant cells they even make up 80% of the cell volume. Another important function is the storage of materials, the removal of waste and protection and growth of the cell.

Organelles - Cytoskeleton



Each of the following families of cytoskeletal proteins has their own specific functions and properties, but they have some common features: they are all built from chains of small subunits, they assemble and disassemble fast and their structure is modulated by accessory proteins.

- **Microtubules**
  - ø: 25 nm, they point in all directions from the centre near the nucleus and are made out of hollow, tubular tubulin molecules.
  - Used for: maintenance of cell shape, cell motility, chromosome movement during cell division, movement of organelles
- **Intermediate Filaments (IF)**
  - ø: 8-12 nm, they are made of keratin proteins, which are wound into thicker helices.
  - Used for: maintenance of cell shape, anchorage of nucleus and other organelles and stabilisation of the nucleus membrane.
- **Actin Filaments (AF)**
  - ø: 5-9 nm, they are a structured in linear bundles, 2D networks or 3D gels and are distributed throughout the cell but most dense in the cortex. They are made out of two helically wound actin strands, which form a flexible fibre.
  - Used for: mainentance of cell shape, changes in cell shape, muscle contraction, cytoplasmic flow, cell motility, cell divison

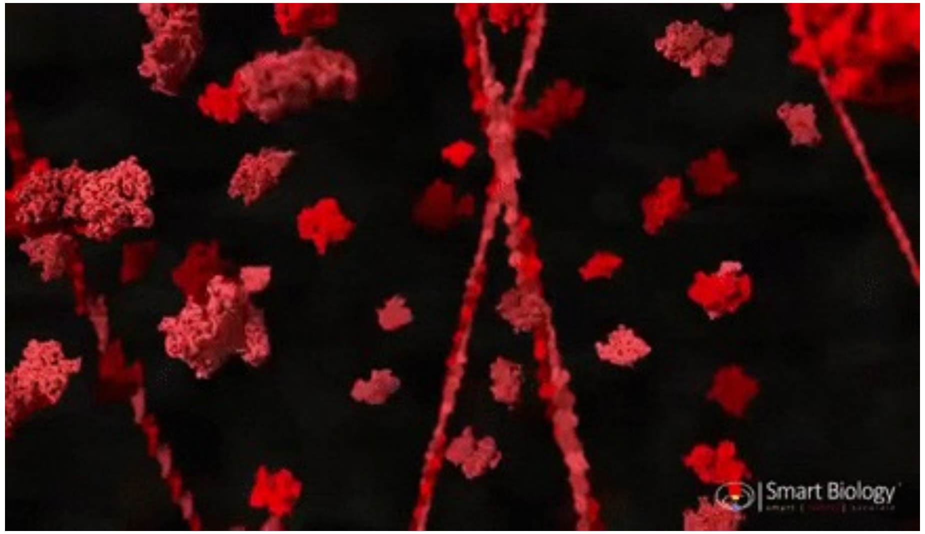


Organelles – Cytoskeletal polymerisation

The cytoskeletal structures consist of mutliple subunits, that are linked to form structures that can span the entire cell. The subunits can disassemble, move and reassemble at desired locations.

The entire process of de- and reassebly is called **polymerisation**. The rate of addition is k_{on}, and the rate of removal is k_{off}. There are three common mechansms of polymerisation:

- **Nucleation**
  - The initial step of polymerisation, here a helical polymer is stabilised through many contacts between adjacent subunits.
  - The mechanism behind the polymerisation here is that the addition of more subunits helps to stabilise the structure.
  - There is a fast-growing (plus) and slow-growing (minus) end – but the polymer does extend in both directions here.
    The speeds of the fast and slow end are determined by the conformational changes of the subunits, when they bind to the polymer – and the number of monomers binding to the polymer depends on the concentration of free monomers. The number of monomers dissolving from the polymer however is concentration independen!
    At the critical contentration, the rate of addition and removal balances out, if the concentration is higher than the critical conc., then bowth ends grow, if the concetration is lower, then both ends get shorter.



Organelles – Cytoskeletal polymerisation

- **Nucleotide hydrolysis**
  - Each actin molecule has an ATP bound, which is hydrolysed to ADP as soon as the monomer binds to the polymer. If the addition rate of the polymers is faster than the hydrolysis of the bound nucleotides, then a so called ATP cap is formed, which protects the polymer against degradation.
- **Dynamic instability**
  - The presence or absence of GTP in a tubulin molecule determines whether the polymer grows (slowly) or degradates (rapidly).
- **Treadmilling**
  - Phenomenon during actin polymerisation – the minus end has a lower concentration of free monomers than the plus end – and if the difference is right around the ccrit, then it can happen that one end poylmerises and one end depolymerises.
  - In treadmilling, the polymerisation and depolymerisation happen at steady state – meaning they happen at the same speed– thus the length of the polymer stays constant, but it does appear to be moving forward.
- Microtubule polymerisation can also be used to generate force, which is used to separate the chromosomes during cell division, as well as locomotion.