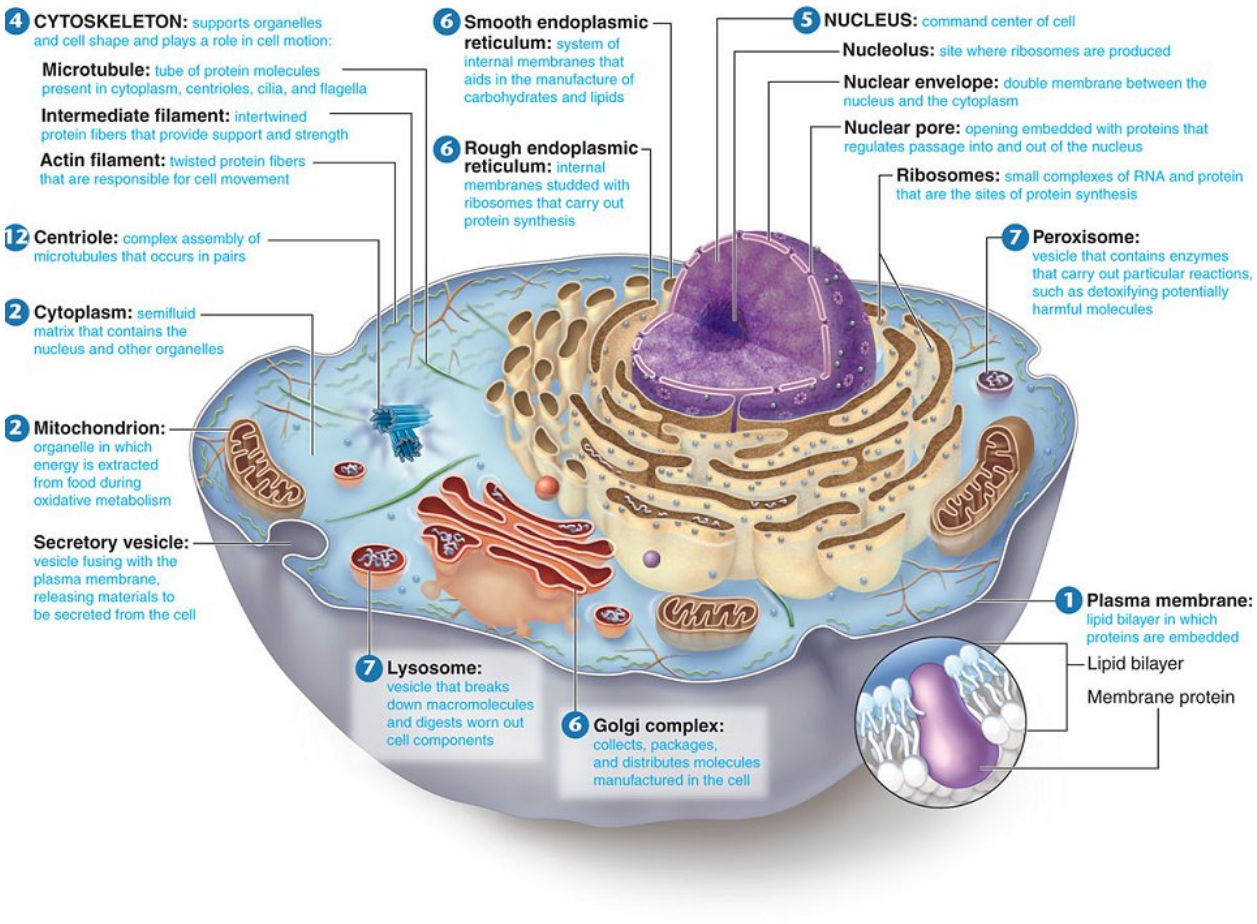
Cell Structure

Typical Eukaryotic Cell

1. Plasma membrane
2. Nucleus
    - Nuclear envelope
    - Nucleolus
3. Cytoplasm
    - Cytosol
    - Organelles
        - Membranous Organelles
            - Endomembrane System
                1. Nucleus (Nuclear envelope)
                2. Rough Endoplasmic Reticulum
                3. Smooth Endoplasmic Reticulum
                4. Golgi apparatus
                5. Lysosomes
                6. Plasma membrane
            - Not endomembrane system
                1. Mitochondrion
                2. (Plant Cell) Chloroplast
        - Non-membraneous Organelles
            1. Ribosomes
            2. Centrioles
    - Cytoskeleton
4. (Plant Cells) Cell wall

