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Programme: M.Sc., Biochemistry
Course Title : Cell biology
Course Code :BC105DCE

Unit-2
CELL ORGANELLES

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Content

- Nucleus
- Mitochondria
- Microbodies
- Peroxisomes
- lysosomes
- Endoplasmic Reticulum
- Golgi apparatus
- Plastids
- Chloroplast
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- Centrosomes
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Organelles bounded by Double membrane Envelopes

Nucleus:

- Nucleus was discovered by Scottish botanist and paleobotanist Robert Brown in 1831
- Discovery of the Nucleus, a lecture-demonstration published in Linnean Society, 5 November
- The cell nucleus is a membrane-bound structure that contains the cell's hereditary information and controls the cell's growth and reproduction
- It is the command center of a eukaryotic cell and is commonly the most prominent organelle in a cell accounting for about 10 percent of the cell's volume
- In general, a eukaryotic cell has only one nucleus. However, some eukaryotic cells are enucleated cells (without a nucleus), for example, red blood cells (RBCs); whereas, some are multinucleate (consists of two or more nuclei), for example, slime molds

- The nucleus is separated from the rest of the cell or the cytoplasm by a nuclear membrane
- As the nucleus regulates the integrity of genes and gene expression, it is also referred to as the control center of a cell
- nuclear envelope composed of two membranes: inner and outer nuclear membranes
- They are separated by a perinuclear space measuring about 20–40 nm across
- outer nuclear membrane is continuous with the endoplasmic reticulum, making the perinuclear space continuous with the lumen of the ER

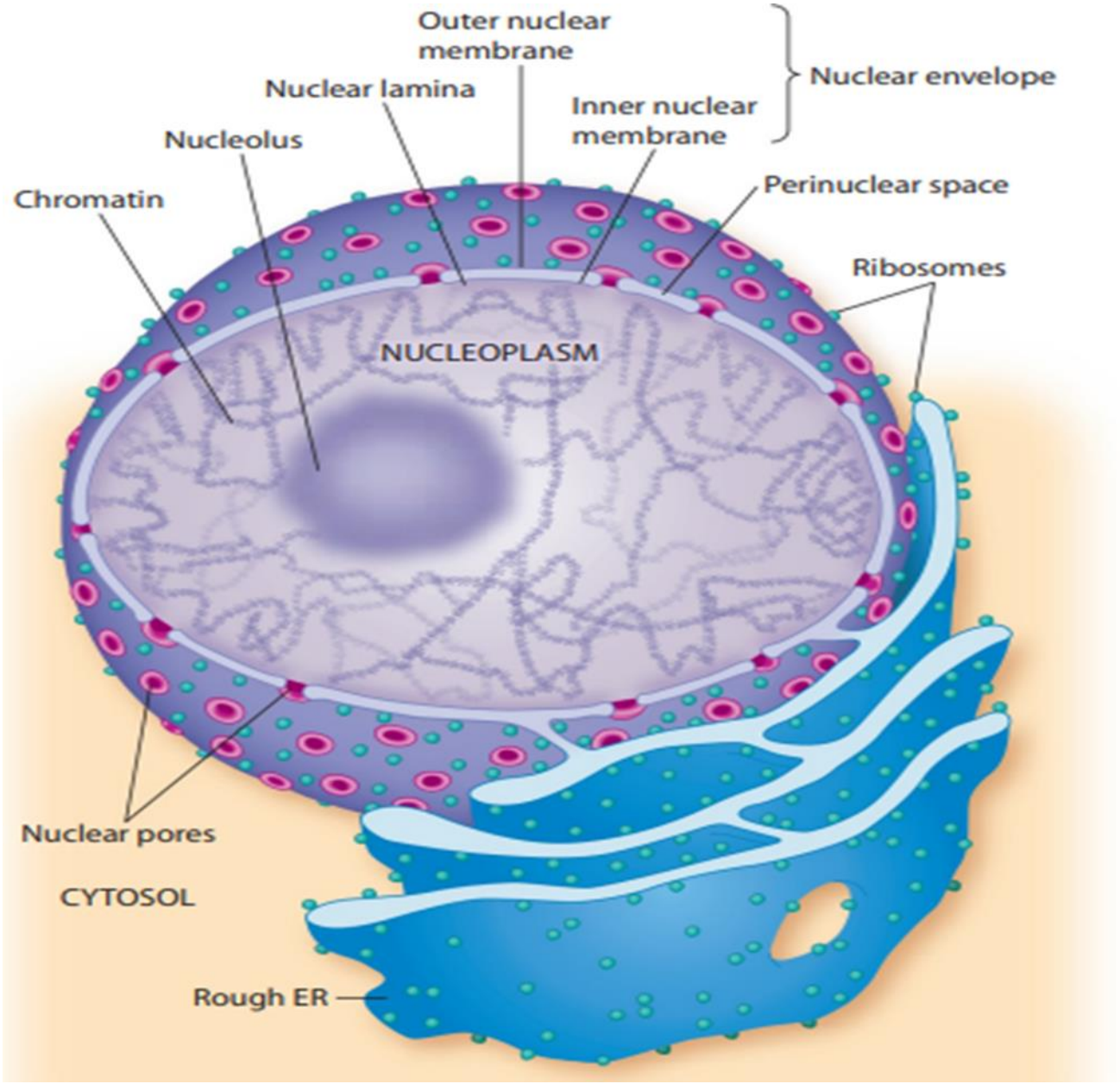


Figure:Becker's World of the Cell NINTH EDITION

- outer membrane of ER is studded on its outer surface with ribosomes engaged in protein synthesis
- Nuclear pore are specialized channels present in the nucleus envelop
- **Figure:Negative staining of an oocyte nuclear envelope reveals the octagonal pattern of the nuclear pore complexes**
- mammalian nucleus has about 3000–4000 pores, or about 10–20 pores per square micrometer of membrane surface area
- At each pore, the inner and outer membranes of the nuclear envelope are fused together, forming a channel that is lined with an intricate protein structure called the nuclear pore complex (NPC)

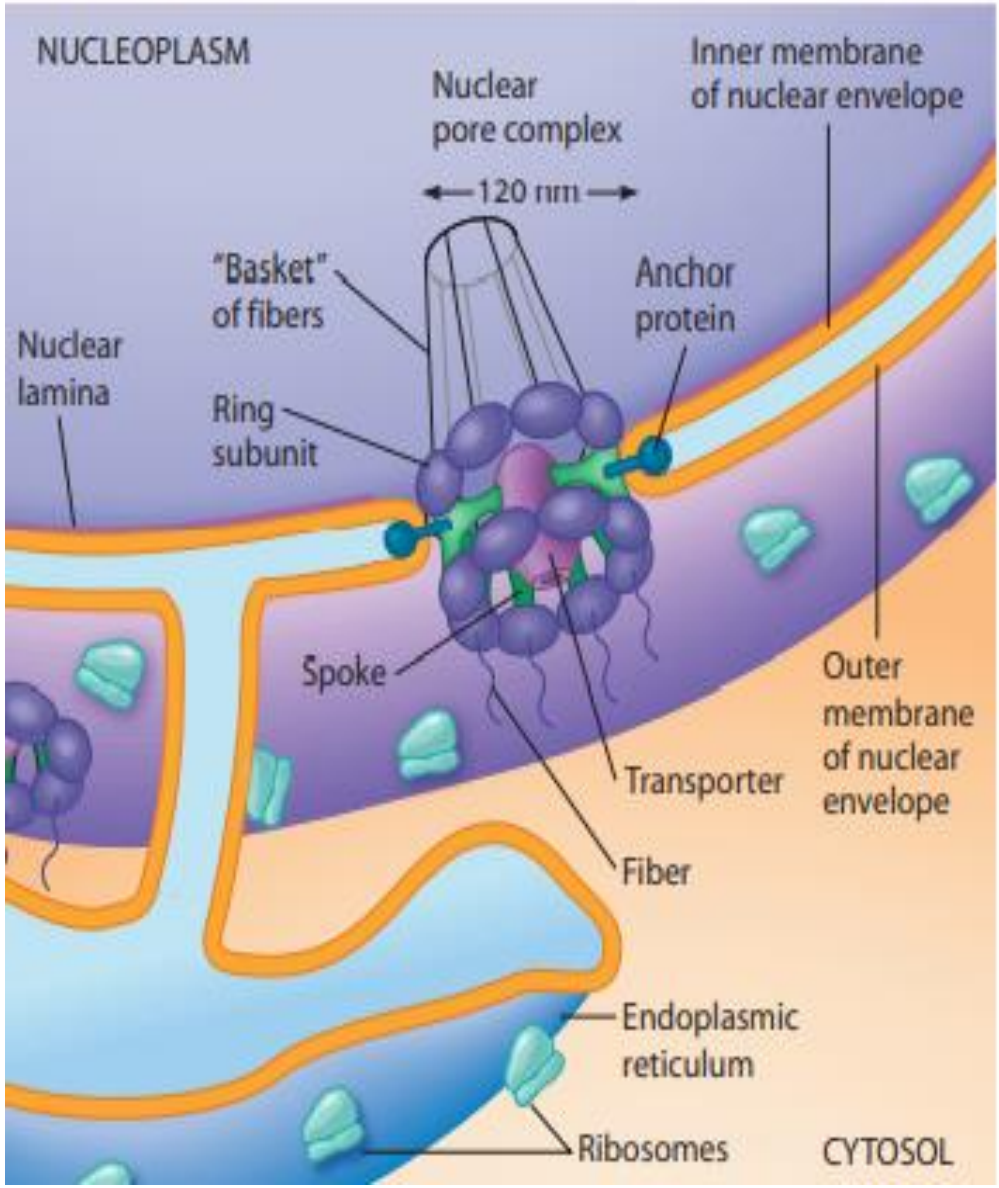


Figure:Becker's World of the Cell NINTH EDITION

Molecules Enter and Exit the Nucleus Through Nuclear Pores

- All the enzymes and other proteins required for chromosome replication and transcription of DNA in the nucleus must be imported from the cytosol,
- all the RNA molecules and partially assembled ribosomes needed for protein synthesis in the cytosol must be obtained from the nucleus
- An actively growing mammalian cell can easily be synthesizing 20,000 ribosomal subunits/min
- cell has about 3000–4000 nuclear pores, so ribosomal subunits must be transported to the cytosol at a rate of about five to six subunits per minute per pore

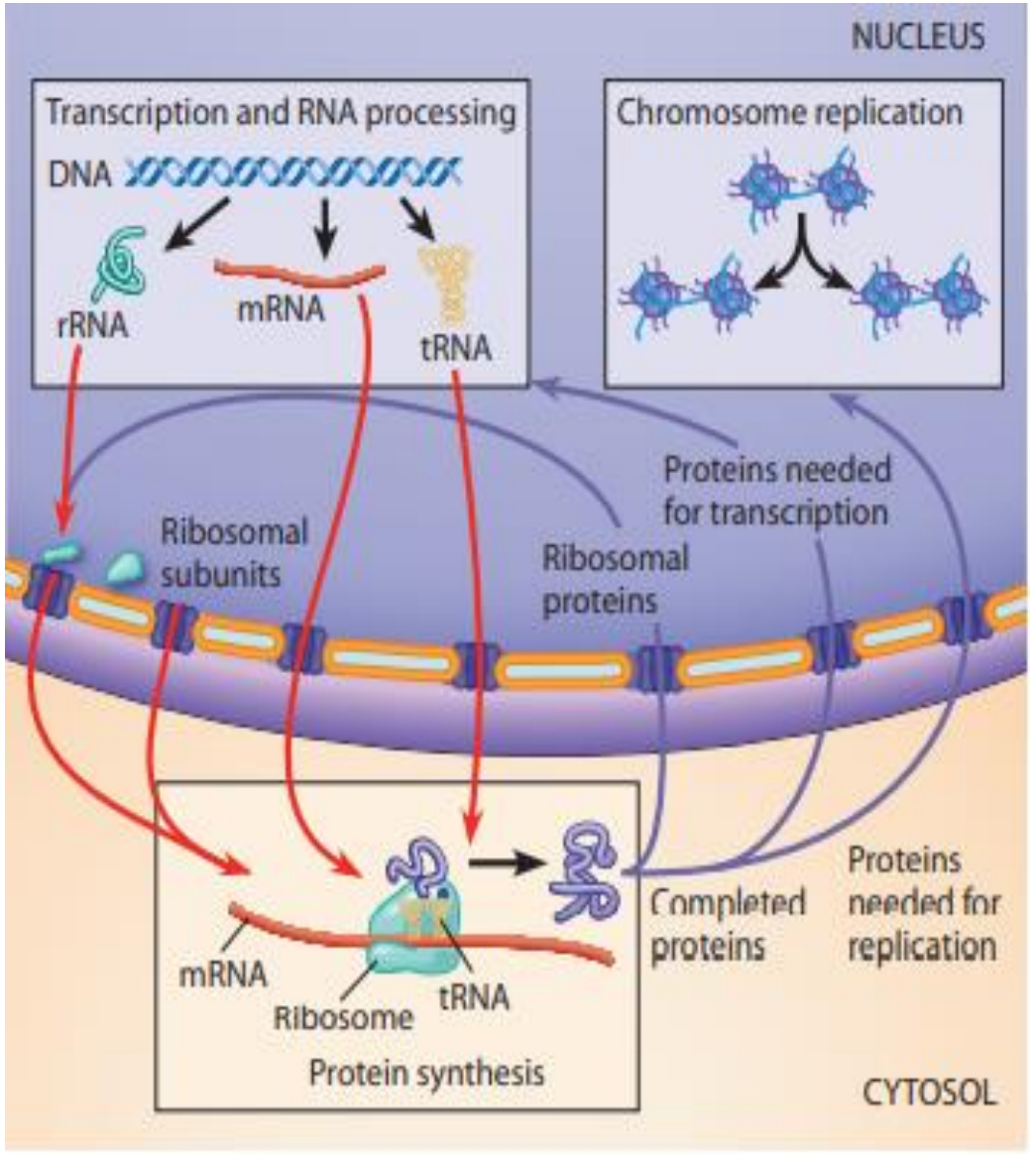


Figure:Becker's World of the Cell NINTH EDITION

- When chromosomes are being replicated, histones are needed at the rate of about 300,000 molecules per minute
- The rate of inward movement must be about 100 histone molecules per minute per pore
- In addition to all this macromolecular traffic, the pores mediate the transport of smaller particles, molecules, and ions

Other transport mechanisms:

1. Simple Diffusion of Small Molecules Through Nuclear Pores

- Maximum diameter 9 nm for simple diffusion

1. Active Transport of Large Proteins and RNA Through Nuclear Pores

- active transport through nuclear pores requires energy and involves specific binding of the transported substance to membrane proteins (Maximum diameter is 26 nm)

- molecular mechanism is best understood for Proteins are actively transported from the cytosol into the nucleus
- they possess one or more nuclear localization signals (NLS), which are amino acid sequences that enable the protein to be recognized by FG nucleoporins and then transported through the nuclear pore
- An NLS is usually 8–30 amino acids in length and often contains proline as well as the positively charged (basic) amino acids lysine and arginine

Nuclear Import via the Ran/Importin Pathway

- NLS-containing proteins are imported into the nucleus via a special receptor protein called an importin
- Mechanism is explained in the following figure

Transport Through the Nuclear Pore Complex

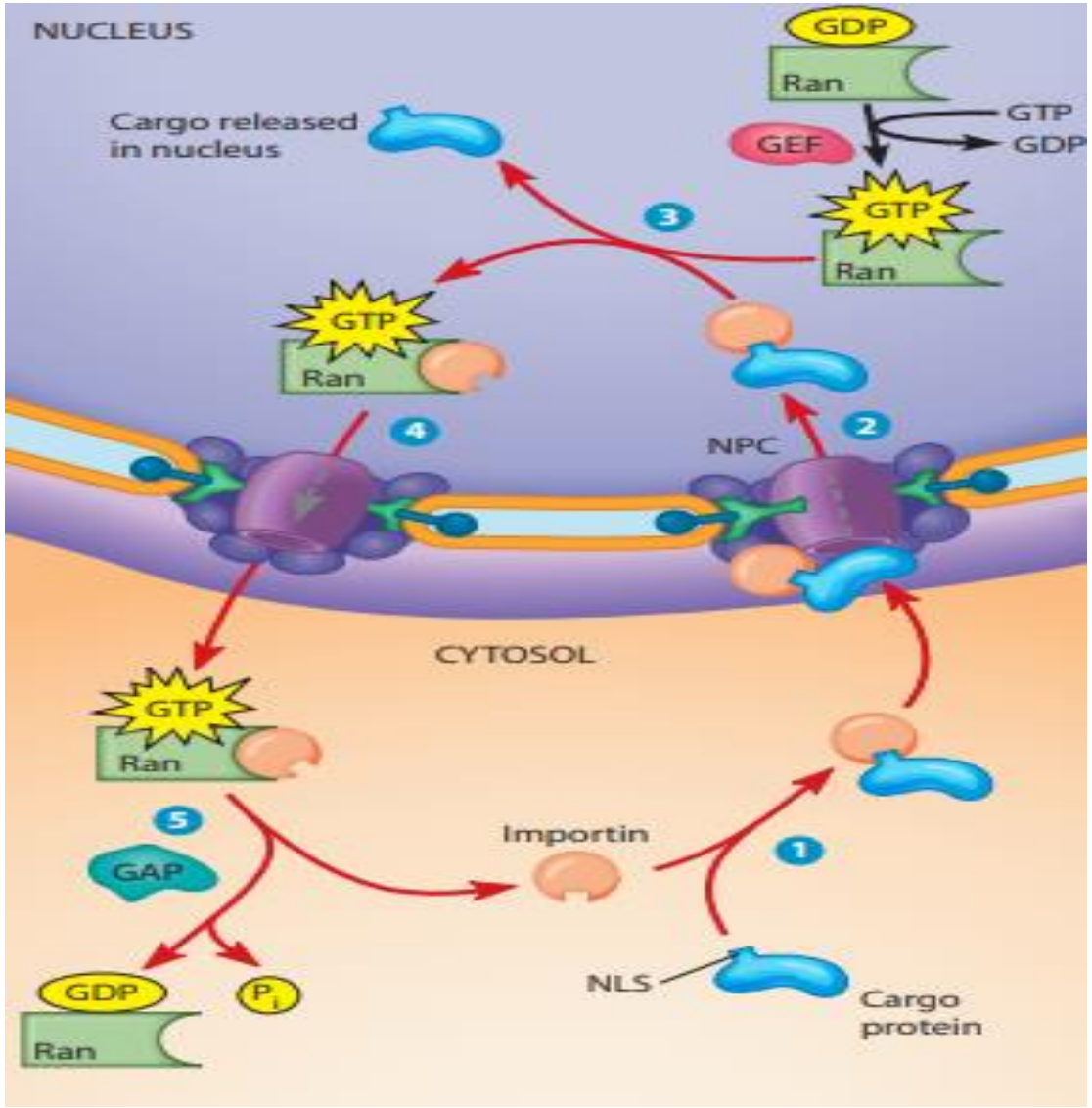


Figure:Becker's World of the Cell NINTH EDITION

Proteins made in the cytosol and destined for use in the nucleus contain a nuclear localization sequence (NLS) that targets them as "cargo" for transport through the nuclear pore complex.

