BHARATHIDASAN UNIVERSITY

Tiruchirappalli – 620024,
Tamil Nadu, India.

Programme: M.Sc., Botany

Course Title : CELL BIOLOGY AND BIOINSTRUMENTATION
Course Code : 22PGBOT104

Unit – I
CELL AND CELL WALL

Topic: Prokaryotic & Eukaryotic Cell

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Prokaryotic and Eukaryotic Cell

Cell

- Robert Hooke – discovered cells.
- Cell theory - functional unit - Theodor Schwann.
- Chemical composition: Water, Proteins, Nucleic acids, Polysaccharides, Phospholipids etc.,
- Broadly classified into two types: Prokaryotes, Eukaryotes.

Prokaryotic cells:

- No membrane bound organelles
- Simple genome organization
- Genes usually do not have introns
- Between 500 - 4000 genes
- Unicellular
- Ribosomes 70S

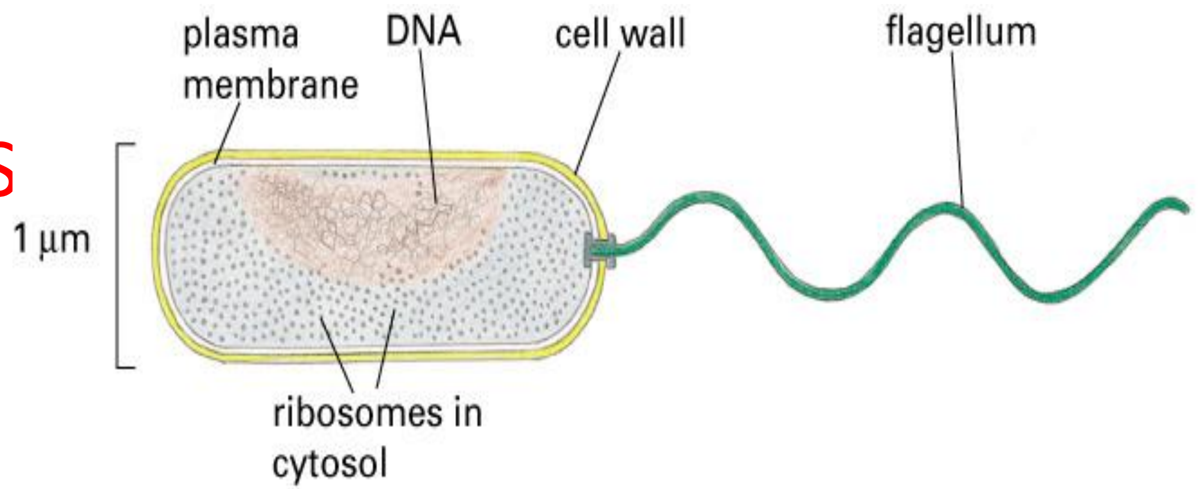
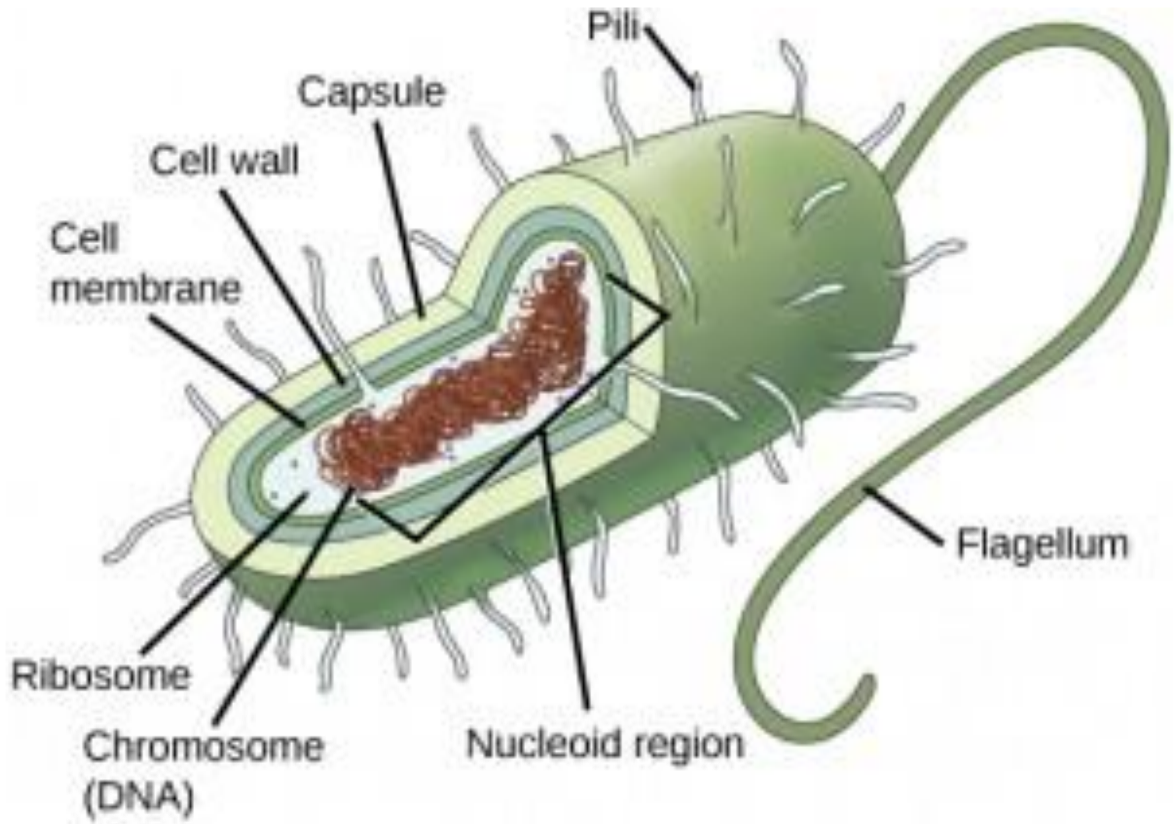


Figure 1–18 part 1 of 2. Molecular Biology of the Cell, 4th Edition.

- Exons : Nucleotide sequences that carry information for protein synthesis
- Introns: Non coding regions of a gene that are removed during the process of RNA splicing.
- After DNA is transcribed into RNA in eukaryotic cell, it is further edited in the nucleus and part of RNA (intron) is cut out
- Prokaryote – No nucleus – absent

Prokaryote

- True membrane bound nucleus –Absent
- DNA complexed with histones -No
- Number of chromosomes - One
- Nucleolus - Absent
- Mitosis - No, Cell division by Binary fission
- Mitochondria, Chloroplast, Endoplasmic reticulum, Golgai apparatus, Lysosome, Peroxisome, Cytoskeleton - Absent.


Pili
Capsule
Cell wall
Cell
membrane
Flagellum
Ribosome
Chromosome
(DNA)
Nucleoid region

- Size 0.5µm to 5 µm.
- Shape vary
- Cell wall forms the outer layer – maintains rigidity and integrity of the cell and function as a selective barrier for the transport of the molecules across the cell.
- The cell wall acts as an extra layer of protection, helps the cell maintain its shape, and prevents dehydration.
- Bacteria - two types based on composition of cell wall.

- have a cell wall made of peptidoglycan, comprised of sugars and amino acids, and many have a polysaccharide capsule.
- Gram positive and gram negative:
- Positive: outer **thick layer of peptidoglycan** and inner layer of plasma membrane in between – periplasmic space.
- Negative: outer thin layer of peptidoglycan, lipid content - high
- The peptidoglycan is surrounded by LPS.

- The capsule enables the cell to attach to surfaces in its environment.
- Some prokaryotes have flagella, pili, or fimbriae (Appendages). Flagella are used for locomotion, while most pili are used to exchange genetic material during a type of reproduction called conjugation.

- Number of flagella varies with bacteria.
- Fimbriae: small, slender tubular structure present in gram negative bacteria.
- - help in attachment

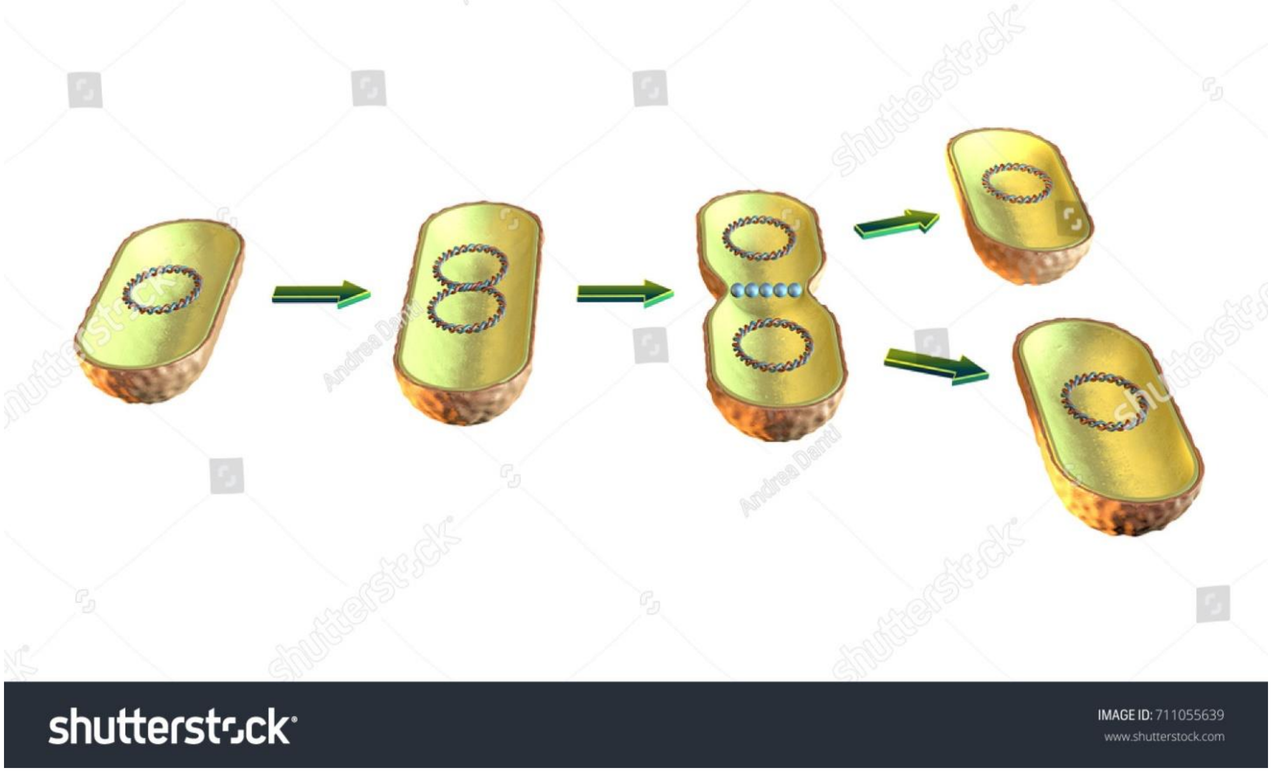
- Crystal violet used to stain the cell.
- Crystal violet is a basic dye possessing positive charge in aqueous solution.
- Cells – dye- penetrate and stain the cell.
- After staining – Gram’s iodine – add – insoluble dye iodine complex.
- Add decolorizing agent – ethanol/acetone.

- Ethanol replaces the water present in the peptidoglycan layer – leads to shrinkage and tighten – the dye complex trapped within the cell. (gram positive - thick)
- Lipid layer – dissolved (gram negative) – loose the color
- Then, safranin - counter stain add
- Penetrates the cell combines with crystal violet and forms a purple-colored complex.
- Appear purple color.