Structure & Function



Nucleus

- Structure
    - Spherical shaped
    - Contains chromosomes
        - When not dividing, exists as thin, elongated threads called chromatin
        - Prior to cell division, chromatin threads is tightly coiled and folded into thicker, shorter structures called chromosomes
            - Helps to pack DNA into a compact form that fits inside the nucleus of the cell
        - During interphase
            - Euchromatin (appears white)
                - Loosely coiled around histones
                - Active in synthesis of RNA as it promotes access of RNA polymerase and transcription factors to promoters of the genes
            - Heterochromatin (appears dark)
                - Tightly coiled around histones
                - Not active in synthesis of RNA as it limits access of RNA polymerase and transcription factors to promoters of genes

- Function
    - Contains hereditary material of organism (DNA)
    - Controls cellular activity by regulating protein synthesis

Nuclear envelope (NOT membrane)

- Structure
    - Double membrane = Inner + Outer phospholipid bilayer
    - Continuous with endoplasmic reticulum
    - Perforated by nuclear pores
- Function
    - Regulate passage of substances in and out of nucleus (via nuclear pores)
        - For transcription (in nucleus) and translation (in cytoplasm)

Nucleolus

- Structure
    - Appears as spherical mass of densely stained granules and fibres
    - One or more nucleoli may be present
    - Contains large concentration of DNA, rRNA and ribosomal proteins
- Function
    - Site of synthesis of rRNA
    - Site of assembly of rRNA and ribosomal proteins into ribosomal subunits

Ribosomes

- Structure
    - Small + Large subunit
        - Small subunit has mRNA binding site made of rRNA
        - Large subunit has peptidyl transferase made of rRNA that catalyses the formation of peptide bonds
    - Subunits are complexes of rRNA and ribosomal proteins
    - Have Aminoacyl tRNA binding site, Peptidyl tRNA binding site and Exit site
    - Prokaryotes have 70S ribosomes = Small 30S subunit + Large 50S subunit
    - Eukaryotes have 80S ribosomes = Small 40S subunit + Large 60S subunit
    - Free ribosomes freely floating in cytosol
    - Bound ribosomes attached to outside surface of rough ER
- Function:
    - Site of protein synthesis
        - i.e. Translation of mRNA to proteins (including enzymes)
    - Free ribosomes
        - Synthesise proteins that function within cytosol
    - Bound ribosomes
        - Synthesise proteins for:
            1. Secretion out of cell

2. Packaging within organelles
3. Insertion into plasma membrane

Rough ER

- Structure
  - Consists of flattened membrane bound sacs called **cisternae** comprising single membrane
  - Continuous with the outer membrane of the nuclear envelope
  - Bound ribosomes stud the outer surface of the membrane
- Function
  1. Synthesis of proteins
     - Bound ribosomes translate mRNA from the nucleus into polypeptides
     - Polypeptides formed enter cisternal space of rough ER to fold into their tertiary conformation
     - Proteins synthesised are meant for
       1. Secretion out of the cell
       2. Packaging into organelles
       3. Insertion into the plasma membrane (membrane proteins)
  2. *Transport of proteins
     - Proteins are transported via transport vesicles to the Golgi apparatus for further modification
  3. *Glycosylation
     - Polypeptides may undergo glycosylation by enzymes to form glycoproteins in the cisternal space
- Secretory cells that actively synthesise proteins contain abundance of rough ER
  - e.g. Liver, Pancreas

Smooth ER

- Structure
  - Comprises of interconnected membrane bound tubules called **cisternae** without bound ribosomes
  - Contains many embedded enzymes that catalyse the synthesis of carbohydrates and lipids
- Function
  - Synthesis of carbohydrates and lipids
  - Detoxification of drugs and poison