1. An NLS containing cargo protein binds to importin
2. the importin-cargo complex is then transported through the nuclear pore complex
3. Nuclear Ran-GTP binds to importin, triggering the release of the cargo protein in the nucleus
4. The Ran-GTP-importin complex is transported back to the cytosol
5. the hydrolysis of GTP to GDP is accompanied by the release of importin

Nucleoplasm is the gelatinous substance within the nuclear envelope

- Also called karyoplasm, this semi-aqueous material is similar to the cytoplasm and is composed mainly of water with dissolved salts, enzymes, and organic molecules suspended within
- The nucleolus and chromosomes are surrounded by nucleoplasm, which functions to cushion and protect the contents of the nucleus
- Nucleoplasm also supports the nucleus by helping to maintain its shape. Additionally, nucleoplasm provides a medium by which materials, such as enzymes and nucleotides (DNA and RNA subunits), can be transported throughout the nucleus. Substances are exchanged between the cytoplasm and nucleoplasm through nuclear pores

Nucleolus: Contained within the nucleus is a dense, membrane-less structure composed of RNA and proteins called the nucleolus

- Some of the eukaryotic organisms have a nucleus that contains up to four nucleoli

- The 45S precursor rRNA is packaged in a large ribonucleoprotein particle containing many ribosomal proteins imported from the cytoplasm
- While this particle remains at the nucleolus, selected components are added and others discarded as it is processed into immature large and small ribosomal subunits
- The two ribosomal subunits attain their final functional form only after each is individually transported through the nuclear pores into the cytoplasm
- Other ribonucleoprotein complexes, including telomerase shown here, are also assembled in the nucleolus

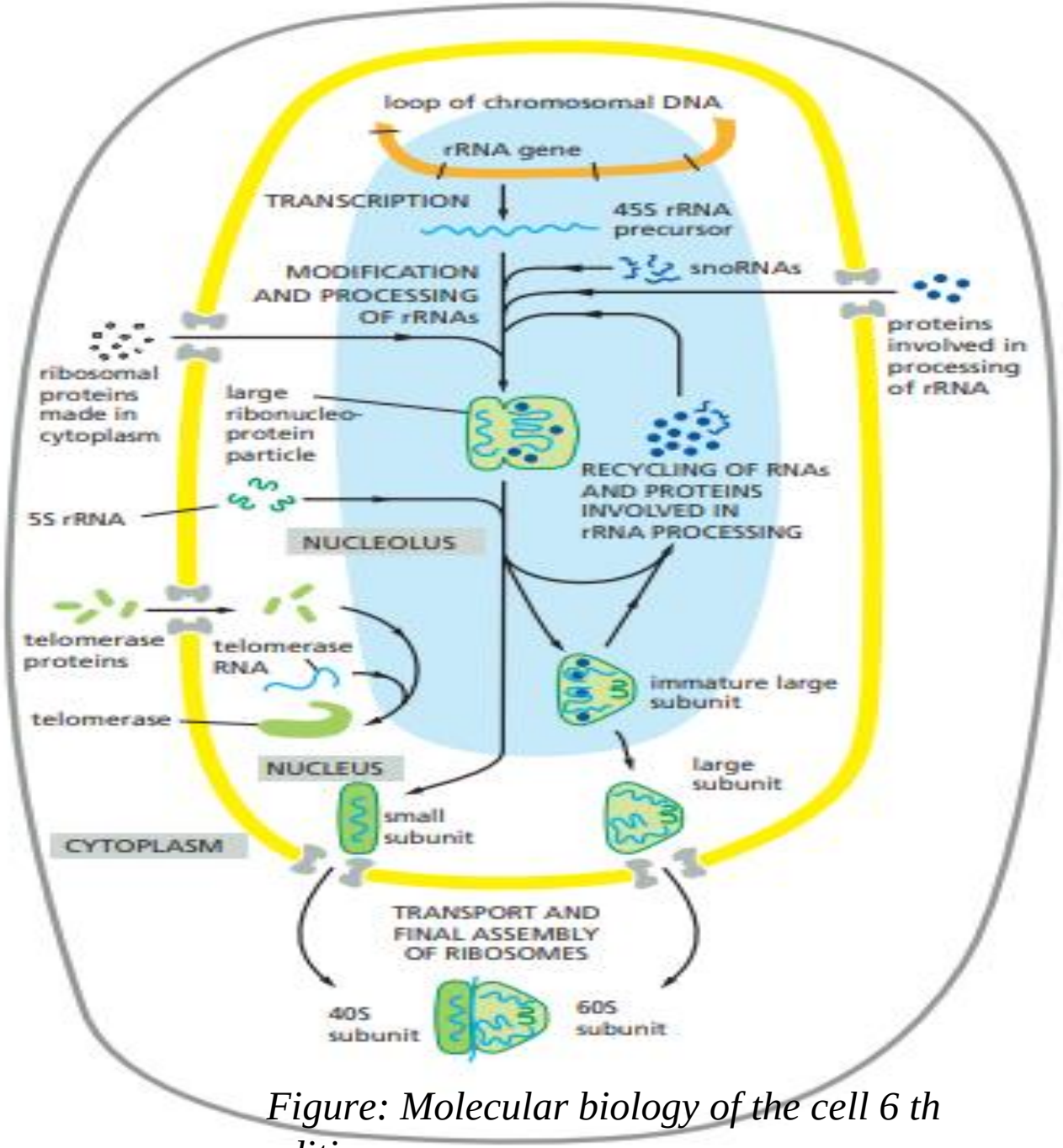


Figure: Molecular biology of the cell 6 th edition

- The nucleolus contains nucleolar organizers, which are parts of chromosomes with the genes for ribosome synthesis on them. The nucleolus helps to synthesize ribosomes by transcribing and assembling ribosomal RNA subunits. These subunits join together to form a ribosome during protein synthesis
- The nucleolus disappears when a cell undergoes division and is reformed after the completion of cell division

Chromatin

- The nucleus is the organelle that houses chromosomes
- Chromosomes consist of DNA, which contains heredity information and instructions for cell growth, development, and reproduction

- Chromosomes are present in the form of strings of DNA and histones (protein molecules) called chromatin
- When a cell is “resting” i.e. not dividing, the chromosomes are organized into long entangled structures called chromatin
- The chromatin is further classified into heterochromatin and euchromatin based on the functions. The former type is a highly condensed, transcriptionally inactive form, mostly present adjacent to the nuclear membrane. On the other hand, euchromatin is a delicate, less condensed organization of chromatin, which is found abundantly in a transcribing cell
- Besides the nucleolus, the nucleus contains a number of other non-membrane-delineated bodies. These include Cajal bodies, Gemini of coiled bodies, polymorphic interphase karyosome association (PIKA), promyelocytic leukemia (PML) bodies, paraspeckles, and splicing speckles
- Nuclear Structure and Dynamics | Basicmedical Key

Table 14-1 MAJOR NUCLEAR SUBDOMAINS

Structure	Comments
Cajal bodies	Formerly known as coiled bodies. About 0.2 to 1 μm in diameter, Cajal bodies have a coiled fibrous substructure. First identified by electron microscopy, up to 10 of these structures are seen per cell. They contain a characteristic protein called p80-coilin. They may be involved in snRNP and snoRNP assembly.
GEMs	GEMs are usually found paired with Cajal bodies, which they may overlap. They contain the survival of motor neurons (SMN) protein, which is encoded by the gene mutated in spinal muscular atrophy, a severe, inherited, human, muscular wasting disease. SMN and its cofactors appear to play an essential role in the assembly and maturation of snRNPs (see Chapter 16).
Nuclear bodies	Function unknown. 5 to 20 spots within the nucleus. Originally observed in electron micrographs of cells following hormonal treatments. However it is not clear that all nuclear bodies described in various cell types are structurally or functionally homologous. A marker antigen for some types of nuclear bodies (called PBC 95K—M_r 95 kD) is recognized by autoantibodies from patients with primary biliary cirrhosis. Some may correspond to PML bodies.
Nucleolus	The nucleolus (typically 1 to 5 structures of 0.5 to 5 μm diameter in mammalian cell nuclei) is the site of rRNA transcription and processing, as well as of preribosomal assembly. It is also the site of processing of several other noncoding RNAs, including the RNA component of the signal recognition particle (SRP—Chapter 20).
PIKA	The polymorphic interphase karyosomal association (PIKA) was later rediscovered and termed the OPT domain. The PIKA may be up to 5 μm in diameter during G_1 phase, but its morphology and number vary across the cell cycle. It appears to correspond to sites of sensing or repair of DNA damage as well as concentrations of certain transcription factors.
PML bodies	Also known as PODs and ND10, 10 to 30 of these structures are scattered throughout the nucleus. They are have links with human disease, and in some cases appear to be targeted during viral infections. Fusion of the marker protein PML to the α-retinoic acid receptor is often found in acute promyelocytic leukemia (hence the name PML), in which the PML bodies appear highly fragmented. The link with cancer appears significant, as treatments that are effective against PML appear to restore the normal morphology of PML bodies (see text).
Speckles	Speckles are concentrations of components involved in RNA processing. They often correspond to clusters of interchromatin granules seen by electron microscopy. They may serve as storage depots of splicing factors, or they may play a more active role in splicing factor modification and/or assembly.

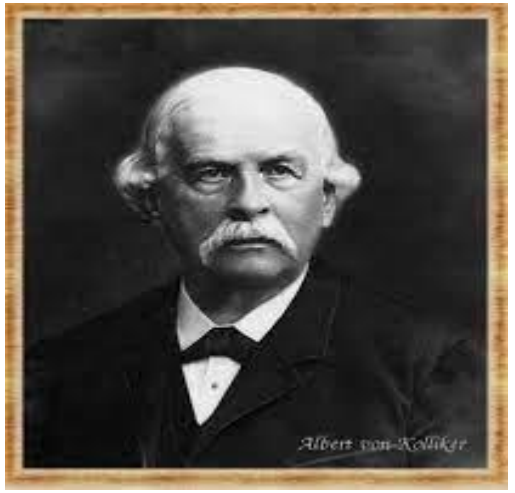
Functions of Nucleus

- The nucleus provides a site for genetic transcription that is segregated from the location of translation in the cytoplasm, allowing levels of gene regulation that are not available to prokaryotes. The main function of the cell nucleus is to control gene expression and mediate the replication of DNA during the cell cycle.
- It controls the hereditary characteristics of an organism.
- The organelle is also responsible for protein synthesis, cell division, growth, and differentiation.
- Storage of hereditary material, the genes in the form of long and thin DNA (deoxyribonucleic acid) strands, referred to as chromatin.
- Storage of proteins and RNA (ribonucleic acid) in the nucleolus.

- The nucleus is a site for transcription in which messenger RNA (mRNA) are produced for protein synthesis.
- During the cell division, chromatins are arranged into chromosomes in the nucleus.
- Production of ribosomes (protein factories) in the nucleolus.
- Selective transportation of regulatory factors and energy molecules through nuclear pores.

Mitochondria:

- Powerhouse of the cell and double membrane bound organelle in cytoplasm
- It was discovered by German pathologist Richard Altman in 1894
- The word mitochondria was coined by German microbiologist Carl Benda in 1898
- Mito-Thread, Chondrion- granule (little granule) meaning in Greek
- Important role is to generate metabolic energy in eukaryotic cells by breaking down the glucose and fatty acids (Aerobic respiration)
- Mitochondrial DNA is maternally inherited in most animals
- Mother will have both genes and cytoplasm in their eggs
- Hence ,mt DNA is called maternal inheritance



Richard Altman

Carl Benda

Morphology

- Size: 0.05- 1.0µm
- Length- 1-10 µm long
- Bean shaped ,it is elongated thread like structure
- Numbers –It depends on the size, type and functional state of the cell
- Eg. An average liver cell contains 1500 mitochondria

Functions of Mitochondria

- The most important function of mitochondria is to produce energy. Mitochondria produce the molecule adenosine triphosphate (ATP), one of the cell's energy currencies that provide the energy to drive a host of cellular reactions and mechanisms
- The simpler molecules of nutrition are sent to the mitochondria to be processed and to produce charged molecules. These charged molecules combine with oxygen and produce ATP molecules. This process is known as oxidative phosphorylation
- Mitochondria may also produce heat (brown fat), and accumulate iron-containing pigments (Heme ferritin), ions of Ca2+ and HPO_4^{2-} (or phosphate; e.g., osteoblasts of bones or yolk proteins)

- Mitochondria help the cells to maintain the proper concentration of calcium ions within the compartments of the cell
- The mitochondria also help in building certain parts of blood and hormones like testosterone and estrogen
- The liver cell’s mitochondria have enzymes that detoxify ammonia
- The mitochondria also play an important role in the process of apoptosis or programmed cell death
- Abnormal death of cells due to the dysfunction of mitochondria can affect the function of an organ

Genetic system of Mitochondria

- Mitochondria contain own genetic system, which is unique from nuclear genome of the cell
- Most mitochondrial proteins are translated on free cytosolic ribosomes and imported into the organelle by specific targeting signals
- In addition, mitochondria are unique among the cytoplasmic organelles they contain their own DNA, which encodes tRNAs, rRNAs, and some mitochondrial proteins
- It thought to be evolved from the bacteria that developed a symbiotic relationship in which it lived in larger cell
- This hypothesis was proposed by Lynn Margulis in 1960
- the results of DNA sequence analysis, showed similarities between the genomes of mitochondria and of the bacterium *Rickettsia prowazekii* (Parasite)
- They may share common ancestor, mitochondrial has circular genome like bacteria

Endosymbiotic Theory –Origin of Mitochondria

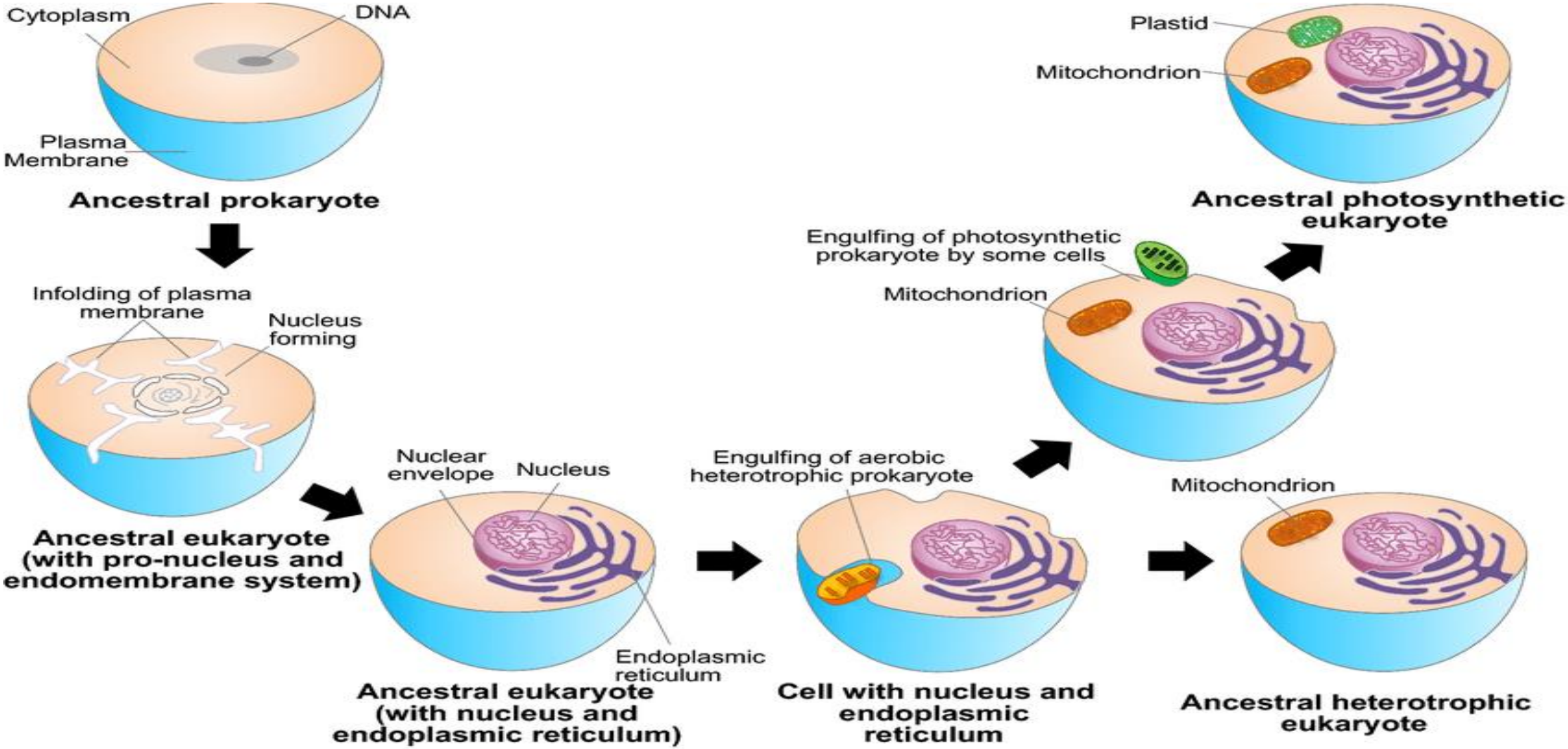


Figure: Cellular and Molecular Life Sciences

- Size of genome is 16 kb in human and most related animals, Plants – (<200 kb)
- Yeast -80 kb ,A.thaliana has 367kb were most of it are non coding.

Biogenesis:

- Human, Mitochonria genome encodes for 13 proteins involved in electron transport and oxidative phosphorylation are designated as components of respiratory complexes I, III, IV, or V (figure)
- The region of the genome designated “D loop” contains an origin of DNA replication and transcriptional promoter sequences
- the genome contains genes for 12S and 16S rRNAs and for 22 tRNAs, which are designated by the one-letter code for the corresponding amino acid

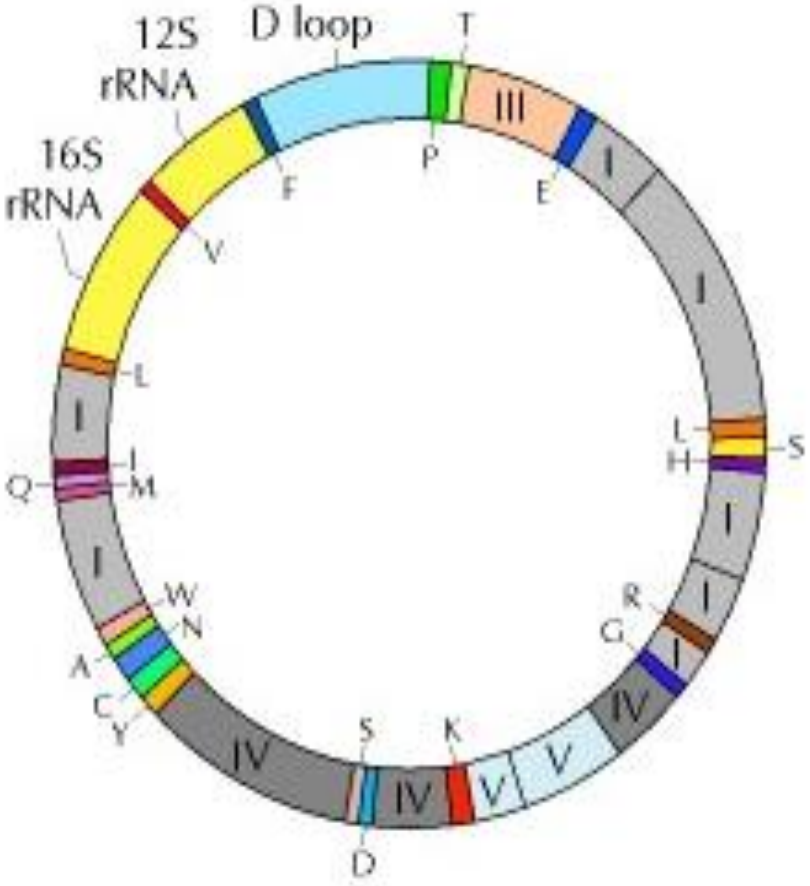


Figure: The Cell: A Molecular Approach. 2nd edition.

- Like other cells Mitochondria also divide and fuse to maintain their number of cells
- Mitochondrial biogenesis is required to compensate for decreased mitochondrial biomass resulting from mitochondrial degradation
- imbalance between mitochondrial fusion, fission, biogenesis and degradation events could cause substantial changes in mitochondrial number, biomass, shape and function
- P indicates a phagophore by which targeted mitochondria are engulfed during the sequestering process required for mitophagy.