Bacterial Reproduction

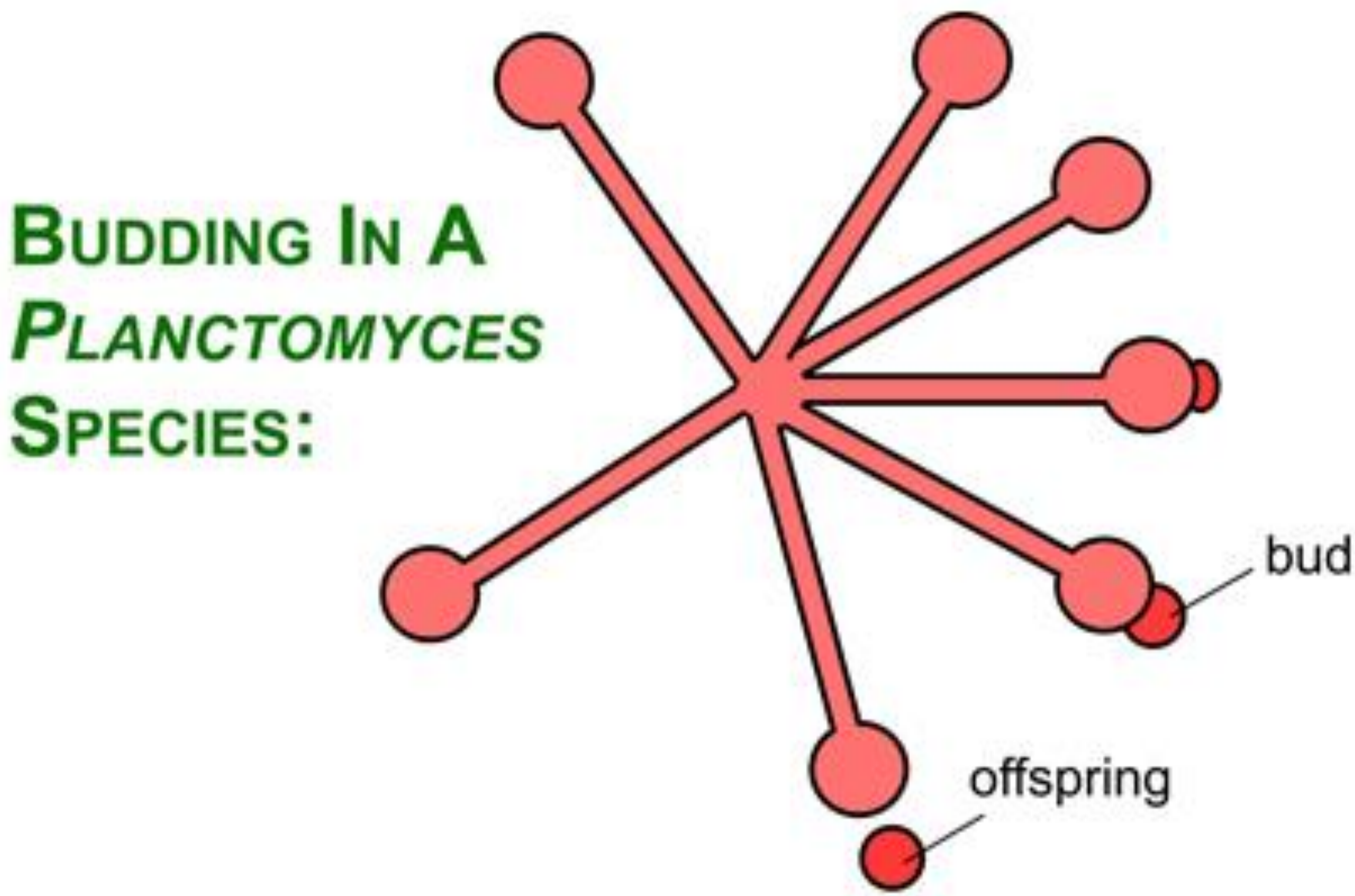
- Asexual and Sexual method.
- Asexual – Binary fission, Budding , Fragmentation
- Sexual – Conjugation, Transformation, Transduction

Binary fission



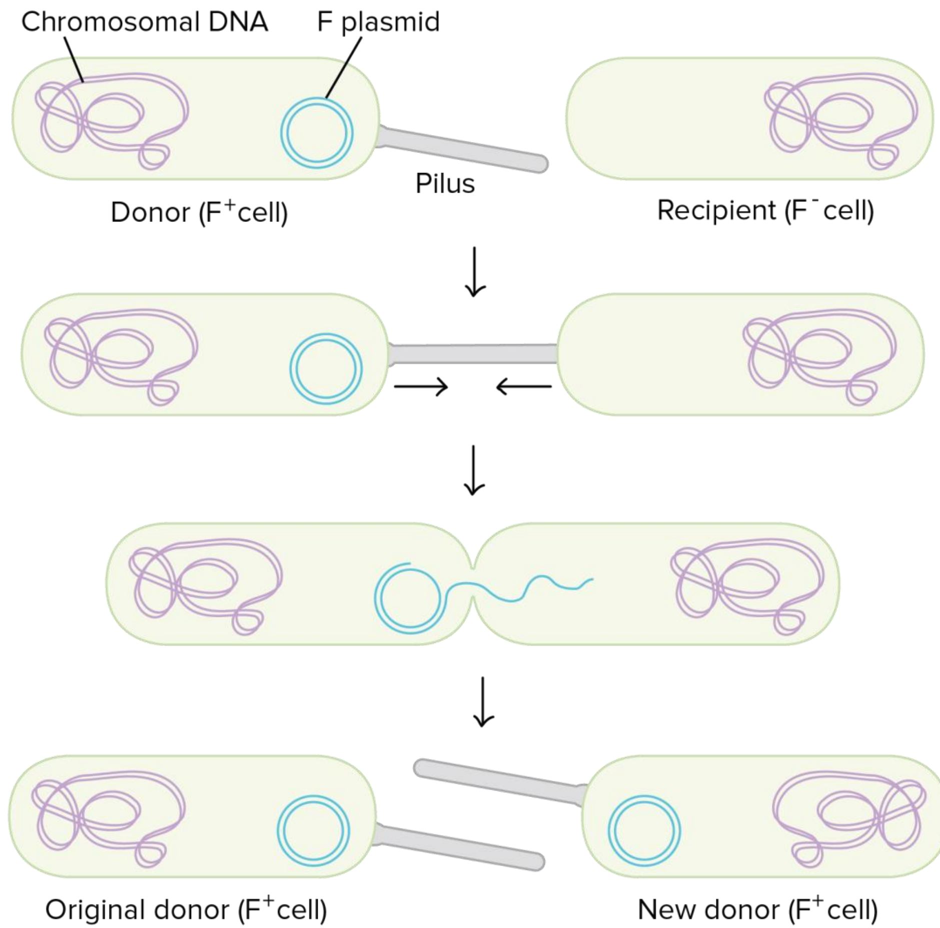
- Binary fission makes **clones**, or genetically identical copies, of the parent bacterium.
- binary fission doesn't provide an opportunity for genetic recombination or genetic diversity

Budding



Sexual reproduction

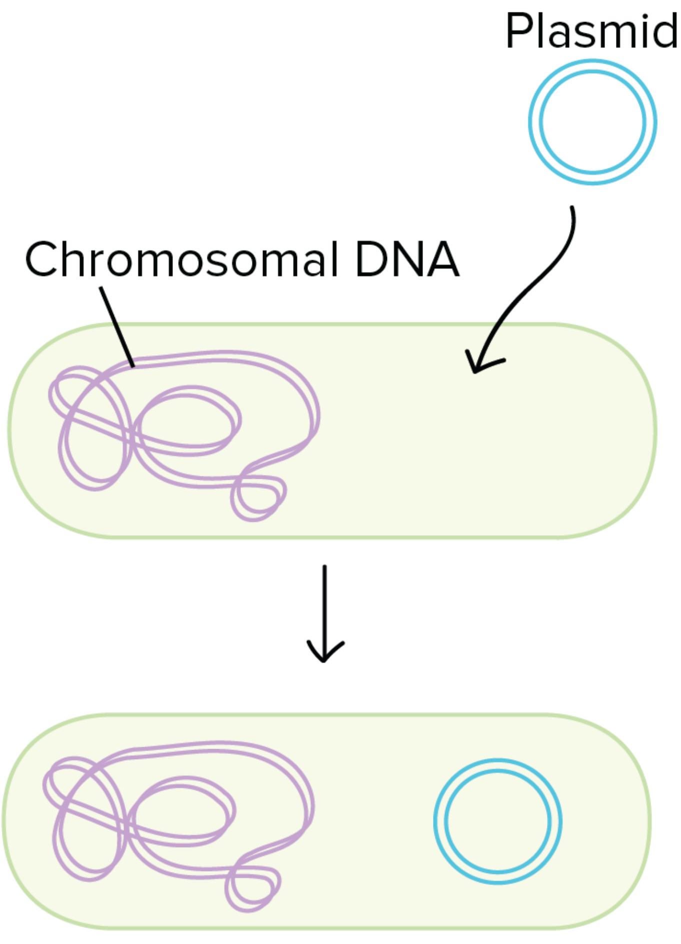
- Conjugation: DNA is transferred between bacteria through a tube between cells.
- In **conjugation**, DNA is transferred from one bacterium to another. After the donor cell pulls itself close to the recipient using a structure called a pilus, DNA is transferred between cells. In most cases, this DNA is in the form of a plasmid.



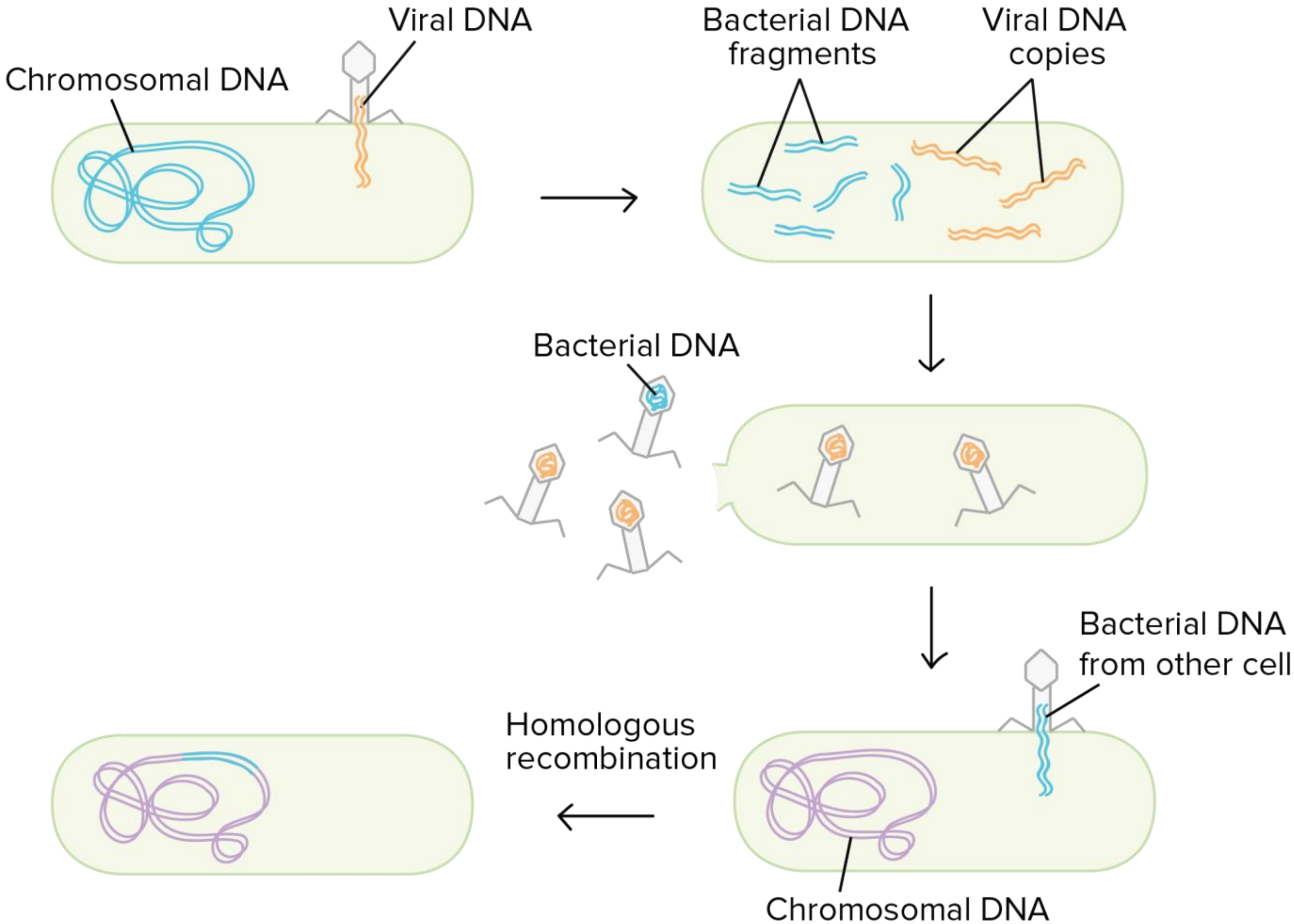
Chromosomal DNA
F plasmid
Pilus
Donor (F+cell)
Recipient (F- cell)
Original donor (F+cell)
New donor (F+cell)

- Donor cells typically act as donors because they have a chunk of DNA called the **fertility factor** (or **F factor**). This chunk of DNA codes for the proteins that make up the sex pilus. It also contains a special site where DNA transfer during conjugation
- If the F factor is transferred during conjugation, the receiving cell – start –
- donor that can make its own pilus and transfer DNA to other cells.

