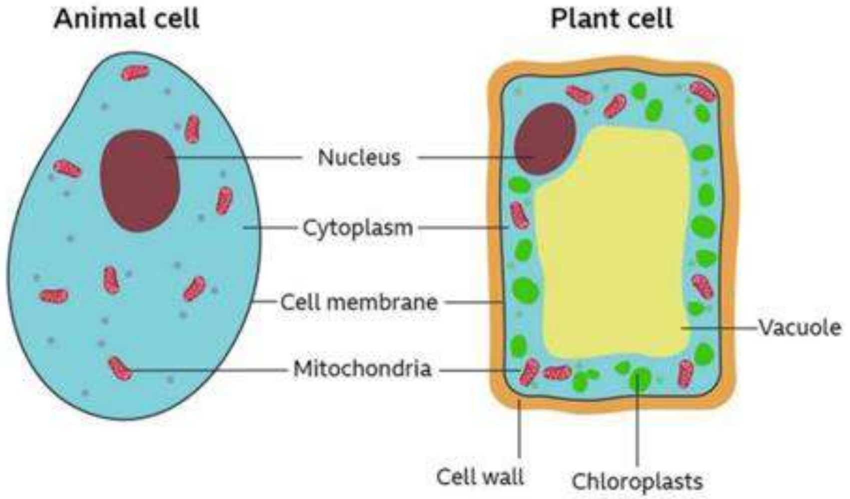
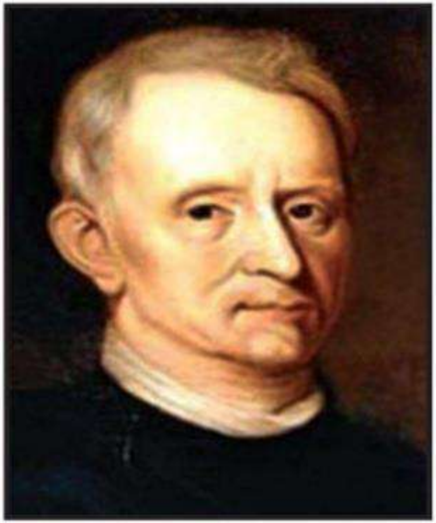
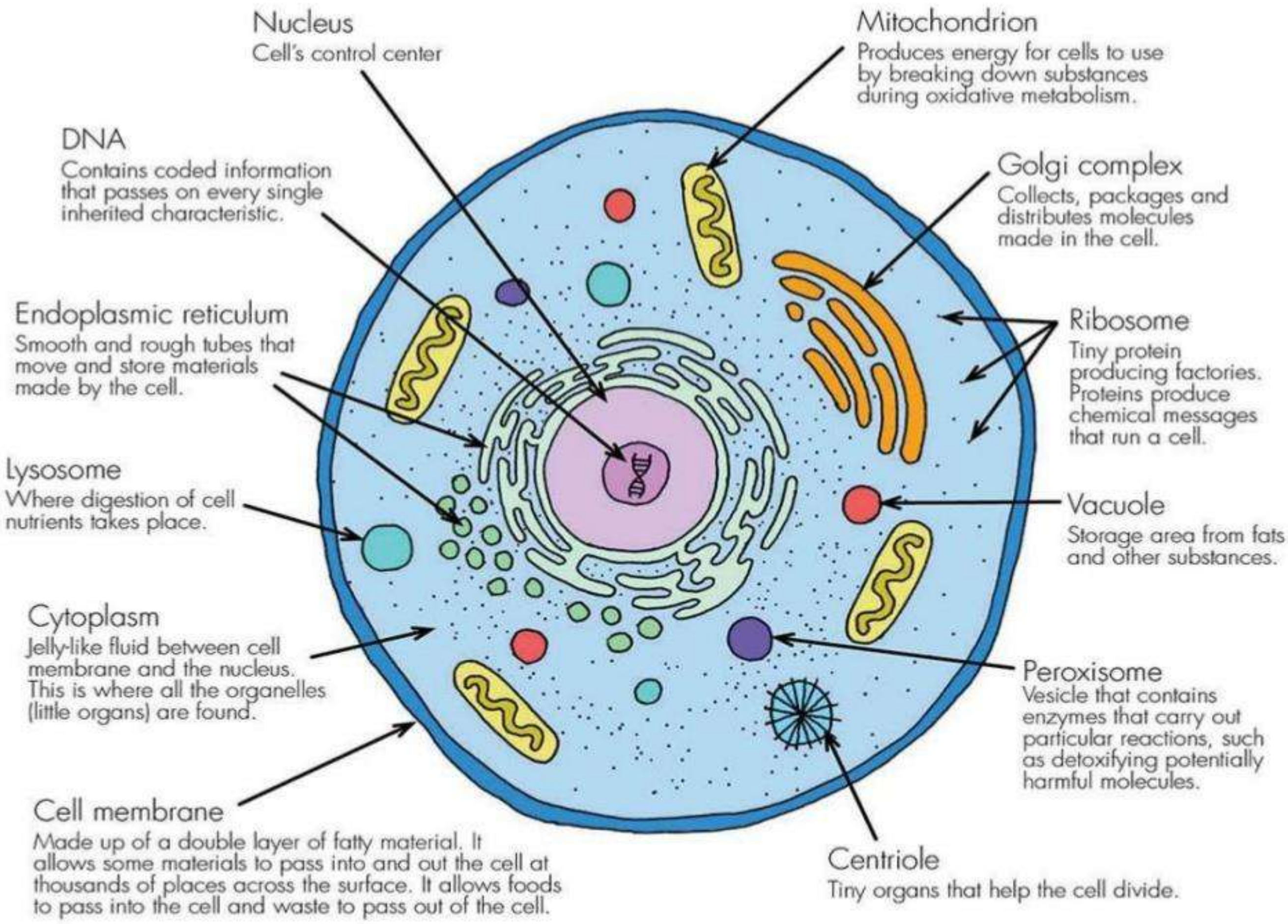
CELL: STRUCTURE AND FUNCTION



INTRODUCTION

- **Fundamental unit of life.**
- Self replicating structure
- The first cells were observed and named by **Robert Hooke** in **1665** from **slice of cork**.
- Some organisms consist of a unicellular organism, others are multicellular.
- **Diameter- 2-120µm.**





Nucleus
Cell's control center
Mitochondrion
Produces energy for cells to use by breaking down substances during oxidative metabolism.
DNA
Contains coded information that passes on every single inherited characteristic.
Golgi complex
Collects, packages and distributes molecules made in the cell.
Endoplasmic reticulum
Smooth and rough tubes that move and store materials made by the cell.
Ribosome
Tiny protein producing factories. Proteins produce chemical messages that run a cell.
Lysosome
Where digestion of cell nutrients takes place.
Vacuole
Storage area from fats and other substances.
Cytoplasm
Jelly-like fluid between cell membrane and the nucleus. This is where all the organelles (little organs) are found.
Peroxisome
Vesicle that contains enzymes that carry out particular reactions, such as detoxifying potentially harmful molecules.
Cell membrane
Made up of a double layer of fatty material. It allows some materials to pass into and out the cell at thousands of places across the surface. It allows foods to pass into the cell and waste to pass out of the cell.
Centriole
Tiny organs that help the cell divide.

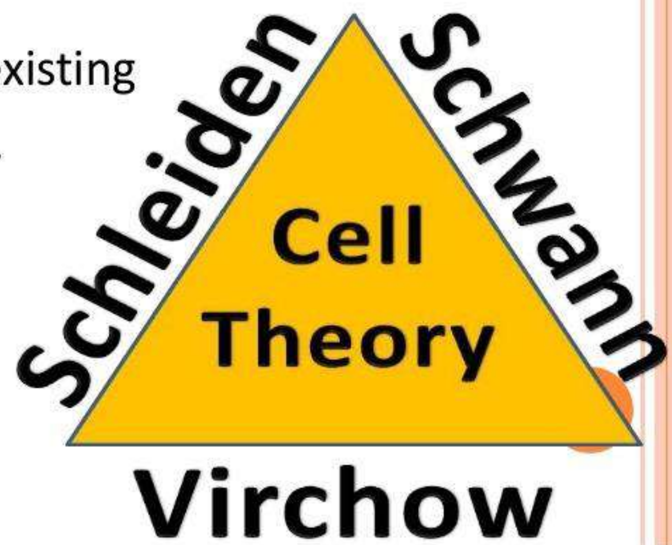
CELL THEORY

- Proposed by **Matthais Schleiden** and **Theodor Schwann** in **1839**:-

  -All living things are made up of cells.

  -Cells are the smallest working unit of all living things.

  -All cells come from pre-existing cells through cell division.



CONSTITUENTS

- Different substances that make a cell are collectively called **Protoplasm.**

- Protoplasm is composed of :-

  1)Water - **70-80% Water** is present in cell.

  2)Carbohydrates

  3)Lipids

  4)Proteins

  5)Electrolyte - Sodium (Na^+), Potassium (K^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Phosphate , Chloride (Cl^-), and Bicarbonate (HCO_3^-).

SUBCELLULAR STRUCTURES

Major Structures Present in a cell are :-

- Cell Membrane
- Cytoplasm and its Organelles
- Nucleus

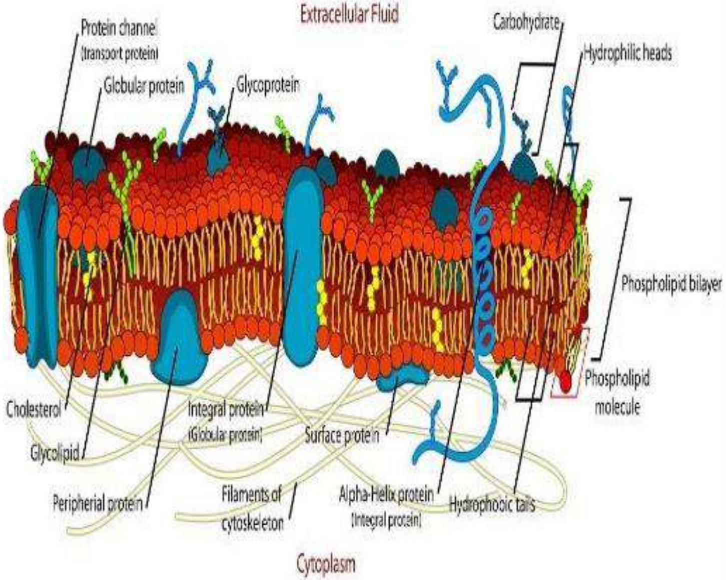
Cell Membrane

- Thin pliable elastic **outermost structure** which envelops the cell.

- It consists of **bilipid layer** with embedded **proteins** that are-

  i)Integral Proteins

  ii)Peripheral proteins



FUNCTIONS OF CELL MEMBRANE

- **Protective**:- Forms outermost boundary of the cell organelles.
- **Digestive**:- Takes in food and excretes waste products.
- **Selective Permeability**:- **a)Non-Polar Molecules**- Gases (like O_2 ,CO_2, N_2), Lipids,Steroid Hormones, Alcohols can dissolve in the non –polar regions of the membrane and move rapidly across the membrane.

b)Polar molecules:- H_2O soluble ions , Glucose, urea etc. have much lower solubility . Therefore Penetrate the membrane much more slowly.

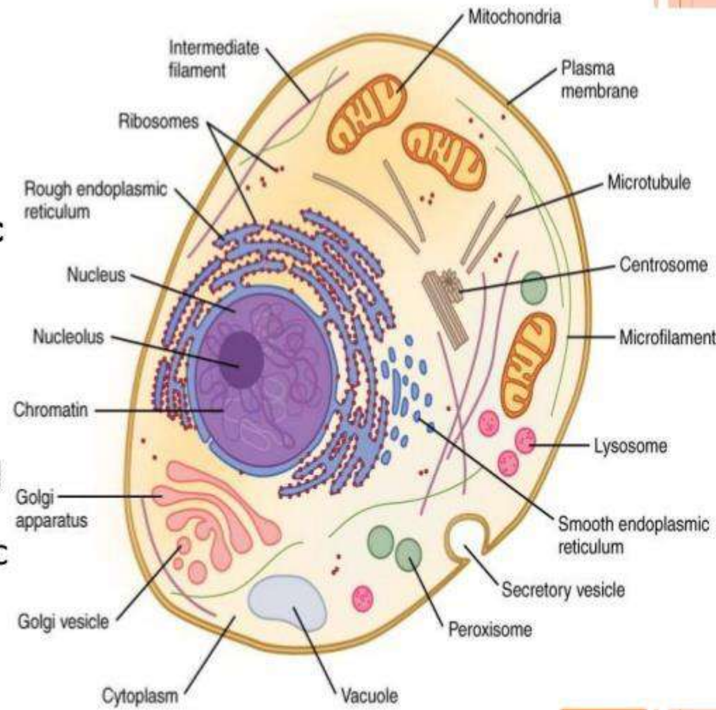
- **b)Chemical and Physical Properties** of membrane control the free passage of ions in and out of cell. This property helps in maintaining components in ICF and ECF.

- Links adjacent cells together by junctional complexes to form tissues.
- **Insulating Properties**:- It acts as **dielectric material** of a charged condenser, thus cell membrane have very high insulating value

CYTOPLASM
AND
ITS ORGANELLES

CYTOPLASM

- **Thick, gel-like semitransparent fluid** that is found in both plant and animal cell.
- The constituent parts of cytoplasm are **cytosol, cell organelles and cytoplasmic inclusions.**
- Bounded by the plasma membrane, and contains many organelles in a eukaryotic cell (cell containing membrane bounded nucleus).



CYTOSOL

- **The cytosol**, the aqueous part of the cytoplasm outside all of the organelles, also contains its own distinctive proteins.

- It accounts for almost 70% of the total cell volume.

- **Gelatinous substance** consisting mainly of cytoskeleton filaments, organic molecules, salt and water.

- Chemically, the cytoplasmic matrix is composed of many chemical elements in the form of atoms, ions and molecules.

ORGANELLES

- Following organelles are present in the Cytoplasm:-

i)Mitochondria
ii)Endoplasmic Reticulum
iii)Lysosomes
iv)Golgi Appartus
v)Peroxisomes
vi)Vacuole

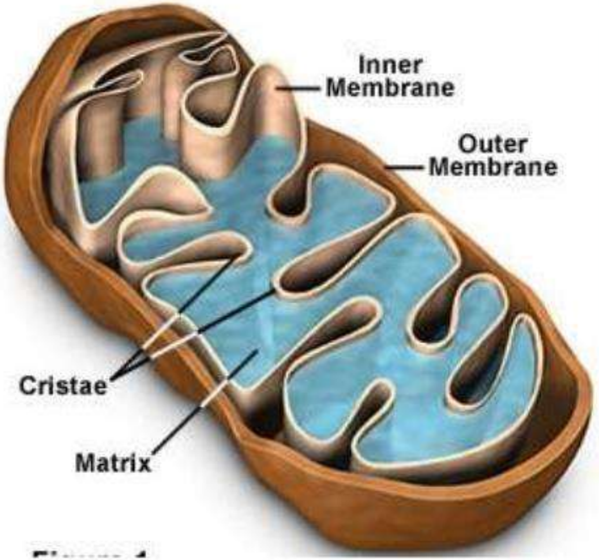
- Each organelle is bounded by a lipid membrane, and has specific functions.

MITOCHONDRIA

- The mitochondria were first observed by **Kolliker** in **1850** as granular structures in the striated muscles.

- Mitochondria are called **the 'powerhouse of the cell'.**

STRUCTURE-



- **Length-** 5-12µm

  Diameter- 0.5-1µm

- Filamentous or globular in shape.

- Components of Mitochondria are -

  i)Outer Membrane

  ii)Inner Membrane

  iii)Intermediate Space- space between outer and inner membranes

  iv)Cristae-Infoldings of inner membrane

  v)Matrix- The space enclosed by inner membrane

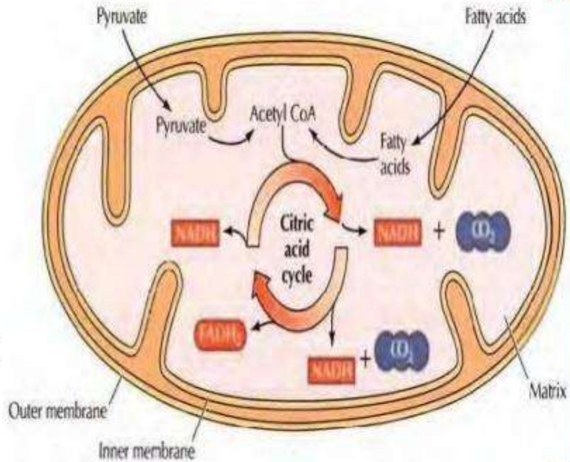
- The membranes are made up of phospholipids and proteins

- **Outermost Membrane-**

a)It contains large numbers of integral membrane proteins called **Porins**.

These porins form channels that allow molecules of 5000 daltons or less to pass.

b)Studded with enzymes concerned with biological oxidation .