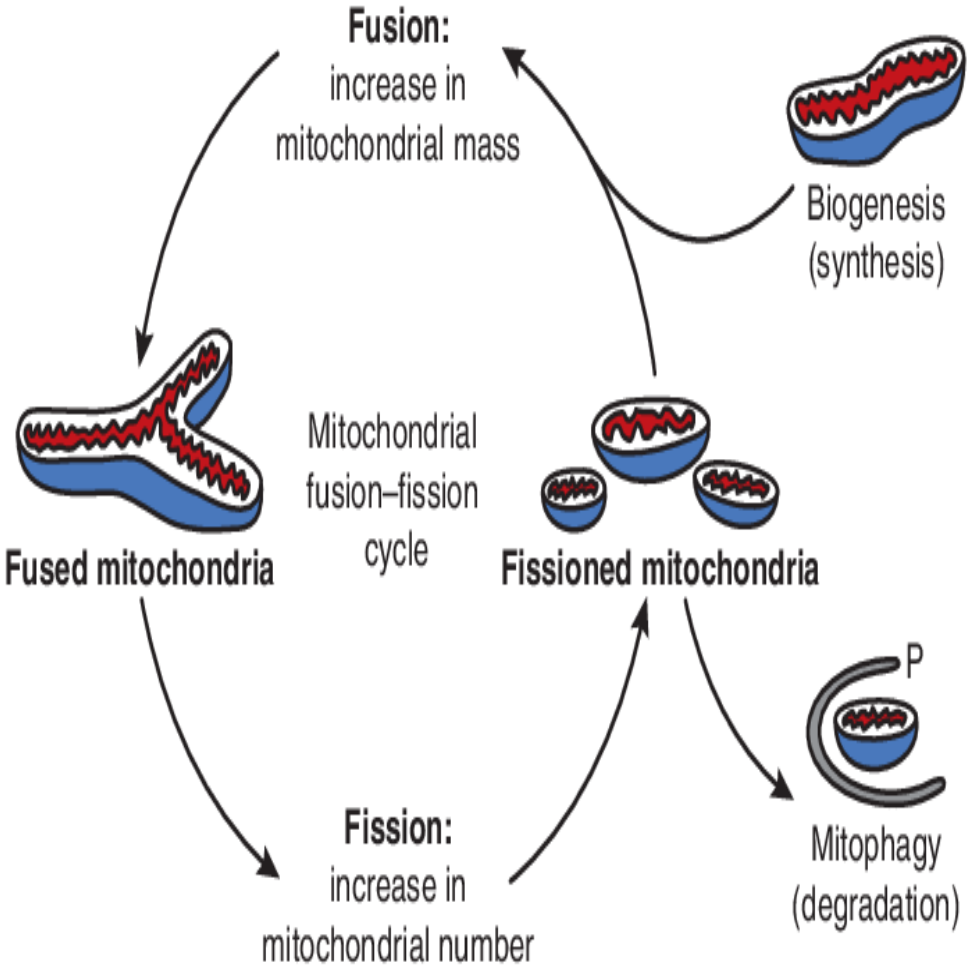


Figure:Journal of cell science

- Mitochondria are surrounded by a double-membrane system, consisting of inner and outer mitochondrial membranes separated by an inter-membrane space
- The inner membrane forms numerous folds (**cristae**), which extend into the interior (or matrix) of the organelle
- Each of these components plays distinct functional roles, with the matrix and inner membrane representing the major working compartments of mitochondria
- Matrix contains genetic information and enzymes responsible for oxidative mechanism.
- Initial stage , Glycolysis takes place in cytosol
- Pyruvate will transport to mitochondria to undergo central pathway of oxidative metabolism

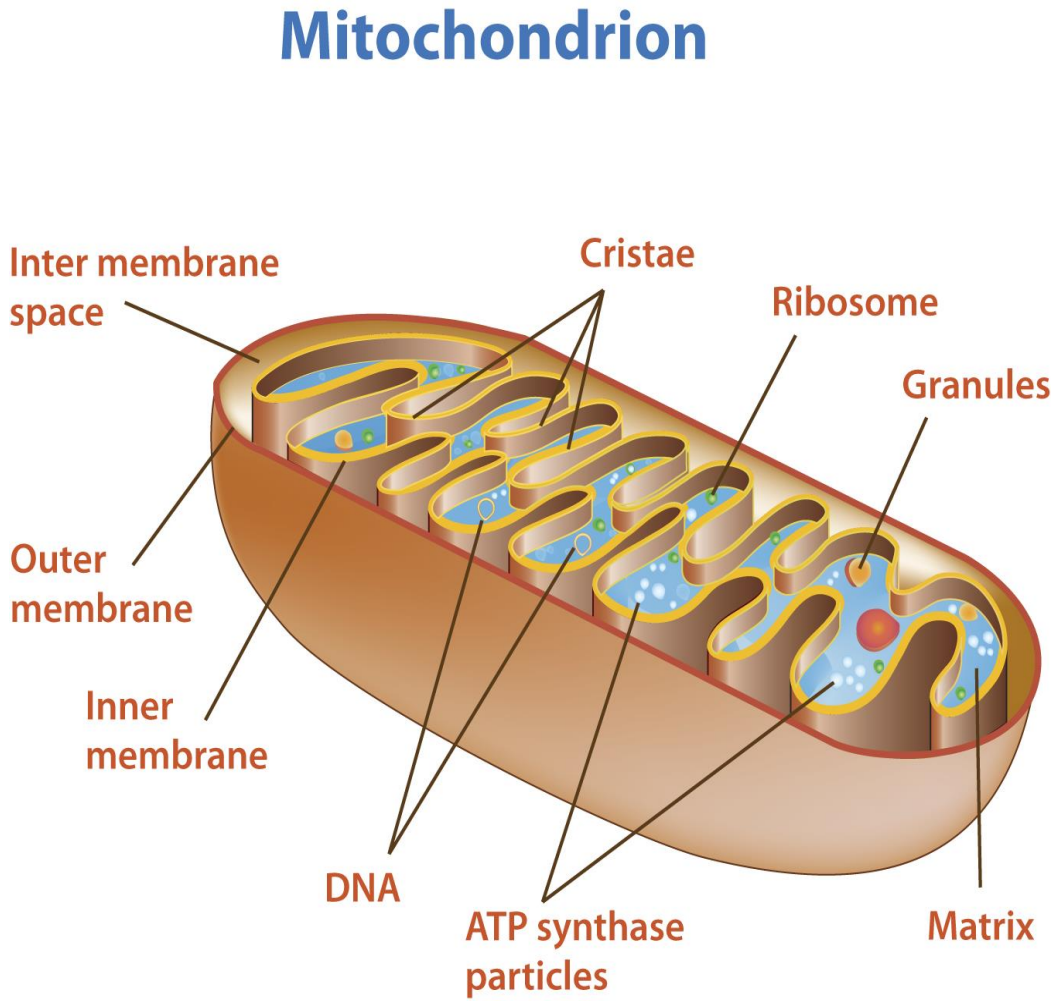


Figure: The Cell: A Molecular Approach. 2nd edition.

- Matrix will have enzymes ,DNA genome, ribosomes, tRNA,granules,fibrils and tubules
- Inner membrane : Oxidative phosphorylation will take place after oxidative mechanism
- high-energy electrons from NADH and $FADH_2$ are transferred through a series of carriers in the membrane to molecular oxygen
- energy derived is converted to potential energy stored in a proton gradient across the membrane
- It is the principal site of ATP generation
- Only permeable to O2,H2O,CO2
- Several antiport system exist in order exchange the anions between the cytosol and mitochondria

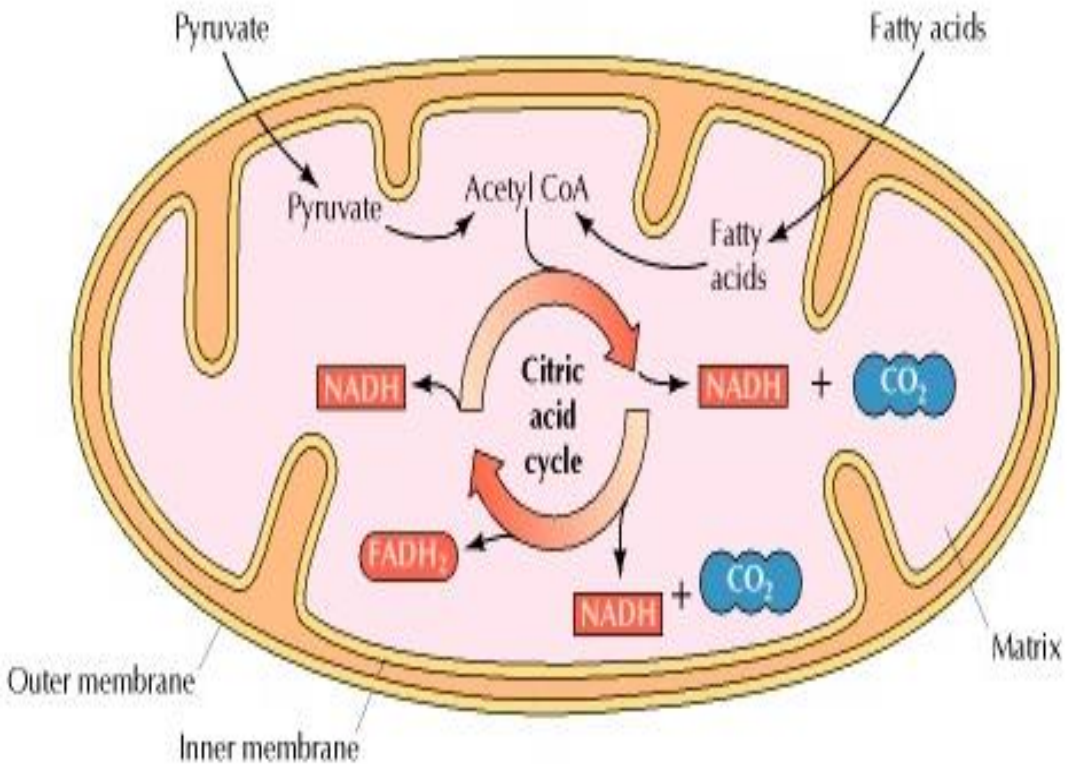


Figure: The Cell: A Molecular Approach. 2nd edition.

- It contains an unusually high percentage (greater than 70%) of proteins, which are involved in oxidative phosphorylation as well as in the transport of metabolites
- It is impermeable to most ions and small molecules—a property critical to maintaining the proton gradient that drives oxidative phosphorylation

Cristae: These are the fold of inner membrane , expand its surface area enhancing its ability to produce ATP

outer mitochondrial membrane : freely permeable to small molecules. Because, it contains proteins called **porins**

- Porins form channels that allow the free diffusion of molecules smaller than about 6000 daltons
- The composition of the intermembrane space is therefore similar to the cytosol with respect to ions and small molecules
- It is the functional barrier to the passage of small molecules between the cytosol and the matrix and maintains the proton gradient

Vacuoles

- Vacuole, in biology, a space within a cell that is empty of cytoplasm, lined with a membrane, and filled with fluid
- Especially in protozoa (single-celled eukaryotic organisms), vacuoles are essential cytoplasmic organs (organelles), performing functions such as storage, ingestion, digestion, excretion, and expulsion of excess water
- The large central vacuoles often found in plant cells enable them to attain a large size without accumulating the bulk that would make metabolism difficult
- Potent secondary metabolites, such as tannins or various biological pigments, are also sequestered in the vacuoles in plants, fungi, algae, and certain other organisms to protect the cell from self-toxicity

- Endocytosis and exocytosis are fundamental to the process of intracellular digestion
- Food particles are taken into the cell via endocytosis into a vacuole
- Lysosomes attach to the vacuole and release digestive enzymes to extract nutrients
- The leftover waste products of digestion are carried to the plasma membrane by the vacuole and eliminated through the process of exocytosis

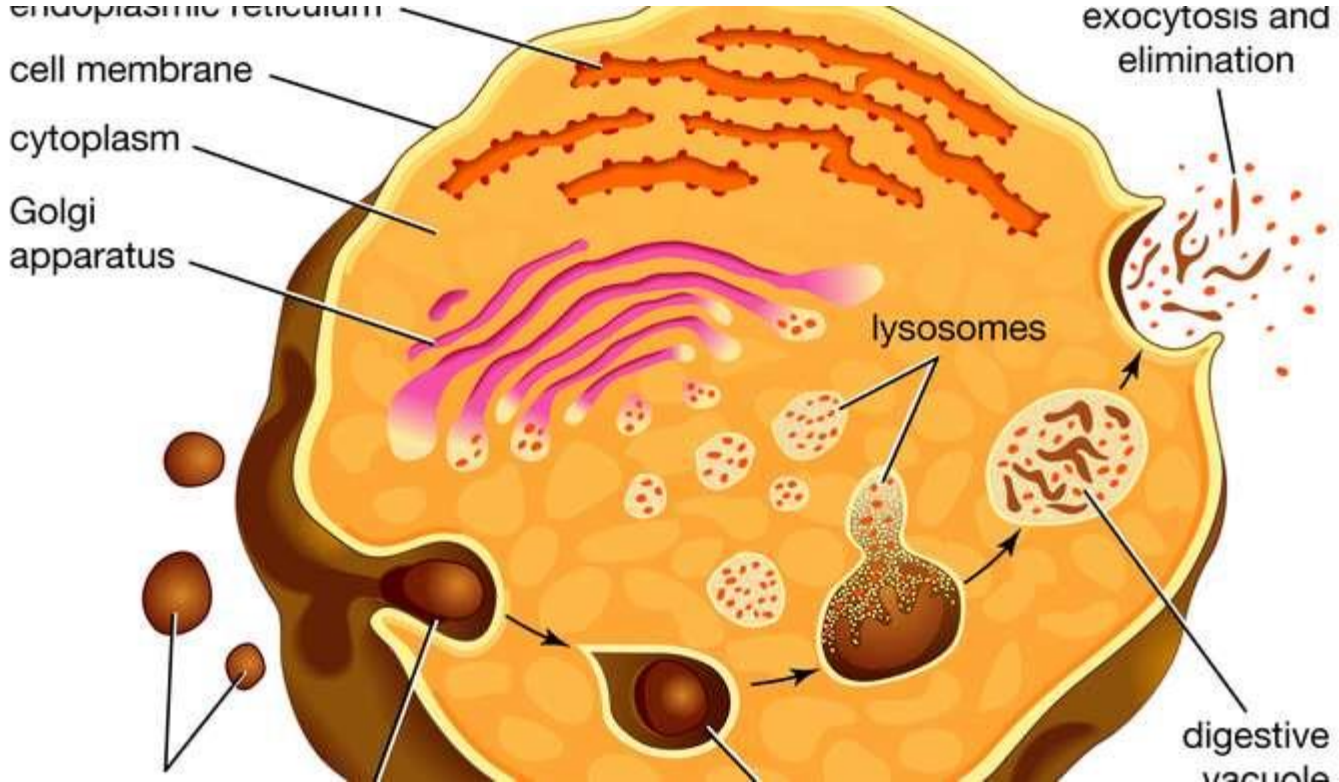


Figure:Britannica

Microbodies

- It contains variety of enzyme bearing, membrane bounded vesicle
- Present in plants, animals, protists and in fungi
- Distribution of enzymes into microbodies is one of the principle ways in which eukaryotic cells organize their metabolism
- While lysosomes bud from the endomembrane system, microbodies grow by incorporating lipids and protein, then replicate by dividing
- In plants, a special microbody called glyoxysome that contains enzymes that convert fats into acetyl-CoA for the glyoxylate bypass. They are temporary organelle present in germinating seeds
- Peroxisome, contains enzymes that catalyze the removal of electrons and associated hydrogen atoms (catalase and Urate oxidase) - Involve in beta-oxidation of fattyacids to acetyl-coA
- Essential biosynthetic function of animal peroxisomes - catalyse first reactions of formation of plasmologens - a abundant class of phospholipids in myelin

- Lysosomes and peroxisomes are vesicles that contain digestive and detoxifying enzymes
- The isolation of these enzymes in vesicles protects the rest of the cell from inappropriate digestive activity
- If these enzymes are not present in microbodies, they will tend to short-circuit the metabolism of the cytoplasm
- They will involve in the process of adding hydrogen atoms to oxygen
- Peroxisomes refers to the hydrogen peroxide produced as a by product of the process of activity of Oxidative enzyme
- Hydrogen peroxides are dangerous because of its violent chemical reactivity
- These enzymes will break down Hydrogen peroxides into water and oxygen

Organelles bounded by single membrane

Peroxisomes

- Peroxisomes are small, membrane-enclosed cellular organelles containing oxidative enzymes that are involved in a variety of metabolic reactions, including several aspects of energy metabolism
- They are considered as an important type of microbody found in both plants and animal cells

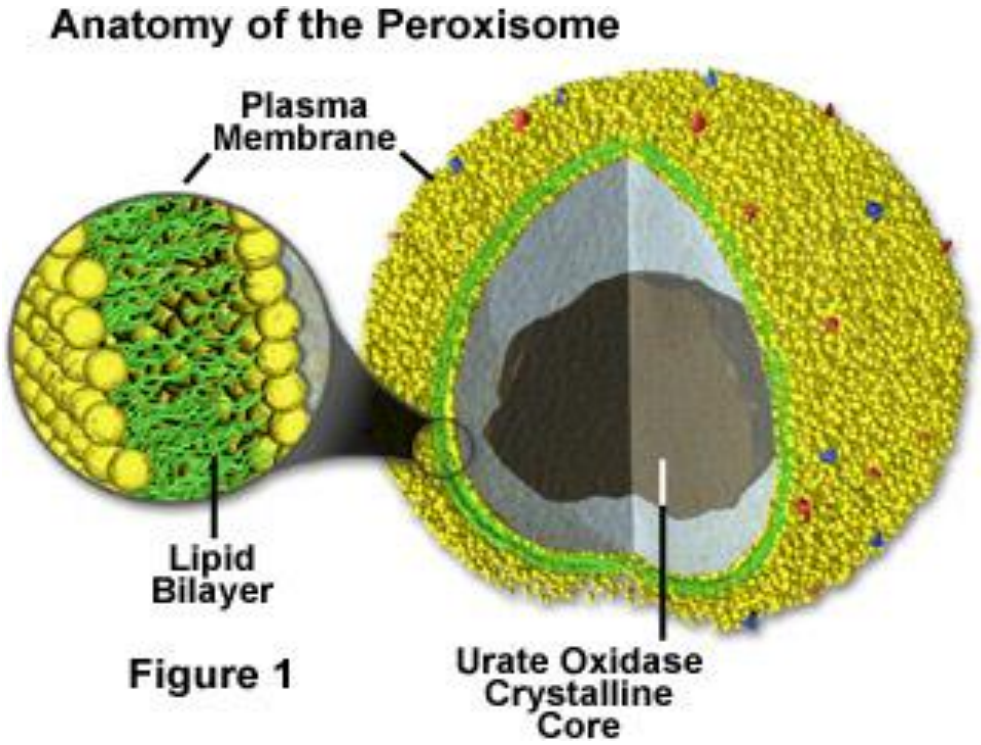


Figure: Molecular Expression

- They were identified as organelles by Belgian cytologist Christian de Duve in 1967
- First peroxisomes to be discovered were isolated from leaf homogenate of spinach
- They are most abundantly found in detoxifying organs such as the liver and kidney cells
- However, they can be induced to proliferate in response to metabolic needs
- They are membrane-bound spherical bodies of 0.2 to 1.5 μm in diameter found in all eukaryotic organisms including both plants and animal cells
- They are found floating freely in the cytoplasm in close association of ER, mitochondria or chloroplast within the cell
- They are among the simplest of eukaryotic organelles
- They exist either in the form of a network of interconnected tubules called peroxisome reticulum or as individual microperoxisomes

- They are variable in size and shape according to the cell and usually circular in cross-section.
- They range from 0.2 -1.5 μm in diameter
- It consists of a single limiting membrane of lipid and protein molecules enclosing the granular matrix
- The matrix consists of fibrils or a crystalloid structure containing enzymes

Peroxisomal Enzymes

- Approximately 60 known enzymes are present in the matrix of peroxisomes.
- They are responsible to carry out oxidation reactions leading to the production of hydrogen peroxide.
- The main groups of enzymes include:
- Urate oxidase
- D-amino acid oxidase
- Catalase

Functions of Peroxisomes

1. Hydrogen Peroxide Metabolism:

2. Fatty acid oxidation:

- Oxidation of fatty acids, in animal cells, occurs in both peroxisomes and mitochondria, but in yeasts and plants, only limited to peroxisomes
- Oxidation is accompanied by the production of H_20_2 which is decomposed by catalase enzyme. This provides a major source of metabolic energy

3. Lipid biosynthesis

- Synthesis of cholesterol and dolichol occurs in both ER and peroxisomes. Bile acid synthesis takes place from cholesterol in the liver
- Peroxisomes contain enzymes to synthesize plasmalogens, a family of phospholipids which are important membrane components of tissues of the heart and brain

4. Germination of seeds

- Peroxisomes in seeds responsible for the conversion of stored fatty acids to carbohydrates, critical to providing energy and raw materials for the growth of germinating plants
- Peroxisomes seen in tomato seeds in near germination (around 4 days) storing fat molecules

5. Photorespiration

- Peroxisomes in leaves particularly in the green ones carry out the photorespiration process along with chloroplasts

6. Degradation of purines

- Carry out the catabolism of purines, polyamines and amino acids especially by uric acid oxidase

7. Bioluminescence

- Luciferase enzyme found in the peroxisomes of fireflies help in bioluminescence and thus aid the flies in finding a mate or its meal

8. Importance of import process in peroxisomes was explained using inherited human disease - zellweger syndrome, in which a defect in importing proteins into peroxisomes leads to profound peroxisomal deficiency. Individuals with cells containing empty peroxisomes have severe abnormalities in their brain, liver and kidneys and they die soon.

Lysosomes

- Lysosomes were discovered by the Belgian cytologist Christian René de Duve in the 1950
- It is membrane-enclosed organelles contains array of enzymes capable of breaking down all types of biological polymers -proteins, nucleic acids, carbohydrates, and lipids
- Function as digestive system of cell, degrade material taken from outside the cell and to digest obsolete components of the cell itself
- They are dense spherical in shape but the shape and size as a result of difference in the size of the material taken up for digestion

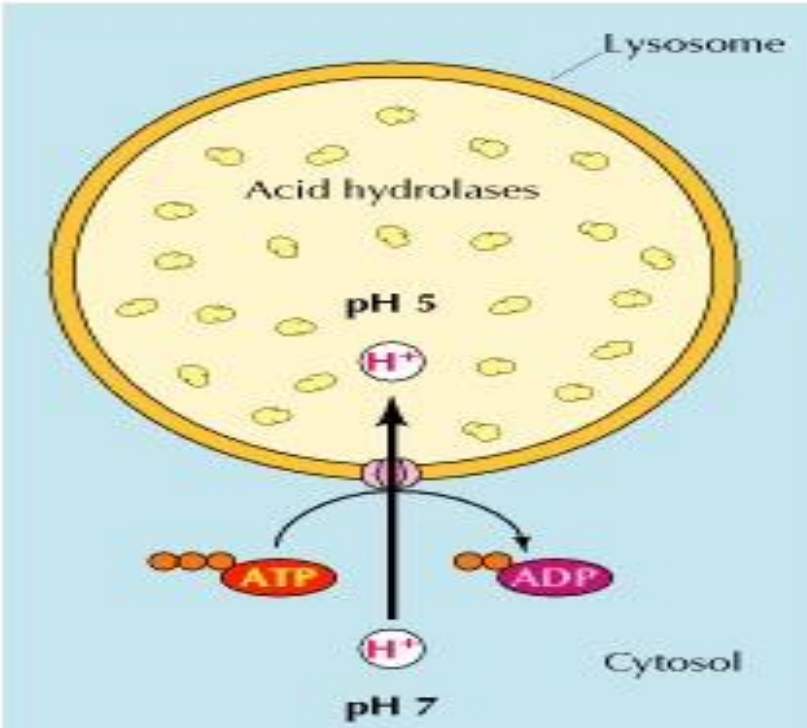


Figure: The Cell: A Molecular Approach. 2nd e

<u>Lysosomal Acid Hydrolases</u>

- It contains more than 50 different degrading enzymes and they are active at 5 pH (inside the lysosomes)
- These will hydrolyze the DNA,RNA,proteins, lipids and Polysaccharides

- All of the lysosomal enzymes are acid hydrolases, the neutral pH (about 7.2) characteristic of the rest of the cytoplasm
- even if the lysosomal membrane were to break down, the released acid hydrolases would be inactive at the neutral pH of the cytosol
- To maintain their acidic internal pH, lysosomes must actively concentrate H^+ ions (protons)
- This pumping requires expenditure of energy in the form of ATP hydrolysis, since it maintains approximately a hundred fold higher H^+ concentration inside the lysosome.
- Mutations in the genes that encode these enzymes are responsible for more than 30 different human genetic diseases, which are called lysosomal storage diseases
- Most of these diseases result from deficiencies in single lysosomal enzymes
- For example, Gaucher’s disease (the most common of these disorders) results from a mutation in the gene that encodes a lysosomal enzyme required for the breakdown of glycolipids

I-cell disease mechanism vs normal

(a) Normal trafficking of lysosomal enzymes depends on addition of mannose to hydrolases in the rough ER. Mannose is then phosphorylated to mannose-6-phosphate (mannose-6-P) in the Golgi

- Mannose-6-P-tagged enzymes move through the Golgi, eventually fuse with endosomes, and are ultimately incorporated into lysosome

(b)In cells of I-cell patients, the enzyme in the Golgi that adds a phosphoryl group to mannose is absent, so the enzymes are misrouted to the plasma membrane.