- In **transformation**, a bacterium takes in DNA from its environment, often DNA that's been shed by other bacteria. If the DNA is in the form of a circular DNA called a **plasmid**, it can be copied in the receiving cell and passed on to its descendants.
-


Plasmid
Chromosomal DNA

- DNA is accidentally moved from one bacterium to another by a virus.
- In **transduction**, viruses that infect bacteria move short pieces of chromosomal DNA from one bacterium to another "by accident."
- The viruses that infect bacteria are called bacteriophages.
- Sometimes, chunks of host cell DNA get caught inside the new bacteriophage as they are made. When one of these "defective" bacteriophages infects a cell, it transfers the DNA.

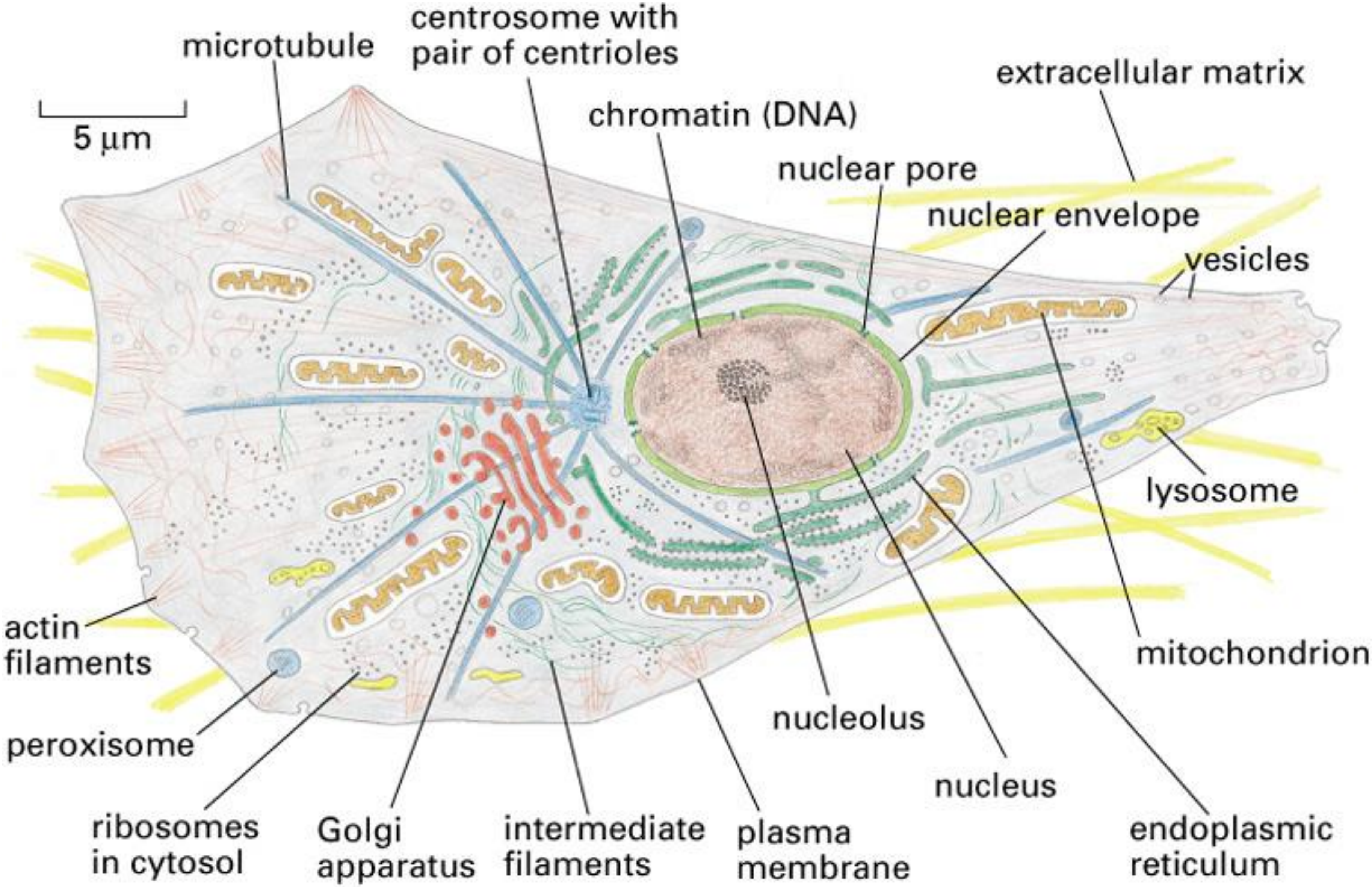

Viral DNA
Chromosomal DNA
Bacterial DNA fragments
Viral DNA copies
Bacterial DNA
Bacterial DNA from other cell
Homologous recombination
Chromosomal DNA

Eukaryotic cells

- All organelles are membrane-bound
- Complex genome organization
- Large genome size
- Between 6,000 - 30,000 genes
- Genes have introns
- Ribosome – 80S
- Large amount of regulatory DNA
  - To control gene expression
- Unicellular or multicellular

Eukaryotic cell

- Division of cells into nucleus and cytoplasm separated by a nuclear envelope containing complex pore structures.
- Organelles present
- Complex cytoskeleton system
- Cellulose containing cell walls (in plants)
- Diploid
- Meiosis

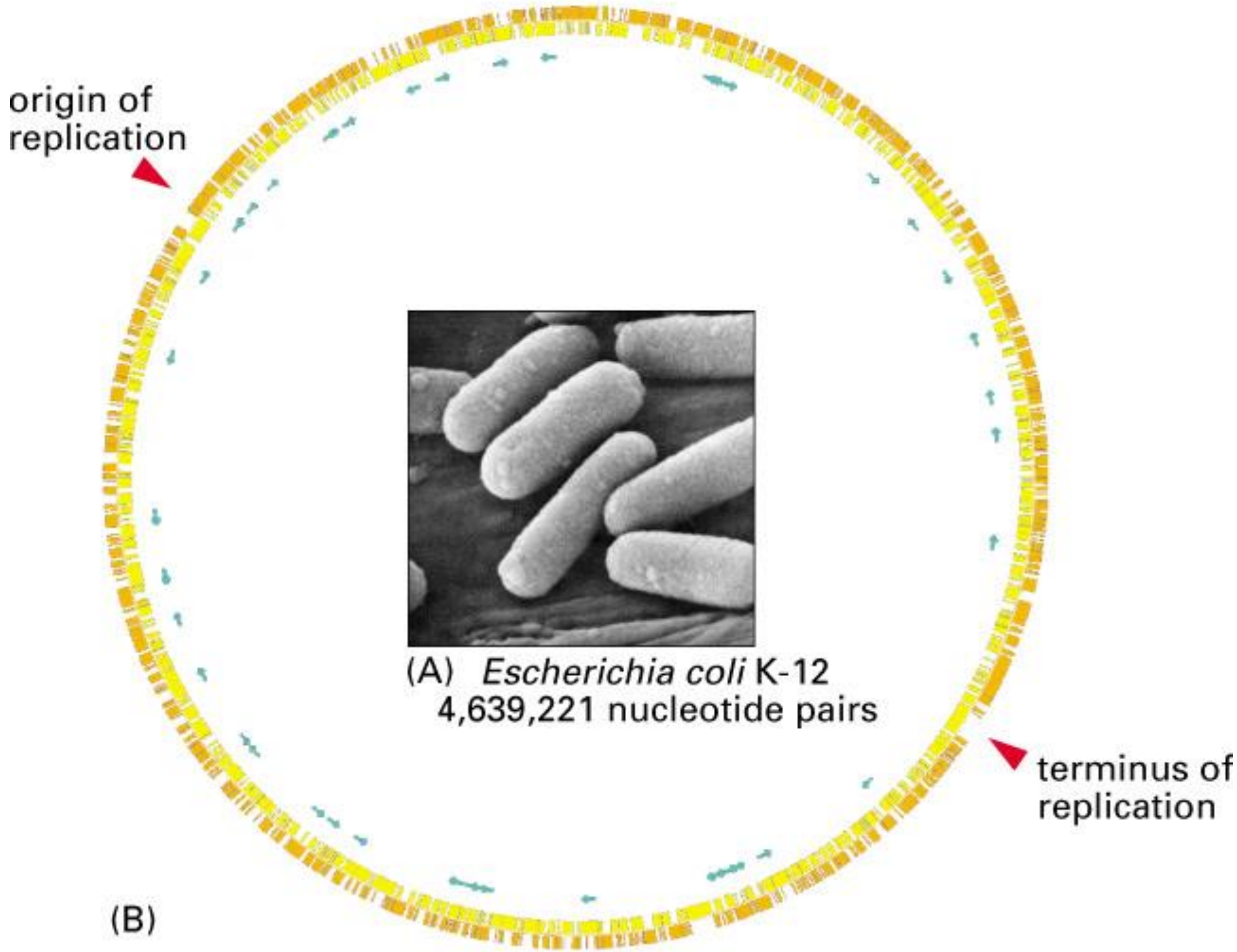

microtubule
centrosome with
pair of centrioles
extracellular matrix
chromatin (DNA)
5 μm
nuclear pore
nuclear envelope
vesicles
lysosome
actin
filaments
mitochondrion
peroxisome
nucleolus
nucleus
ribosomes
in cytosol
Golgi
apparatus
intermediate
filaments
plasma
membrane
endoplasmic
reticulum

[redacted]

Genome organization in Prok. and Euk.

- Prokaryotes
  - Circular DNA
    - mtDNA very similar
- Eukaryotes
  - Linear DNA
  - nuclear DNA

Prokaryotic DNA



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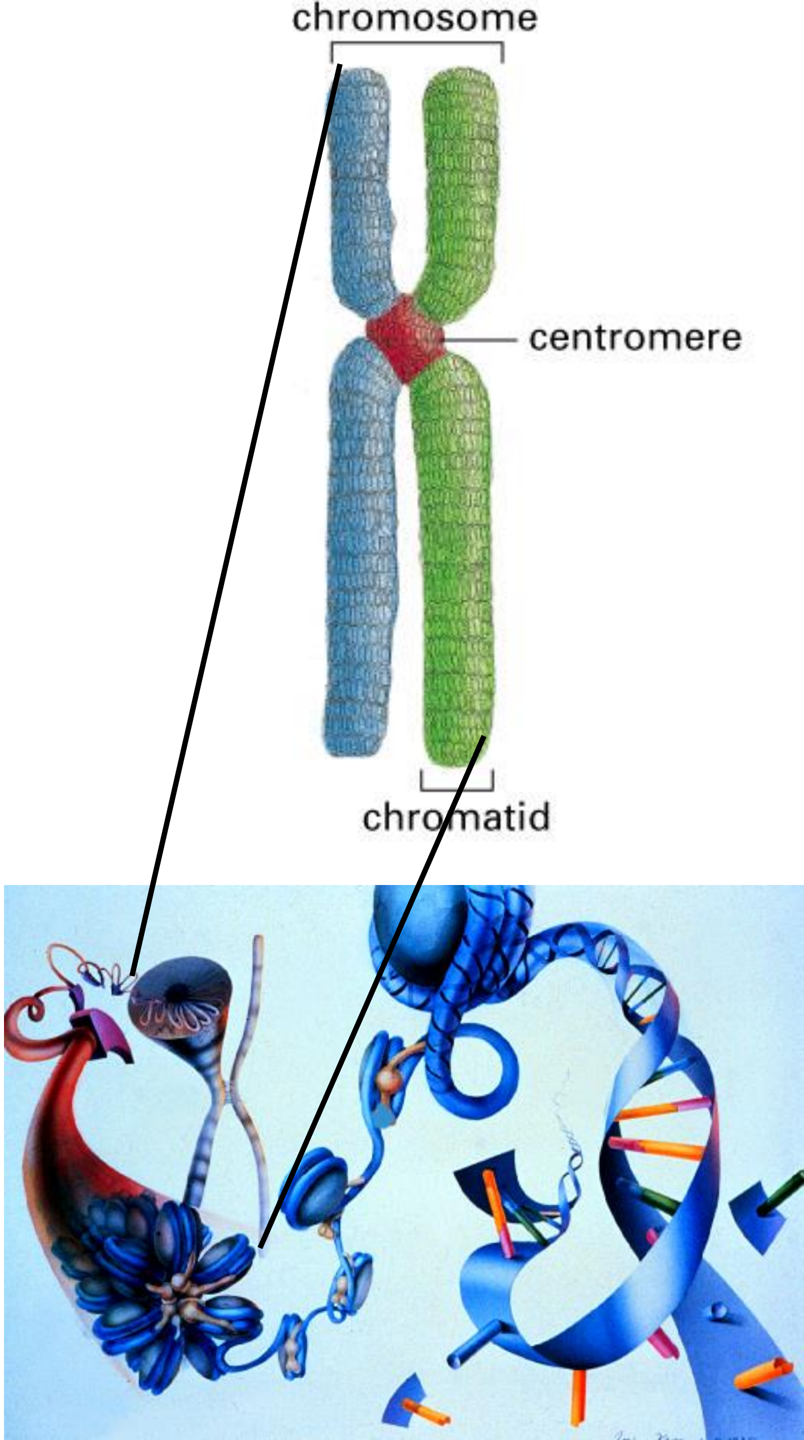
Eukaryotic DNA