- **Interior (Matrix)** of the Mitochondria contains enzymes concerned with *'citric acid cycle'* and *'respiratory chain oxidation'*.
- Major metabolic pathways involved in oxidation of carbohydrates, lipids and amino acids and part of special biosynthetic pathways involving urea and heme synthesis are located in inner matrix.

- **Inner Membrane** :

  It contains ATPase and other enzymes concerned with synthesis and metabolism of ATP.

  Contains enzymes of Electron Transport Chain.

- The ultimate purpose of these mechanisms is *oxidative phosphorylation* and *synthesis of ATP.*

- Mitochondria has some protein synthesised by Mitochondrial DNA.

FUNCTIONS

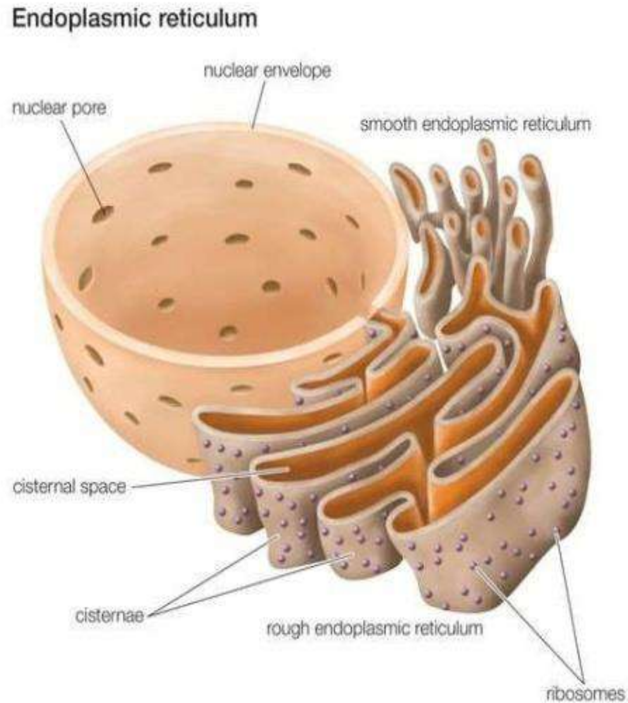
- Power generating units of the cells.
- Important to maintain proper concentration of calcium ions within the various compartments of the cell.
- Energy transduction through respiration.
- Responsible for thermogenesis.

Endoplasmic Reticulum

- Network of **tubular and flat vesicular structures** in the cytoplasm.

- An extensive network of closed, flattened membrane-bounded sacs called **cisternae** .

- Space inside the tubules is filled with Endoplasmic Matrix.



- **TWO TYPES-**

Smooth Endoplasmic Reticulum	Rough Endoplasmic Reticulum
▪ Ribosomes absent ▪Site of synthesis of lipid and steroid hormones. ▪Mainly present in lipid forming cells such as adipocytes, interestitial cells of testis, glycogen storing cells of liver, adrenal cortex cells, muscle cells, leucocytes etc.	▪Contains ribosomes ▪Site of protein synthesis,processing and packaging. ▪Mainly present in protein forming cells such as pancreatic acinar cells ,Goblet cells ,antibody producing plasma cells, Nissl's granules of nerve cells etc.

FUNCTION

- Synthesis of proteins.
- Protein segregation.
- Unsaturation of fatty acid.
- Muscle contraction.ER is commomly known as Sarcoplasmic Reticulum in muscle fibers.

GOLGI BODIES

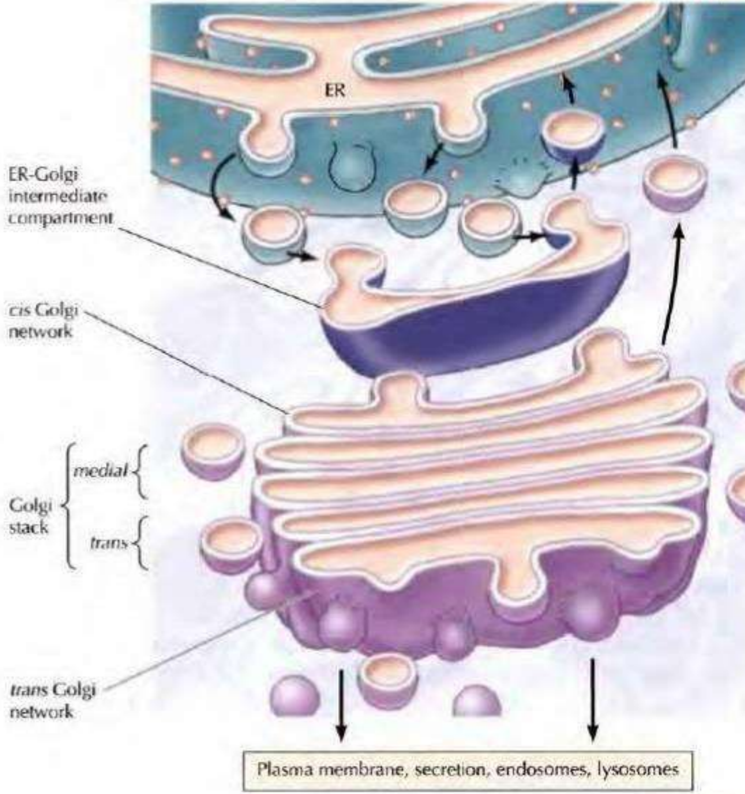
- Golgi Bodies is a collection of membrane enclosed sacs composed of four or more stacked layers of thin, flat enclosed vessels lying near the side of the nucleus.
- Consist of multiple discrete compartments.
- Consist of four functionally distinct regions:

i)The cis Golgi network

ii)Golgi stack –which is divided into

- a) The medial and
- b) Trans sub compartments

iii)The trans Golgi network.



Function

- Wrapping and Packaging department of the cell.
- Produces secretion granules i.e. membrane enclosed complexes, which store hormones and enzymes in the protein secreting cells, it packages proteins.
- Site of formation of lysosomes i.e. large irregular structures surrounded by membrane which are present in the cytoplasm.
- It adds certain carbohydrates to form glycoproteins, which play an important role in the association of the cells to form tissues

LYSOSOMES

- **Diameter**- 250 -750nm
- These are the irregular structures surrounded by the unit membrane.
- More acidic than rest of the cytoplasm and external bacteria as well as worn out cell components are digested in them.

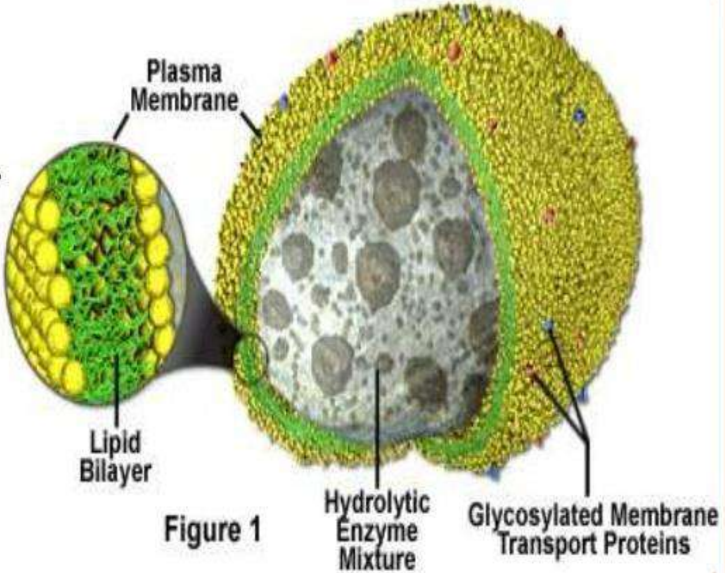


Figure 1

- The interior is kept acidic(near pH 5.0) by the action of proton pump or H^+ or ATPase.
- Lysosomes are cell hydrolases and they function best at the acidic pH.

Functions

- Acts as a form of digestive (lytic) system or the cell, because enzymes present in it can digest essentially all macromolecules.
- Engulf worn out components of the cells in which they are located.
- Engulf exogenous substances e.g. bacteria and degrade them.
- When a cell dies ,lysosomal enzymes causes autolysis of the remanant . Thats why lysosomes are called as ***Suicidal Bags***.

PEROXISOMES

- **Diameter**- 0.5µm

- A lipid bilayer membrane surrounds which regulates what enters or exits the peroxisomes.

- Urate oxidase crystalline core.

- Structure is similar to that of the lysosomes but with a different composition .

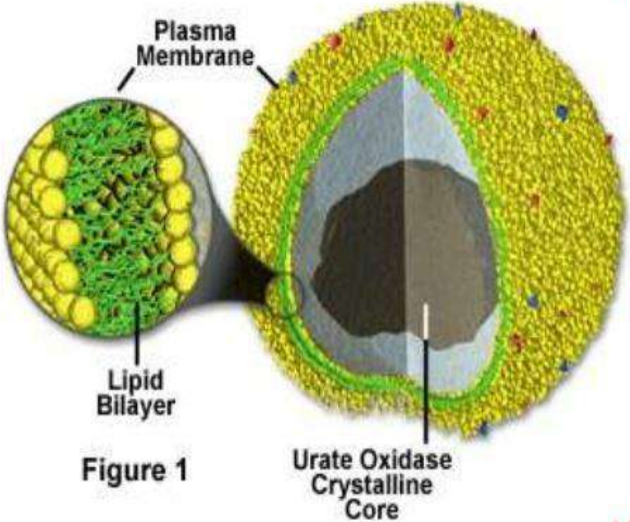


Figure 1

- Peroxisomes can be formed by the budding of ER, or by division

CONTD.

- Contains oxidases that produces H_2O_2.
- Catalases degrades hydrogen peroxide to yield water and oxygen
- Proteins are directed to the Peroxisomes by a unique signal sequence with the help of protein chaperones, **Peroxins.**

FUNCTION

- H_2O_2 metabolism and detoxification
- Helps in Photorespiration in plants
- Biosynthesis of lipids .
- Cholesterol and dolichol are synthesized in animals.
- Synthesis of bile acids in liver.
- Synthesis of plasmalogens (myelin sheath).

CYTOSKELETON

- System of fibers that not only maintains the structure of the cell but also permit it to change shape and move.

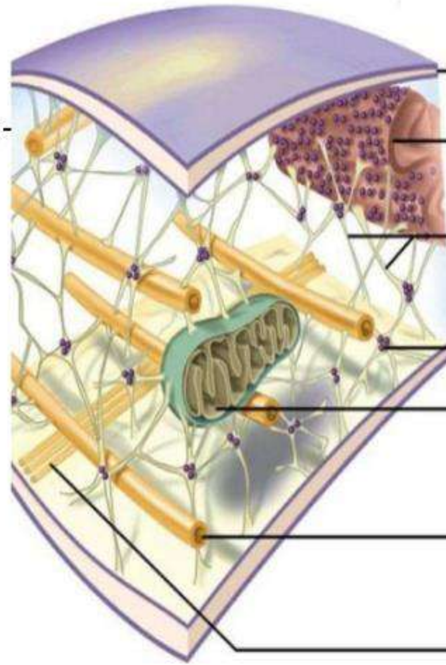
- The cytoskeleton is made up primarily of:-

  i)Microtubules

  ii)Intermediate Filaments

  iii)Microfilaments

  along with protein that anchor tie them together.



- **Microtubules-** These are long hollow structures approx. 25nm in diameter. Determine shape of the cell, role in the contraction of the spindle and movement of chromosomes and centrioles as well as in ciliary and flagellar motion.
- **Intermediate Filaments-** They are 8-14nm in diameter and are made up of various subunits. They form a flexible scaffolding or cell and help it resist external pressure.

  In their absence cell ruptures more easily and when they are abnormal in human, blistering in common.
- The proteins that makeup intermediate filament are cell types specific and are thus frequently used as cellular markers.
- **Microfilaments**- They are long solid fibers 4-6 nm in diameter. They comprise the contractile protein actin and are responsible for the cell motion.

FUNCTION

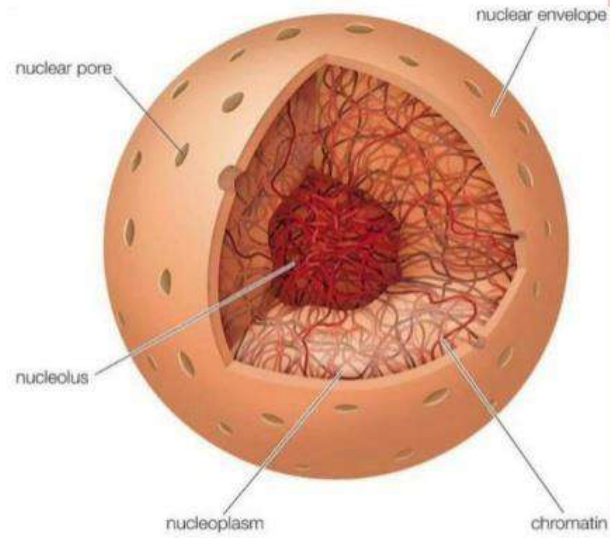
They are involved in the:-

- Movement of the chromosomes
- Cell movement
- Processes that move secretion granules in the cell
- Movement of proteins within the cell membrane.

NUCLEUS

THE NUCLEUS

- The nucleus contains chromatin, RNAs, and nuclear proteins move freely in aqueous solution.
- Nucleus has an internal structure that organizes the genetic material and localizes nuclear functions.
- A loosely organized matrix of nuclear lamins extends from the nuclear lamina into the interior of the nucleus.



CONTD.

- These lamins serve as sites of chromatin attachment and organize other proteins into functional nuclear bodies.

- Chromatin within the nucleus is organized into large loops of DNA, and specific regions of these loops are bound to the lamin matrix by lamin-binding proteins in the chromatin.

Nuclear Envelope

- Complex structure consisting of two nuclear membranes, an underlying nuclear lamina, and nuclear pore complexes.
- Two concentric membranes, called the inner and outer nuclear membranes .
- The outer membrane is continuous with the endoplasmic reticulum, so the space between the inner and outer nuclear membranes is directly connected with the lumen of the endoplasmic reticulum.

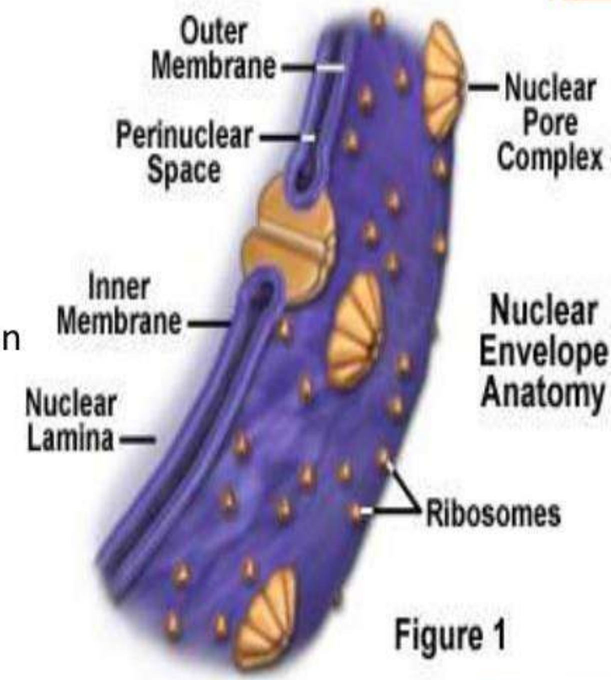


Figure 1

CONTD.

- Nuclear membrane is permeable only to small nonpolar molecules.

- Underlying the inner nuclear membrane is the nuclear lamina, a fibrous meshwork that provides structural support to the nucleus.

FUNCTION

- Serves both as the repository of genetic information and as the cell's control center.
- The presence of a nucleus thus allows gene expression to be regulated by posttranscriptional mechanisms, such as alternative splicing.
- The nuclear envelope provides novel opportunities for the control of gene expression at the level of transcription.

SUMMARY

COMPARTMENTS	MAJOR FUNCTIONS
Plasma Membrane	Transport of ions and molecules
Cytosol	Metab. of carbohydrate, lipids and amino acids
Mitochondria	Energy production
Endoplasmic Reticulum	Synthesis of proteins and lipids
Golgi apparutus	Modification and sorting of proteins
Lysosomes	Cellular digestion
Peroxisomes	Utilisation of H_2O_2
Cyotoskeleton	Cell Morphology and cell motility
Nucleus	DNA synthesis and Repair

THANK YOU


1.1 WATER
1.2
CARBOHYDRATES
1.3 LIPIDS
MOLECULES OF LIFE
1.5
NUCLEIC ACIDS
1.4 PROTEINS

Carbohydrates

Carbohydrates

Requirements for carbohydrate

- Carbohydrates are not essential nutrients, because the carbon skeletons of amino acids can be converted into glucose .
- However, the absence of dietary carbohydrate leads to ketone body production ,and degradation of body protein whose constituent amino acids provide carbon skeletons for gluconeogenesis .