- Ultimately, lysosomes become swollen in such cell

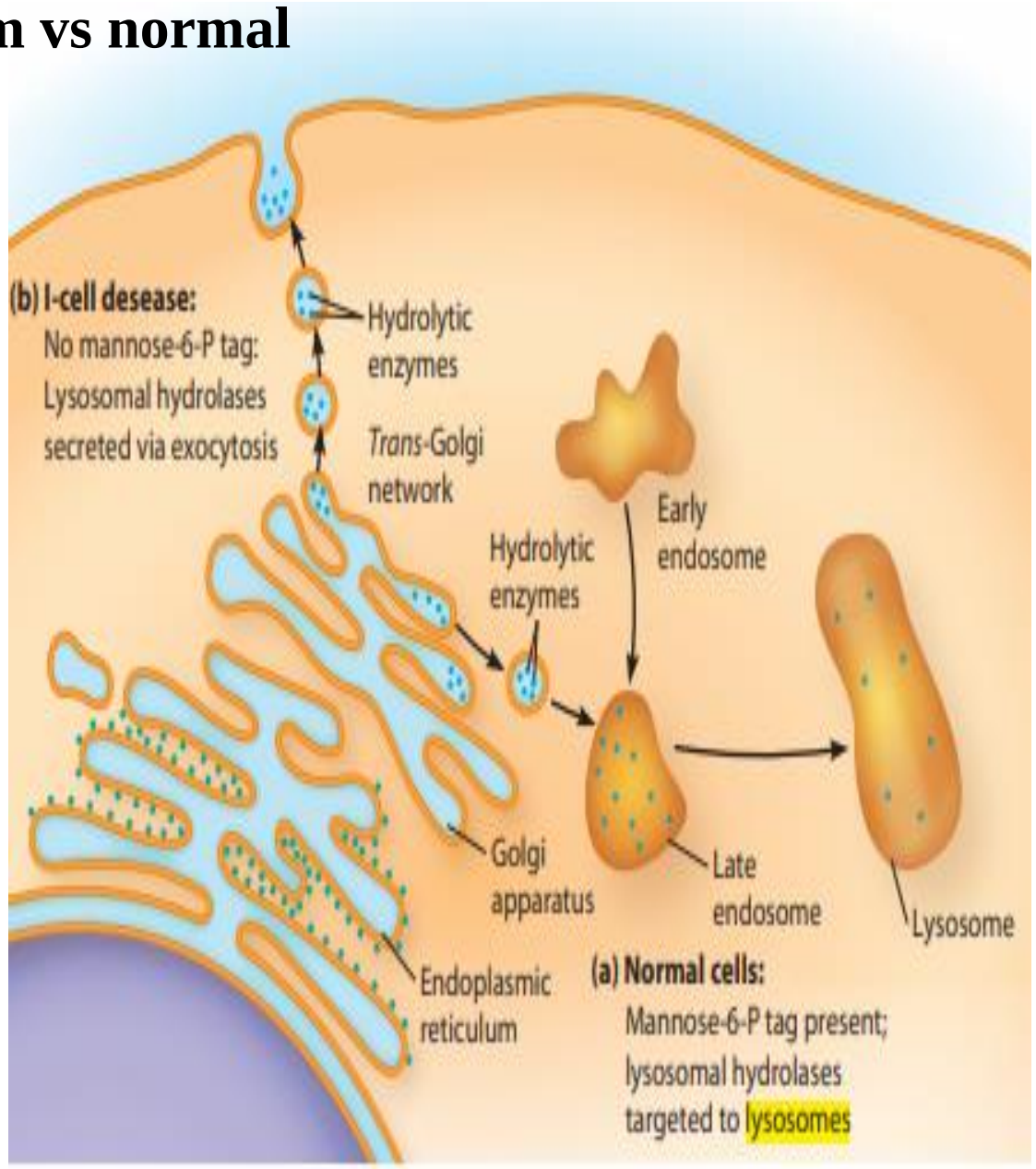


Figure:Becker's World of the Cell NINTH EDITION

- lysosomes digest material derived from two other routes: phagocytosis and autophagy
- In phagocytosis, specialized cells, such as macrophages, take up and degrade large particles, including bacteria, cell debris, and aged are taken up in phagocytic vacuoles (**phagosomes**), which then fuse with lysosomes, resulting in digestion of their contents.
- The lysosomes formed in this way (**phagolysosomes**)
- can be quite large and heterogeneous, since their size and shape is determined by the content of material that is being digested Lysosomes
- for autophagy, the gradual turnover of the cell's own components. The first step of autophagy appears to be the enclosure of an organelle (e.g., a mitochondrion) in membrane derived from the ER.
- The resulting vesicle (an **autophagosome**) then fuses with a lysosome, and its contents are digested

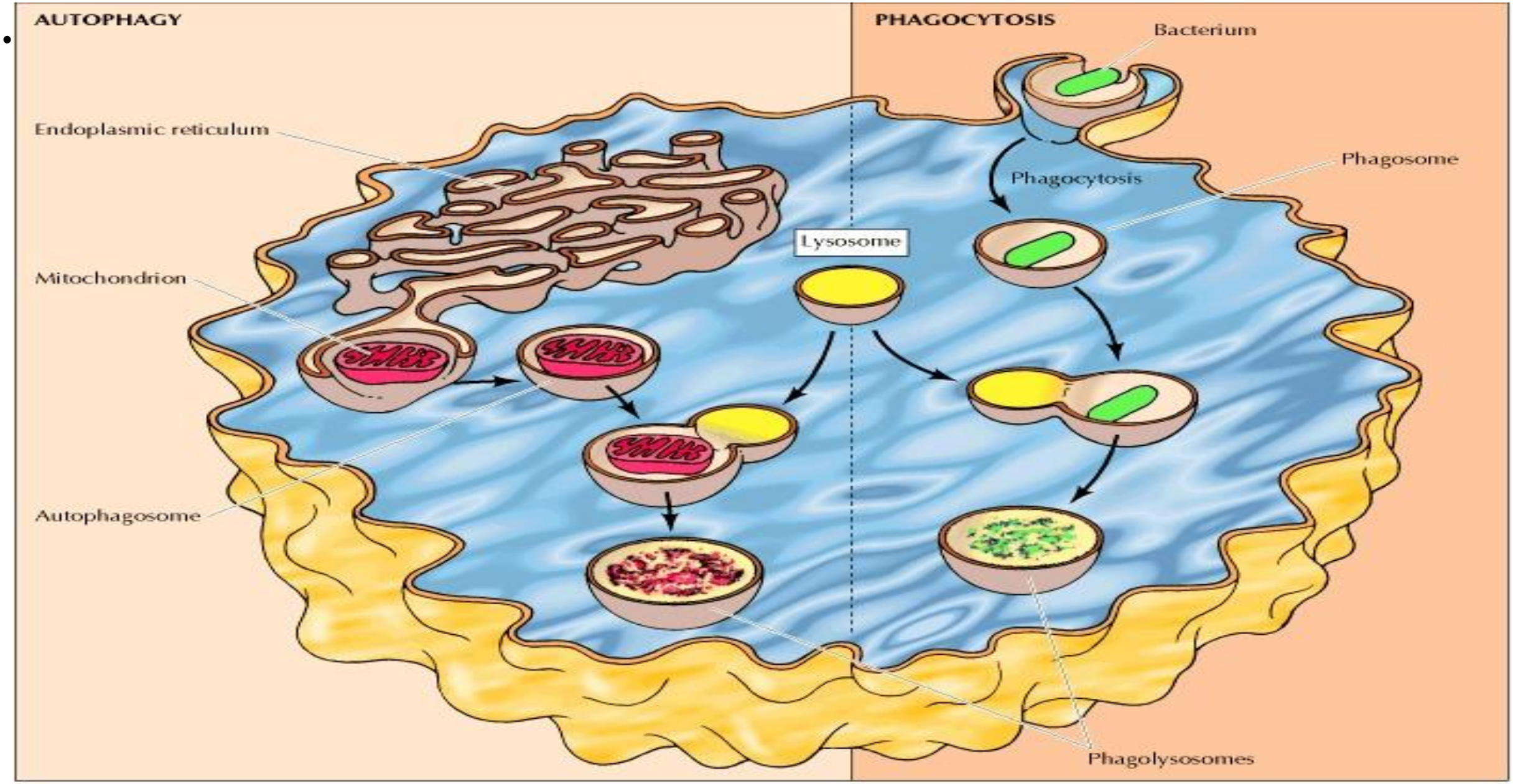


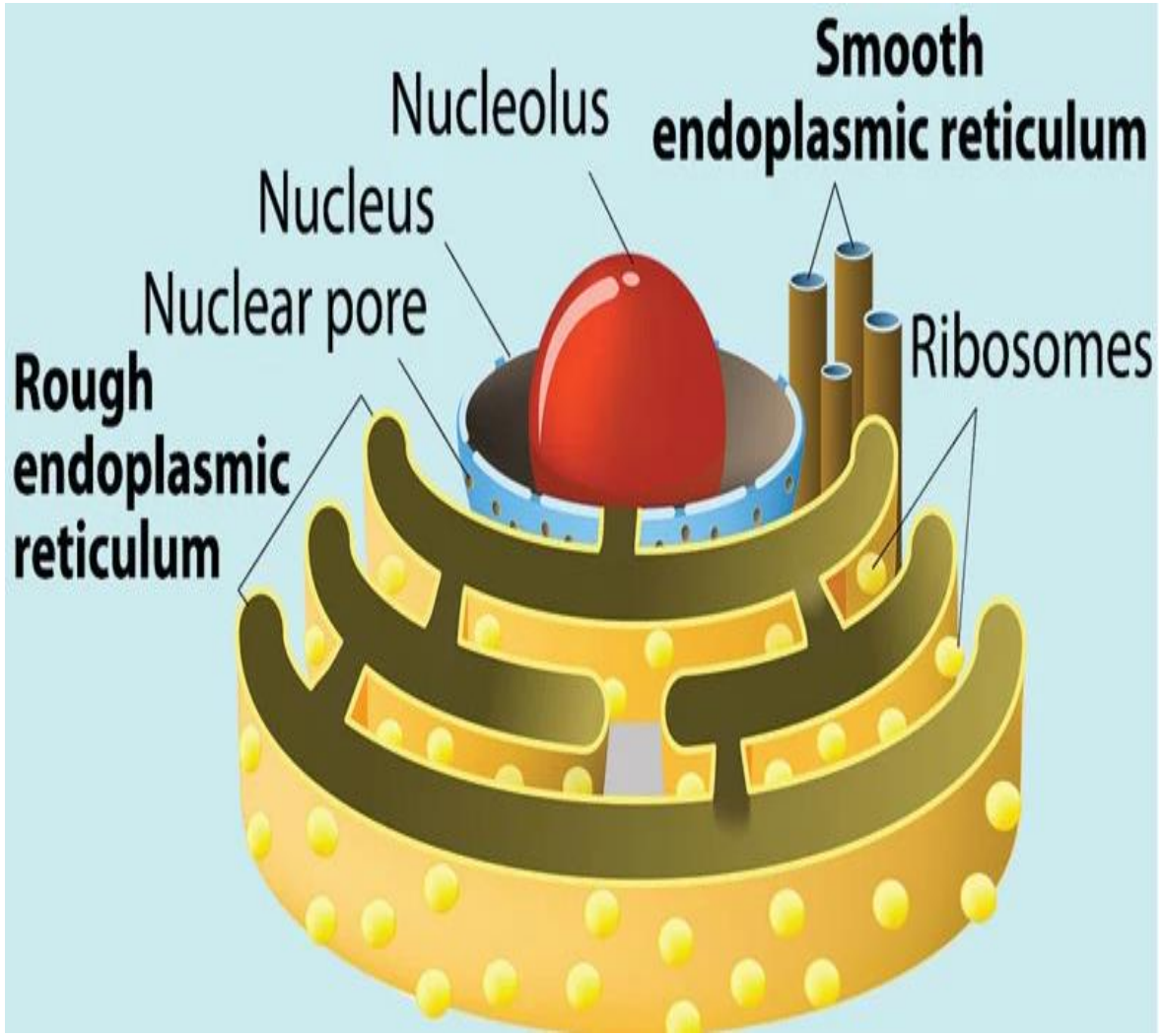
Figure: The Cell: A Molecular Approach. 2nd edition.

Endoplasmic Reticulum (ER)

- It was discovered independently by **Porter (1945) and Thompson (1945)**.
- The name was given by Porter in 1953
- Endoplasmic reticulum is a 3-dimensional, complicated and interconnected syncretic of membrane-lined channels that run through the cytoplasm.

Albert Claude

Keith Porter



- Within the cytoplasm of most animal cells is an extensive network (reticulum) of membrane-limited channels, collectively called the endoplasmic reticulum (or ER)
- The endoplasmic reticulum is a name derived from the fact that in the light microscope it looks like a “net in the cytoplasm”
- The endoplasmic reticulum is only present in the eukaryotic cells. However, the occurrence of the endoplasmic reticulum varies from cell to cell
- For example, the erythrocytes (RBC), egg and embryonic cells lack in the endoplasmic reticulum
- Some portion of ER membranes remains continuous with the plasma membrane and the nuclear envelope
- ER may be rough or smooth. The outer surface of rough ER has attached ribosomes, whereas smooth ER does not have attached ribosomes
- The endoplasmic reticulum acts as secretory, storage, circulatory and nervous system for the cell. It is also the site of the biogenesis of cellular membranes

Structure :

- The membrane of the endoplasmic reticulum is 50 to 60 Aº thickness and fluid-mosaic like the unit membrane of the plasma membrane.
- The membranes of the endoplasmic reticulum are found to contain many kinds of enzymes that are needed for various important synthetic activities. The most important enzymes are the stearases, NADH-cytochrome C reductase, NADH diaphorase, glucose-6-phosphatase, and Mg++ activated ATPase.
- The membrane of endoplasmic reticulum remains continuous with the membranes of the plasma membrane, nuclear membrane, and Golgi apparatus.
- The cavity of the endoplasmic reticulum is well developed and acts as a passage for the secretory products.

The endoplasmic reticulum may occur in the following three forms:

- Lamellar form or cisternae
- Vesicular form or vesicle and
- Tubular form or tubules
- **The Cisternae**
- RER usually exists as cisternae that occur in those cells which have synthetic roles as the cells of the pancreas, notochord, and brain.
- The cisternae are long, flattened, sac-like, unbranched tubules having a diameter of 40 to 50 μm.
- They remain arranged parallelly in bundles or stakes.

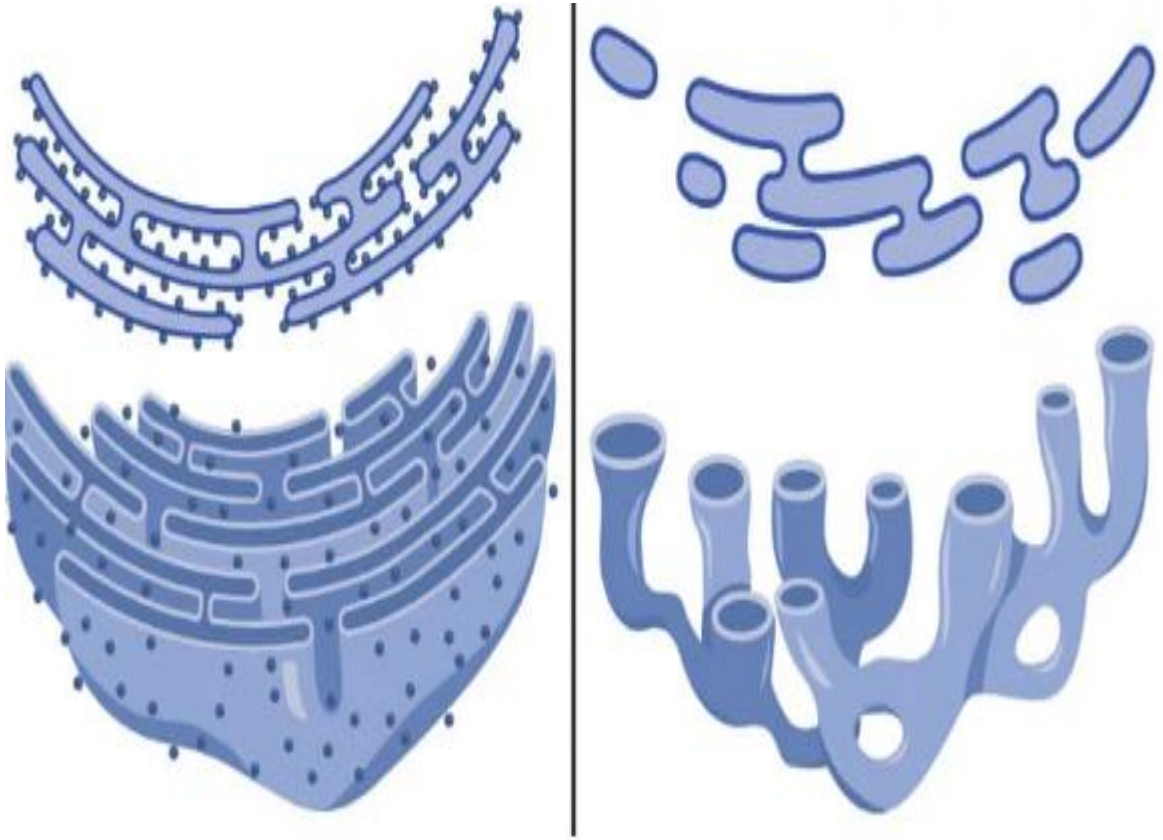
- **The Vesicles**
- The vesicles are oval; membrane-bound vacuolar structures having a diameter of 25 to 500 μm
- They often remain isolated in the cytoplasm and occur in most cells but especially abundant in the SER
- **The Tubules**
- The tubules are branched structures forming the reticular system along with the cisternae and vesicles
- They usually have a diameter from 50 to 190 μm and occur almost in all the cells
- Tubular form of ER is often found in SER and is dynamic in nature, i.e., it is associated with membrane movements, fission and fusion between membranes of cytocavity network

Types of Endoplasmic Reticulum (ER)

- **1. Smooth Endoplasmic Reticulum**
- They are also called as the agranular endoplasmic reticulum.
- This type of endoplasmic reticulum possesses smooth walls because the ribosomes are not attached to its membranes.
- The smooth type of endoplasmic reticulum occurs mostly in those cells, which are involved in the metabolism of lipids (including steroids) and glycogen. Eg. adipose cells, interstitial cells, glycogen storing cells of the liver, conduction fibers of heart, spermatocytes, and leucocytes.

2. Rough Endoplasmic Reticulum

- It possesses rough walls because the ribosomes remain attached to its membranes.
- On their membranes, rough ER (RER) contains certain ribosome specific, transmembrane glycoproteins, called ribophorin I and II, to which are attached the ribosomes while engaged in polypeptide synthesis.
- The rough type of endoplasmic reticulum is found abundantly in those cells which are active in protein synthesis such as pancreatic cells, plasma cells, goblet cells, and liver cells.



Basis for comparison	Rough endoplasmic reticulum (RER)	Smooth endoplasmic reticulum (SER)
Definition	The rough endoplasmic reticulum is a type of endoplasmic reticulum consisting of flattened sacs, studded with protein-synthesizing particles termed ribosomes on the outer surface.	Smooth endoplasmic reticulum (SER) is a type of endoplasmic reticulum consisting of tubular vesicles that lack ribosomes on the outer surface and is involved in the synthesis and storage of lipids.
Ribosomes	Rough ER has ribosomes on the outer surface.	Smooth ER doesn' thave ribosomes on the outer surface.
Location	The rough endoplasmic reticulum is mostly found around the nuclear membrane.	The smooth endoplasmic reticulum is mostly found near the cell membrane.
Origin	Rough ER is formed from the nuclear membrane.	Smooth ER is formed after the shedding of ribosomes from rough ER.