- DNA packaged in a chromosome
- Linear DNA
- Associated proteins



Common in both cells

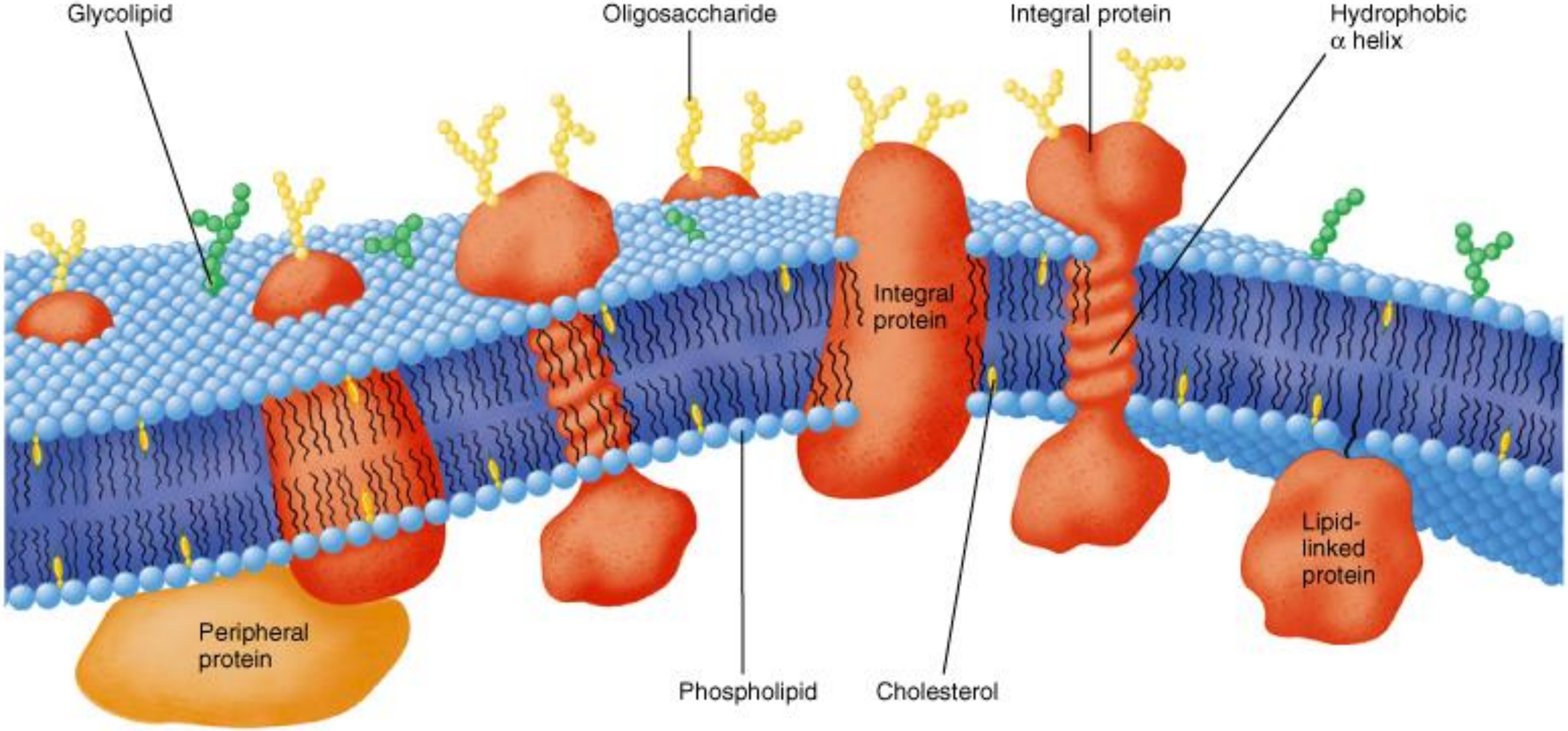
- Plasma membrane similar construction
- Genetic information is encoded in DNA – identical gene code
- Similar mechanism of photosynthesis
- Similar mechanism of synthesizing and inserting membrane proteins
- Proteosomes of similar construction

- Thank you

Transport

- Passive diffusion
- Facilitated diffusion
- Active transport
- Group translocation
- In eukaryotes – no group translocation/ only endocytosis

- Passive and facilitated diffusion – movement of molecules down concentration gradient.
- Other two – against concentration gradient
- Diffusion - Higher to lower eg. Glycerol
- Facilitated Diffusion - carrier mediated movement (permeases – transport proteins)
- Common in Eukaryotes than in prokaryotes



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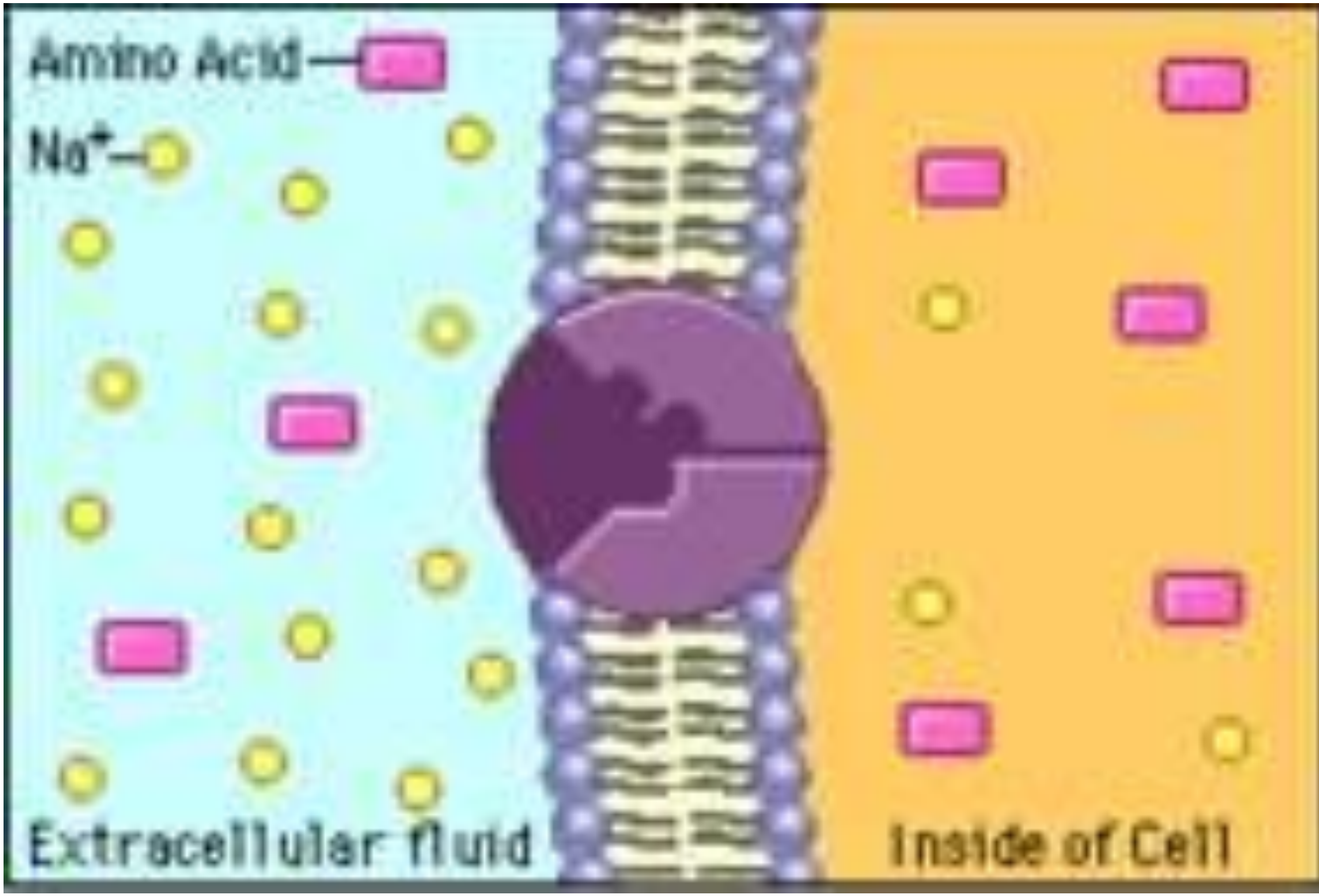
- Simple diffusion
- Movement of molecules from region of higher concetration to lower concentration (diffusion of solutes towards equilibrium eg. Glycerol transport to cell. No energy is required.
- Facilitated Diffusion (carrier mediated) – Membrane bound carriers called permeases (transport proteins) attach to substrates to which they have an affinity. Energy is not required for this movement. Because this is aided by carrier – facilitated diffusion. Carrier proteins- selective in nature and transport closely related solutes.

- Carrier proteins bind one or more solute molecule on one side of membrane and then undergo confirmational changes that transfer solute to other side of the membrane.
- In bacteria – channel through membrane and allow passage of solutes without any confirmational changes in protein. These channels appear as pores – outer membrane porin.
- Carrier proteins carry either one or two solutes.

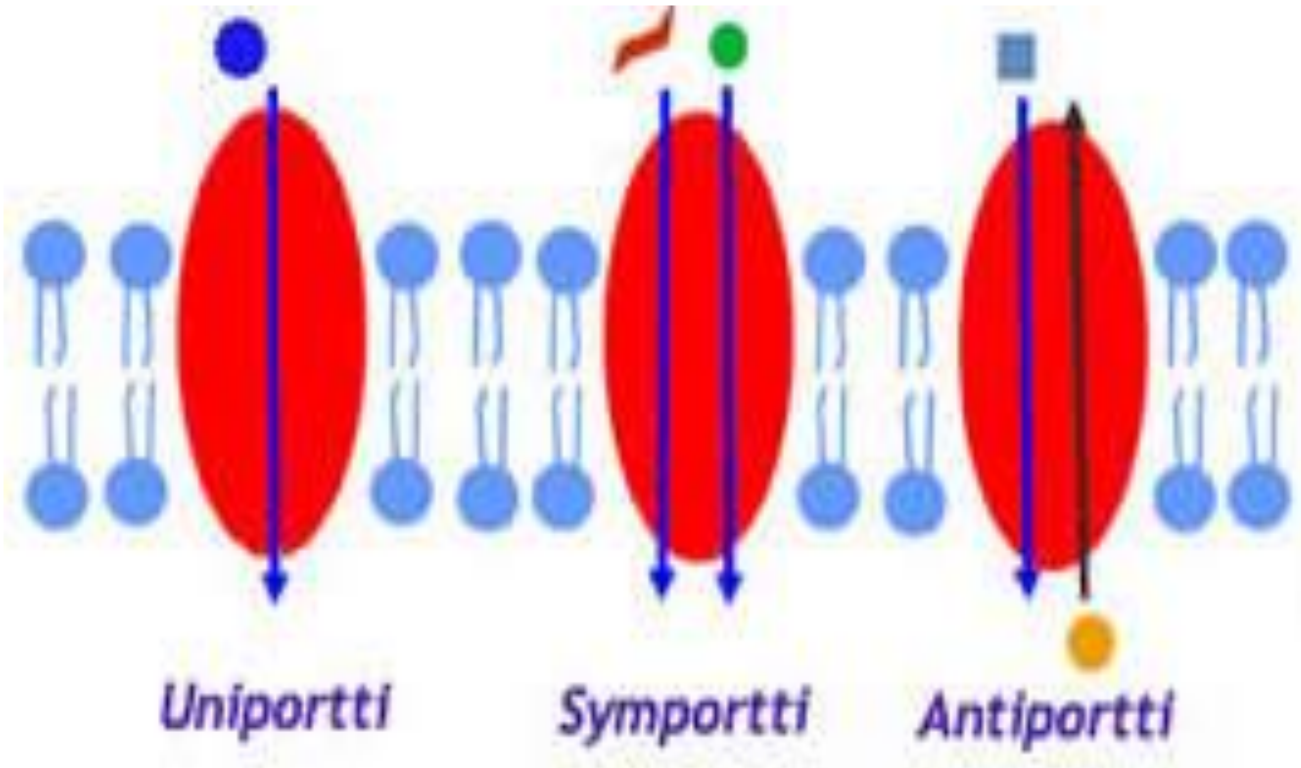

Amino Acid
Na+
Extracellular fluid
Inside of Cell

- Fac.diffusion – Uniporter

  Co-transporter

- Uniporter - carry one substance at a time
- Co-transporter - more than one substance at a time - Symport
- Antiport

- Symport - two substances carried across the membrane in same direction
- Antiport - substances transported across the membrane in opposite direction


Uniportti
Symportti
Antiportti

- Active transport
- Protein mediated movement up the gradient – require energy.
- Energy might be used to reversibly modify the confirmation of the protein carrier, which spans the membrane, when this occurs the carrier accepts the substance, opens a channel through the membrane and extrudes the substrate on the other side.
- Allows secretary products, waste materials to be carried/ removed from cell – even when concentration outside is greater.