Function of Carbohydrates

- Energy Supply for body function
- Essential for the Oxidation of Fats
- Proteins sparing action
- Provide Carbon for synthesis of Non-essential Amino acids
- Are present in some tissue Constituents
- Add flavour to Diet
- Nucleic acid of Connective tissue Matrix, Galactosides of Nerve Tissue
- Necessary for proper functioning of CNS
- Adequate hepatic Glycogen Storage enhances normal liver detoxification ability.

Carbohydrates

CLASSIFICATION OF CARBOHYDRATES

(1) **Monosaccharides** – simpler unit of carbohydrate eg.glucose, fructose, sucrose etc...

(2) **Disaccharides** - condensation products of two monosaccharide units e.g. maltose and sucrose.

(3) **Oligosaccharides** - condensation products of three to ten monosaccharides e.g. maltotriose, raffinose

(4) **Polysaccharides** – condensation products of more than ten monosaccharide units e.g. starch, glycogen, cellulose, dextrin etc, which may be linear or branched polymers.

Classification of Carbohydrates

Monosaccharides

A. Structure and Nomenclature

- The general formula $C_nH_{2n}O_n$
- with one of the carbons being the carbonyl group of either an aldehyde or a ketone.
- The most common monosaccharides have three to eight carbon atoms.
- The suffix-ose indicates that a molecule is a carbohydrate, and the prefixes *tri-*, *tetr-*, *pent-*, and so forth indicate the number of carbon atoms in the chain.
- Monosaccharide containing an aldehyde group are classified as aldoses; those containing a ketone group are classified as ketoses.
- A ketose can also be indicated with the suffix ulose; thus, a five- carbon ketose is also termed a Pentulose.

Disaccharides

- Composed of 2 monosaccharides
- cells can make disaccharides by joining two monosaccharides by biosynthesis.

Glucose + fructose = sucrose

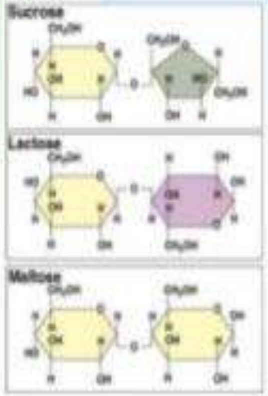
- Table sugar
- Found naturally in plants: sugar cane, sugar beets, honey, maple syrup
- Sucrose may be purified from plant sources into Brown, White and Powdered Sugars.

Glucose + galactose = lactose

- The primary sugar in milk and milk products.
- Many people have problems digesting large amounts of lactose (lactose intolerance)

Glucose + glucose = Maltose

- Produced when starch breaks down.
- Used naturally in fermentation reactions of alcohol and beer manufacturing.



Classification of polysaccharides

When polysaccharides are composed of a single monosaccharide building block, they are termed homopolysaccharides.

They are Branched or unbranched

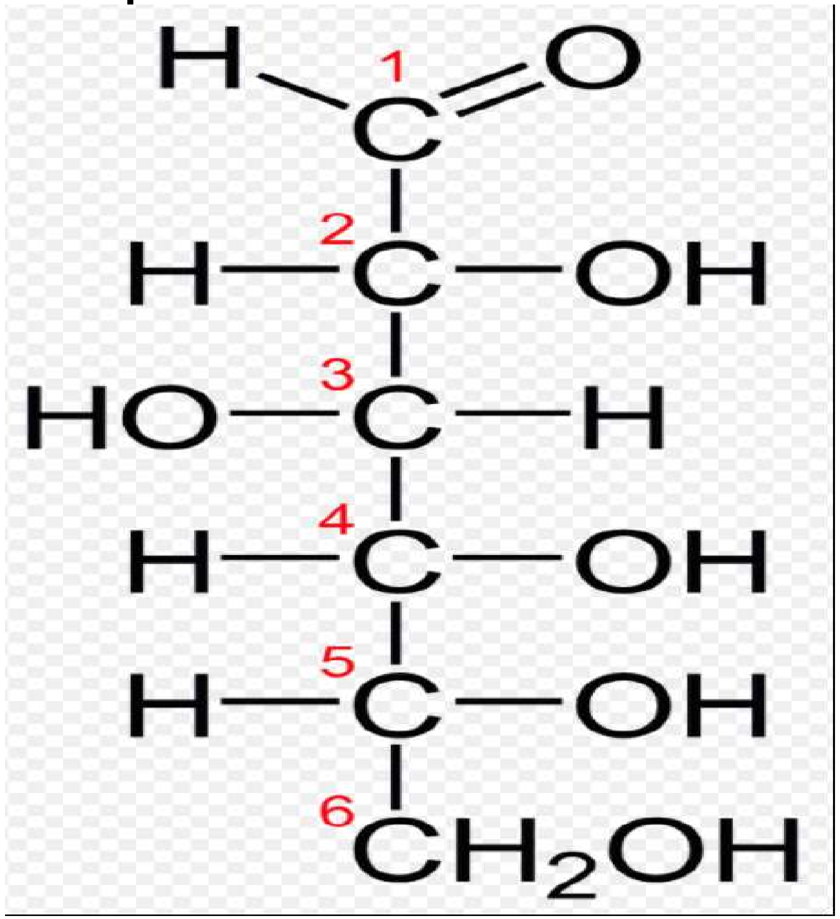
Storage or structural

Polysaccharides composed of more than one type of monosaccharide are termed heteropolysaccharides

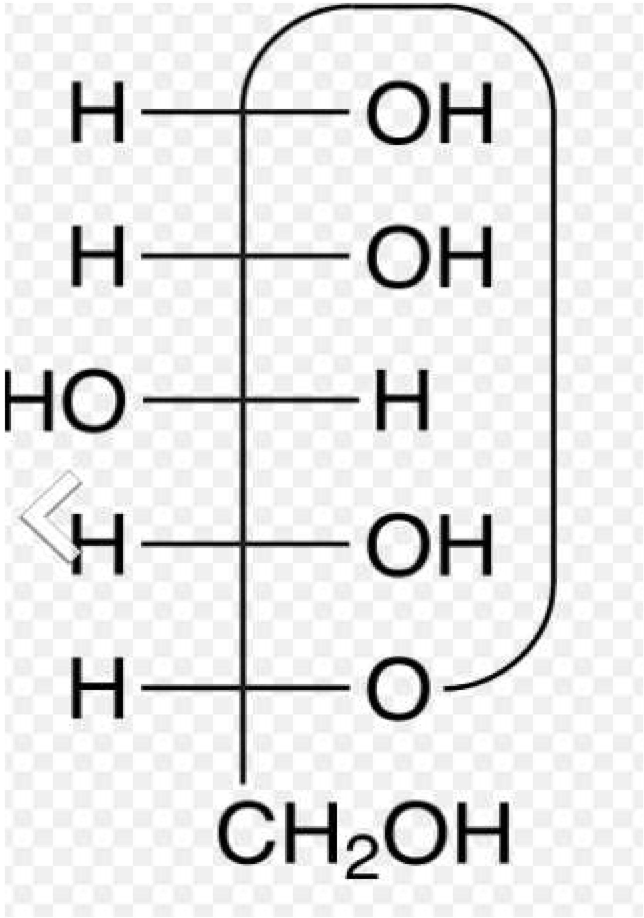
- E.g’s of Homopolysaccharides
- Starch , Glycogen , Inulin
- Cellulose (non- digestible polysaccharide)
- E.g;s of Heteropolysaccharides
- Hyaluronic acid , Heparin , Chondritin sulphate

Structure of D - Glucose

- Open chain formula

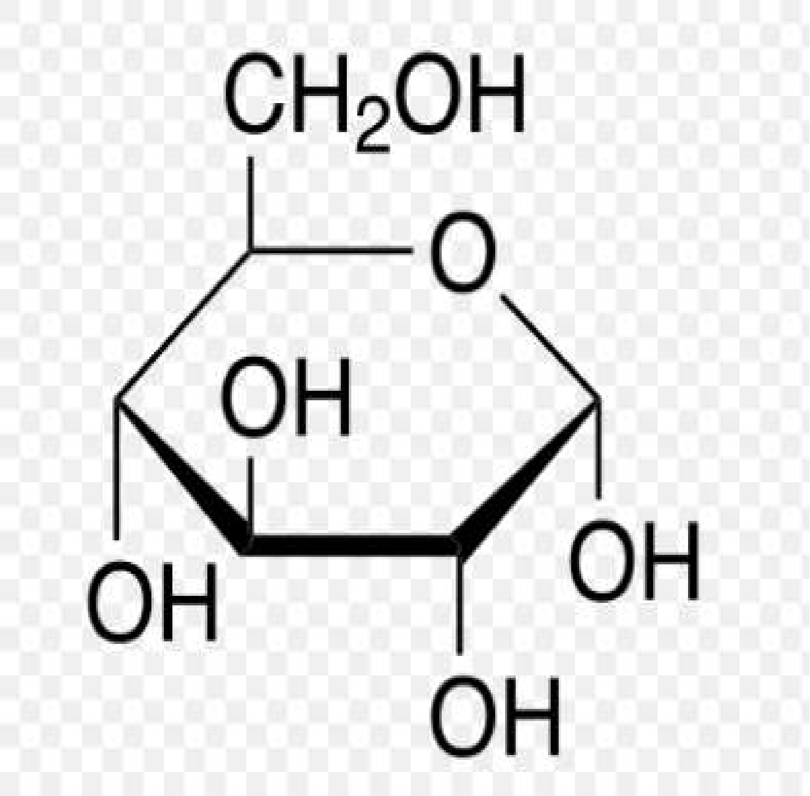


- Tollen's formula

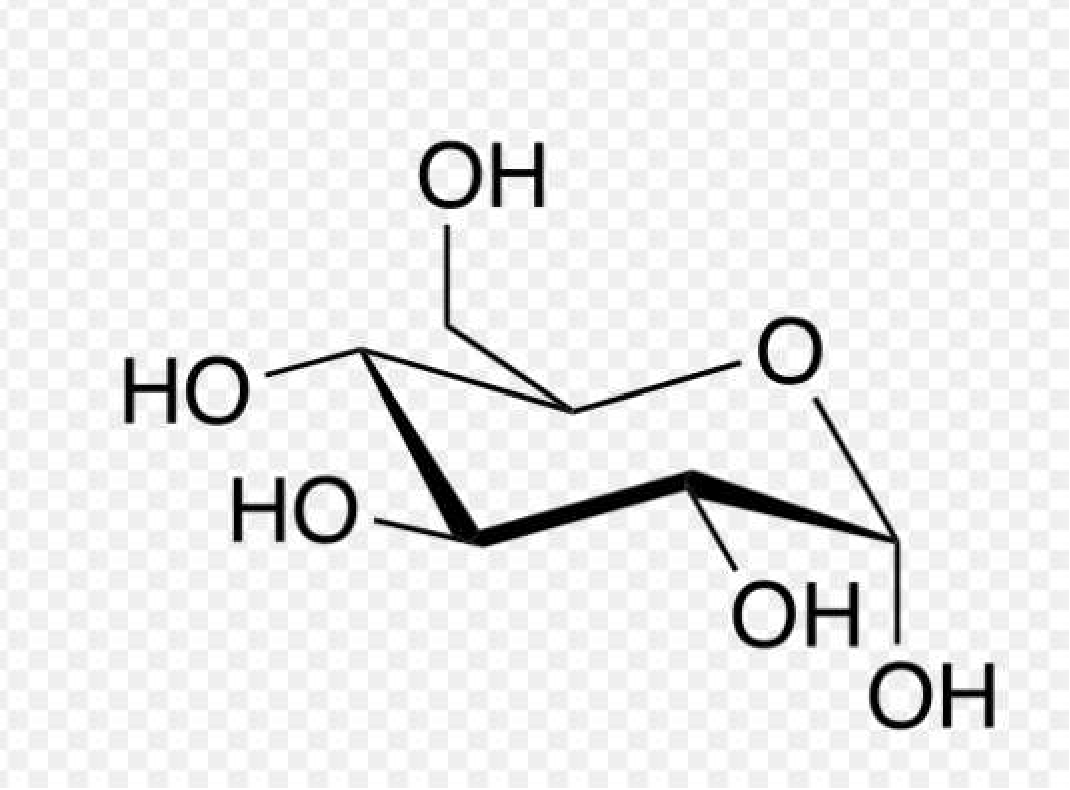


Structure of D - Glucose (contd.)

- Haworth Formula



- Chair formula



Isomers

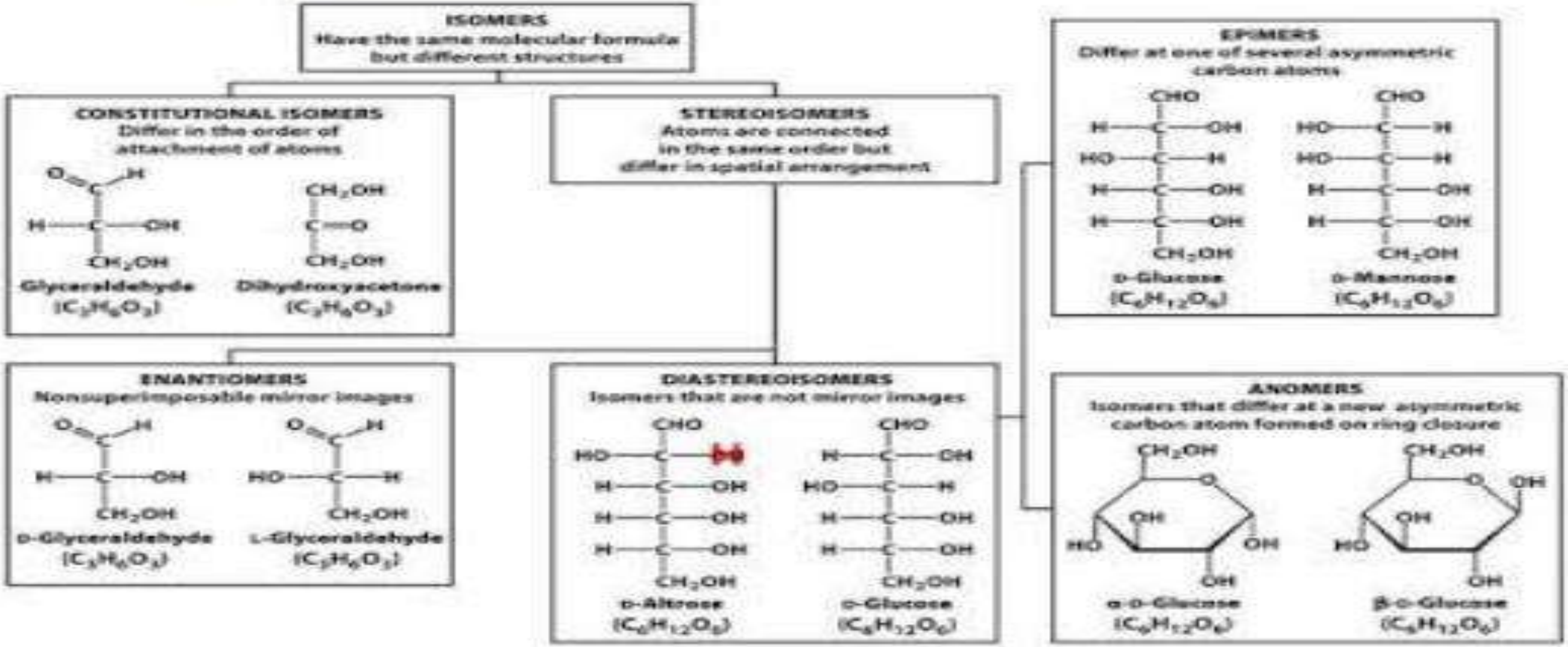
Isomers

- Isomers are molecules that have the same chemical formula but different structures
- Stereoisomer differs in the 3-D orientation of atoms
- Diastereomers are isomers with > 1 chiral center.
  - Pairs of isomers that have opposite configurations at one or more of the chiral centers but that are not mirror images of each other.
- Epimers are a special type of diastereomer.
  - Stereoisomers with more than one chiral center which differ in chirality at only one chiral center.
  - A chemical reaction which causes a change in chirality at one one of many chiral center is called an epimerisation.