Golgi Apparatus

- Structure
  - Consists of a stack of flattened, membrane bound sacs called **cisternae**, together with associated Golgi vesicles
  - Transport vesicles which bud off from rough and smooth ER carrying protein and

lipid products respectively will fuse with the cis face of the Golgi apparatus, releasing their contents into the cisternal space
    - Golgi vesicles bud off from the trans face of the Golgi apparatus, carrying the finished products through vesicles
- Functions
    1. *Glycosylation
        - Protein and lipid products from the rough and smooth ER are further modified by glycosylation to give a variety of glycoprotein and glycolipid products
    2. Modify existing glycoproteins and glycolipids made in the ER by cleaving a sugar molecule from sugar chain or modifying the sugar(s)
    3. *Sorts and transports completed materials to different parts of the cell such as the plasma membrane for insertion into the membrane or for secretion out of the cell through **exocytosis**
    4. *Formation of lysosomes
    5. Produces polysaccharides (e.g. pectin) in plant cells

Role of Golgi

1. Transport vesicles which bud off from rough and smooth ER carrying protein and lipid products respectively will fuse with the cis face of the Golgi apparatus, releasing their contents into the cisternal space
2. Golgi apparatus consists of a stack of flattened, membrane bound sacs called **cisternae**, together with associated Golgi vesicles
3. Protein and lipid products from the rough and smooth ER are further modified by **glycosylation** to give a variety of glycoprotein and glycolipid products
4. Golgi vesicles bud off from the trans face of the Golgi apparatus, carrying the finished products through vesicles
5. Sorts and transports completed materials to different parts of the cell such as the plasma membrane for insertion into the membrane or for secretion out of the cell through **exocytosis**
6. Formation of lysosomes

Structure	**Function**
Stacks of cisternal with cis and trans face	Receive proteins from the transport vesicles of the RER and lead proteins through a process of modification and maturation from the cis to the trans face of the Golgi apparatus and into secretory vesicles
	Create a suitable environment within the cisternal space for the modification of

Single bilayer membrane	proteins, either by providing a suitable pH or compartmentalising enzymes that modify proteins
Phospholipid bilayer membrane that is similar to other membranes in basic components	Allows it to be continuous with the endomembrane system so that vesicles from the ER can fuse to the Golgi apparatus and vesicles from the Golgi apparatus can fuse with the plasma membrane for exocytosis or to form lysosomes
Secretory vesicles from the Golgi apparatus are bound by a lipid bilayer	Allow incorporation into the cytoplasmic membrane, enabling it to release contents via exocytosis
Presence of secretory vesicles	Remain in the cytoplasm as lysosomes for digesting foreign substances such as bacteria or food particles
Presence of enzymes in the lumen of the cisternae or embedded in the Golgi apparatus bilayer with the functional parts of the enzymes facing the lumen	Glycosylate or further modify proteins in the lumen of the Golgi apparatus
High surface area of membranes provided by the cisternal	Allows for a higher concentration of embedded enzymes/formation of more vesicles
Attachment of vesicles from the Golgi apparatus to the cytoskeleton	Direct the movement of secretory vesicles to the cell membrane

Lysosome

- Structure
  - Membrane-bound vesicles containing hydrolytic enzymes used to digest macromolecules that bud off from trans face of Golgi apparatus
- Function
  1. Fuses with endocytotic vesicles to digest ingested materials within them or with phagocytic vesicles to destroy bacteria within them
     - Useful products may be absorbed and assimilated into cytoplasm
     - Unwanted products are released by exocytosis
  2. Fuses with autophagic vesicles containing unwanted structures within the cell to break them down and recycle the organic products from the digestion
  3. Release of hydrolytic enzymes by exocytosis for the breakdown of extracellular

structures
4. Contents of lysosome are released within the cell during autolysis to create an acidic environment where hydrolytic enzymes can function (cell death)