Structure	Rough ER is mainly composed of cisternae with few tubules.	Smooth ER is mainly composed of a network of tubules with few cisternae.
	Rough ER posses narrow pores below the ribosomes that allow the passage of newly synthesized polypeptides to the cytosol.	No such pores are present on the surface of the smooth ER.
Ribophorins	Ribophorins are present on the surface of the rough ER.	Ribophorins are absent on the surface of the smooth ER.
Involved in	Rough ERs are involved in the formation of lysosomes.	Smooth ERs are involved in the formation of spherosomes or oleosomes.
Found in	Numerous rough ER is found in lipid synthesizing cells.	Numerous smooth ER is found in protein synthesizing cells.
Type of cell	RER is mostly found in cells of glands and protein-producing organs.	SER is mostly found in cells like muscle cells and nerve cells.
Golgi apparatus	Rough ER provides proteins and lipids for the Golgi apparatus.	Smooth ER provides vesicles for the cis-face of the Golgi apparatus.

Function	The rough endoplasmic reticulum is mostly associated with the production, modification, and transfer of proteins.	The smooth endoplasmic reticulum is mostly associated with the production of lipids and the storage of calcium ions.
Diseases	Disease like spondyloepimetaphyseal dysplasia is attributed due to the accumulation of misfolded collagen proteins in the RER.	Prolonged SER stress might result in the development and progression of many diseases, including neurodegeneration, atherosclerosis, type 2 diabetes, liver disease, and even cancer.

Functions

- Functions of smooth ER include lipid metabolism (both catabolism and anabolism; they synthesize a variety of phospholipids, cholesterol, and steroids).
- Glycogenolysis (degradation of glycogen; glycogen being polymerized in the cytosol).
- Drug detoxification (by the help of the cytochrome P-450).
- The endoplasmic reticulum provides an ultrastructural skeletal framework to the cell and gives mechanical support to the colloidal cytoplasmic matrix.
- The exchange of molecules by the process of osmosis, diffusion and active transport occurs through the membranes of the endoplasmic reticulum.
- The endoplasmic reticulum is the main component of the endomembrane system, also called the cytoplasmic vacuolar system or cytocavity network.

- The endoplasmic membranes contain many enzymes that perform various synthetic and metabolic activities. Further, the endoplasmic reticulum provides an increased surface for various enzymatic reactions
- The endoplasmic reticulum acts as an intracellular circulatory or transporting system
- As a growing secretory polypeptide emerges from the ribosome, it passes through the RER membrane and gets accumulated in the lumen of RER
- Here, the polypeptide chains undergo tailoring, maturation, and molecular folding to form functional secondary or tertiary protein molecules
- RER pinches off certain tiny protein-filled vesicles which ultimately get fused to cis Golgi

- The ER membranes are found to conduct intra-cellular impulses. For example, the sarcoplasmic reticulum transmits impulses from the surface membrane into the deep region of the muscle fibers
- The ER membranes form the new nuclear envelope after each nuclear division
- The SER contains several key enzymes that catalyze the synthesis of cholesterol which is also a precursor substance for the biosynthesis of two types of compounds— the steroid hormones and bile acids
- RER also synthesize membrane proteins and glycoproteins which are cotranslationally inserted into the rough ER membranes. Thus, the endoplasmic reticulum is the site of the biogenesis of cellular membranes

The Golgi Apparatus

- The Golgi stain and the cytological studies performed by Camillo Golgi were destined, however, to exert a great impact not only on the neurosciences, but also on cell biology
- Golgi made his observations leading to the discovery of the intracellular organelle in the last years of the nineteenth century
- Functions as a factory process and sort the protein (from ER) transport to their destination
- Glycolipids and shingomyelin are synthesized
- In Plants, complex polysaccharides of the cell wall are synthesized
- It involve in the processing of broad range of cellular constituents that travels along the secretory pathways

Organization of the Golgi

- the Golgi is composed of flattened membrane-enclosed sacs (cisternae) and associated vesicles
- distinct polarity in both structure and function
- Proteins from the ER enter at its *cis* face (entry face), which is convex and usually oriented toward the nucleus
- They are then transported through the Golgi and exit from its concave *trans* face (exit face)
- As they pass through the Golgi, proteins are modified and sorted for transport to their eventual destinations within the cell
- It is also known as **dictyosomes**

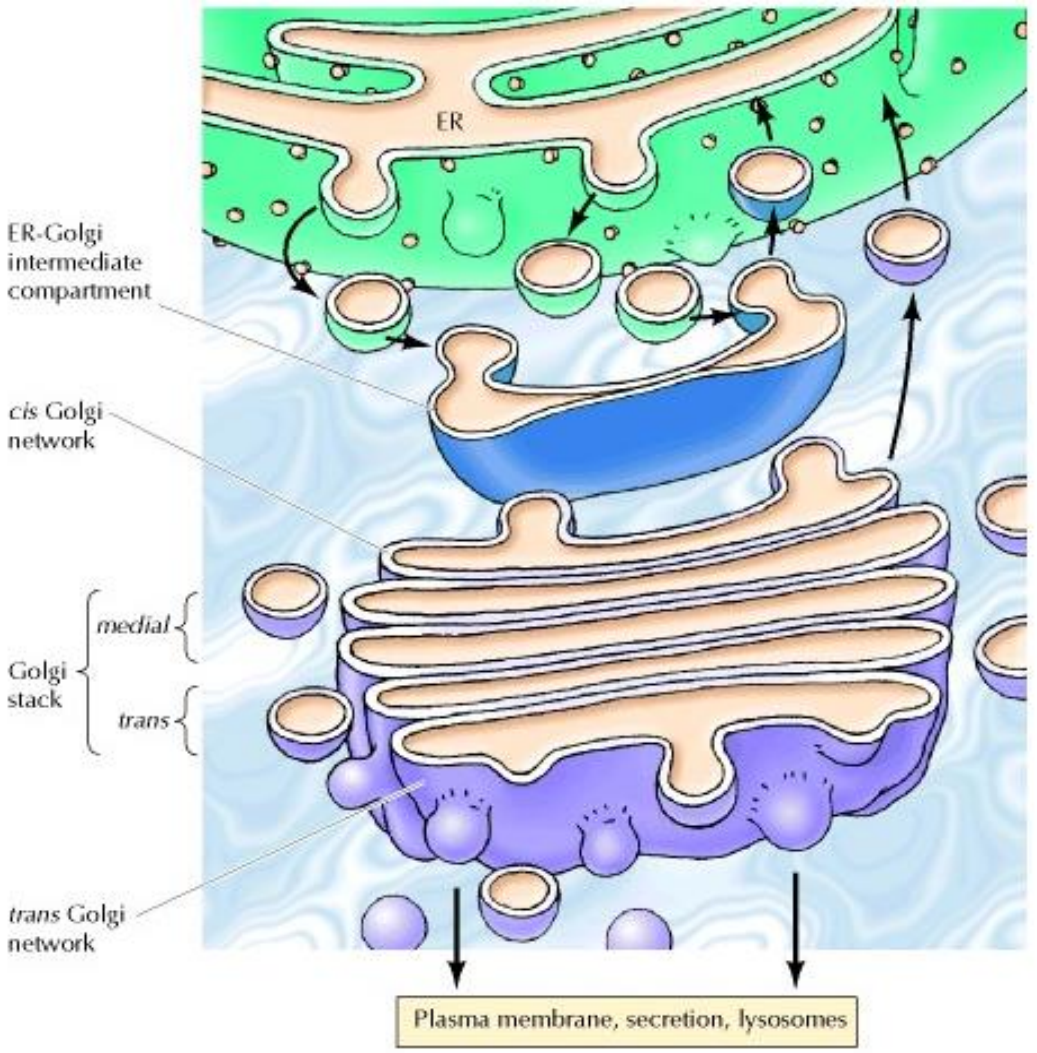


Figure: The Cell: A Molecular Approach. 2nd edition

- Functional region :cisGolgi network, the Golgi stack (which is divided into the medial and trans subcompartments), and the transGolgi network
- Proteins from the ER are transported to the ER-Golgi intermediate compartment and then enter the Golgi apparatus at the *cis* Golgi network

area of controversy among cell biologists:

Two possibilities are

1. transport vesicles carry proteins between the cisternae of the Golgi compartments
2. proteins are simply carried through compartments of the Golgi within the Golgi cisternae, which gradually mature and progressively move through the Golgi in the *cis* to *trans* direction

Protein Glycosylation within the Golgi

- proteins are modified within the ER by the addition of an oligosaccharide consisting of 14 sugar residues
- Three glucose residues and one mannose are then removed while the polypeptides are still in the ER
- Following transport to the Golgi apparatus, the *N*-linked oligosaccharides of these glycoproteins
- Image description: Processing of *N*-linked oligosaccharides in the Golgi. The *N*-linked oligosaccharides of glycoproteins transported from the ER are further modified by an ordered sequence of reactions in the Golgi

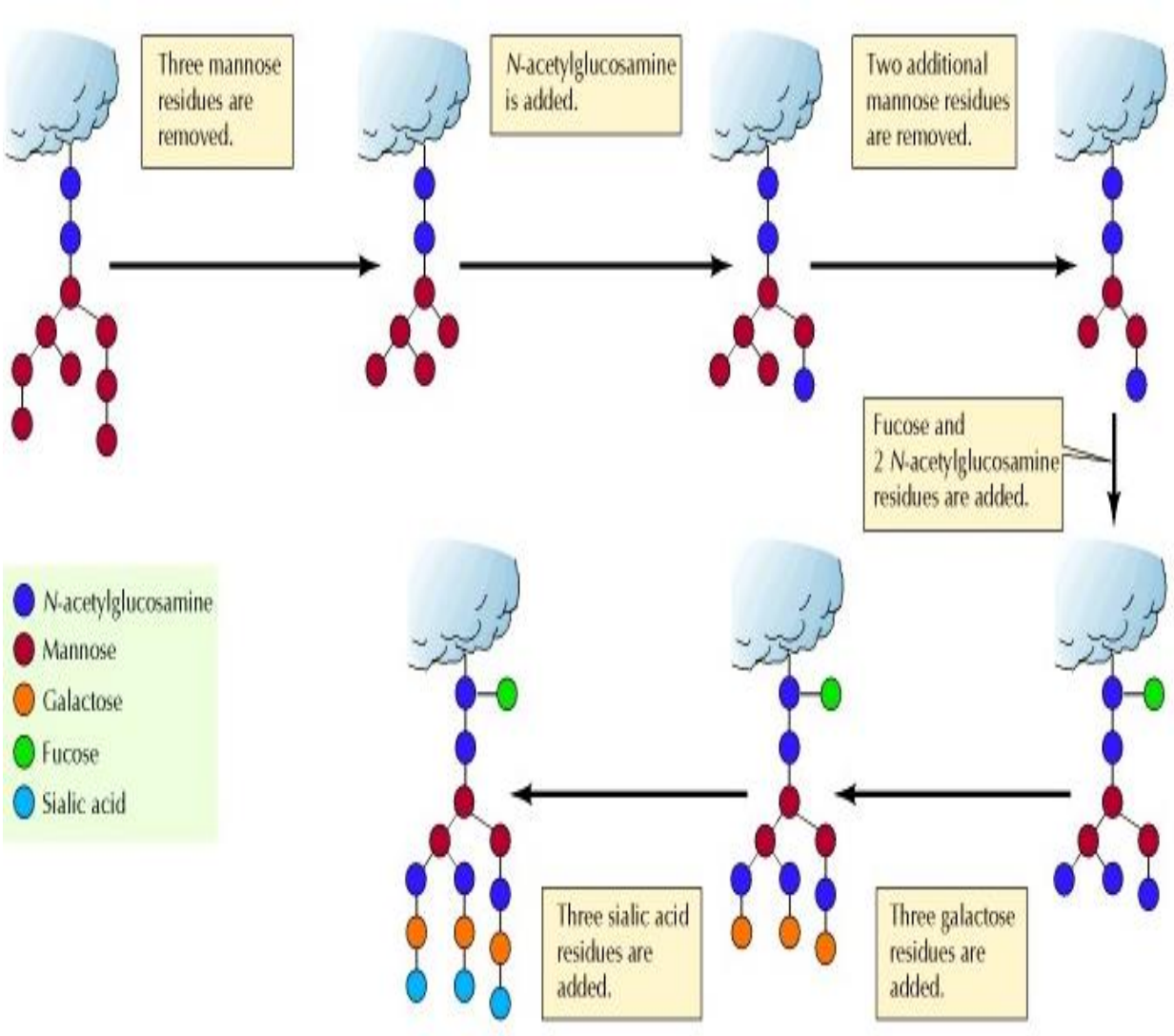


Figure: The Cell: A Molecular Approach. 2nd edition.

- different glycoproteins are modified to different extents during their passage through the Golgi, depending on both the protein structure and on the amount of processing enzymes that are present within the Golgi complexes of different types of cells
- proteins can emerge from the Golgi with a variety of different *N*-linked oligosaccharides
- The processing of the *N*-linked oligosaccharide of lysosomal proteins differs from that of secreted and plasma membrane proteins
- In the first step of this reaction, *N*-acetylglucosamine phosphates are added to specific mannose residues, probably while the protein is still in the *cis* Golgi network

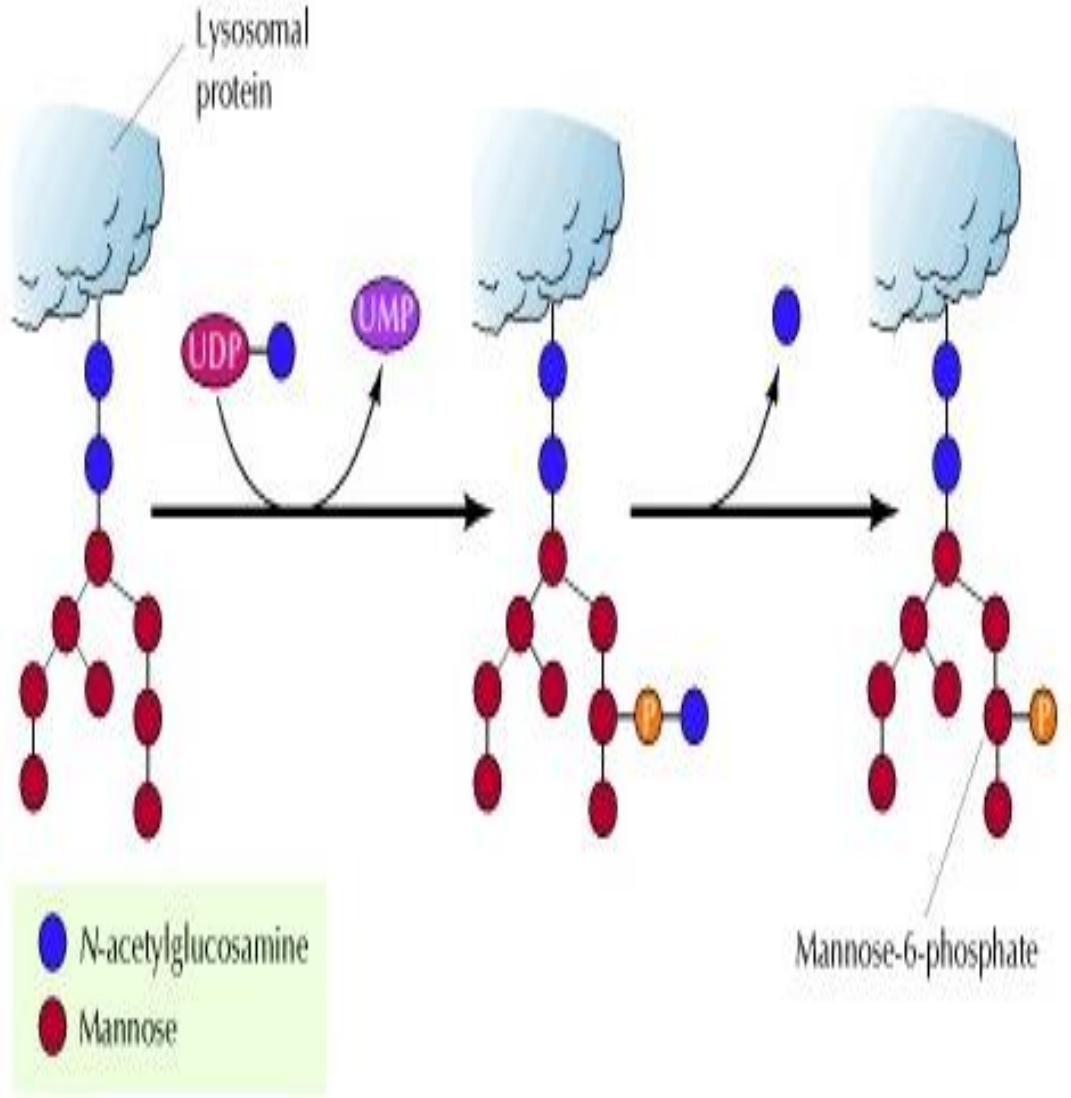


Figure: The Cell: A Molecular Approach. 2nd edition.

- removal of the *N*-acetylglucosamine group, leaving **mannose-6-phosphate** residues on the *N*-linked oligosaccharide
- these residues are not removed during further processing
- These are specifically recognized by a mannose-6-phosphate receptor in the *trans* Golgi network, which directs the transport of these proteins to lysosomes
- Phosphorylation is the crucial step in sorting the lysosomes
- the selective addition of *N*-acetylglucosamine phosphates to lysosomal proteins act as structure determinant which is not present in secretion and plasma membrane proteins
- Recognition determinants are not simply in sequence, but it formed in the folded protein by the juxtaposition of amino acids
- **signal patches :**the recognition determinant that leads to mannose phosphorylation, and targets proteins to lysosomes, depends on the 3D conformation of the folded protein

- Protein modification by the addition of carbohydrates to the side chains of acceptor serine and threonine residues within specific sequences of amino acids (*O*-linked glycosylation)
- serine or threonine is usually linked directly to *N*-acetylgalactosamine, to which other sugars can then be added

Lipid and Polysaccharide Metabolism in the Golgi

- the Golgi apparatus functions in lipid metabolism—in particular, in the synthesis of glycolipids and sphingomyelin
- glycerol phospholipids, cholesterol, and ceramide are synthesized in the ER
- Sphingomyelin - only nonglycerol phospholipid in cell membranes
- It is synthesized by the transfer of a phosphorylcholine group from phosphatidylcholine to ceramide
- Addition of carbohydrates to ceramide can yield a variety of different glycolipids

- It is synthesized on the lumenal surface of the Golgi, glucose is added to ceramide on the cytosolic side
- Glucosylceramide flips, additional carbohydrates are added on the lumenal side of the membrane
- sphingomyelin, glycolipids are not able to translocate across the Golgi membrane, they are found only in the lumenal half of the Golgi bilayer
- Following vesicular transport, they are localized to the exterior half of the plasma membrane, with their polar head groups exposed on the cell surface
- oligosaccharide portions of glycolipids are important surface markers in cell-cell recognition