Isomerisation in Carbohydrates

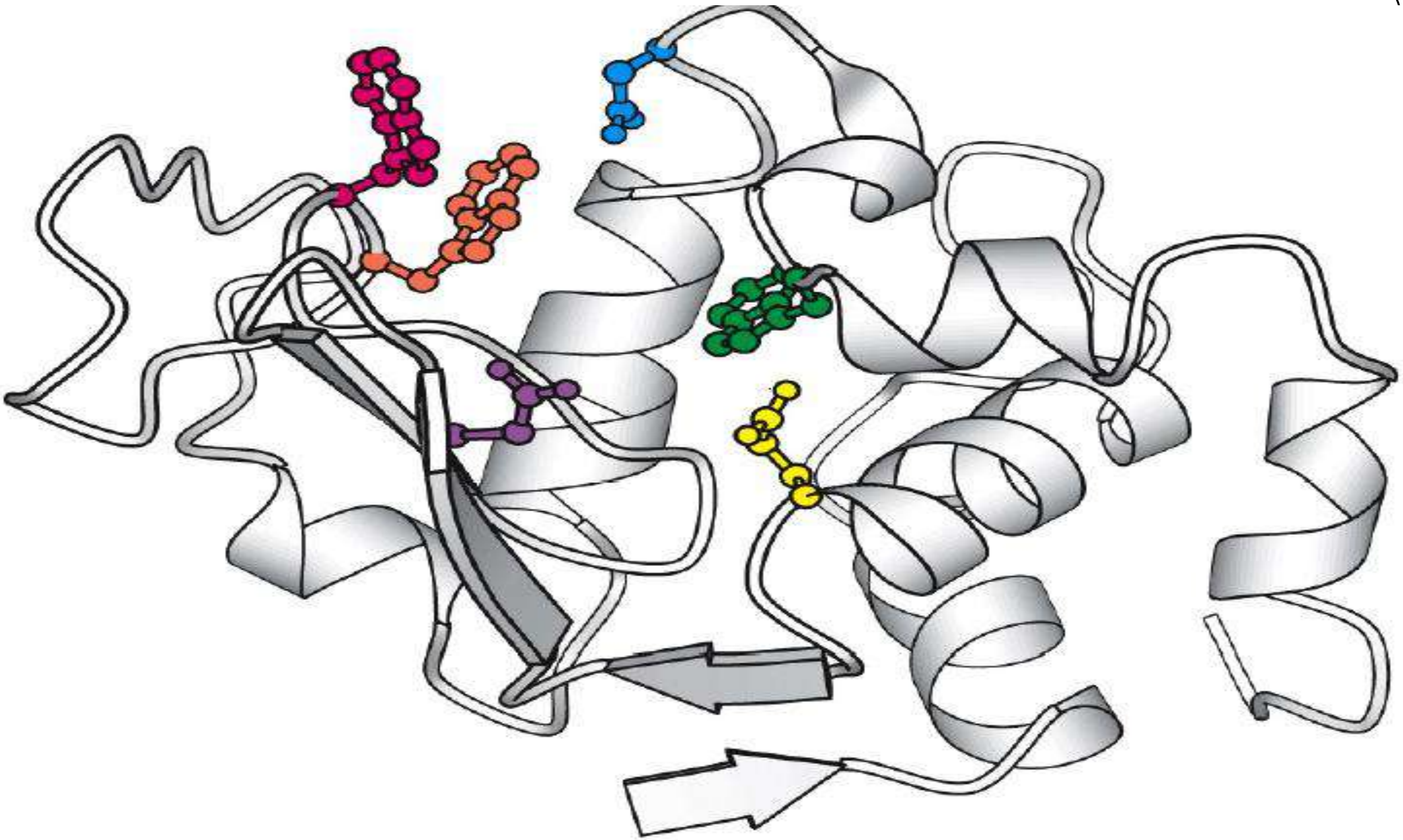
- The presence of asymmetric carbon atoms (A carbon atom to which four different atoms or groups attached is known as asymmetric carbon) in a compound produces following effect;
- It gives rise to the formation of sterioisomerism of that compound
- It also confers optical activity to the compound.

Ca


ISOMERS
Have the same molecular formula but different structures
CONSTITUTIONAL ISOMERS
Differ in the order of attachment of atoms
Glyceraldehyde
(C3H6O3)
Dihydroxyacetone
(C3H6O3)
STEREOISOMERS
Atoms are connected in the same order but differ in spatial arrangement
EPIMERS
Differ at one of several asymmetric carbon atoms
D-Glucose
(C6H12O6)
D-Mannose
(C6H12O6)
ENANTIOMERS
Nonsuperimposable mirror images
D-Glyceraldehyde
(C3H6O3)
L-Glyceraldehyde
(C3H6O3)
DIASTEREOISOMERS
Isomers that are not mirror images
D-Altrose
(C6H12O6)
D-Glucose
(C6H12O6)
ANOMERS
Isomers that differ at a new asymmetric carbon atom formed on ring closure
α-D-Glucose
(C6H12O6)
β-D-Glucose
(C6H12O6)

Proteins structure, classification and biological functions

DR.ACHYUTHA



Biochemistry - as science; Structure, properties and biological functions of proteins. Methods of secretion and purification. Peptides. Complex proteins, their biological role.

Peptides and Proteins

20 amino acids are commonly found in protein.

These 20 amino acids are linked together through “peptide bond forming peptides and proteins (what’s the difference?).

- The chains containing less than 50 amino acids are called **“peptides”,** while those containing greater than 50 amino acids are called **“proteins”.**

Shape = Amino Acid Sequence

- A typical 200-300 amino acids (Titin largest protein contains 26,926 a.a.sfound in skeletal and cardiac muscle.

History

- Protein –greekword.Proteios=primary
- First discovered and named by-Jons Jakob Berzelius in 1838.
- First sequence protein-insulin by frederick Sanger.(Nobel prize-1958)

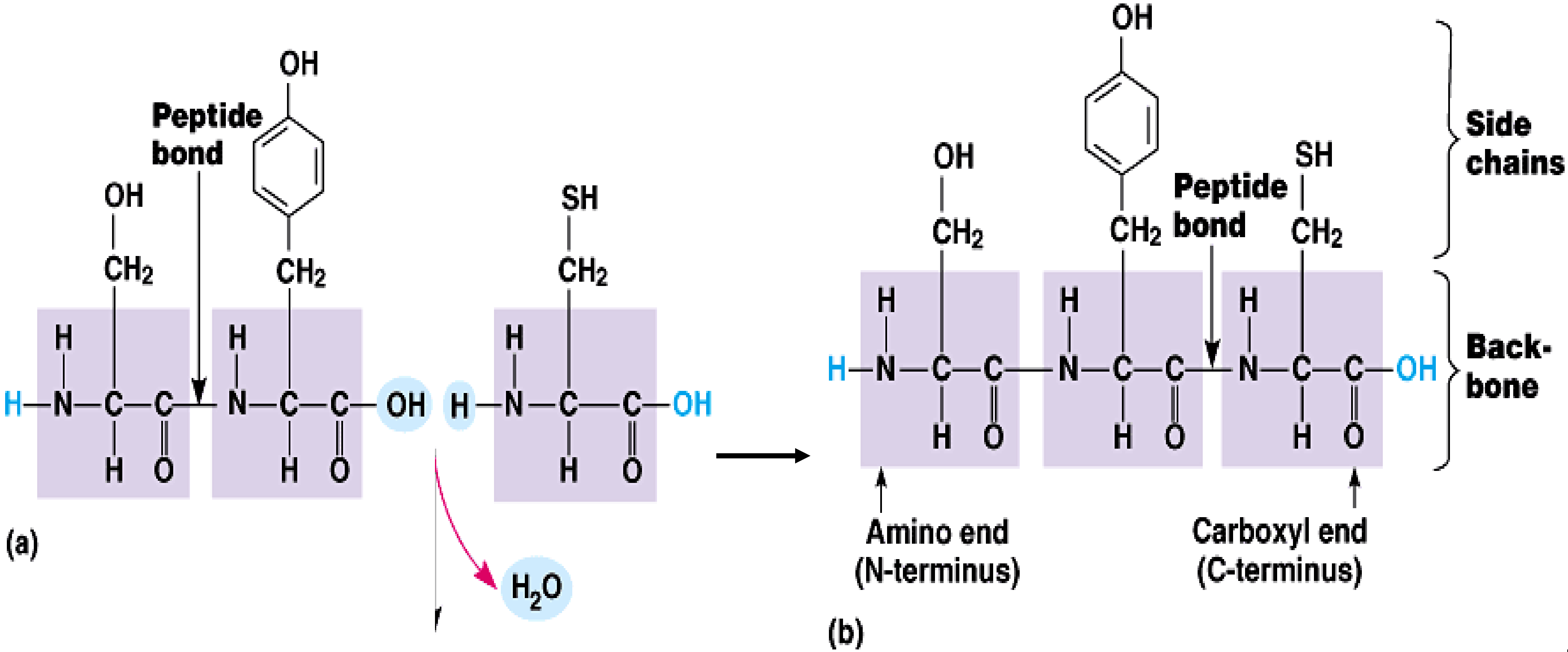
Structure of proteins

- Proteins are made of 20 amino acids linked by peptide bonds
- Polypeptide backbone is the repeating sequence of the N-C-C-N-C-C… in the peptide bond
- The side chain or R group is not part of the backbone or the peptide bond

Peptide bond formation

- α-carboxyl group of one amino acid (with side chain R1) forms a covalent peptide bond with α-amino group of another amino acid (with the side chain R2) by removal of a molecule of water. The result is : **Dipeptide** (i.e. Two amino acids linked by one peptide bond). By the same way, the dipeptide can then forms a second peptide bond with a third amino acid (with side chain R3) to give **Tripeptide.** Repetition of this process generates a polypeptide or protein of specific amino acid sequence.

Peptide bond formation:



- Each polypeptide chain starts on the left side by free amino group of the first amino acid enter in chain formation . It is termed (N- terminus).

- Each polypeptide chain ends on the right side by free COOH group of the last amino acid and termed (C-terminus).

Proteins

- Make up about 15% of the cell
- Have many functions in the cell
  - Enzymes
  - Structural
  - Transport
  - Motor
  - Storage
  - Signaling
  - Receptors
  - Gene regulation
  - Special functions

Classification of proteins

- Classified in several ways. Basing on levels of organization,solubility,a.a composition,structure, shape,physical properties,functions,3d configuration.
- 1.solubility:Albumins,globulins protamines histones, sclero proteins.

Classification of proteins;Physical and chemical properties

I- Simple proteins:

i.e. on hydrolysis gives only amino acids

Examples:

1- Albumin and globulins: present in egg, milk and blood

They are proteins of high biological value i.e. contain all essential amino acids and easily digested.

Types of globulins:

α1 globulin: e.g. antitrypsin

α2 globulin: e.g. hepatoglobin: protein that binds hemoglobin to prevent its excretion by the kidney

β-globulin: e.g. transferrin: protein that transport iron

γ-globulins = **Immunoglobulins** (antibodies) : responsible for immunity.

2- Globins (Histones): They are basic proteins rich in histidine amino acid.

They are present in : a - combined with DNA

b - combined with heme to form hemoglobin of RBCs.

3- Gliadines are the proteins present in cereals.

4- Scleroproteins: They are structural proteins, not digested.

include: keratin, collagen and elastin.

a- α-keratin: protein found in hair, nails, enamel of teeth and outer layer of skin.

- It is α-helical polypeptide chain, rich in cysteine and hydrophobic (non polar) amino acids so it is water insoluble.

b- collagens: protein of connective tissues found in bone, teeth, cartilage, tendons, skin and blood vessels.

Conjugated proteins

i.e. On hydrolysis, give protein part and non protein part and subclassified into:

1- Phosphoproteins: These are proteins conjugated with phosphate group.
Phosphorus is attached to oh group of serine or threonine.
e.g. Casein of milk and vitellin of yolk

. **2- Lipoproteins:**
These are proteins conjugated with lipids.
Functions: a- help lipids to transport in blood
b- Enter in cell membrane structure helping lipid soluble substances to pass through cell membranes.

3- Glycoproteins:
proteins conjugated with sugar (carbohydrate)
e.g. – Mucin
- Some hormones such as erythropoeitin
- present in cell membrane structure
- blood groups.

4- Nucleoproteins: These are basic proteins (e.g. histones) conjugated with nucleic acid (DNA or RNA).
e.g. a- chromosomes: are proteins conjugated with DNA
b- Ribosomes: are proteins conjugated with RNA

5- Metalloproteins: These are proteins conjugated with metal like iron, copper, zinc, ……

a- Iron-containing proteins: Iron may present in heme such as in

- hemoglobin (Hb)
- myoglobin (protein of skeletal muscles and cardiacmuscle),
- cytochromes,
- catalase, peroxidases (destroy H2O2)
- tryptophan pyrrolase (desrtroy indole ring of tryptophan).

Iron may be present in free state (not in heme) as in:

- Ferritin: Main store of iron in the body. ferritin is present in liver, spleen and bone marrow.
- Hemosidrin: another iron store.
- Transferrin: is the iron carrier protein in plasma.

b- Copper containing proteins:

e.g. - Ceruloplasmin which oxidizes ferrous ions into ferric ions.

- Oxidase enzymes such as cytochrome oxidase.

c- Zn containing proteins: e.g. Insulin and carbonic anhydrase

d- Mg containing proteins: e.g. Kinases and phosphatases.

6-Chromoproteins: These are proteins conjugated with pigment. e.g.

- All proteins containing heme (Hb, myoglobin, ………..)
- Melanoprotein:e.g proteins of hair or iris which contain melanin.

Derived proteins

Produced from hydrolysis of simple proteins.

e.g. - Gelatin: from hydrolysis of collagen

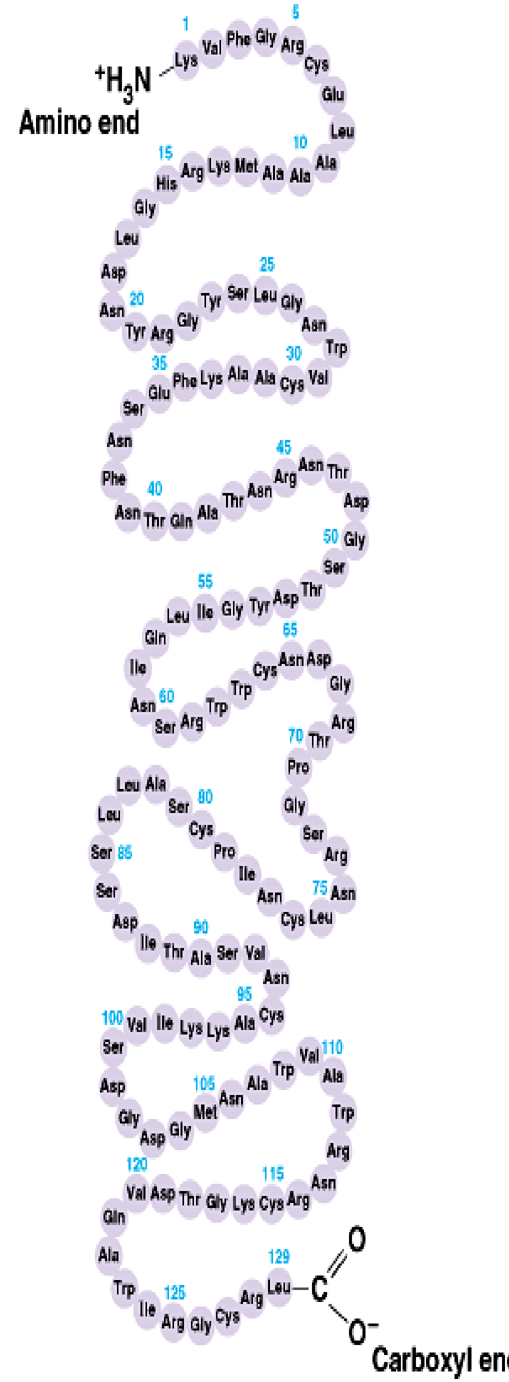
- Peptone: from hydrolysis of albumin

Protein structural configuration:

There are four levels of protein structure (primary, secondary, tertiary and quaternary)

Primary structure:

- The **primary structure** of a protein is its unique sequence of amino acids.
  - The order of amino acids determines funcion.The precise primary structure of a protein is determined by inherited genetic information.
  - At one end is an amino acid with a free amino group the (the N-terminus) and at the other is an amino acid with a free carboxyl group the (the C-terminus).