- Group translocation – Here molecules are transported into cell while being chemically altered.
- Eg. Sugar phosphorylation to enter the cell in E.coli – which occurs in two steps.

- 1st step: Activation of heat stable carrier protein (HPr) by phosphoenol pyruvate (PEP)
- HPr + PEP → pyruvate + P-HPr

Next step, the phosphate group is transferred from carrier protein to the sugars to be transport.

P-HPr + Sugar (outside) → Sugar – P + HPr. (inside)

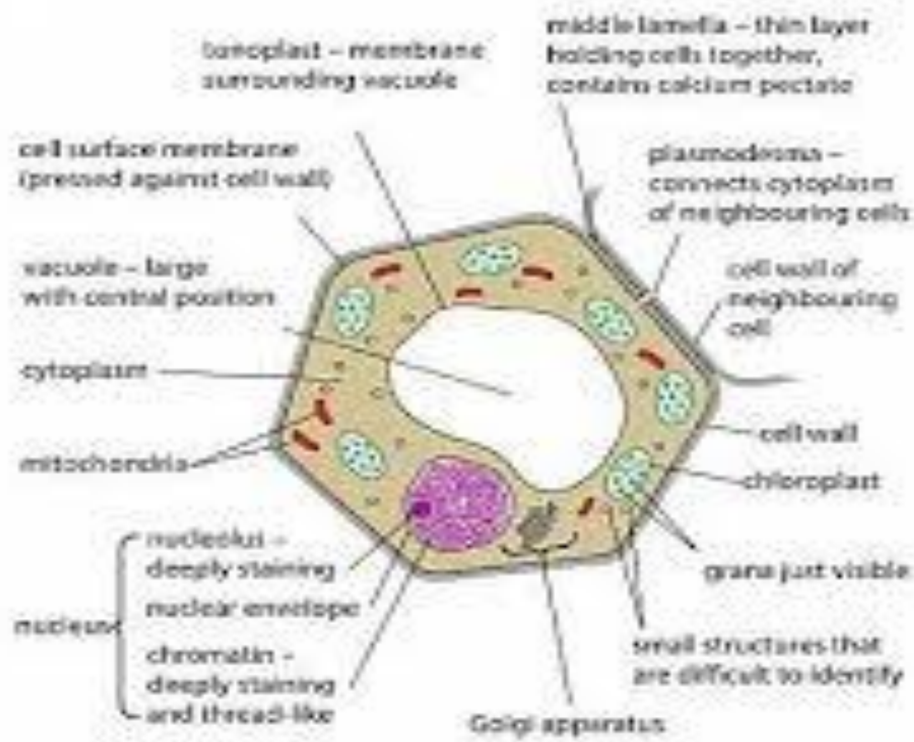
i.e. PEP + sugar → pyruvate + S- P. (PEP – phosphate donor)

- Low molecular weight molecules pass through membrane. Larger molecules also enter this membrane.
- Endocytosis - Fluid, dissolved solutes etc.,
- Phagocytosis – particulate matter

- Endocytosis: Cell internalises cell surface receptors and bound extracellular ligands.
- Phagocytosis: uptake of particulate matter (cell eating) eg. Amoeba. - when the particles come near the cell surface – the pseudopodia enlarge – engulf the material.

Plant cell

- Cytoplasm, Nucleus, Cell membrane, Cell wall, Plasmodesmata, Filamentous cytoskeleton, double membrane organelles.
- Cytoplasm: The jelly- like substance present between the cell membrane and nucleus is known as the cytoplasm. Various other components, or organelles, of cells are present in the cytoplasm. These are Mitochondria, Golgi bodies, Ribosomes, Endoplasmic reticulum, Lysosomes, Vacuole, Peroxisomes etc. The cytoplasm is about 80% water and usually colorless.


tonoplast – membrane surrounding vacuole
middle lamella – thin layer holding cells together, contains calcium pectate
cell surface membrane (pressed against cell wall)
plasmodesma – connects cytoplasm of neighbouring cells
vacuole – large with central position
cell wall of neighbouring cell
cytoplasm
cell wall
mitochondria
chloroplast
nucleolus – deeply staining
grana just visible
nuclear envelope
nucleus
chromatin – deeply staining and thread-like
small structures that are difficult to identify
Golgi apparatus

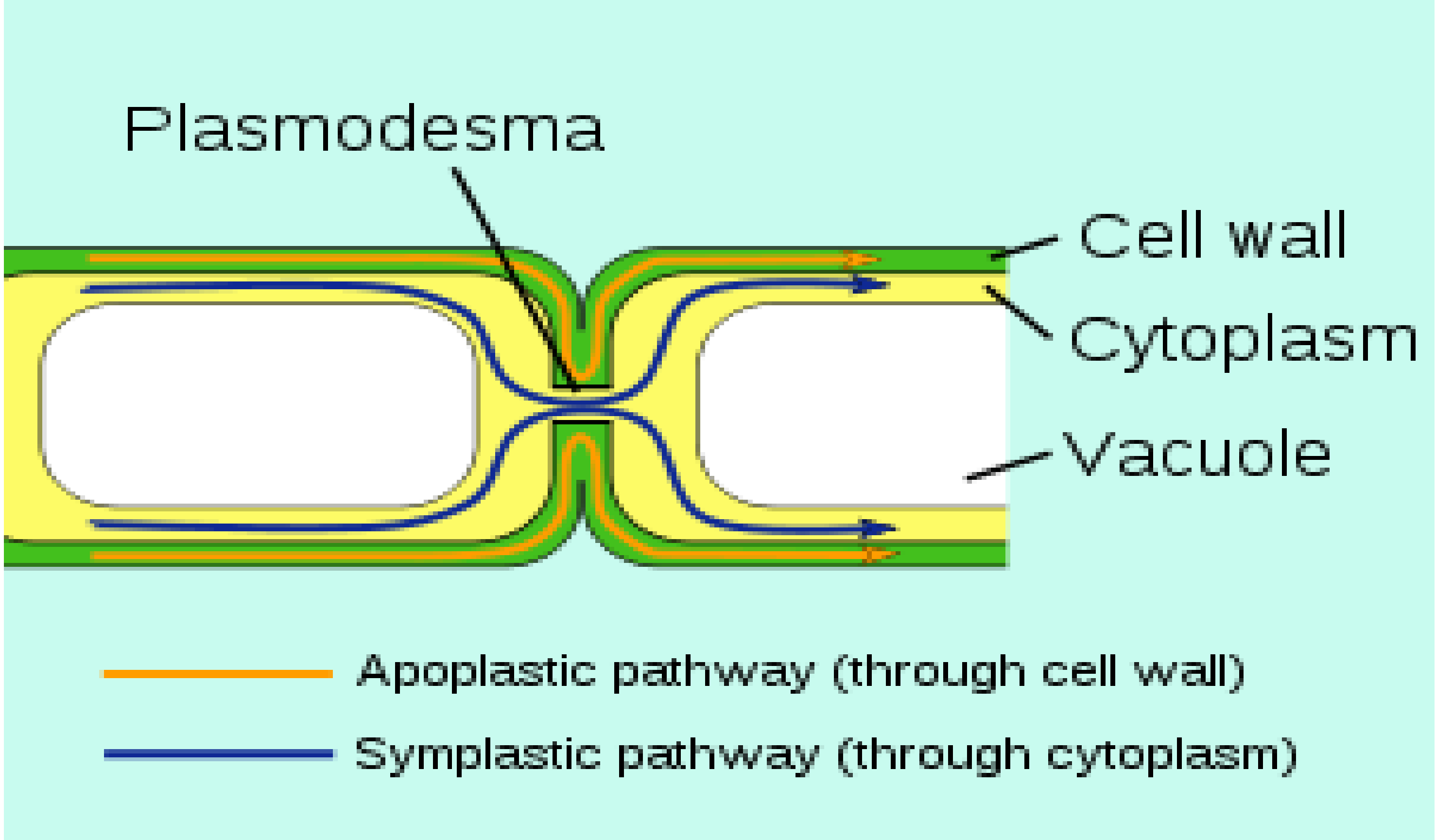
- Nucleus: The nucleus is generally spherical. The nucleus contains thread- like structures called chromosomes which carry genes. The function of the nucleus is to maintain the integrity of these genes and to control the activities of the cell by regulating gene expression—the nucleus is, therefore, the control center of the cell.
- The main structures making up the nucleus are the nuclear envelope, a double membrane that encloses the entire organelle and isolates its contents from the cellular cytoplasm, the nucleolus and nuclear pores.
- Nuclear pores regulate the transport of molecules across the envelope. The nucleolus is a smaller spherical body in the nucleus.

- CELL MEMBRANE: The cytoplasm and the nucleus and other parts of the cell are enclosed within the cell membrane which separates cell from one another and also the cell from the surrounding medium. The membrane is porous and allows the movement of substances or materials both inward and outward.

- Cell wall: The cell wall is a very tough, flexible and sometimes fairly rigid layer that surrounds plant cells. It surrounds the cell membrane and provides these cells with structural support and protection.
- In addition the cell wall is acting as a filtering mechanism. A major function of the cell wall is to act as a pressure vessel, preventing over-expansion when water enters the cell.

- Plasmodesmata are microscopic channels which allow molecules to travel between plant cells. Neighboring plant cells are separated by a pair of cell walls, forming an extracellular domain known as the apoplast. Although cell walls allow small soluble proteins and other solutes to pass through them, Plasmodesmata enable direct, regulated, symplastic intercellular transport of substances between cells.

- Enable transport (proteins, nutrients) and communication.


Plasmodesma
Cell wall
Cytoplasm
Vacuole
Apoplastic pathway (through cell wall)
Symplastic pathway (through cytoplasm)

Formation

- Plasmodesmata are formed when portions of the endoplasmic reticulum are trapped across the middle lamella as new cell wall is laid down between two newly divided plant cells and these eventually become the cytoplasmic connections between cells (primary plasmodesmata). Here the wall is not thickened further, and depressions or thin areas known as pits are formed in the walls. Pits normally pair up between adjacent cells. Alternatively, plasmodesmata can be inserted into existing cell walls between non-dividing cells (secondary plasmodesmata)

- A typical plant cell may have between 10^3 and 10^5 plasmodesmata connecting it with adjacent cells, equating to between 1 and 10 per μm^2. Plasmodesmata are approximately 50-60 nm in diameter at the mid-point and are constructed of three main layers, the plasma membrane, the *cytoplasmic sleeve*, and the *desmotubule*. They can transverse cell walls that are up to 90 nm thick.

- The filamentous cytoskeleton is a network of fibers composed of proteins contained within a cell's cytoplasm.
- It is a dynamic structure, parts of which are constantly destroyed, renewed or newly constructed.
- It gives the cell shape and mechanical resistance to deformation, it stabilizes entire tissues, it can actively contract, thereby deforming the cell and the cell's environment and allowing cells to migrate, it divides chromosomes. It is involved in the division of a mother cell into two daughter cells etc.