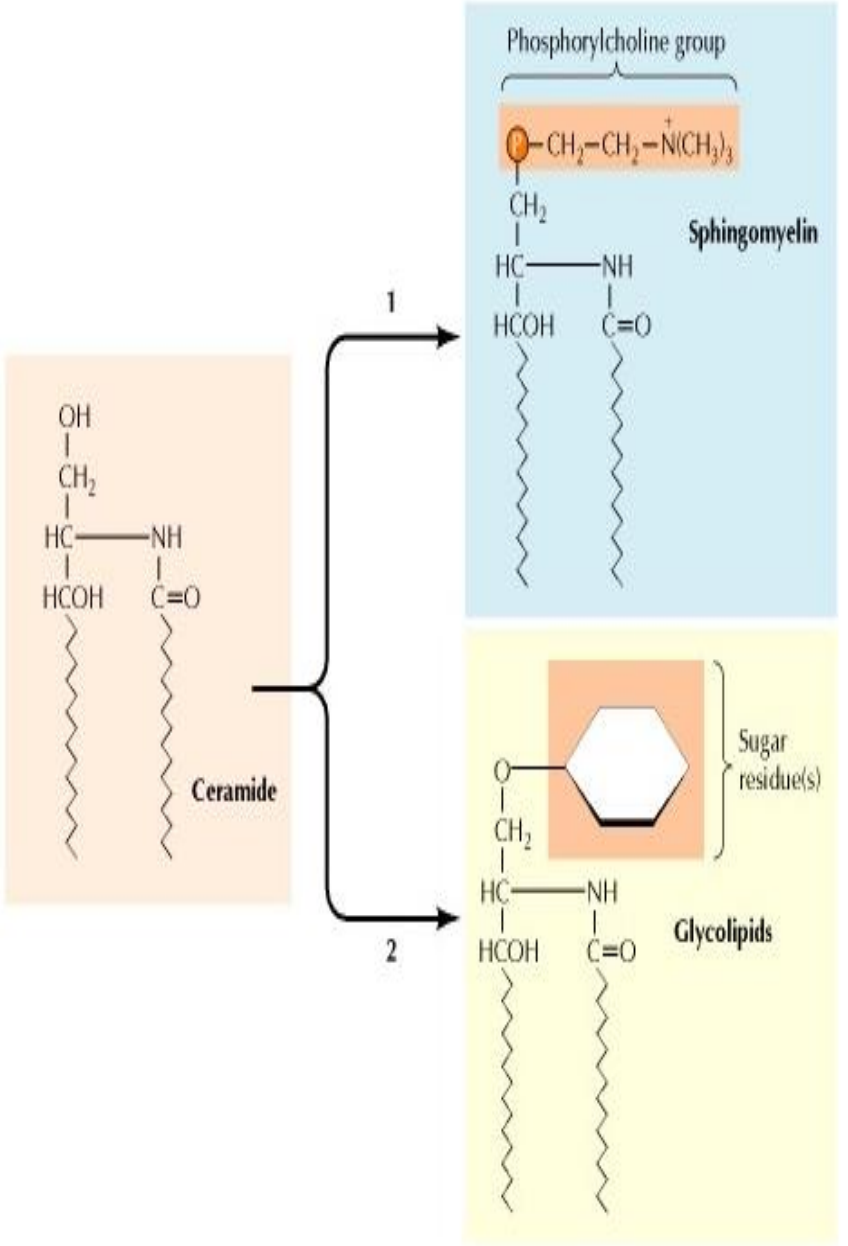


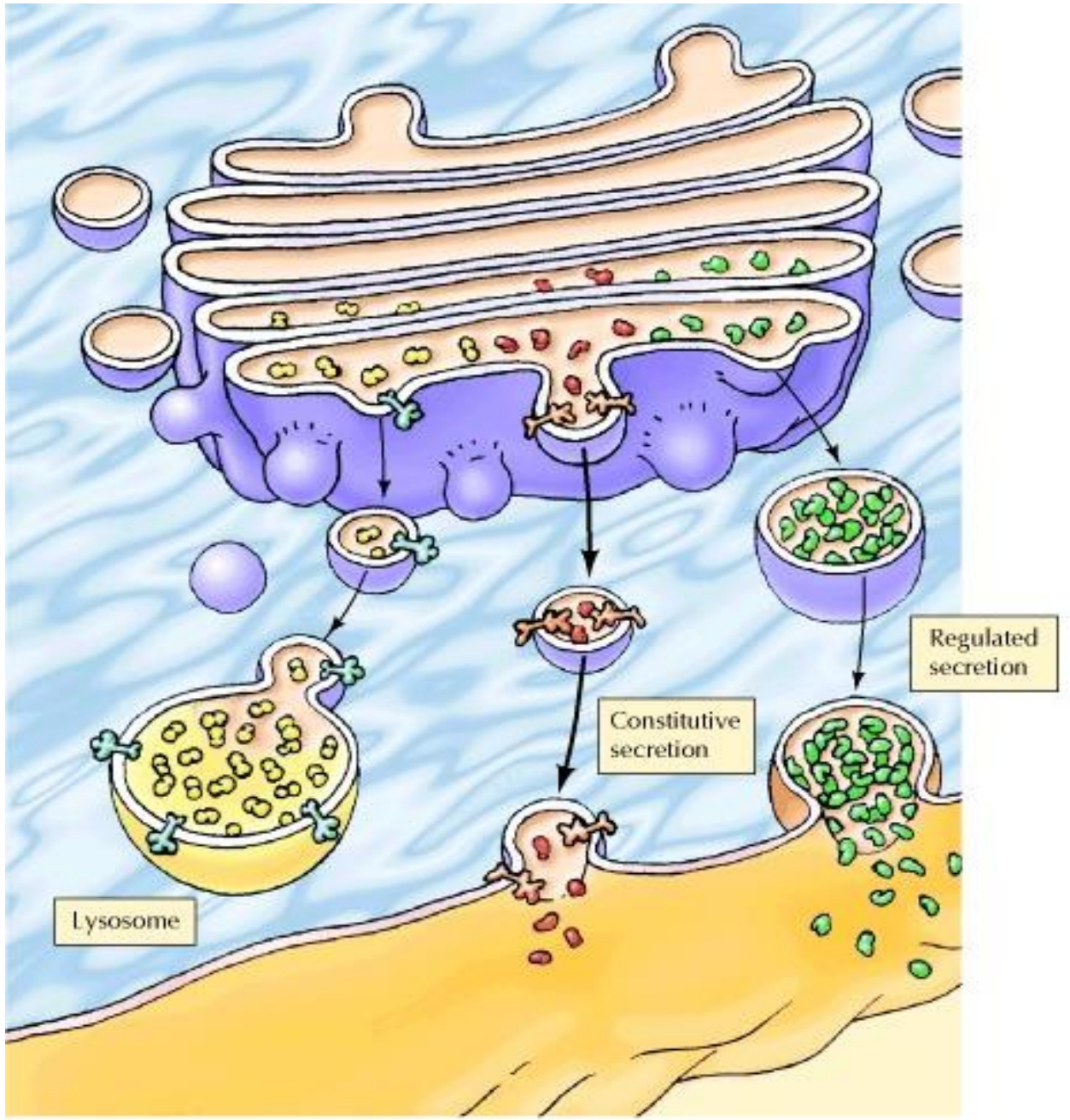
Figure: The Cell: A Molecular Approach. 2nd edition.

- In plants, cell wall polysaccharides (hemicelluloses and pectins), complex branched chain molecules are synthesized in the Golgi apparatus
- then transported in vesicles to the cell surface
- The synthesis of these cell wall polysaccharides is a major cellular function, and as much as 80% of the metabolic activity of the Golgi apparatus in plant cells may be devoted to polysaccharide synthesis

Protein Sorting and Export from the Golgi Apparatus

- Proteins are sorted into different transport vesicles, which bud from the *trans* Golgi network and deliver their contents to the appropriate cellular locations
- Proteins are transport to plasma membrane by consecutive secretory pathway

- Functional proteins of GA are retained, signals from cytoplasmic tails of some Golgi proteins will help these proteins from packing in transport vesciles
- some cells also possess a distinct regulated secretory pathway in which specific proteins are secreted in response to environmental signals
- Examples: release of hormones from endocrine cells, the release of neurotransmitters from neurons, and the release of digestive enzymes from the pancreatic acinar cells
- secretory vesicles larger than other transport vesicles, store their contents until specific signals direct their fusion with the plasma membrane



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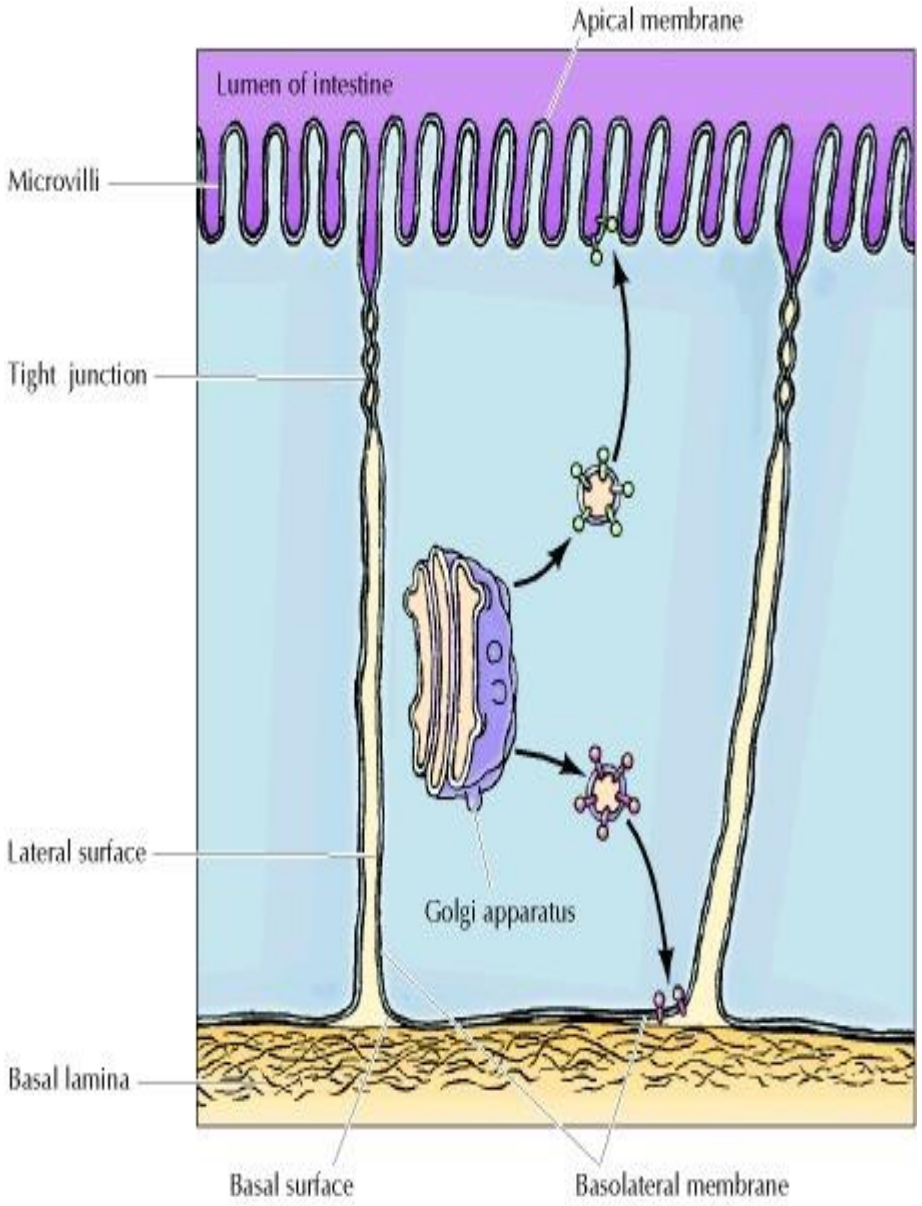


- Complication of transport arises in many epithelial region is they are polarized when organized into tissues
- The plasma membrane is divided into two separate regions, the apical domain and the basolateral domain, contains proteins related to their particular functions
- Examples: apical membrane of intestinal epithelial cells faces the lumen of the intestine for the efficient absorption of nutrients
- the remainder of the cell is covered by the basolateral membrane
- Distinct domains are present in all types of cell
- the constitutive secretory pathway must selectively transport proteins into at least two types of constitutive secretory vesicles that leave the *trans* Golgi network targeted specifically for the apical or basolateral plasma membrane domains of the cell

Figure: The Cell: A Molecular Approach. 2nd edition.

Plastids

- All plastids contain the same genome as chloroplasts, but they differ in both structure and function
- All develop from **proplastids**, small (0.5 to 1 μm in diameter)
- **Chloroplasts** are so named because they contain chlorophyll
- **Chromoplasts** lack chlorophyll but contain carotenoids; they are responsible for the yellow, orange, and red colors of some flowers and fruits, although their precise function in cell metabolism is not clear
- **Leucoplasts** are non-pigmented **plastids**, which store a variety of energy sources in non-photosynthetic tissues
- **Amyloplasts** and **elaioplasts** are examples of leucoplasts that store starch and lipids, respectively

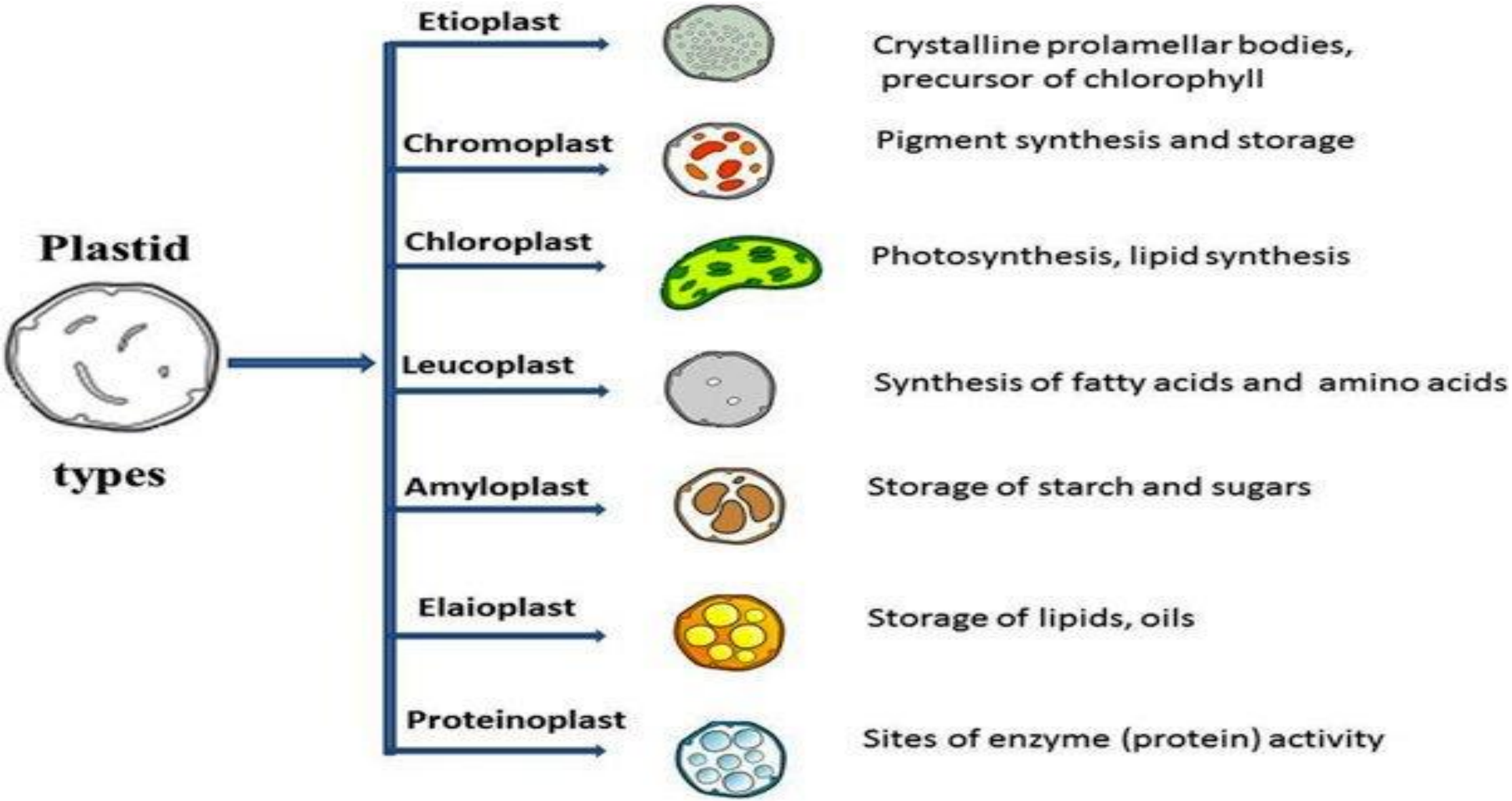


Figure:Microbenotes.com

- If plants are kept in the dark, the development of proplastids in leaves is arrested at an intermediate stage (called **etioplasts**), in which a semicrystalline array of tubular internal membranes has formed but chlorophyll has not been synthesized
- Chromoplasts develop from chloroplasts, for example, during the ripening of fruit (e.g., tomatoes). During this process, chlorophyll and the thylakoid membranes break down, while new types of carotenoids are synthesized
- dual control of **plastid** development involves the coordinated expression of genes within both the **plastid** and nuclear genomes

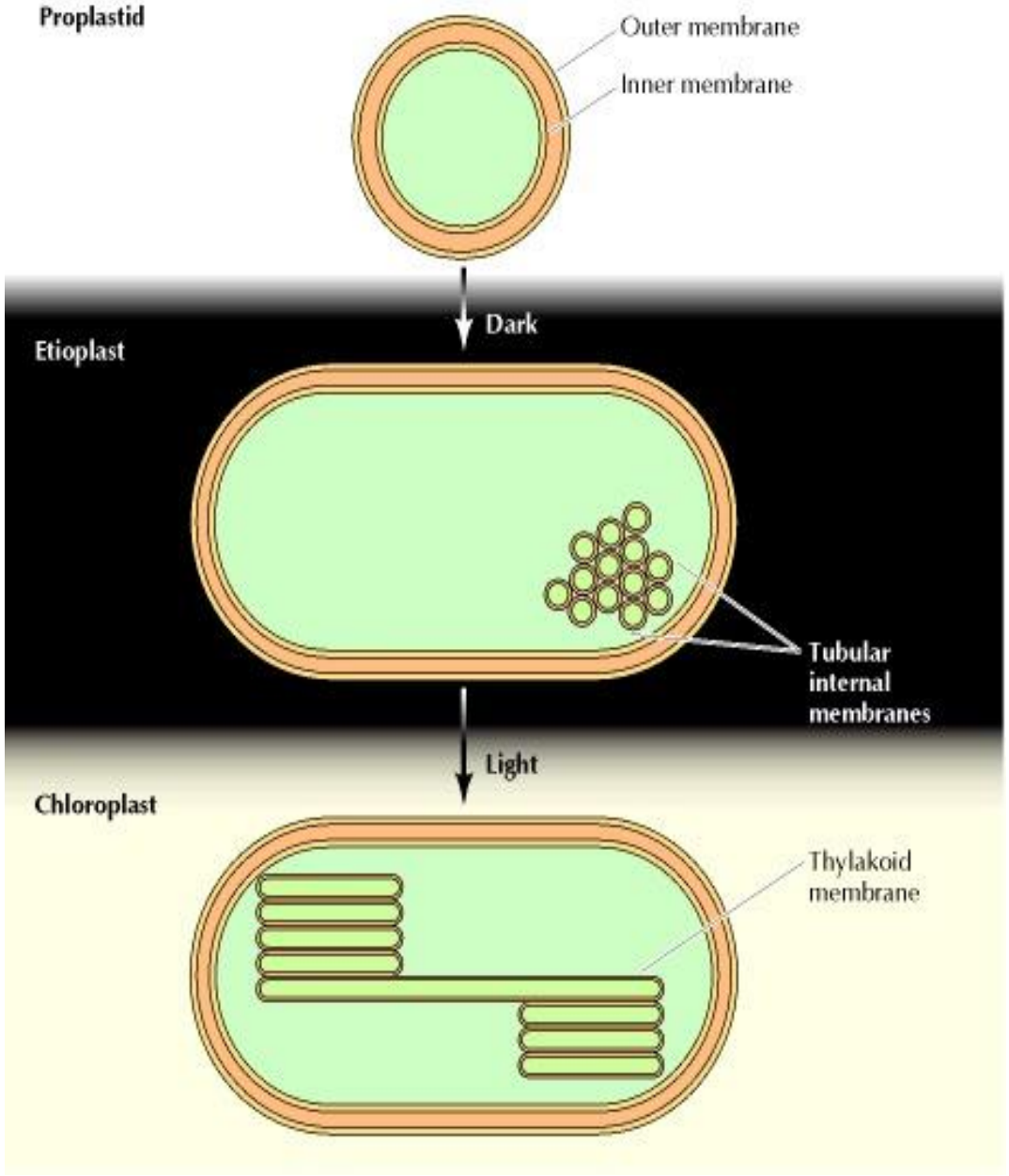


Figure: The Cell: A Molecular Approach. 2nd edition.

Chloroplast

- The word *chloroplast is* derived from the Greek words *chloros*, which means green, and *plastes*, which means “the one who forms”.
- Chloroplasts are a type of membrane-bound plastids that contain a network of membranes embedded into a liquid matrix and harbor the photosynthetic pigment called chlorophyll.
- It is this pigment that imparts a green color to plant parts and serves to capture light energy.
- Chloroplasts can be found in the cells of the mesophyll in plant leaves.
- There are usually 30-40 per mesophyll cells.
- These organelles have an even more complex structure than mitochondria

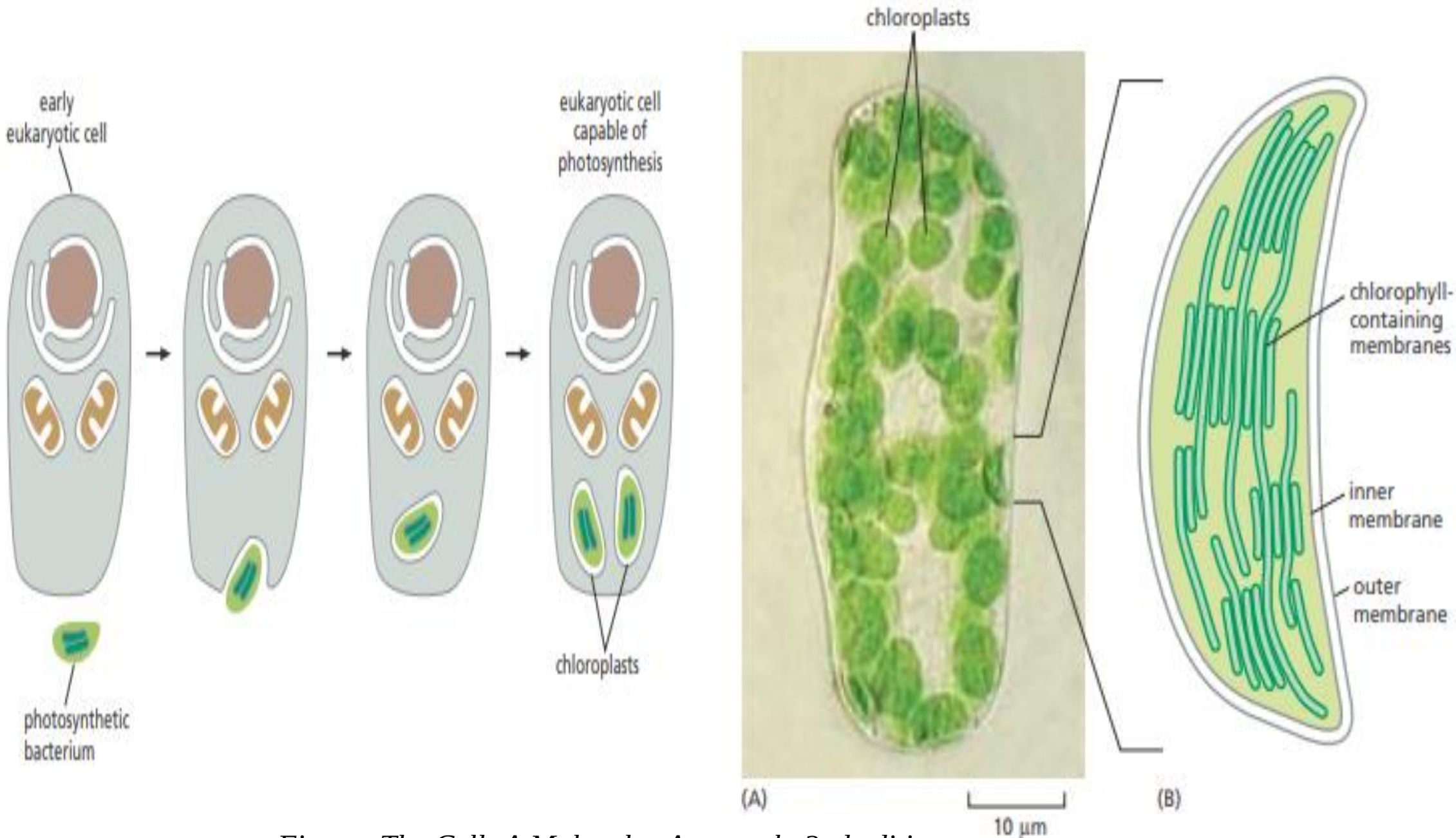


Figure: The Cell: A Molecular Approach. 2nd edition.