High orders of Protein structure

- **A functional protein** is **not just** a polypeptide chain, but **one or more** polypeptides precisely **twisted, folded and coiled** into a molecule of unique shape (**conformation).** This conformation is essential for some protein function e.g. Enables a protein to recognize and bind specifically to another molecule e.g. hormone/receptor; enzyme/substrate and antibody/antigen.
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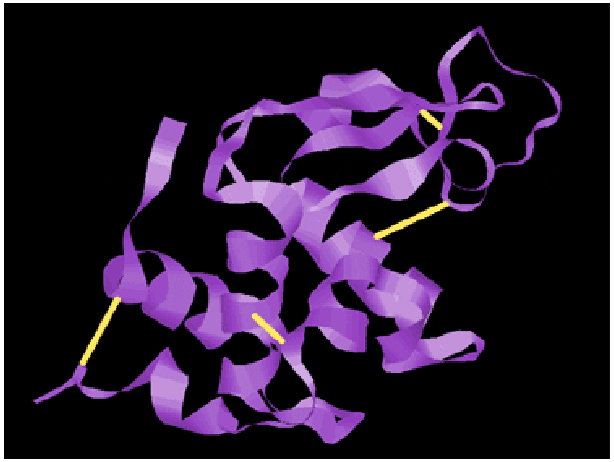
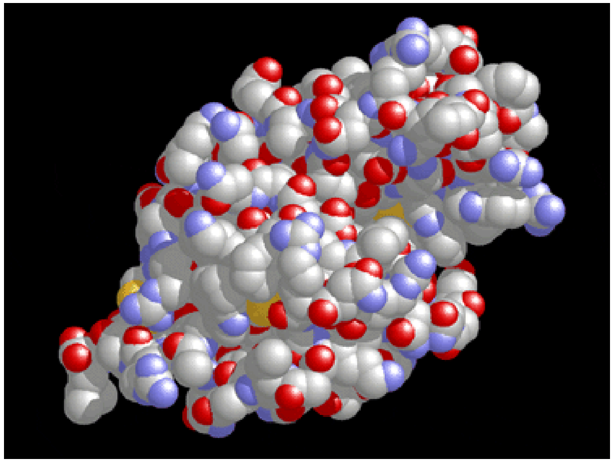


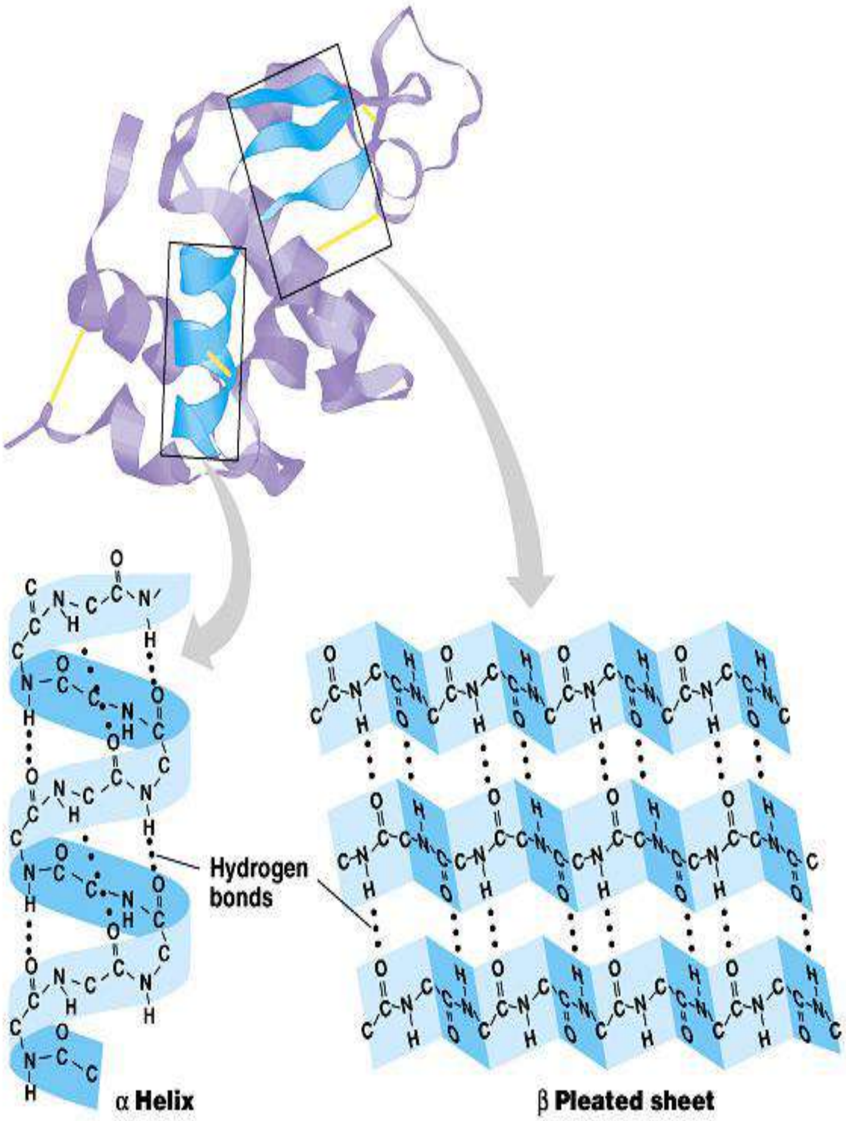


2- Secondary structure:

Results from hydrogen bond formation between hydrogen of –NH group of peptide bond and the carbonyl oxygen of another peptide bond. According to H-bonding there are two main forms of secondary structure:

α-helix: It is a spiral structure resulting from hydrogen bonding between one peptide bond and the fourth one eg;nails,hair,wool

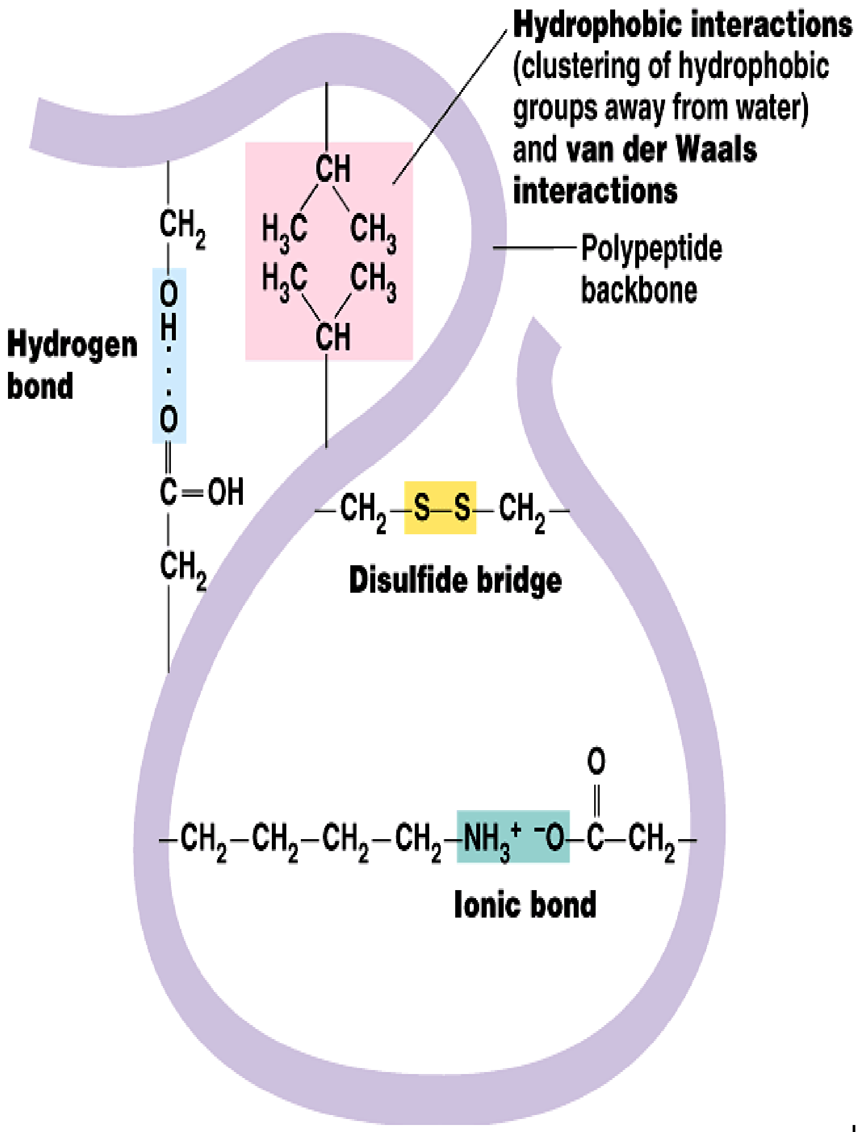
β-sheets: is another form of secondary structure in which two or more polypeptides (or segments of the same peptide chain) are linked together by hydrogen bond between H- of NH- of one chain and carbonyl oxygen of adjacent chain (or segment).eg;silk



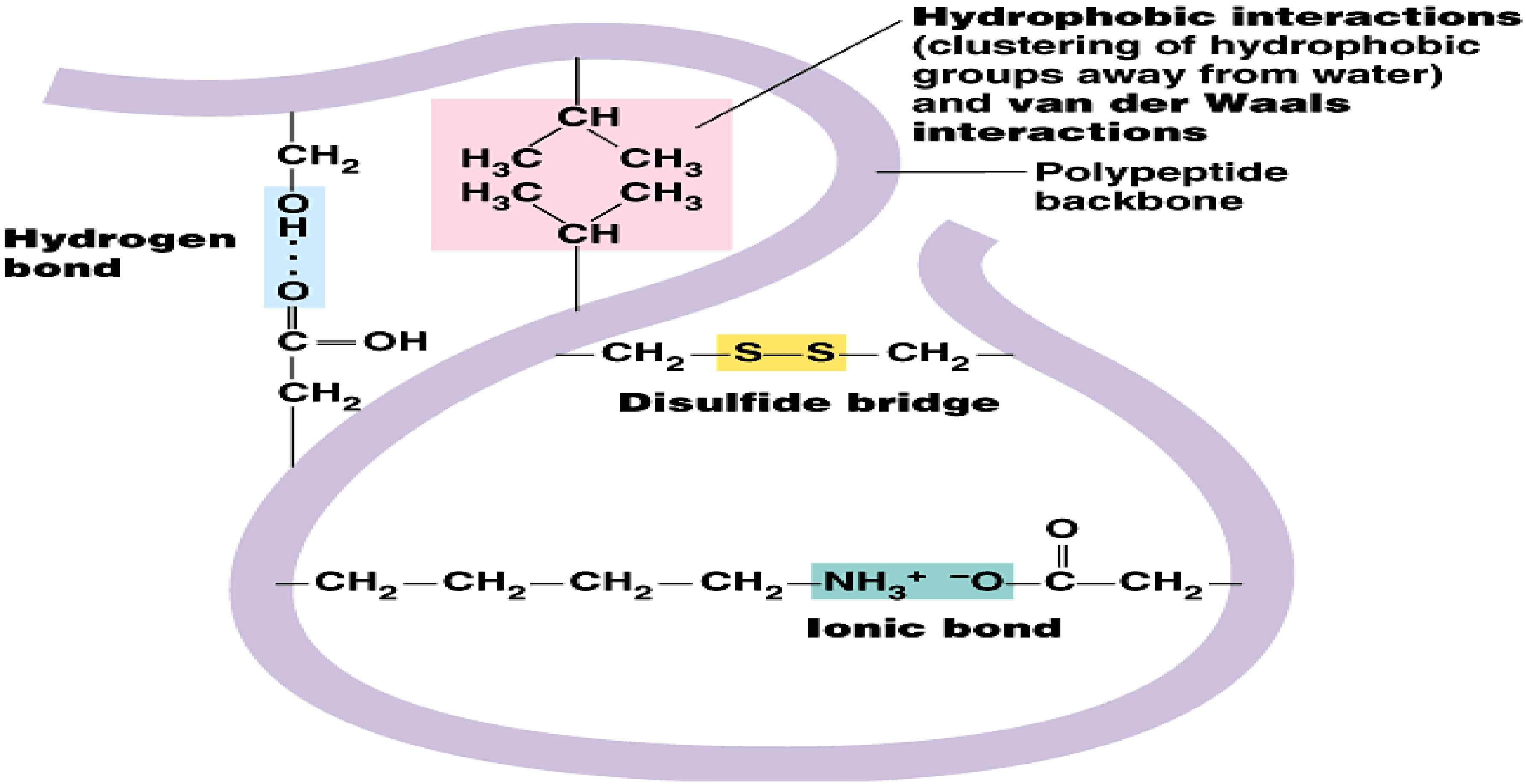
<u>Tertiary structure</u> is determined by a variety of interactions (bond formation) among R groups and between R groups and the polypeptide backbone.

a. **<u>The weak interactions</u>** include:

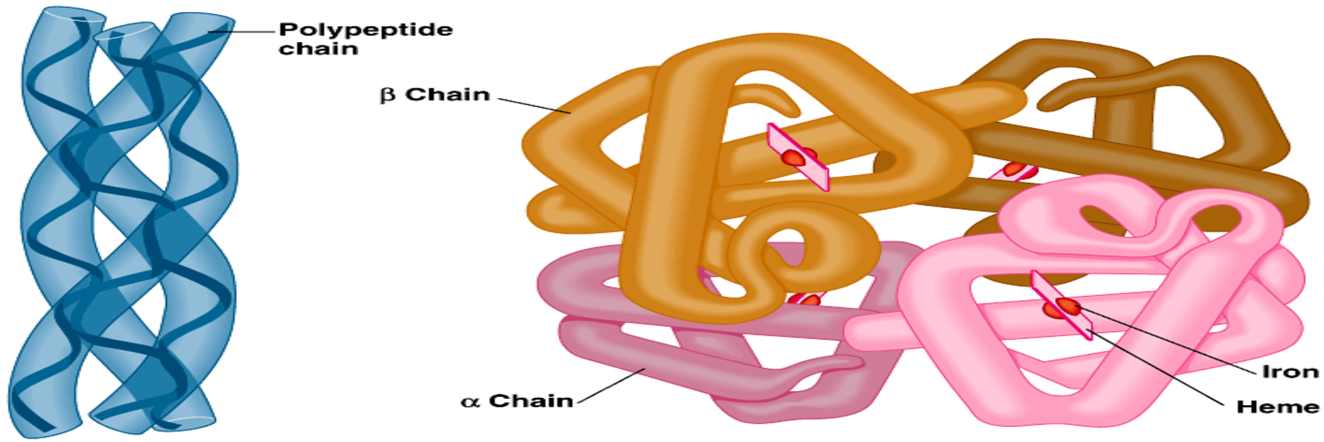
- **Hydrogen bonds** among polar side chains
- **Ionic bonds** between charged R groups (basic and acidic amino acids)
- **Hydrophobic interactions** among hydrophobic (non polar) R groups.



b. <u>**Strong covalent bonds**</u> include **disulfide bridges**, that form between the sulfhydryl groups (SH) of cysteine monomers, stabilize the structure.



- **Quaternary structure:** results from the aggregation (combination) of two or more polypeptide subunits held together by non-covalent interaction like H-bonds, ionic or hydrophobic interactions.
- Examples on protein having quaternary structure:
  - **Collagen** is a fibrous protein of three polypeptides (trimeric) that are supercoiled like a rope.
- This provides the structural strength for their role in connective tissue.
  - **Hemoglobin** is a globular protein with four polypeptide chains (tetrameric)
  - **Insulin** : two polypeptide chains (dimeric)



(a) Collagen (b) Hemoglobin

functons

- 1. enzymes- biochemical reactons,vital to metabolism
- Strural or mechanical;eg; Actin, myosin in muscle,proteins in cyto skeleon/shape
- Cell signallng,immune responses,cell adhesion,cell cycle
- Animal diets;essential aas
- Imp functions are;
- Building new cells,replace old cells
- Provideenergy 4 cal/gr
- Regulate hormones

- Catalyze chemical reactions(enzymes)
- Transfer hereditory information(DNA)
- Movement;contractile proteins
- Cell structure-extracellular matrix
- Transport of proteins
- Receptors for hormones
- Essentia nutrients for heterotrophs
- Transcription factors
- Physical basis of life

Amino Acids

- Amino Acids are the building units of proteins. Proteins are polymers of amino acids linked together by what is called " Peptide bond" (see latter).

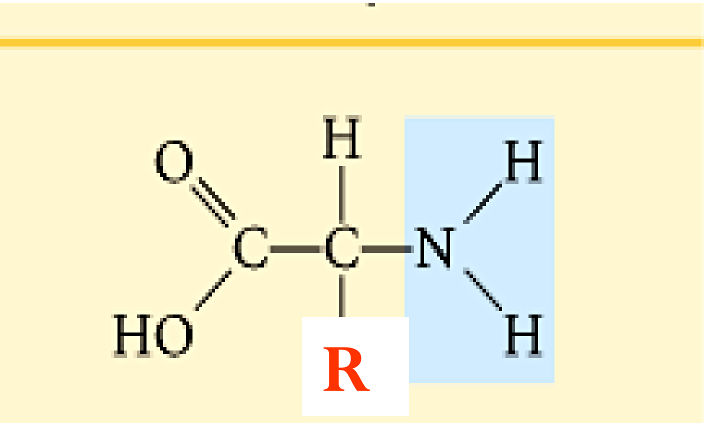
- There are about 300 amino acids occur in nature. Only 20 of them occur in proteins.