- Microtubules are thick, they consist of straight, hollow tubes made from globular proteins forming a spiral tube. They have an important role in the cilia, flagella and centrioles.

- Lysosomes are tough membranous bags which contain digestive enzymes. They have been called ‘suicide bags’ because they could potentially digest the cell itself.

- The endoplasmic reticulum consists of a network of tubes. These form fluid-filled spaces surrounded by membranes. In most cells the spaces seem to be inter connected. The ER acts as a transport system, the synthesis of certain compounds takes place on the membranes.
- Smooth ER: The smooth ER has a smooth outer surface on it. It plays a role in lipid synthesis, produces steroids.
- Rough ER: Rough ER is especially numerous in cells that secrete proteins. It is used to secrete proteins.

- Golgi bodies consist of a stack of flat disc like membranous sacs. These sacs are called cisternae. The Golgi apparatus is like a manufacturing warehouse, plus sorting and shipping.
- Here the products of the endoplasmic reticulum are stored, then modified by having other molecules attached to the proteins, and finally are sent out to their destinations.

- Ribosomes are the site of protein synthesis. Ribosomes are made out of protein and RNA. They function in 2 places: Some are free in the cytoplasm. Others are attached to the outer membrane of the endoplasmic reticulum (ER). These are known as bound Ribosomes. The free Ribosomes tend to make proteins for use inside the cell cytoplasm.
- However the bound Ribosomes tend to make proteins to be secreted by the cell or used in membranes.

- Mitochondria convert energy from food into a form that a cell can use ATP (adenosine triphosphate). It is the site of aerobic respiration. The mitochondria consists of a double membrane. Each membrane is a phospholipid bilayer with particular proteins embedded on it.

- Plants have a large central vacuole. This is usually filled with an aqueous solution of ions. Vacuoles are prominent in plants and function in storage, waste disposal and growth.
- They provide a place to store organic compounds and non organic ions.
- The vacuole contains the enzymes usually held by the Lysosomes.

- Some store metabolic wastes that would be poisonous to the cell.
- Some vacuoles contain the pigments that colour the petals of flowers or the stems of plants.
- Some store poisons as a defence against a herbivore eating them.

- Plastids are membrane bound structures which includes the green chloroplasts that carry out photosynthesis. There are three different types of plastids, they are:
- Leucoplasts – these are starch stored plastids.
- Chromoplasts – these contain pigments of colour which then give the colour to flowers etc.
- Chloroplasts – these are large, oval shaped organelles. They are found in the green parts of plants and are the site of photosynthesis.

- A chloroplast is a specialized plastid which contains the green pigment chlorophyll. They contain dense stacks of membranes (grana) within a colourless stroma. Chloroplasts are the site for photosynthesis and occur mainly in leaves.

Plant Cell wall

- The **cell wall** is the tough, usually flexible but sometimes fairly rigid layer that surrounds some types of cells. It is located outside the cell membrane and provides these cells with structural support and protection, and also acts as a filtering mechanism. A major function of the cell wall is to act as a pressure vessel, preventing over-expansion when water enters the cell. They are found in plants, bacteria, fungi, algae, and some archaea. Animals and protozoa do not have cell walls.

- The material in the cell wall varies between species, and can also differ depending on cell type and developmental stage. In plants, the strongest component of the complex cell wall is a carbohydrate called cellulose, which is a polymer of glucose.
- In bacteria, peptidoglycan forms the cell wall. Archaean cell walls have various compositions, and may be formed of glycoprotein S-layers, pseudopeptidoglycan, or polysaccharides.
- Fungi possess cell walls made of the glucosamine polymer chitin, and algae typically possess walls made of glycoproteins and polysaccharides. Unusually, diatoms have a cell wall composed of silicic acid.

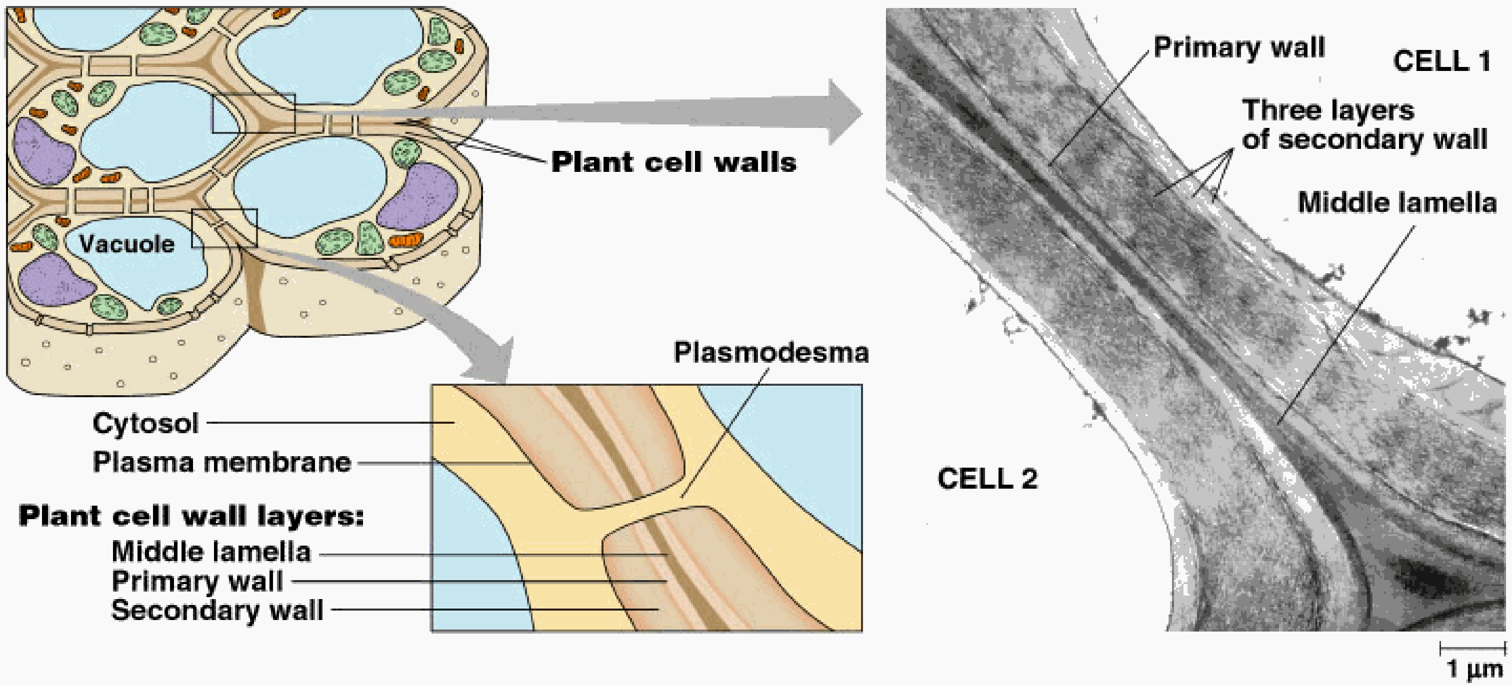


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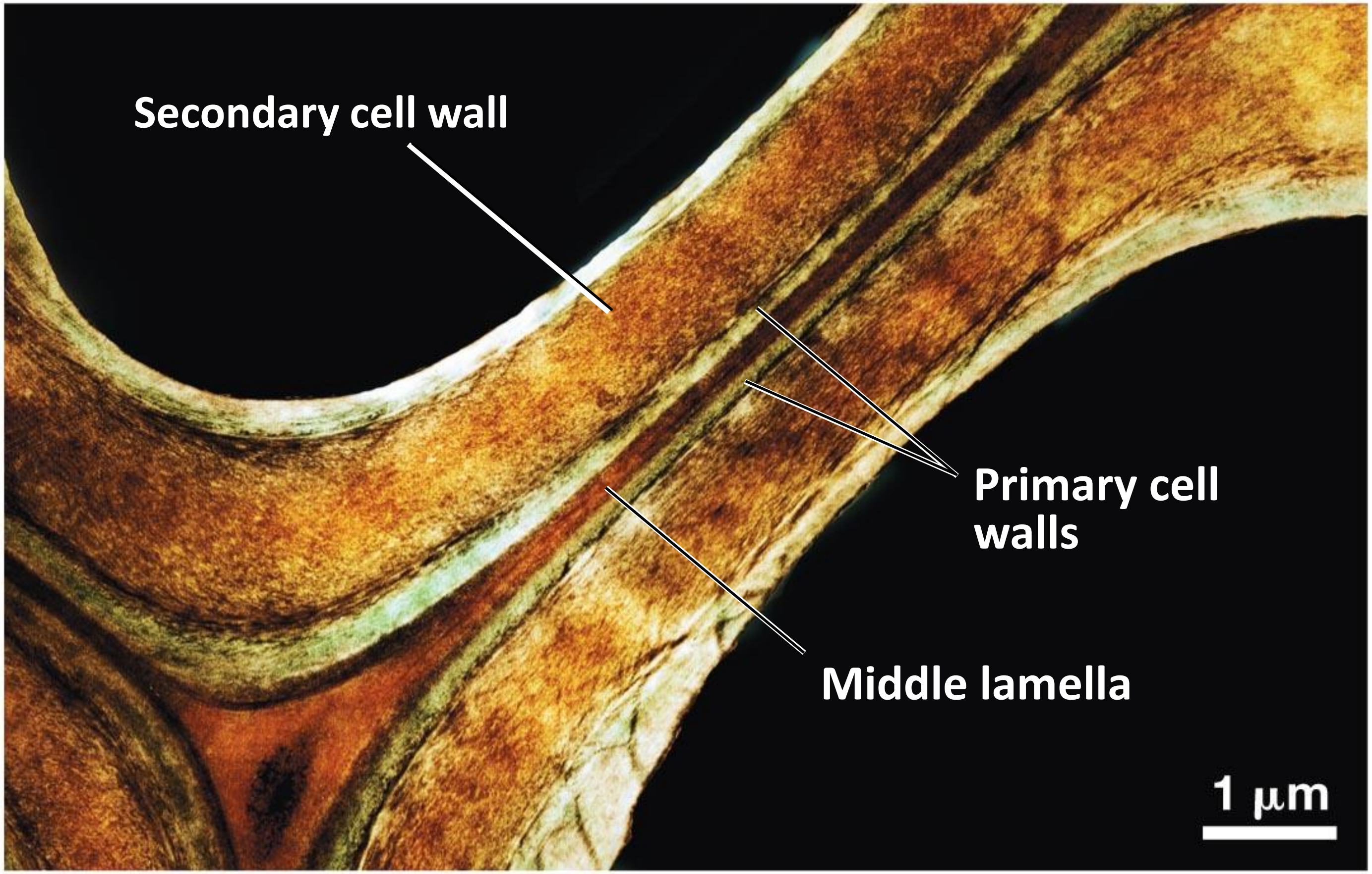
Figure 8-9



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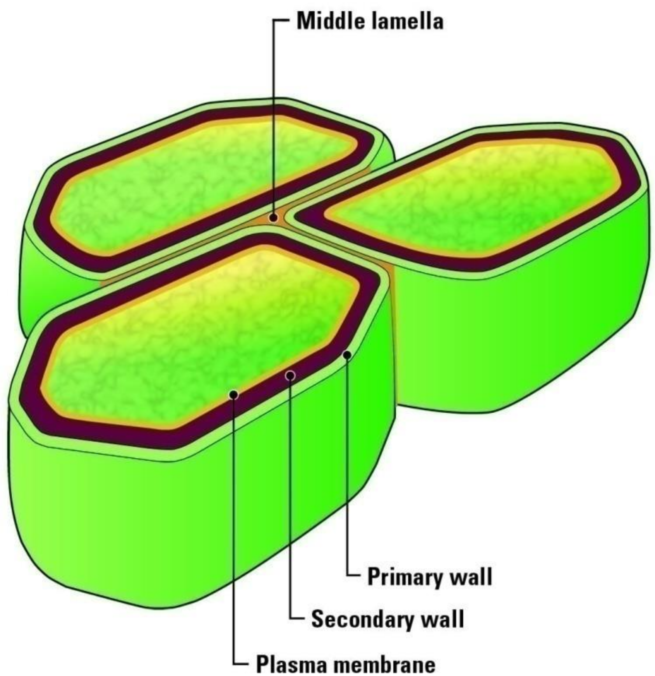
Cell walls consist of 3 types of layers

Middle lamella is formed during cell division. It makes up the outer wall of the cell and is shared by adjacent cells. It is composed of pectic compounds and protein.