Mitochondrion

- Structure
  - Spherical/Rod shaped
  - Enclosed by double membrane
    - Smooth outer membrane
    - Highly infolded inner membrane forming numerous cristae
      - Divides mitochondria into intermembrane space and mitochondrial matrix
  - Mitochondrial matrix contains 70S ribosomes, circular DNA and enzymes involved in Krebs cycle
  - Contains stalked particles for ATP synthesis
- Function
  - Site of cellular respiration
    - Generate ATP
  - Krebs cycle occurs in mitochondrial matrix
  - Oxidative phosphorylation occurs in cristae
- Specialised cells (e.g. RBC) may not contain mitochondria
- Cells with high energy requirements (e.g. Liver/Muscle cells) contain abundance of mitochondria

Chloroplast

- Structure
  - Lens shaped
  - Bound by double membrane
  - Space between membranes is intermembrane space
  - Within chloroplast, there are a series of <u>interconnected sacs</u> called **thylakoids**
    - Stacks of thylakoids = Grana
  - Chlorophyll and other pigments/enzymes involved in photophosphorylation located on thylakoid membrane and organised into photosystems
  - Fluid within inner membrane called stroma
    - Contains circular DNA, ribosomes, enzymes and starch grains
  - Contains stalked particles for ATP synthesis
- Function
  - Site of photosynthesis
  - Stroma site for Calvin cycle

Chloroplast vs Mitochondria
<u>Similarities</u>

- Both are bound by a double membrane
- Inner membrane encloses a fluid filled cavity
- Both contain 70s ribosomes
- Both contain circular DNA strands and enzymes
- Both contain stalked particles/ATP synthase

Differences

	Chloroplast	**Mitochondria**
Size	Larger	Smaller
Shape	Lens shaped	Generally rod or spherical shaped
Inner membrane	Not folded, not arranged into folds and do not contain stalked particles	Extensive folded into folds known as cristae and inner membrane contains stalked particles
Granules/grains present	Starch grains are present	Numerous phosphate granules present
Internal membrane system	Present in the form of stacks of thylakoids and intergranal lamella	Internal membrane system absent
Location of stalked particles (ATP synthase)	Found on thylakoid membranes	Found on inner membrane
Coloured pigments	Presence of photosynthetic pigments on thylakoid membranes	Absence of coloured pigments

Vacuole

- Structure
    - Fluid filled sac bound by a single membrane
    - Large vesicles derived from rER and Golgi apparatus
    - Numerous smaller vacuoles in animal cells
    - Single large central vacuole in plant cells which contains cell sap
- Function
    - Animal cells

        - Food vacuoles formed by phagocytosis enclosed with material for digestion by lysosome
        - Fresh water protists have contractile vacuoles that pump excess water out of the cell to maintain a suitable ion and molecule concentration in the cell
    - Plant cells
        - Concentrated cell sap draws water into the vacuole by osmosis and helps to maintain the turgor pressure of the cell for support
        - During plant cell growth, vacuole enlarges with minimal increase in cytoplasm when cell increases in size
        - Store waste products (calcium oxalate) and food (proteins)

Microtubules

- Structure
    - Hollow rods made of tubulin arranged in helix structure
        - Tubulin is a dimer made of 2 subunits
    - Growth can be inhibited by chemicals (e.g. colchicine)
- Function
    1. Help maintain shape of cells by acting as cytoskeleton, providing rigidity to parts of the cell where they occur
    2. Intracellular transport by serving as tracks
    3. Spindle fibres composed of microtubules aid in chromosome movement during cell division
    4. Form structural component of centrioles, cilia and flagella

Centrioles

- Structure
    - Pair of cylindrical, rod-like structures positioned at right angles to each other
    - Each centriole contains **nine triplets of microtubules** arranged in a ring
    - Found in **centrosome**
    - Absent in higher plant cells (i.e. plants that produce seeds)
- Function
    - During cell division, centrioles replicate and move to opposite ends of cell, determining the polarity of the cells
    - Form part of the microtubule-organising centre which help to organise formation of spindle fibres
    - Spindle fibres help in separation of chromosomes during mitosis and meiosis

Microtubule-organising centre (e.g. centrosome)

- Structure which microtubules emerge from
- Function
    1. Organise eukaryotic flagella and cilia (basal bodies)
    2. Organise mitotic and meiotic spindle apparatus (centrosome)