Structure of amino acids:

Each amino acid has 4 different groups attached to α- carbon (which is C-atom next to COOH). These 4 groups are : amino group, COOH gp,

Hydrogen atom and side

Chain (R)

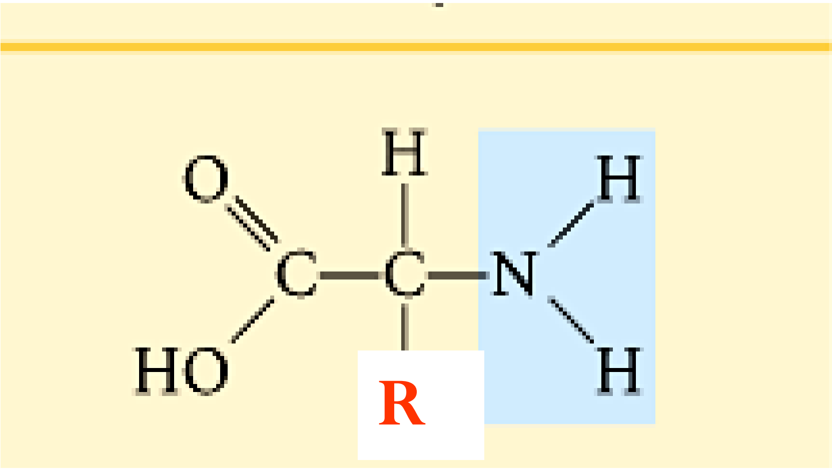


- **At physiological PH (7.4), -COOH gp is dissociated forming a negatively charged carboxylate ion (COO^-) and amino gp is protonated forming positively charged ion (NH_3^+) forming Zwitter ion**
- **N.B. Proline is an imino acid not amino acid (see latter)**

Classification of amino acids

I- Chemical classification: According to number of COOH and NH_2 groups i.e. according to net charge on amino acid.

A- **Monobasic, monocarboxylic amino acids i.e. neutral or uncharged:**



Subclassification of neutral amino acids:

All structures are required (See structures in hand out)

1- **Glycine** R= H

2- **Alanine** R= CH_3

3- **Branched chain amino acids:** R is branched such as in:

a - **Valine** R= isopropyl gp

b- **Leucine** R= isobutyl gp

c- **Isoleucine** R = is isobutyl

R is isobutyl in both leucine and isoleucine but branching is different: in leucine → branching occurs on γ carbon

in isoleucine→ branching occurs on β- carbon

4- Neutral Sulfur containing amino acids:

e.g. Cysteine and Methionine. What is cystin?

5- Neutral, hydroxy amino acids:

e.g. Serine and Threonine

6- Neutral aromatic amino acids:

a- Phenyl alanine : It's alanine in which one hydrogen of CH_3 is substituted with phenyl group. So it's called phenyl alanine

b-Tyrosine: - it is P- hydroxy phenyl alanine

- it is classified as **phenolic amino acid**

c-Tryptophan: as it contains indole ring so it is classified as **heterocyclic amino acid**

7- Neutral heterocyclic amino acids:

a-Tryptophan: contains indole ring

b- Proline: In proline, amino group enters in the ring formation being α-imino gp so proline is an α-imino acid rather than α-amino acid

B- Basic amino acids: Contain two or more NH_2 groups or nitrogen atoms that act as base i.e. can bind proton.

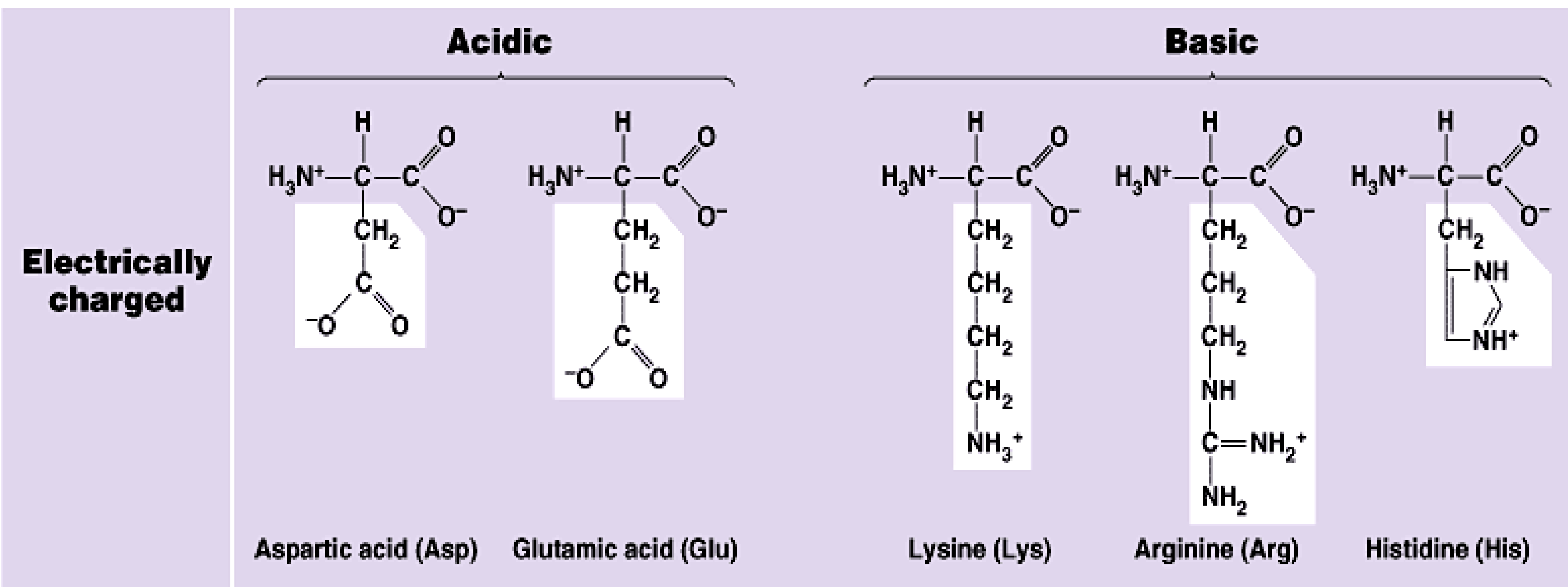
At physiological pH, basic amino acids will be **positively charged**.

e.g.

a- Lysine

b- Arginine: contains guanido group

c- Histidine: is an example on basic heterocyclic amino acids



C- **Acidic Amino acids:** at physiological pH will carry negative charge.

e.g. Aspartic acid (aspartate) and Glutamic acid (glutamate). see structures in hand out.

Aspargine and Glutamine: They are amide forms of aspartate and glutamate in which side chain COOH groups are amidated.

They are classified as neutral amino acids.

II- Classification according to polarity of side chain (R):

A- Polar amino acids: in which R contains polar hydrophilic group so can forms hydrogen bond with H_2O. In those amino acids, R may contain:

1- OH group : as in serine, threonine and tyrosine
2- SH group : as in cysteine
3- amide group: as in glutamine and aspargine
4- NH_2 group or nitrogen act as a base (basic amino acids): as lysine, arginine and histidine
5- COOH group (acidic amino acids): as aspartic and glutamic .

B- Non polar amino acids:

R is alkyl hydrophobic group which can't enter in hydrogen bonf formation. 9 amino acids are non polar (glycine, alanine, valine, leucine, isoleucine, phenyl alanine, tryptophan, proline and methionine)

III- Nutritional classification:

1- Essential amino acids: These amino acids can't be formed in the body and so, it is essential to be taken in diet. Their deficiency affects growth, health and protein synthesis.

2- Semiessential amino acids: These are formed in the body but not in sufficient amount for body requirements especially in children.

Summary of essential and semiessential amino acids:

Villa HM = Ten Thousands Pound

V= valine i= isoleucine l= lysine l= leucine

A = arginine* H= histidine* M= methionine

T= tryptophan Th= threonine P= phenyl alanine

*= arginine and histidine are semiessential

3- Non essential amino acids: These are the rest of amino acids that are formed in the body in amount enough for adults and children. They are the remaining 10 amino acids.

IV- Metabolic classification: according to metabolic or degradation products of amino acids they may be:

1- Ketogenic amino acids: which give ketone bodies . **Lysine** and **Leucine** are the only pure ketogenic amino acids.

2- Mixed ketogenic and glucogenic amino acids: which give both ketonbodies and glucose.These are: isoleucine, phenyl alanine, tyrosine and tryptophan.

3- Glucogenic amino acids: Which give glucose. They include the rest of amino acids. These amino acids by catabolism yields products that enter in glycogen and glucose formation.

properties of AA's

- Colourless crystalline substances
- Soluble in polar solvents like water, ethanol
- In soluble in non-polar solvents like Benzene,Ether
- Exists as zwitter ions.

VITAMINS

Definition And Classification

- Vitamins are group of organic compounds required in small amounts available from natural foods taken daily for a variety of biochemical functions occurring in the living beings for their normal growth and development.
- Can't be synthesized by human beings
- Need to be supplied in diet.
- Not incorporated into structural components.
- Don't provide energy like carbohydrate, lipid and protein
- Mainly classified into Fat soluble & Water Soluble Vitamins

Comparison of two types of Vitamins

FAT SOLUBLE VITAMINS

- Solubility - Not soluble in water Apolar hydrophobic, soluble in fat
- Digestion & Absorption -- Along with fats, require bile salts
- Transport -- Carrier proteins like lipoprotein
- Storage – Stored in liver
- Deficiency– appears when stores get depleted
- Availability from plant sources – Provitamins e.g Beta Carotene
- Toxicity -- Hypervitaminosis

WATER SOLUBLE VITAMINS

- Soluble in water ,Hydrophilic
- Not soluble in fat
- Simple Absorption
- No carrier protein
- Deficiency appears rapidly as there is no storage
- As such
- No Hypervitaminosis as excess is excreted

Biochemical names of vitamins

- Include A,D,E,K

Vitamin A --Retinol,Retinal,Retinoic acid Provitamin A- BetaCarotene

Vitamin D --- Calciol,Calcidiol & Calcitriol formed from 7- dehydro cholesterol, Ergocalciferol from Ergosterol

VitaminE– Tocopherol

Vitamin K– Phylloquinone , Napthoquinone & Menadione

Include B group & C

B group --- Thiamin, Riboflavin,Niacin , Pyridoxine,Folicacid, Biotin,Pantothenic acid (CoenzymeA) & Vitamin B12)

Vitamin C– L- Ascorbic acid

Fat soluble vitamins

- Vitamin A – Retinol, Retinal,Retinoic acid

Daily requirements –

For Adults -750 - 1000micrograms/day,

Children – 400 – 600 micrograms/day

During pregnancy-- :1000micrograms/ day

- Vitamin D– Ergocalciferol(plant source) , Cholecalciferol, 25hydroxycholecalciferol , 1,25 dihydroxy cholecalciferol
- Daily requirements– 400 I.U/day
- or 10micrograms/day
- In India 200 I.U/ day or 5 micrograms%/ day

Fat Soluble Vitamins

Dietary sources for vitamin A

Milk,milk products,carrots, green leafy vegetables ,mango,papaya,egg yolk, liver ,fish liver oils

Absorption and transport---

Requires fats & bile salts, retinol is esterified with fatty acids,incorporated into chylomicrons& transported to lymph, stored in liver ,when needed ,released from liver,transported in circulation by RBP& Prealbumin

- Dietary sources of vitamin D
- Fish liver oils,egg yolk
- Exposure of skin to sun light for synthesis Of vit D(cholecalciferol from 7 dehydro cholesterol) Consumption of natural foods
- Absorption requiresfats & bile salts, through lymph vit D enters the circulation ,bound to alpha2 globulin & distributed ,stored in small amounts in liver & other tissues Active form -- Calcitriol

FAT SOLUBLE VITAMINS

- Vitamin E--- Tocopherol
- Daily requirements
- Adults Male–10 mg / day(15 I.U)
- Female --- 8mg/ day(12 I.U)
- Pregnant & lactating mother– 10mg/ day
- Dietary Sources--- vegetable oils,wheat germ oil, cotton seed,sunflower, corn oils, meat,milk ,butter,eggs.

- Vitamin K--- K1– Phylloquinone , K2Menaquinone, K3 – Menadione

Daìly requirements– 50-100 miçrograms/ day

Dietary sources- cabbage, cauliflower, tomatoes,spinach& other green vegetables, egg yolk,meat,liver, cheese & dairy products.

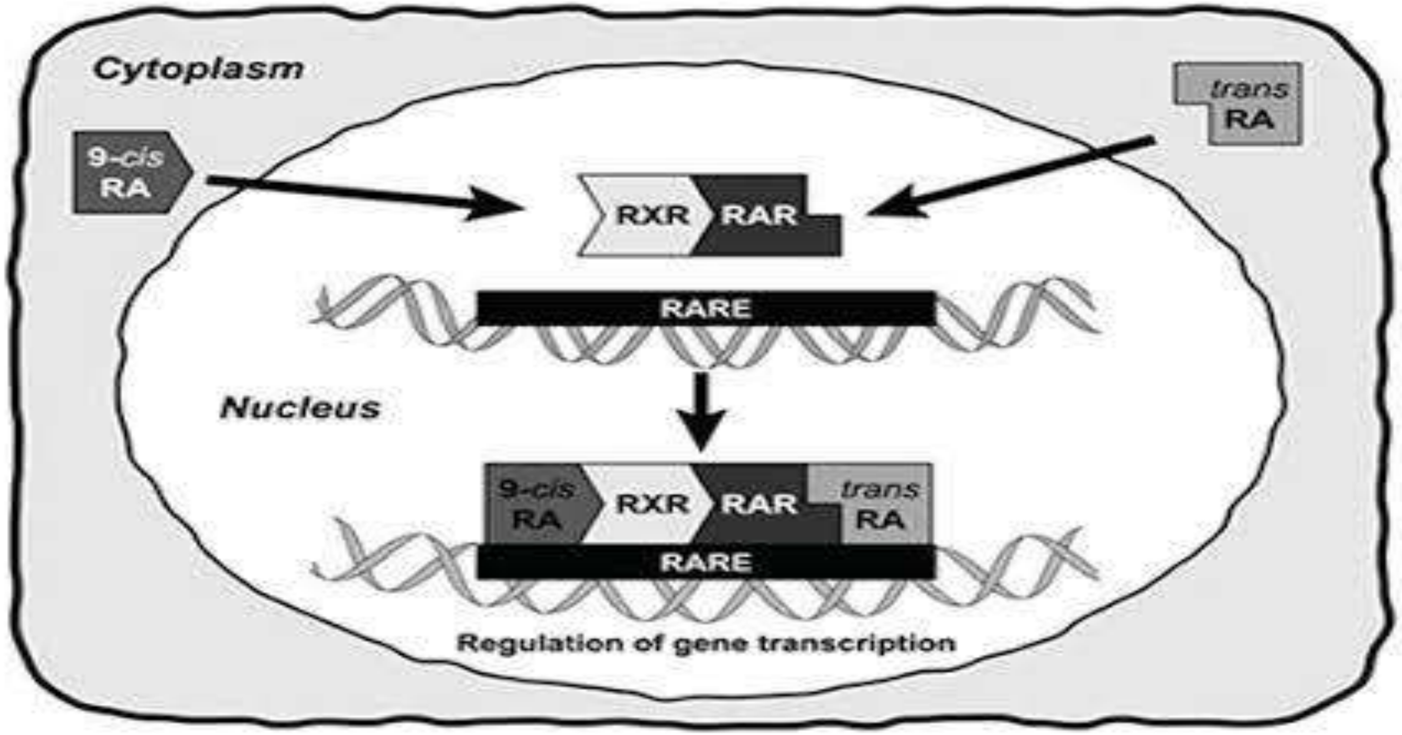
- Absorption of E & K requires fat & bilesalts,incorporated in lipoproteins ,transported & stored in adipose tissue and liver respectively.