Primary wall: This is formed after the middle lamella and consists of a skeleton of cellulose microfibrils embedded in a gel-like matrix of pectic compounds, hemicellulose, and glycoproteins.

Secondary wall: formed after cell enlargement is completed provides compression strength. It is made of cellulose, hemicellulose and lignin. The secondary wall is often layered.


Middle lamella
Primary wall
Secondary wall
Plasma membrane

Properties

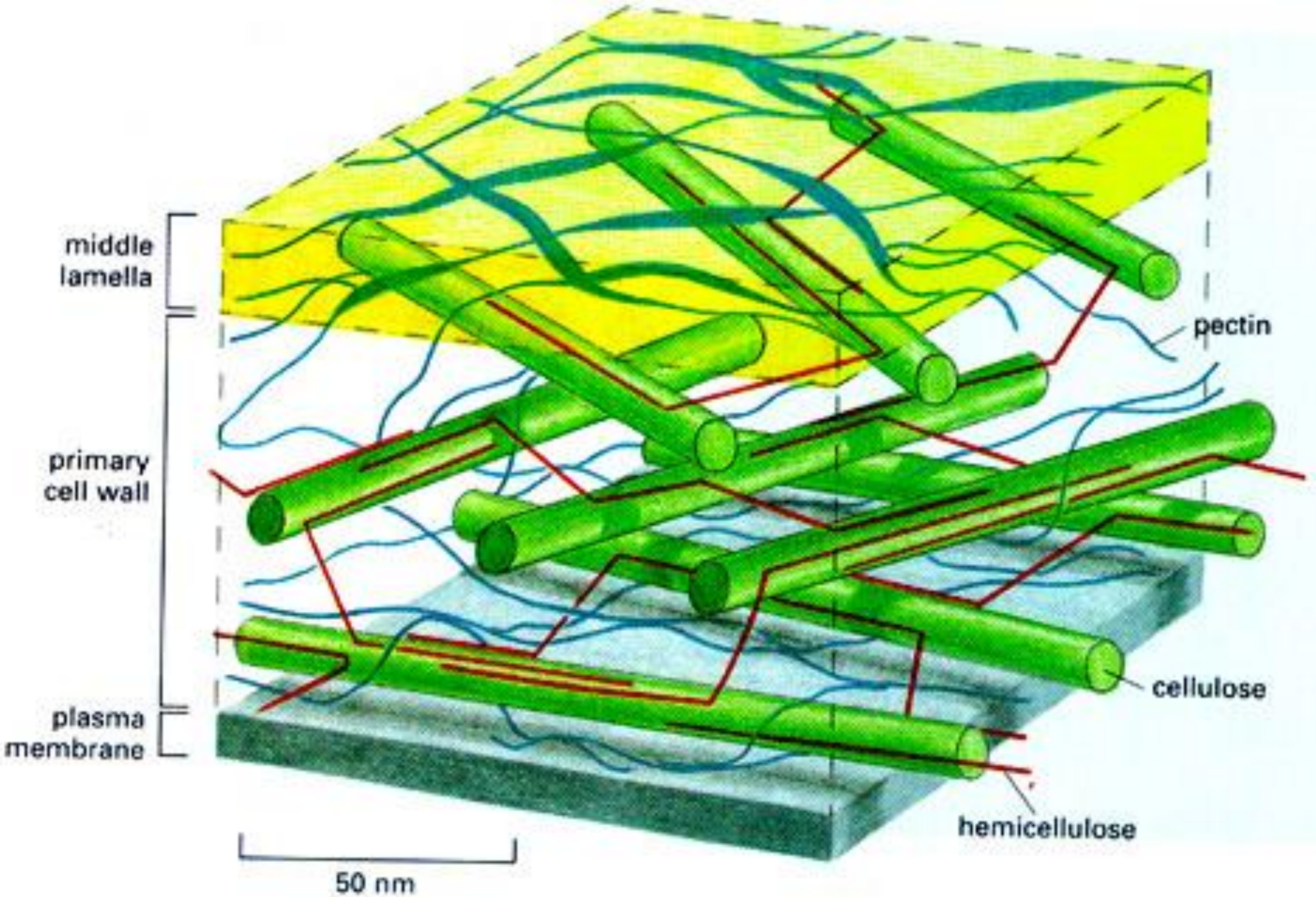
- The wall gives cells rigidity and strength, offering protection against mechanical stress. In multicellular organisms, it permits the organism to build and hold its shape (morphogenesis). The cell wall also limits the entry of large molecules that may be toxic to the cell. It further permits the creation of a stable osmotic environment by preventing osmotic lysis and helping to retain water. The composition, properties, and form of the cell wall may change during the cell cycle and depend on growth conditions.

- Functions:
- Mechanical functions
- - Like a skeleton around each cell
- – Determine shape and size of cell
- – Determines the limits of expansion and water uptake
- Metabolic Activity
- - Receives signals such as hormones.
- – Wall signals transmitted through plasmalemma and into cytoplasm,
- -biochemical response
- Absorption or secretion – root hairs, rhizoids.

- The cell walls vary much in thickness in relation to age and type of cells.
- Young cells have thinner cell walls than the fully developed ones.
- The cell wall is complex in its structure and usually consists of three layers:
- Primary cell wall (usually consists of one layer)
- Intercellular substance (middle lamella) cements together primary wall of two adjacent cells. Secondary cell wall (made up of one- many layers , frequently three)

- Up to three layers may be found in plant cell walls
- The **middle lamella**, a layer rich in pectins. This outermost layer forms the interface between adjacent plant cells and glues them together.
- The **primary cell wall**, generally a thin, flexible and extensible layer formed while the cell is growing (Cellulose, hemicellulose and pectin).
- The **secondary cell wall**, a thick layer formed inside the primary cell wall after the cell is fully grown. It is not found in all cell types. In some cells, such as found xylem, the secondary wall contains lignin, which strengthens and waterproofs the wall (Cellulose, hemicellulose and lignin).

- Middle lamella: It is a common structure between adjacent cells and therefore, binds them with each other
- It is an amorphous layer and is composed of calcium and magnesium pectate
- The middle lamella remains unlignified in case of softer living tissues namely Parenchyma, collenchyma, but in woody tissues Sclerenchyma it becomes highly lignified


middle
lamella
primary
cell wall
plasma
membrane
pectin
cellulose
hemicellulose
50 nm

- Primary cell wall: Consists of cellulose (45%), hemicellulose (25%), pectins (35%) and structural proteins (upto 8%) on the basis of dry weight
- The primary wall is thin and elastic
- It is capable of growth and expansion
- The backbone of the primary wall is formed by the cellulose fibrils.
- The matrix is composed of hemicellulose, pectin, gums, tannins, resins, silica, waxes etc. and small structured proteins

- Primary Cell Wall: (Three major polysaccharides)
- Cellulose (linear polymer of β- 1,4 linked glucose)
- Several chains associate in parallel with one another form cellulose microfibrils.
- Within the cell wall cellulose microfibrils embedded in a matrix consisting of proteins and other types of polysaccharides –
- Hemicellulose (highly branched long chains of glucose)

- Microfibrils are coated with the fibrous hemicellulose, xyloglucan
- Hydrogen bonds with cellulose
- Xyloglucan is, in turn, chemically bonded to another hemicellulose that serves as a cross-link between pectin molecules.

- Pectin:
- Cellulose and hemicellulose embedded in.
- Form a separate network that interdigitates with the cellulose-hemicellulose network. middle lamella (region between cells) is composed of pectin- glues cells together - Hydrophilic = holds up to 65% water in primary walls - function in Cell adhesion, regulate porosity

- Proteins:
- Structural and enzymes (10% dry weight) Peroxidases, cellulases, pectinases, phosphotases
- Hydroxyproline rare amino acid found in plasma membrane bounded to polysaccharides of the wall forming glycoproteins rich proteins
- Function :-wall expansion - Involved in growth and development

- Lipids
- Cutin -Found in cuticle and walls of epidermal cells
- Suberin - Important for waterproofing cork cells (periderm)
- Also found in Casparian strips of endodermis - Waxes

- The primary cell wall -Thinner than secondary wall
- -Cellulosic microfibrils randomly arranged. -Found in parenchyma cells in mesophyll of leaf, storage parenchyma of roots and tubers.
- -the primary may become thick as in collenchyma cells in stems , leaves and endosperms of some seeds
- - thickening because of increase in amount of cellulose and noncellulosic components and water.

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functions of the primary wall

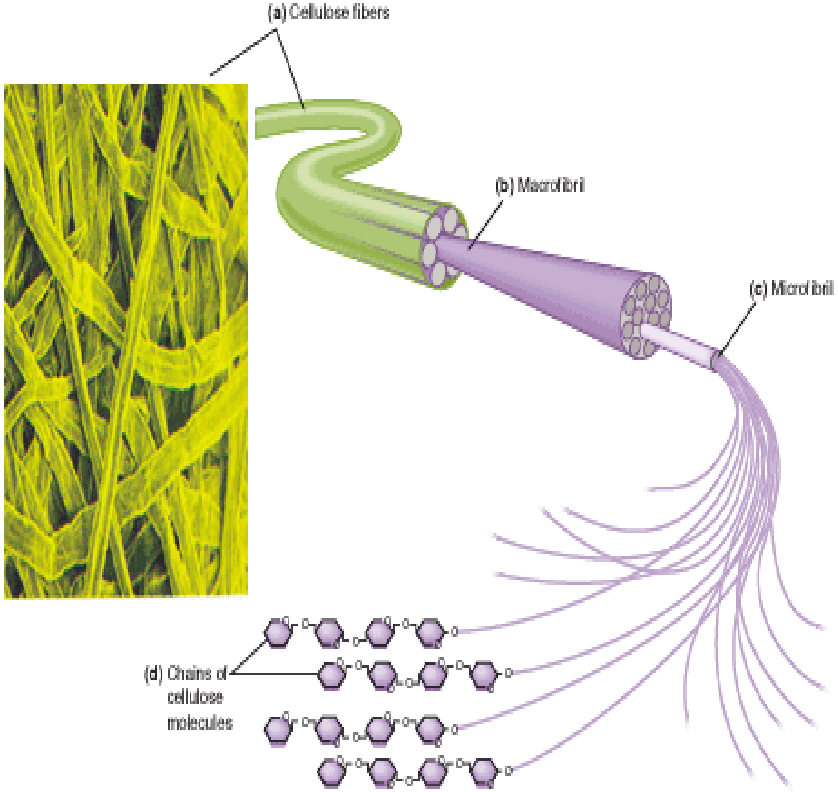
- Structural and mechanical support.
- maintain and determine cell shape.
- resist internal turgor pressure of cell.
- control rate and direction of growth.
- regulate diffusion of material through the apoplast.
- protect against pathogens, dehydration, and other environmental factors.
- source of biologically active signalling molecules.
- cell-cell interactions.