Structure of Chloroplasts

- Chloroplasts found in higher plants are generally biconvex or planoconvex shaped.
- In different plants, however, chloroplasts may have different shapes, varying from spheroid, filamentous saucer-shaped, discoid or ovoid-shaped.
- They can be found in the cells of the mesophyll in plant leaves. They are vesicular and have a colorless center.
- The average size of the chloroplast is 4-6 Âµ in diameter and 1-3 Âµ in thickness.
- The chloroplast has an inner and outer membrane with an empty intermediate space in between. Inside the chloroplast are stacks of thylakoids, called grana, as well as stroma, the dense fluid inside of the chloroplast
- These thylakoids contain the chlorophyll that is necessary for the plant to go through photosynthesis. The space the chlorophyll fills is called the thylakoid space.

- A chloroplast thus has the following parts:

Envelope (Outer membrane)

- It is a semi-porous membrane and is permeable to small molecules and ions, which diffuses easily. The outer membrane is not permeable to larger proteins.

Intermembrane Space

- It is usually a thin inter-membrane space about 10-20 nanometers and it is present between the outer and the inner membrane of the chloroplast

Inner membrane

- The inner membrane of the chloroplast forms a border to the stroma. It regulates the passage of materials in and out of the chloroplast. In addition to regulation activity, fatty acids, lipids, and carotenoids are synthesized in the inner chloroplast membrane

Stroma

- Stroma is an alkaline, aqueous fluid that is protein-rich and is present within the inner membrane of the chloroplast
- The space outside the thylakoid space is called the stroma
- The chloroplast DNA chloroplast ribosomes and the thylakoid system, starch granules and many proteins are found floating around the stroma.

Thylakoid System

- The thylakoid system is suspended in the stroma
- The thylakoid system is a collection of membranous sacs called thylakoids
- The chlorophyll is found in the thylakoids and is the sight for the process of light reactions of photosynthesis to happen

- The thylakoids are arranged in stacks known as grana
- Each granum contains around 10-20 thylakoids.

Peripheral Reticulum

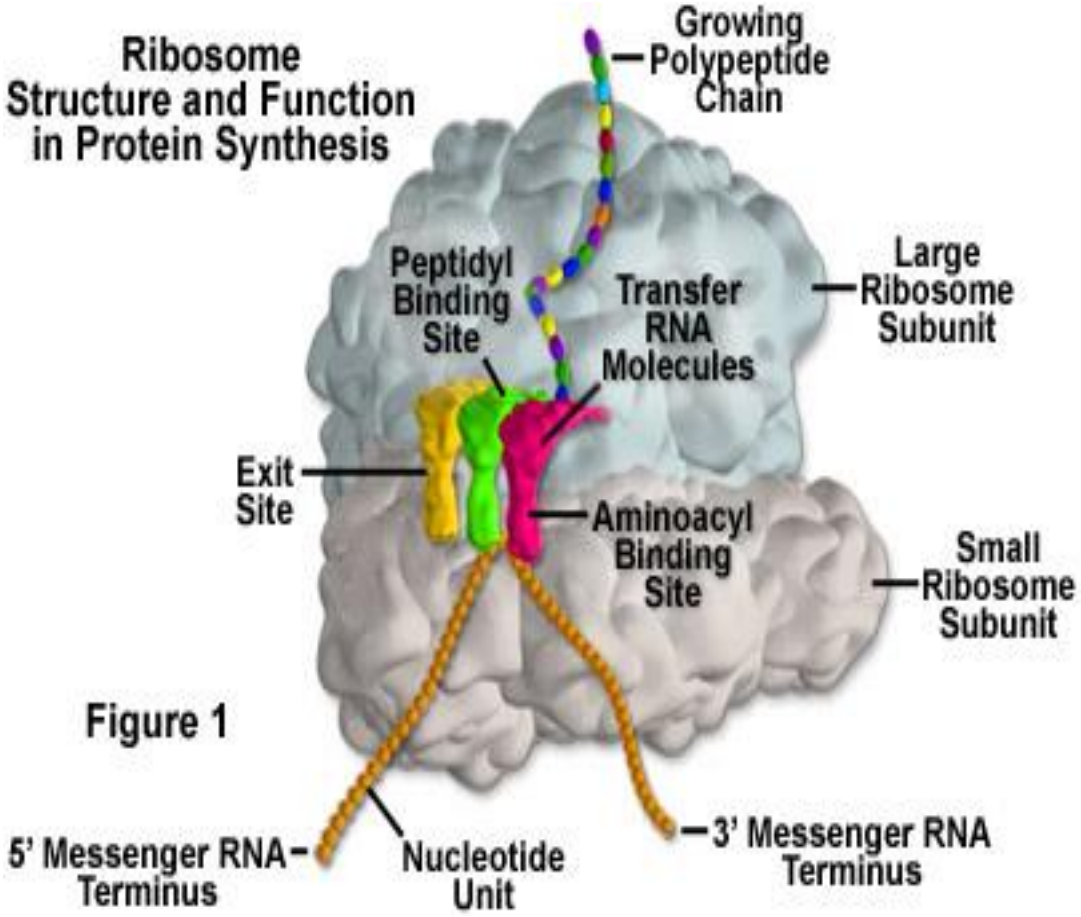
- The chloroplasts of certain plants contain an additional set of membranous tubules called peripheral reticulum that originates from the inner membrane of the envelope
- Tiny vesicles bud off from the inner membrane of the chloroplast and assemble to form the tubules of the peripheral reticulum.

Functions of Chloroplasts

- Chloroplasts are the sites for photosynthesis, which comprises a set of light-dependent and light-independent reactions to harness solar energy and convert it into chemical energy
- The components of chloroplast participate in several regulatory functions of the cell as well as in photorespiration
- Chloroplasts also provide diverse metabolic activities for plant cells, including the synthesis of fatty acids, membrane lipids, isoprenoids, tetrapyrroles, starch, and hormones
- Plants lack specialized immune cells—all plant cells participate in the plant response
- The chloroplasts with the **nucleus** and cell membrane and **ER** are the key organelles of pathogen defense
- Chloroplasts can serve as cellular sensors

Ribosomes

- In 1955, George E. Palade discovered ribosomes and described them as small particles in the cytoplasm that preferentially associated with the endoplasmic reticulum membrane
- Along with other scientists, Palade discovered that ribosomes performed protein synthesis in cells, and he was awarded the Nobel Prize in 1974 for his work



- the RNA components of the ribosome are final gene products
- synthesize approximately 10 million copies of each type of ribosomal RNA in each cell generation to construct its 10 million ribosomes
- The cell can produce adequate quantities of ribosomal RNAs only because it contains multiple copies of the rRNA genes that code for ribosomal RNAs (rRNAs)
- There are four types of eukaryotic rRNAs, each present in one copy per ribosome
- Three of the four rRNAs (18S, 5.8S, and 28S) are made by chemically modifying and cleaving a single large precursor rRNA (Figure)
- the fourth (5S RNA) is synthesized from a separate cluster of genes by a different polymerase, RNA polymerase III, and does not require chemical modification

- chemical modifications occur in the 13,000-nucleotide-long precursor rRNA before the rRNAs are cleaved out of it and assembled into ribosomes
- These include about 100 methylations of the 2′-OH positions on nucleotide sugars and 100 isomerizations of uridine nucleotides to pseudouridine

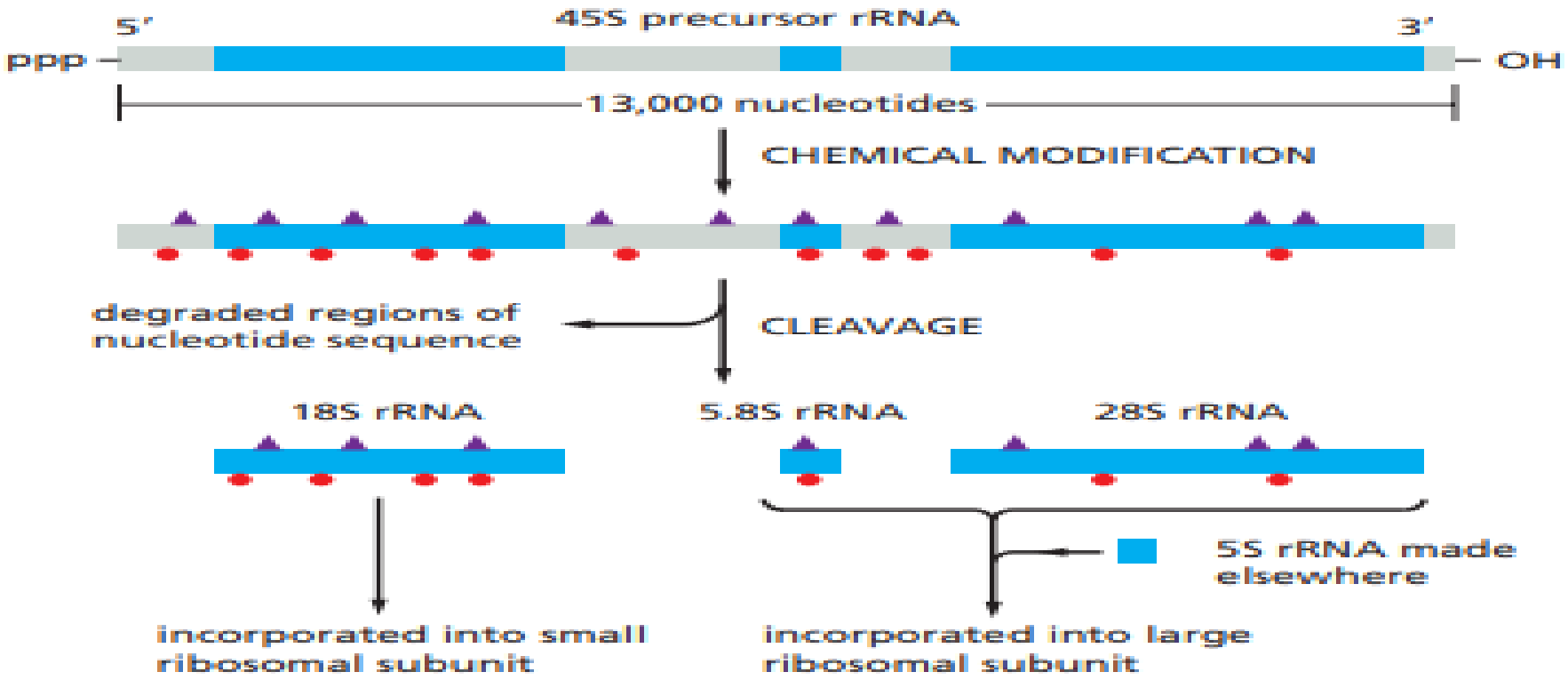
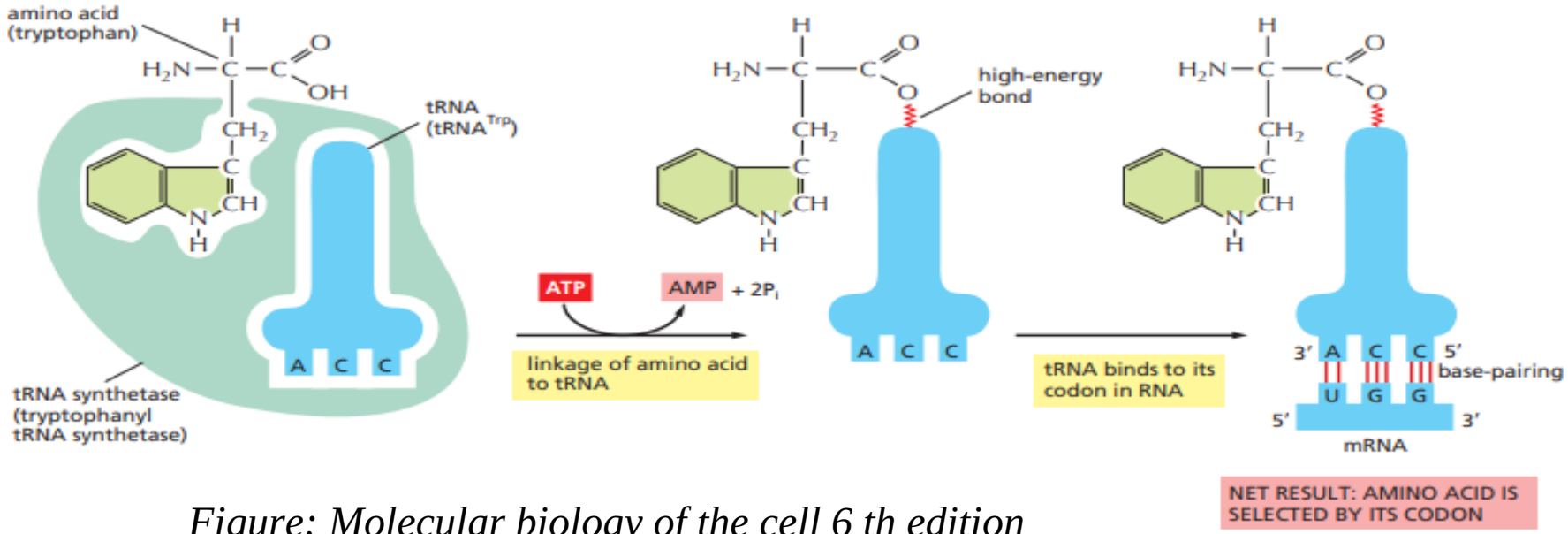


Figure: Molecular biology of the cell 6 th edition

- Figure. The chemical modification and nucleolytic processing of a eukaryotic 45S precursor rRNA molecule into three separate ribosomal RNAs
- Two types of chemical modifications are made to the precursor rRNA before it is cleaved.
- Nearly half of the nucleotide sequences in this precursor rRNA are discarded and degraded in the nucleus by the exosome
- The rRNAs are named according to their “S” values, which refer to their rate of sedimentation in an ultracentrifuge
- The larger the S value, the larger the rRNA

Editing by tRNA Synthetases Ensures Accuracy

- Several mechanisms working together ensure that an aminoacyl-tRNA synthetase links the correct amino acid to each tRNA
- Most synthetase enzymes select the correct amino acid by a two-step mechanism
- The correct amino acid has the highest affinity for the active-site pocket of its synthetase and is therefore favored over the other 19; in particular, amino acids larger than the correct one are excluded from the active site



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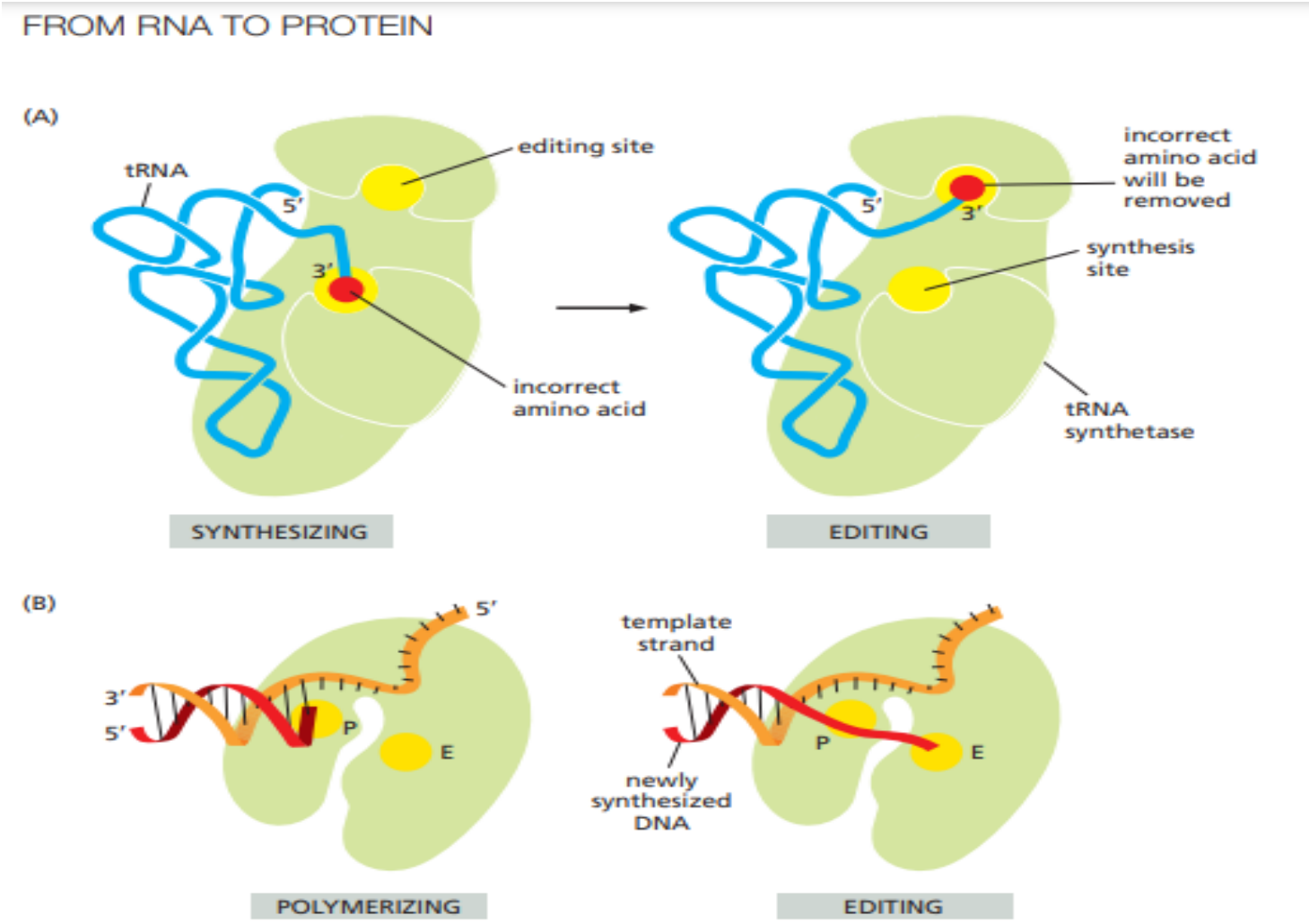

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Hydrolytic editing.

(A) Aminoacyl tRNA synthetases correct their own coupling errors through hydrolytic editing of incorrectly attached amino acids. the correct amino acid is rejected by the editin

(B) The error-correction process performed by DNA polymerase has similarities; however, it differs because the removal process depends strongly on a mispairing with the template

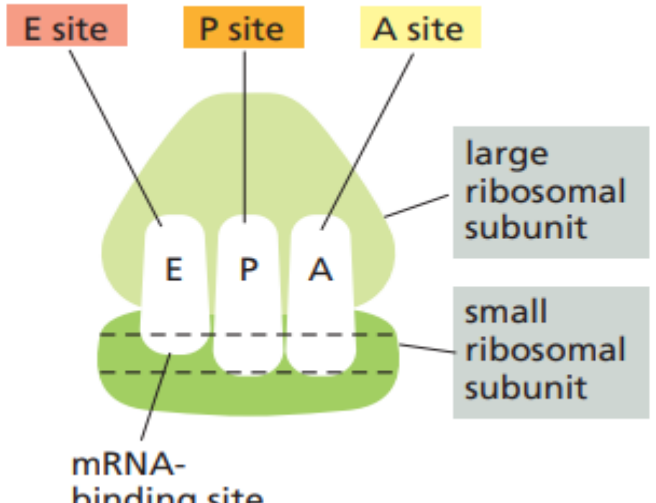
(P, polymerization site; E, editing site.)