BIOCHEMICAL FUNCTIONS OF VITAMINS

- Vitamin A – active form reqd for normal vision (dim light & color vision) – 11-cis retinal formed from All trans retinal from Retinol
- Retinoic acid active form of vitamin A act as hormone in synthesis of glycoproteins, required for growth ,differentiation of tissues, maintenance of immune system, reproduction and cholesterol synthesis

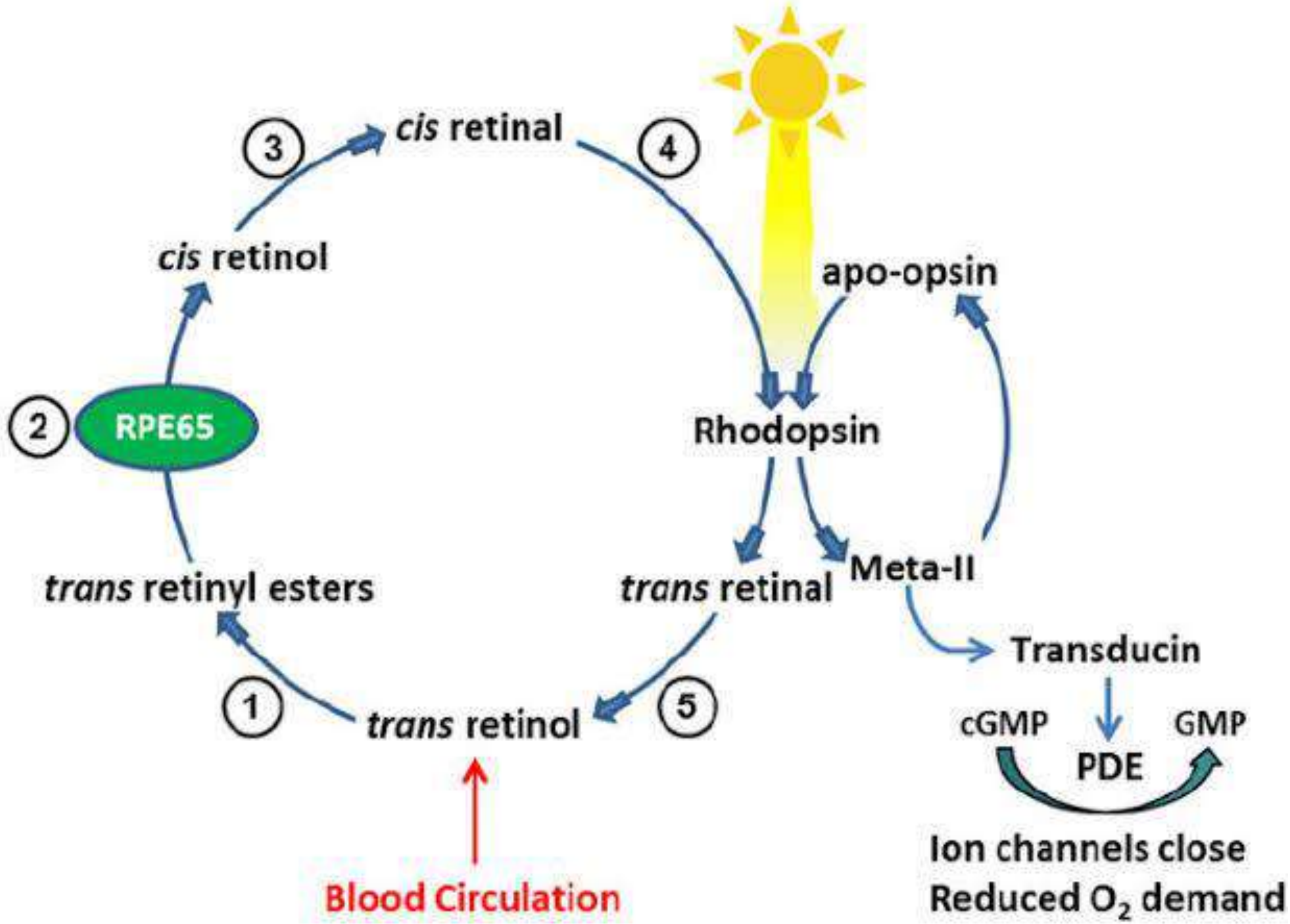
- Vitamin D active form– Calcitriol
- Regulates the plasma levels of calcium & phosphate at 3 different levels (intestine,kidney & bone)
- Calcitriol increases absorption of calcium & phosphate from intestine
- In the osteoblasts of bone ,vitD stimulates calcium uptake for calcification of bone along with parathyroid hormone
- In kidney ,It minimizes the excretion of calcium & phosphate.

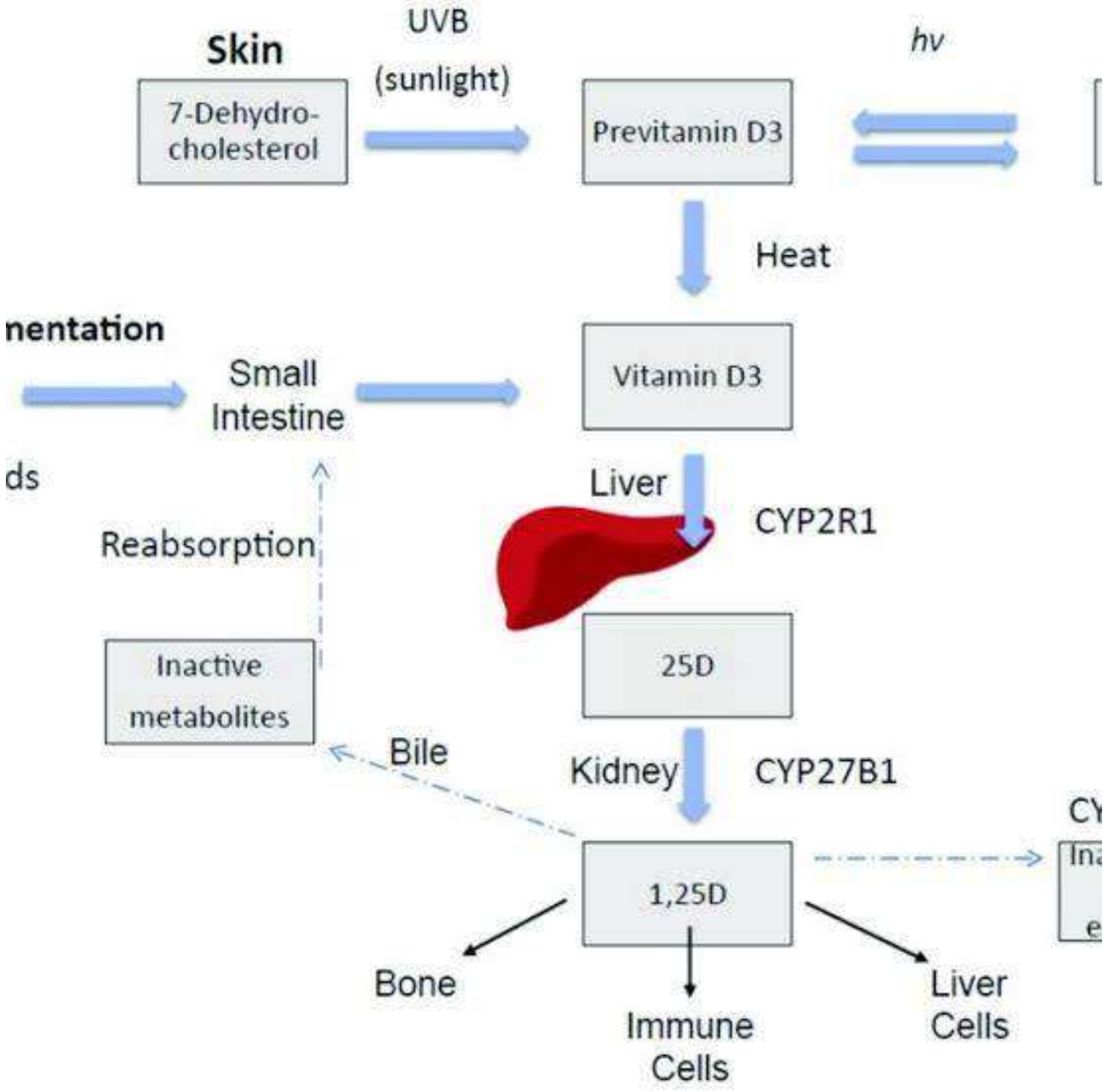
Figure 3. A Simplified Model of the Regulation of Gene Expression by Retinoic Acid (RA) Isomers



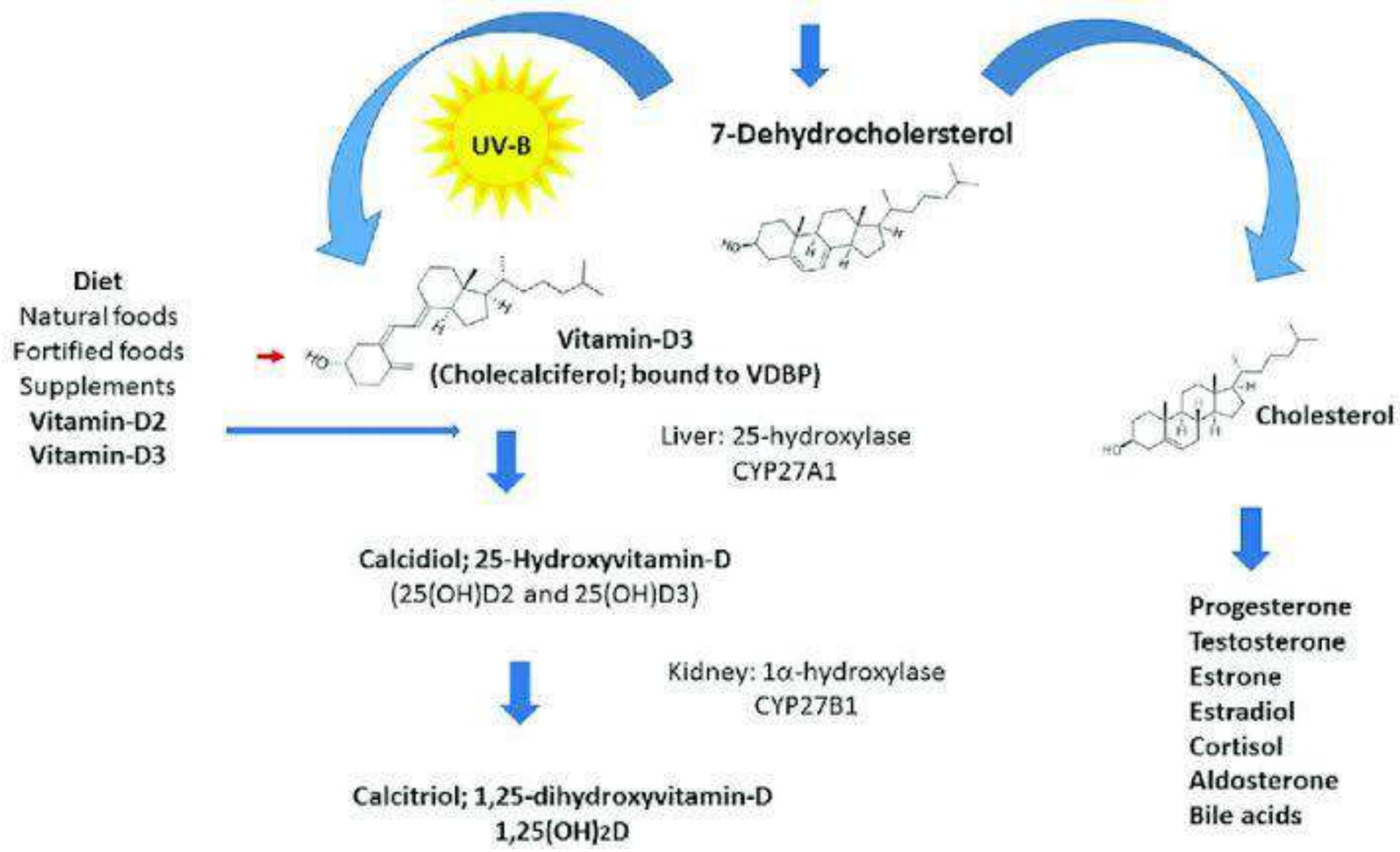
All-*trans*-RA and 9-*cis*-RA are transported to the nucleus of the cell bound to cytoplasmic retinoic acid-binding proteins. Within the nucleus, all-*trans*-RA binds to retinoic acid receptors (RAR) and 9-*cis*-RA binds to retinoid receptors (RXR). RAR and RXR form RAR/RXR heterodimers, which bind to regulatory regions of the chromosome called retinoic acid response elements (RARE). Binding of all-*trans*-RA and 9-*cis*-RA to RAR and RXR respectively allows the complex to regulate the rate of gene transcription.

The Visual Cycle





Skin
UVB
(sunlight)
hv
7-Dehydro-
cholesterol
Previtamin D3
Heat
nentation
Small
Intestine
Vitamin D3
ds
Liver
CYP2R1
Reabsorption
Inactive
metabolites
25D
Bile
Kidney
CYP27B1
1,25D
Bone
Immune
Cells
Liver
Cells



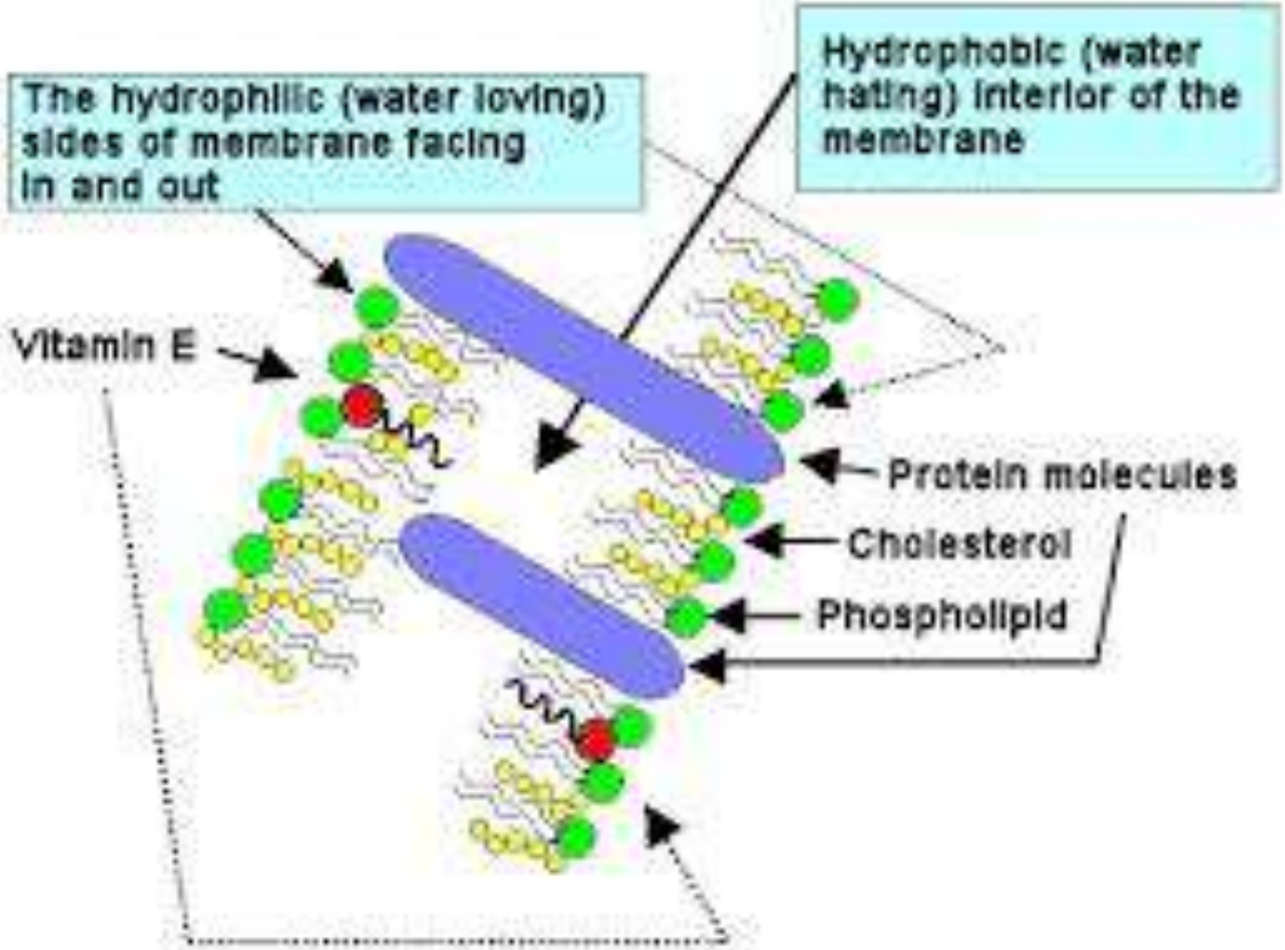
UV-B
7-Dehydrocholersterol
Diet
Natural foods
Fortified foods
Supplements
Vitamin-D2
Vitamin-D3
Vitamin-D3
(Cholecalciferol; bound to VDBP)
Liver: 25-hydroxylase
CYP27A1
Cholesterol
Calcidiol; 25-Hydroxyvitamin-D
(25(OH)D2 and 25(OH)D3)
Kidney: 1α-hydroxylase
CYP27B1
Calcitriol; 1,25-dihydroxyvitamin-D
1,25(OH)2D
Progesterone
Testosterone
Estrone
Estradiol
Cortisol
Aldosterone
Bile acids