Cellulose

- It has a very high molecular weight
- It is a linear polymers of glucose molecules
- The cellulose fibrils are about 0.16 µm2 wide and up to 1 µm long
- Each fibril is made up of 250 microfibrils.
- Each microfibril composed of about 20 micelles Each micelle is made up of 2000 to 25000 individual cellulose molecules
- The microfibrills arranged in the form of loose mat These give maximum tensile strength to the wall

Cellulose

- Synthesized at the plasma membrane
- Synthesized by Cellulose synthase
- A (1,4)-ß-linked glucan
- Major component of parental cell wall
- Minor concentration in cell plate
- Replaces callose from the TN stage



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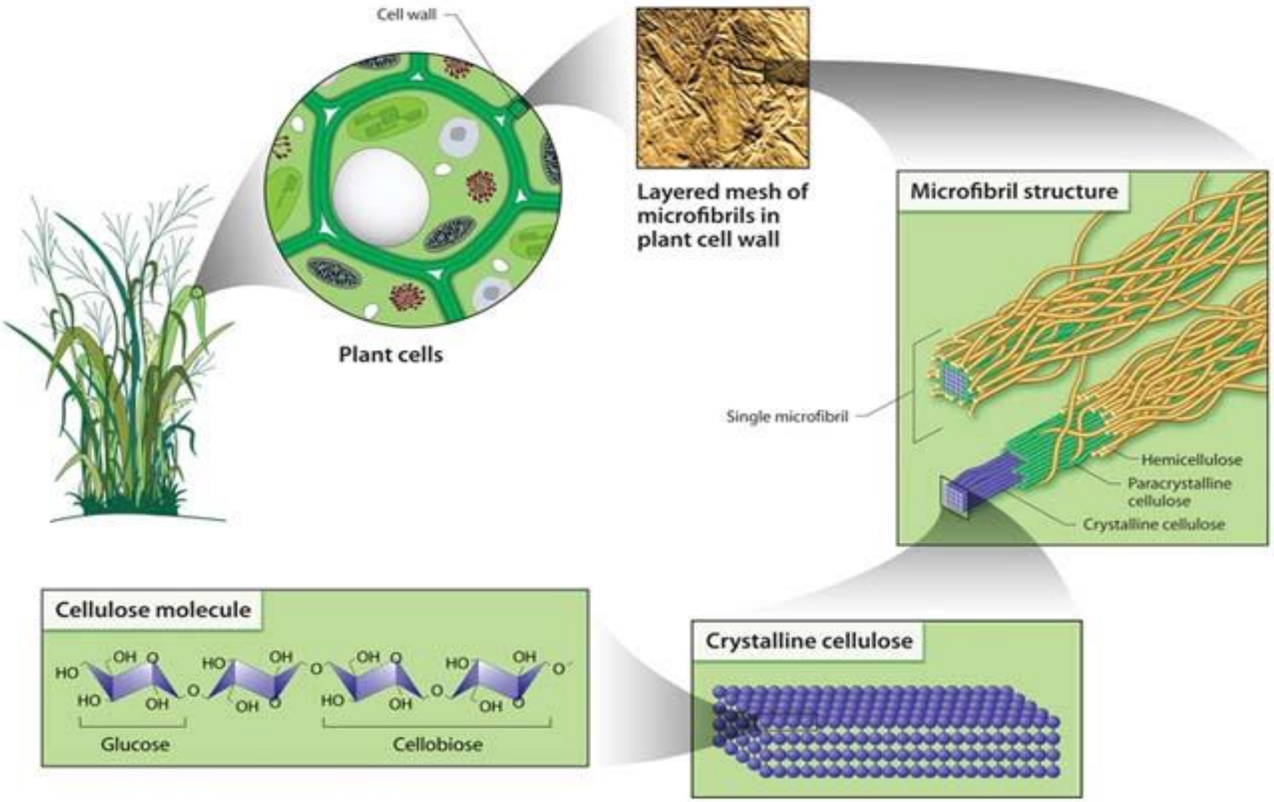
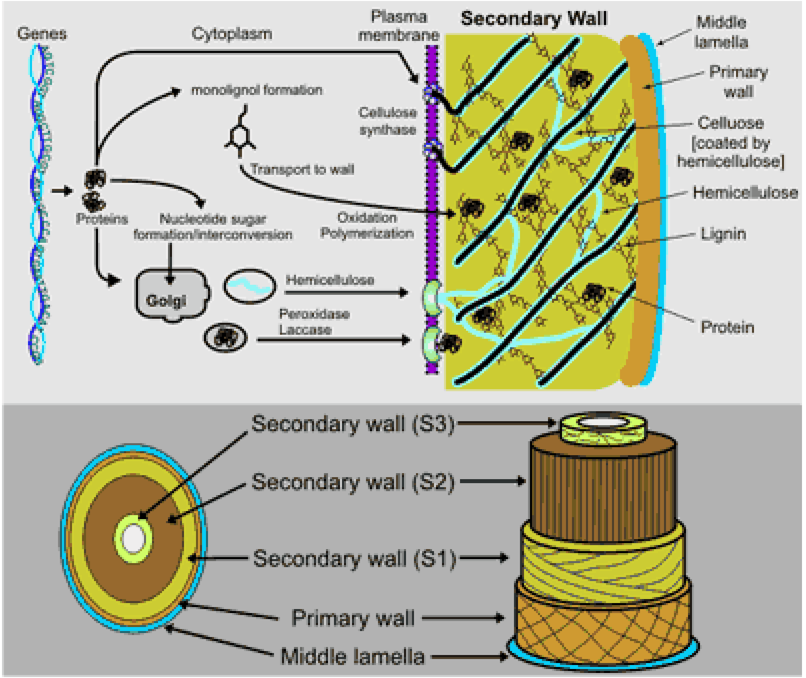

Cell wall
Plant cells
Layered mesh of microfibrils in plant cell wall
Microfibril structure
Single microfibril
Hemicellulose
Paracrystalline cellulose
Crystalline cellulose
Cellulose molecule
HO
OH
O
HO
OH
O
HO
OH
OH
O
Glucose
Cellobiose
Crystalline cellulose

- Secondary cell wall
- - wall is very thick (lignin), rigid and inelastic and consists of three layers known as S1 (outer), S2 (middle)and S3 (inner)
- The microfibrils in these layers run parallel to each other but the directions are different in three layers
- The microfibrils are transversely arranged in the S3 and are at an angle of 10 -200 to the longitudinal axis in S2 and are at the angle of 500 in S1
- The lignin is formed from three different phenyl propanoid alcohols: coniferyl, coumaryl and sinapyl alcohols
- Lignin is covalently bonded to cellulose and other polysaccharides of cell wall.

Secondary cell wall:

- Frequently made of three layers
- S1
- S2: the thickest and
- S3: may be very thin or lacking, some times called tertiary wall
- Because the different orientations of cellulose microfibrils in the three layers which are helically oriented but with different slopes
- impregnated with lignin, which replaces pectin
- – Lignin is Polyphenol that strengthens the wall, makes it waterproof and resistant to decay



Genes
Cytoplasm
Plasma membrane
Secondary Wall
Middle lamella
Primary wall
monolignol formation
Cellulose synthase
Celluose [coated by hemicellulose]
Transport to wall
Hemicellulose
Proteins
Nucleotide sugar formation/interconversion
Oxidation Polymerization
Lignin
Golgi
Hemicellulose
Peroxidase Laccase
Protein
Secondary wall (S3)
Secondary wall (S2)
Secondary wall (S1)
Primary wall
Middle lamella

- In the primary (growing) plant cell wall, the major carbohydrates are cellulose, hemicellulose and pectin. The cellulose microfibrils are linked via hemicellulosic tethers to form the cellulose-hemicellulose network, which is embedded in the pectin matrix. The most common hemicellulose in the primary cell wall is xyloglucan.

- Primary and secondary walls contain cellulose, hemicellulose and pectin, in different proportions. Approximately equal amounts of pectin and hemicellulose are present in dicot primary walls whereas hemicellulose is more abundant in grasses (e.g., switchgrass).
- The secondary walls of woody tissue and grasses are composed predominantly of cellulose, lignin, and hemicellulose (xylan, glucuronoxylan, arabinoxylan, or glucomannan).

- The cellulose fibrils are embedded in a network of hemicellulose and lignin. Cross-linking of this network is believed to result in the elimination of water from the wall and the formation of a hydrophobic composite that limits accessibility of hydrolytic enzymes and is a major contributor to the structural characteristics of secondary walls.

- Secondary walls are mainly found in tracheary elements (tracheids in seedless vascular plants and gymnosperms and vessels in angiosperms) and fibers in the primary xylem and the secondary xylem (wood)
- They provide mechanical strength to these cell types, which serve as mechanical tissues to enable vascular plants to grow to a great height.
- Deposition of lignified secondary walls in tracheary elements not only reinforces these water conduits to resist the negative pressure generated during transpiration, but also renders them water-proof for efficient water transport

- The major components of secondary walls are cellulose, hemicelluloses (xylan and glucomannan) and lignin.
- Cellulose is the load-bearing unit, in which cellulose microfibrils cross-link with hemicelluloses to form the framework of secondary walls.
- Hemicelluloses, such as xylan, are required for the normal assembly and mechanical strength of secondary walls; reduction in xylan content causes a severe decrease in cellulose deposition, secondary wall thickening and mechanical strength of vessels and fibers

- The composition of secondary walls, i.e. the proportion of cellulose, hemicelluloses and lignin, may vary among different plant species and even in different secondary wall-containing cell types of the same species.
- For example, wood from a gymnosperm species (*Pinus strobus*) consists of 41% cellulose, 9% arabinoglucuronoxylan, 18% galactoglucomannan and 29% lignin
- whereas wood from an angiosperm species (*Populus tremuloides*) contains 48% cellulose, 24% glucuronoxylan, 3% glucomannan and 21% lignin

- Xylan, which accounts for up to 30% of the mass of the secondary walls in wood and grasses contributes to the recalcitrance of these walls to enzymic degradation. A high xylan content in wood pulp increases the economic and environmental costs of bleaching in paper manufacturing. Thus, reducing the xylan content of secondary walls and altering xylan structure, molecular weight, ease of extractability, and susceptibility to enzymic fragmentation are key targets for the genetic improvement of plants. However, progress in these areas is limited by our incomplete understanding of the mechanisms of xylan biosynthesis.

- **Pectin**
- - polymer of around 200 galacturonic acid molecules
  - many of the carboxyl groups are methylated ($COOCH_3$)
- **Cellulose**: polymer of glucose - typically consisting of 1,000 to 10,000 beta-D-glucose residues

- Cellulose polymers associate through H-bonds. The H-bonding of many cellulose molecules to each other results in the formation of **micro fibers** and the micro fibers can interact to form **fibers**. Certain cells, like those in cotton ovules, can grow cellulose fibers of enormous lengths.

- **Hemicellulose** is a polysaccharide composed of a variety of sugars including xylose, arabinose, mannose. Hemicellulose that is primarily xylose or arabinose are referred to as xyloglucans or arabinoglucans, respectively.
- Hemicellulose molecules are often branched. Like the pectic compounds, hemicellulose molecules are very hydrophilic. They become highly hydrated and form gels. Hemicellulose is abundant in primary walls but is also found in secondary walls.

- The outer part of the primary cell wall of the plant epidermis is usually impregnated with cutin and wax, forming a permeability barrier known as the plant cuticle.
- Secondary cell walls contain a wide range of additional compounds that modify their mechanical properties and permeability. The major polymers that make up wood (largely secondary cell walls) include:
- cellulose, 35-50%
- xylan, 20-35%, a type of hemicellulose
- lignin, 10-25%, a complex phenolic polymer that penetrates the spaces in the cell wall between cellulose, hemicellulose and pectin components, driving out water and strengthening the wall.

- Additionally, structural proteins (1-5%) are found in most plant cell walls; they are classified as hydroxyproline-rich glycoproteins (HRGP), arabinogalactan proteins (AGP), glycine-rich proteins (GRPs), and proline-rich proteins (PRPs).
- Cell walls of the epidermis and endodermis may also contain suberin or cutin, two polyester-like polymers that protect the cell from herbivores.[

- The relative composition of carbohydrates, secondary compounds and protein varies between plants and between the cell type and age.
- Plant cells walls also contain numerous enzymes, such as hydrolases, esterases, peroxidases, and transglycosylases, that cut, trim and cross-link wall polymers.

Difference

Primary	Secondary
In all cells	In mature and non diving Cells
Elastic and thinner	Inelastic, rigid and thicker
Pits Absent	Present
cellulose Low	High
fibrils Wavy and loosely arranged	Closely, straight and parallel
Hydration More (60%)	Less (30 -40%)

Algal cell walls

- Like plants, algae have cell walls. Algal cell walls contain either polysaccharides (such as cellulose (a glucan)) or a variety of glycoproteins (Volvocales) or both. The inclusion of additional polysaccharides in algal cells walls is used as a feature for algal taxonomy.
- Mannans: They form microfibrils in the cell walls of a number of marine green algae including those from the genera, *Codium*, *Dasycladus*, and *Acetabularia* as well as in the walls of some red algae, like *Porphyra* and *Bangia*.
- Xylans:
- Alginic acid: It is a common polysaccharide in the cell walls of brown algae.
- Sulfonated polysaccharides: They occur in the cell walls of most algae; those common in red algae include agarose, carrageenan, porphyran, furcelleran and funoran.

Fungal cell wall

- Most true fungi have a cell wall consisting largely of chitin and other polysaccharides. True fungi do not have cellulose in their cell walls, but some fungus-like organisms do.

- Not all species of fungi have cell walls but in those that do, the plasma membrane is followed by three layers of cell wall material. From inside out these are:

- a chitin layer (polymer consisting mainly of unbranched chains of N-acetyl-D-glucosamine)
- a layer of β-1,3-glucan (zymosan)
- a layer of mannoproteins (mannose-containing glycoproteins) which are heavily glycosylated at the outside of the cell.

- a chitin layer (polymer consisting mainly of unbranched chains of N-acetyl-D-glucosamine)
- a layer of β-1,3-glucan (zymosan)
- a layer of mannoproteins (mannose-containing glycoproteins) which are heavily glycosylated at the outside of the cell.

- Thank You