Translating an mRNA molecule

- Each amino acid added to the growing end of a polypeptide chain is selected by complementary basepairing between the anticodon on its attached tRNA molecule
- the next codon on the mRNA chain
- Because only one of the many types of tRNA molecules in a cell can base-pair with each codon, the codon determines the specific amino acid to be added to the growing polypeptide chain
- The four-step cycle shown is repeated over and over during the synthesis of a protein
- A site- site for Aminoacyl binding site for charged t-RNA molecules

during protein synthesis

- P site –Polymerisation site
- E site-editing site



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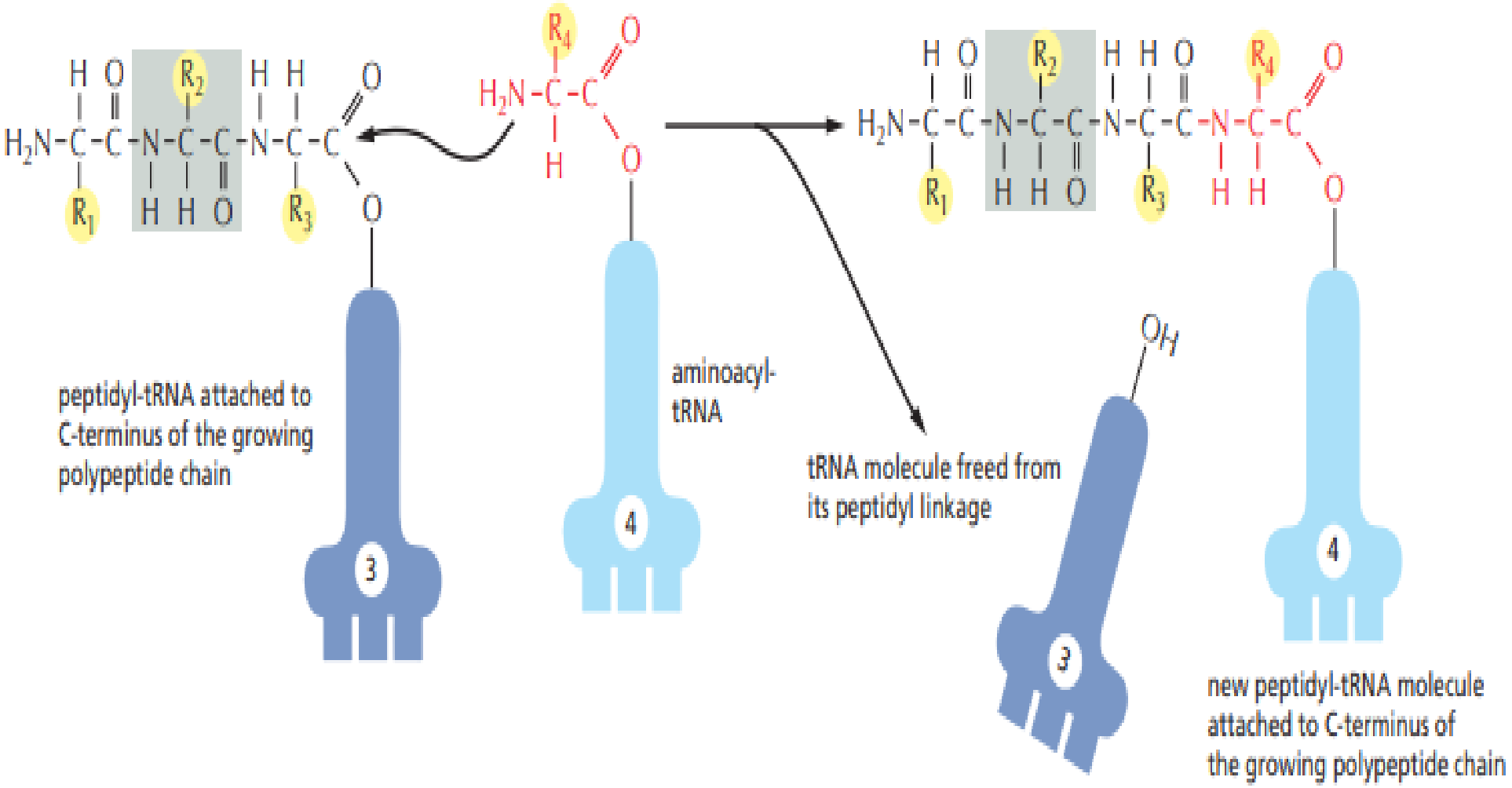
The incorporation of an amino acid into a protein



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- step 1, an aminoacyl-tRNA molecule binds to a vacant A site on the ribosome
- step 2, a new peptide bond is formed
- step 3, the large subunit translocates relative to the small subunit, leaving the two tRNAs in hybrid sites: P on the large subunit and A on the small, for one; E on the large subunit and P on the small, for the other
- step 4, the small subunit translocates carrying its mRNA a distance of three nucleotides through the ribosome. This “resets” the ribosome with a fully empty A site, ready for the next aminoacyl-tRNA molecule to bind
- As indicated, the mRNA is translated in the 5’-to-3’ direction, and the N-terminal end of a protein is made first, with each cycle adding one amino acid to the C-terminus of the polypeptide chain

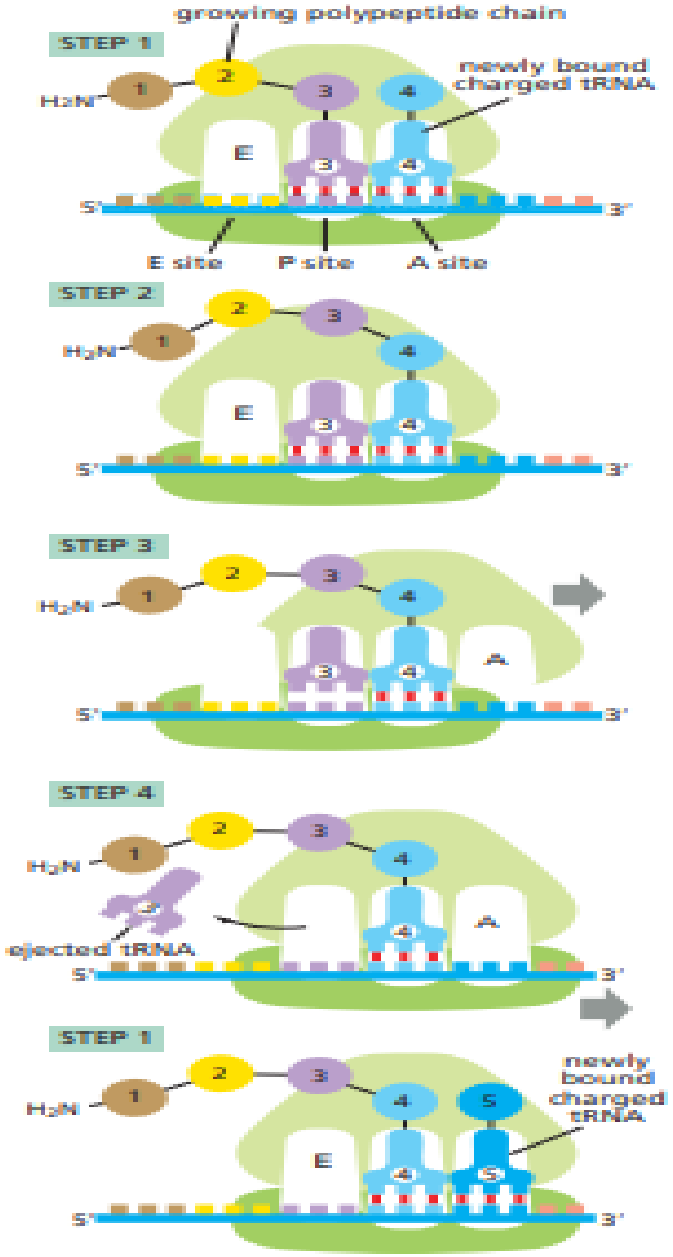
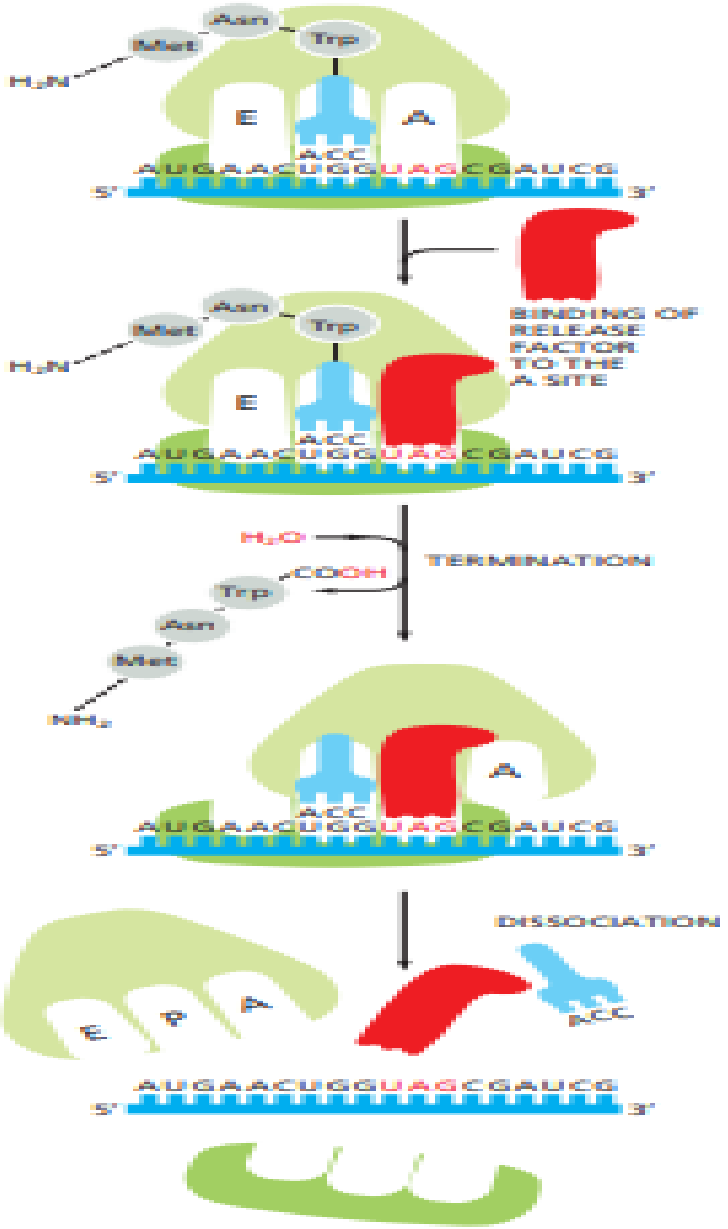


Figure: Molecular biology of the cell 6 th edition

The final phase of protein synthesis.

- The binding of a release factor to an A site bearing a stop codon terminates translation
- The completed polypeptide is released and, in a series of reactions that requires additional proteins and GTP hydrolysis (not shown), the ribosome dissociates into its two separate subunits



Centrosomes

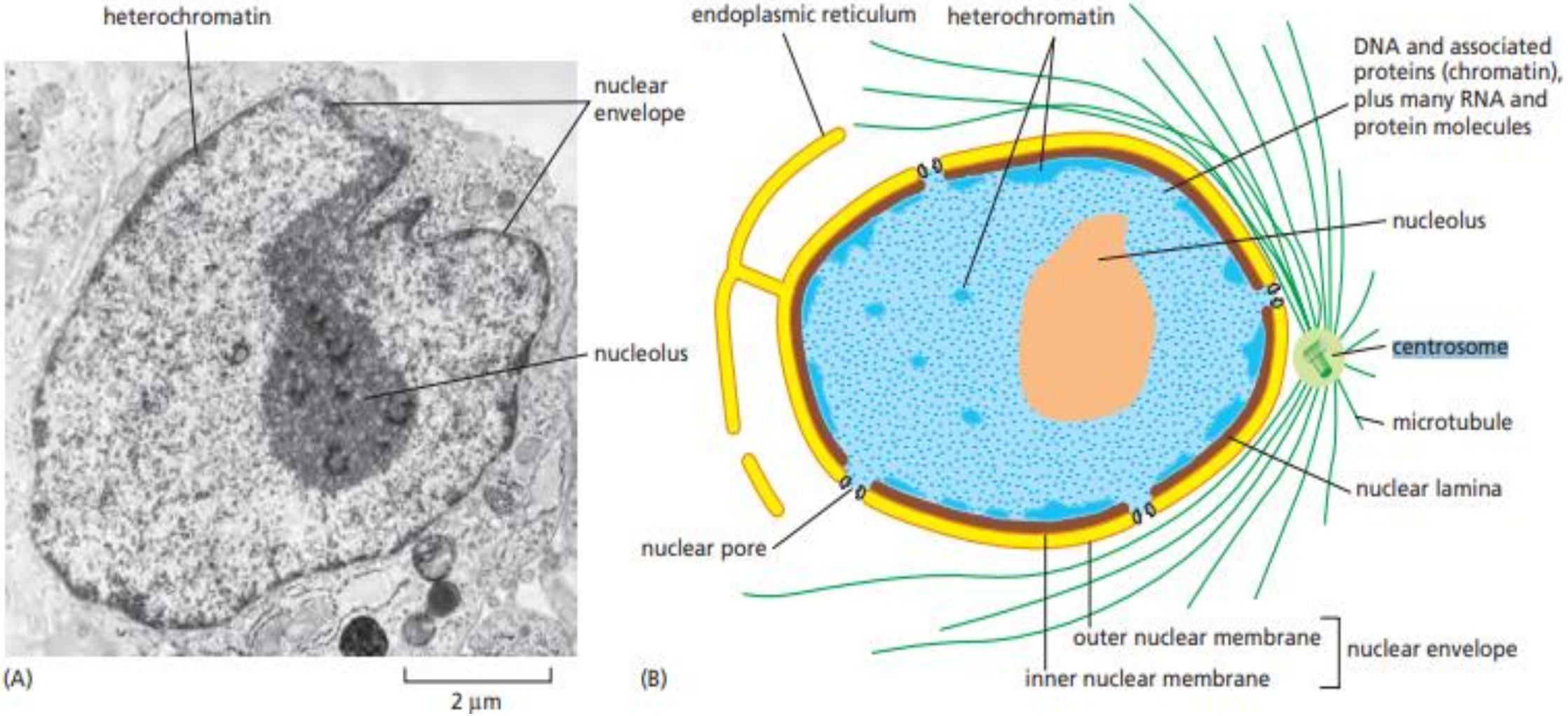


Figure: Molecular biology of the cell 6 th edition

- The centrosome is considered to be the main microtubule-organizing center (MTOC) therefore regulating cell adhesion, motility, and polarity
- It also promotes the spindle pole organization in an animal cell during mitotic replication
- Defects in the function of spindle-organization are present in many cancers and may be attributed to genomic instability
- Irrregular or extra centrosomes may contribute to abnormal cell division.

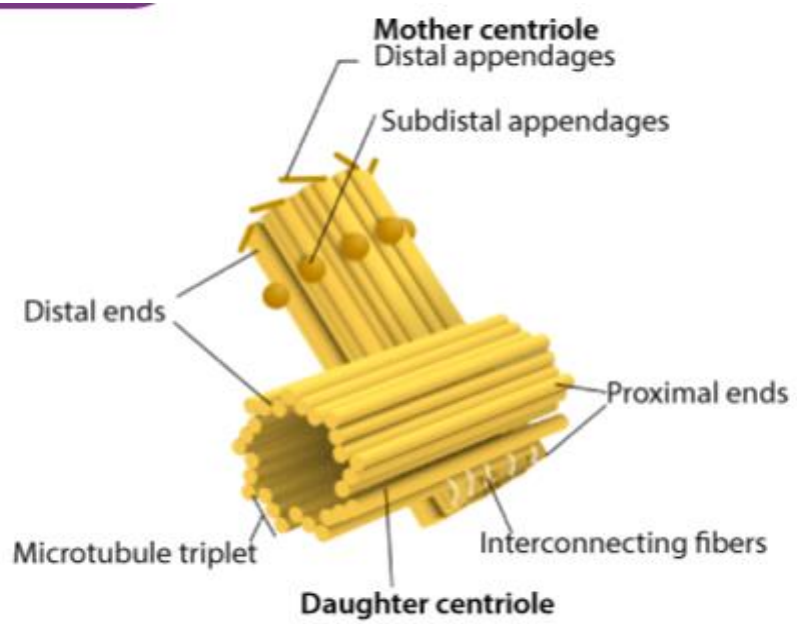
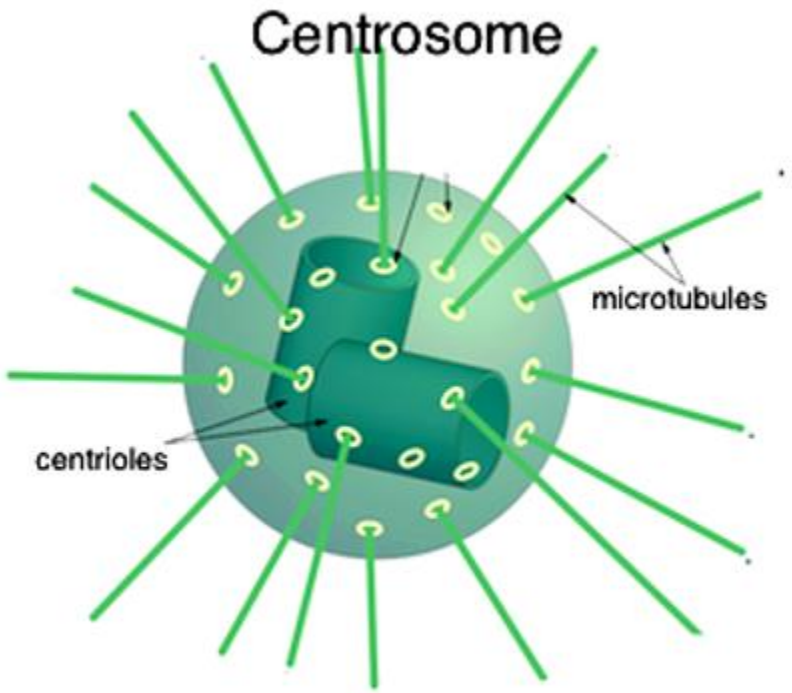


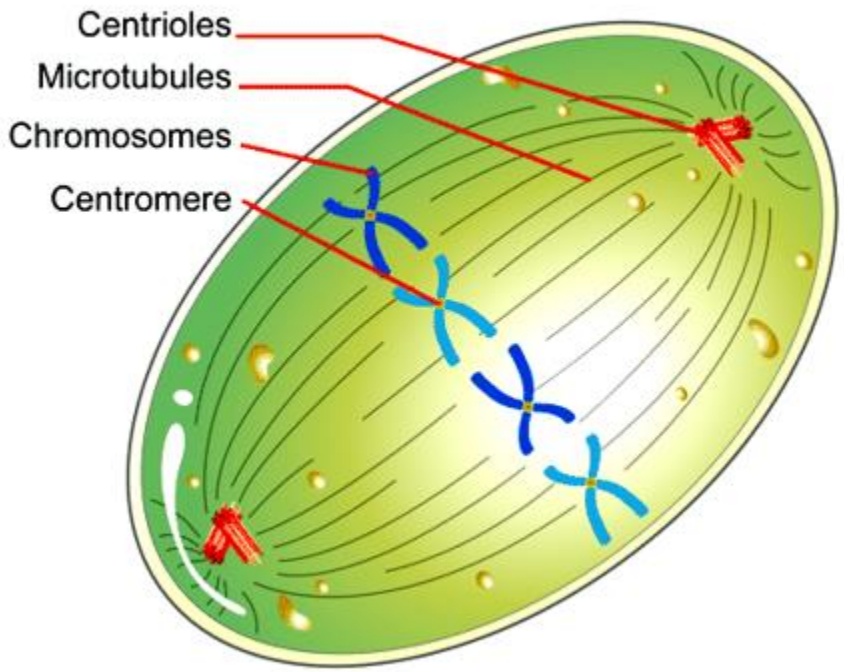
Figure:BYJU's

- The centrosome is made up of two perpendicular centrioles, a daughter centriole, and a mother centriole, linked together by interconnecting fibres
- It consists of a complex of proteins that helps in the formation of additional microtubules
- An amorphous pericentriolar matrix surrounds the centrioles
- It is involved in the nucleation and anchoring of cytoplasmic microtubules
- Centrosome in the animal cells is very much like DNA. During cell division, one centrosome from the parent cell is transferred to each daughter cell
- In proliferating cells, the centrosome starts dividing before the S-phase begins
- The newly formed centrosomes participate in organizing the mitotic spindles
- During Interphase, the centrosome organizes an astral ray of microtubules that help in intracellular trafficking, cell adhesion, cell polarity, etc

The centrosome cycle consists of four phases:

- G1 phase where the duplication of centrosome takes place
- G2 phase where the centrosome maturation takes place
- The mitotic phase where the centrosome separation takes place
- A late mitotic phase where the chromosome disorientation takes place





Centrosome Function

- The major functions of centrosome are listed below:
- The centrosomes help in cell division
- They maintain the chromosome number during cell division
- They also stimulate the changes in the shape of the cell membrane by phagocytosis
- In mitosis, it helps in organizing the microtubules ensuring that the centrosomes are distributed to each daughter cell
- They regulate the movement of microtubules and cytoskeletal structures, thereby, facilitating changes in the shapes of the membranes of the animal cell

Reference

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