Vitamin
E

Biochemical functions of Vitamins

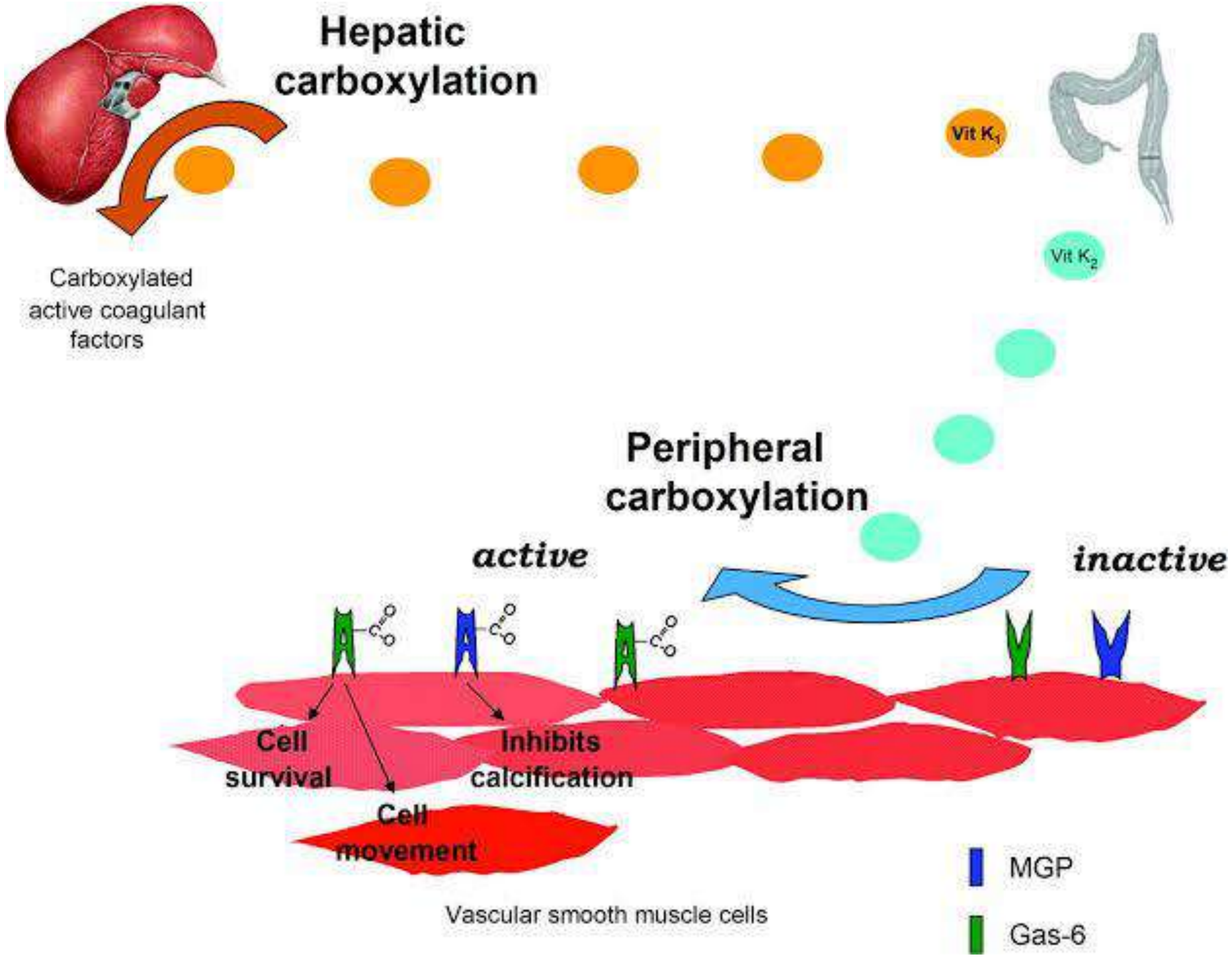
- Vitamin E – natural antioxidant
- Inactivates free radicals. (generated free radicals degenerate biomembranes)
- Prevents hemolysis & protects RBC
- Reduces the risk of MI by reducing oxidation of LDL
- Vit E & Selenium act synergically to minimize lipid peroxidation

- Vitamin K –Required for coagulation factor2 (prothrombin)& factor 9
- (Christmas factor)
- -- Act as cofactor for gamma carboxylation of L- glutamic acid residues in inactive forms of prothrombin &Christmas factor to make these coagulation factors active.

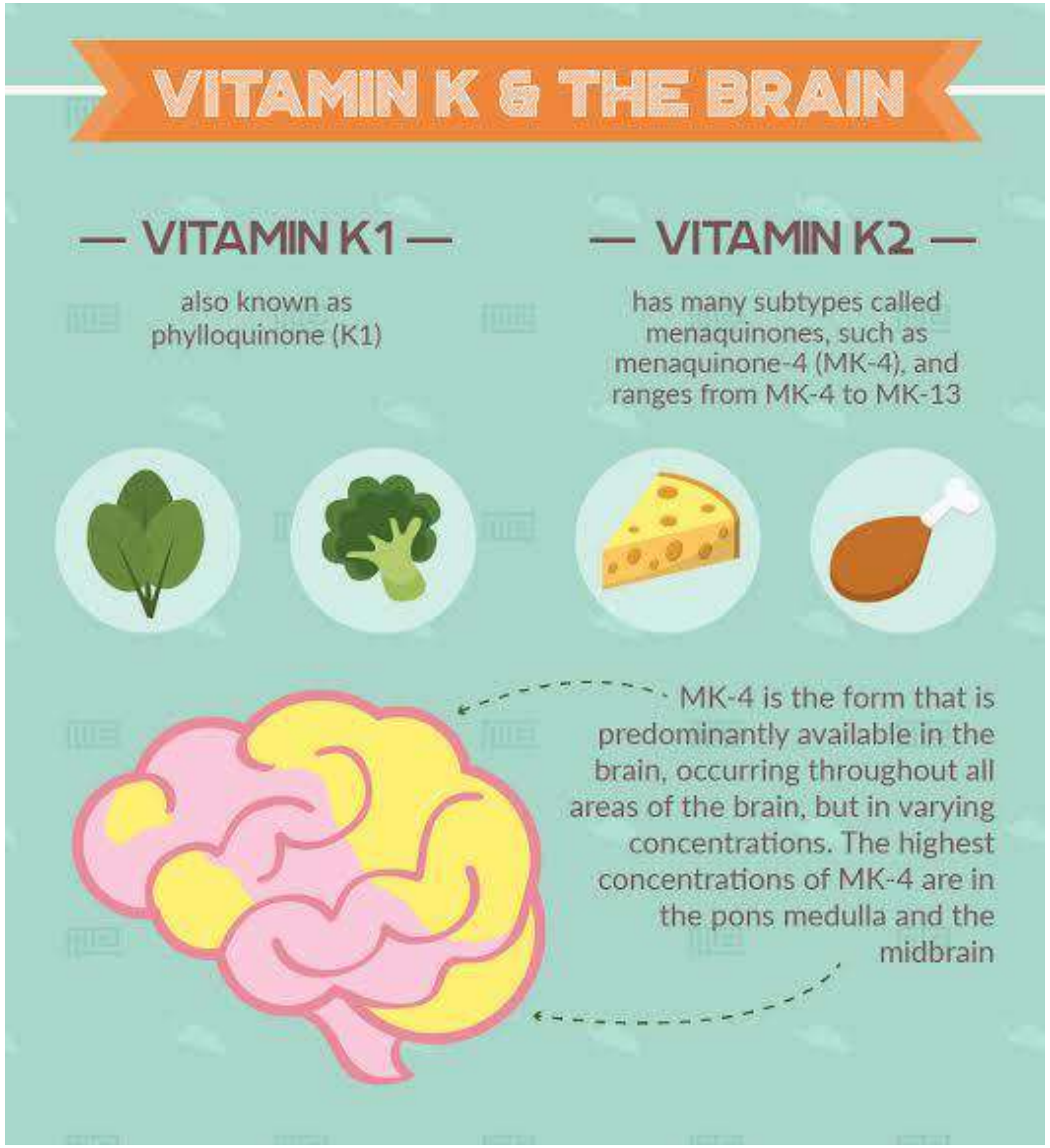

The hydrophilic (water loving) sides of membrane facing in and out
Hydrophobic (water hating) interior of the membrane
Vitamin E
Protein molecules
Cholesterol
Phospholipid

VITAMIN K

- Vitamin K helps blood clotting, essential to stop bleeding from wounds.
- People with vitamin K deficiency may experience easy bruising, nosebleeds, etc., although the deficit of this vitamin is rare to occur.
- The sources of vitamin K are animal fats (egg yolks, whole milk, red meat, ...) and dark green vegetables (spinach, asparagus, ...)



Hepatic carboxylation
Vit K1
Carboxylated active coagulant factors
Vit K2
Peripheral carboxylation
active
inactive
Cell survival
Inhibits calcification
Cell movement
Vascular smooth muscle cells
MGP
Gas-6


VITAMIN K & THE BRAIN
— VITAMIN K1 —
also known as phylloquinone (K1)
— VITAMIN K2 —
has many subtypes called menaquinones, such as menaquinone-4 (MK-4), and ranges from MK-4 to MK-13
MK-4 is the form that is predominantly available in the brain, occurring throughout all areas of the brain, but in varying concentrations. The highest concentrations of MK-4 are in the pons medulla and the midbrain

DEFICIENCY SYMPTOMS OF FAT SOLUBLE VITAMINS

- VitaminA --- Night blindness , Xeropthalmia , Keratamalacia
- Vitamin D--- Rickets in Children
- Osteomalacia in Adults

- VitaminE ---- Peripheral neuropathy , Hemolytic Anemia
- Vitamin K
- Bleeding disorders, fractures, osteoporosis ,Prolongation of prothrombin time and delayed clotting time.
- Warfarin& dicumarol inhibit gamma carboxylation system,used as anticoagulants

Water Soluble Vitamins

- Thiamin—Anti-beriberi factor(B1)
- Coenzyme form– (TPP)- Thiamin pyrophosphate
- Sources– Whole grains,bean sprouts, peas,bran& nuts
- RDA- Recommended daily intake For Children – 1.2 mg/day
- For Adults --1.5 mg/ day

- Riboflavin – (B2)
- Coenzyme form – FMN,FAD
- FMN- Flavin mono nucleotide ,Flavin adenosine dinucleotide
- Sources- Milk & its products, cereals,fruits , vegetables & eggs
- RDA – For children- 1– 1.8 mg/day increased during adolescence , for adults – 1.5 mg/ day ,increases to 2- 2.5 mg/ day during pregnancy and lactation

Water Soluble vitamins

- Niacin- Pellagra preventive factor of Goldberg
- Coenzyme forms- NAD+ & NADP+
- Sources- Whole grains, cereals, pulses,yeast ,milk ,vegetables , eggs & fish
- RDA – 15- 20 mg for adults
- 10- 15 mg for children
- Increased during pregnancy & lactation

- Pyridoxine—(VITAMIN B6)
- Vitamins of B6 – pyridoxine, pyridoxine & pyridoxamine
- Active form – pyridoxal phosphate
- Excreted in urine as 4- pyridoxine acid
- Sources – Wheat,corn ,cabbage,roots, tubers ,egg yolk, fish, milk & meat
- RDA- 1.5 – 2.0 mg for adults ,increased during pregnancy & lactation
- Depends upon the intake of protein

Biochemical Functions Of Vitamin B1& B2

- Thiamine (B1)
- TPP- Coenzyme form – involved in the following Rxs catalyzed by Enzymes
- Oxidative decarboxylation of alpha keto acids e.g.
- Pyruvic acid is broken down AcetylCoA and carbondioxide by Pyruvate dehydrogenase complex
- Alpha keto glutaric acid converted to succinylCoA and carbondioxide by Alpha keto dehydrogenase complex
- Transketolase in HMP shunt pathway

- Riboflavin (B2)
- Coenzyme forms-- FMN& FAD
- Act as Coenzymes in oxidation & reduction Rxs e.g.FADdependant
- Succinate to Fumarate by Succinate dehydrogenase
- Pyruvate to acetyl CoA by Pyruvate dehyrogenase
- Alpha ketoglutarate to succinyl CoA by alpha keto glutaratedehydrogenase
- Acyl CoA to alpha beta unsaturated acyl CoA by AcylCoA dehydrogenase
- FMN dependant
- L-Aminoacid to alphaketo acid & ammonia by L- amino acid oxidase .

Biochemical Functions of Niacin & Pyridoxine

- Niacin– NAD+, NADP+
- Act as Coenzymes in oxidation reduction Rxs catalyzed by oxidoreductases in carbohydrate, lipid & protein metabolism
- NAD+ dependent Enzymes
- Glyceraldehyde 3- phosphate dehydrogenase, LDH,PDH, alpha ketoglutarate dehydrogenase
- NADP+ dependent Enzymes
- Glutamate dehydrogenase

- Pyridoxine– PLP
- Act as Coenzyme reactions of amino acid metabolism like
- Transamination – Conversion of L- amino acid to keto acid by Transaminase
- Decarboxylation of L- Aminoacids by Decarboxylases
- Formation of Serotonin from Tryptophan
- Histamine from Histamine
- GABA from Glutamic acid
- Heme synthesis,
- Transsulfuration – cysteine formation
- Deamination- Serine to pyruvate
- Absorption **Of Aminoacids from the intestine**
- **Glycogen phosphorylase**
-

Water Soluble Vitamins Biotin & Pantothenic Acid

- Biotin -- Anti- egg white injury factor / VitaminH / Vitamin B7
- Sources – milk, tomatoes, grains, egg yolk, liver & kidney
- RDA– 20 – 30 miçrograms for adults, normally synthesized by intestinal bacteria

- Pantothenic acid –
- Its metabolic role as Coenzyme A
- Sources– widely distribution in plants & animals ,milk,egg, liver ,meat ,yeast etc
- RDA –5-10 mg for adults

Biochemical Functions

- Biotin----Act as carrier of CO2in carboxylation reactions catalyzed by following enzymes
- Pyruvate carboxylase, Alpha keto glutamate dehydrogenase ,Acyl CoA dehydrogenase , Propionyl CoA carboxlase and beta Methyl crotonyl CoA carboxylase in carbohydrate, lipid & protein metabolism
- Also involved in regulation of cell cycle

- Pantothenic acid (CoA)
- Serves as carrier of activated or acyl groups catalyzed by following enzymes

WATER SOLUBLE VITAMINS

- Pantothenic acid – Antidermititis factor
- Active form– CoenzymeA
- RDA– 1-2 mg for infants ,4- 5 mg for children
- Increased during Pregnancy lactation and old age
- Dietary sources- widely distributed in plants & animals ,the rich sources – milk, egg, yeast & meat etc.

- Folic acid --- B9/ Vitamin M
- Active form – THF (Tetrahydrofolic acid)
- RDA--- 200- 250 miçrograms
- 400 miçrograms during pregnancy & lactation
- Dietary sources – dried peas, beans,yeast, milk, leafy green vegetables like spinach,cauliflower, lettuce.
- Liver, kidney and fish

WATER SOLUBLE VITAMINS

- Pantothenic acid–
- Biochemical Functions
- Acts as Coenzyme in metabolic reactions catalyzed by enzymes in metabolism of carbohydrate, lipid and protein
- Pyruvate dehydrogenase, alpha keto dehydrogenase
- AcetylCoA used for synthesis of Cholesterol, Fattyacids, ketone bodies, citric acid
- Pantothenic acid also involved in formation of ACP for Fattyacid synthesis, branched chain Aminoacids metabolism

- FOLIC ACID B9/ Vitamin M
- Biochemical Functions
- Act as Coenzyme in transfer of methyl,formyl, formamino, hydroxy methyl group

In synthesis of purine, pyrimidine, methionine, choline and creatine metabolism.

-- maturation of red blood cells.

WATER SOLUBLE VITAMINS

- Vitamin B12 known as anti- pernicious anemia factor, Cobalamin .
- RDA-0.4-1.8 miçrograms for Children ,2- 4 miçrograms for adults
- Present in dietary sources

– Curd, liver,,chicken

Biochemical Functions

For methionine, myelin synthesis and normal red blood cells

Act as coenzyme for reactions catalyzed by methyl Maloney CoA isomerase,Homocysteine methyl transferase.

- Vitamin C--- L- Ascorbic acid
- Antioxidant, Scurvy preventing factor
- RDA -1mg/kg body weight for children
- 75- 90mg for adults
- Dietary sources– citrus fruits, fresh vegetables, banana, potatoes gooseberry (amla).
- Biochemical Functions
- Act as Coenzyme for hydroxylation
- Reactions involved in
- Collagen synthesis at post transcription level for bone &teeth formation
- Synthesis of Serotonin, norepinephrine & epinephrine, carnitine
- Metabolism of cholesterol to bile acids
- As antioxidant, keeps vitamin A,E & B complex active
- Iron absorption,Hemoglobin metabolism ,synthesis of corticosteroid hormo es & Immunoglobulins
- Reduces risk of cataract,cancer and heart disease

Water Soluble vitamins

- Biotin-7 or H, known as anti egg white injury factor
- RDA– 150-300 miçrograms
- Dietary sources -- milk, egg yolk ,liver ,kidney & intestinal bacteria

- Folic acid
- Coenzyme form – Tetrahydrofolic acid (THF)
- Dietary sources - cereals,whole grains, green leafy vegetables& liver
- RDA–100-300 miçrograms ,
- Absorption- The monoglutamate of Folicacid is absorbed from the intestine.
- As polyglutamate ,is stored in the liver upto 10-12 mg, usually last for 2- 3 months

Water Soluble Vitamins

- Biochemical functions of Thiamine
- Act as Coenzyme in the TPP form in carbohydrate, lipid & protein metabolism for example
- Oxidative decarboxylation reactions for oxidation reduction reactions
- As Coenzyme in HMP shunt pathway for transketolase catalyzed reactions

- Riboflavin --- Biochemical functions
- Act as Coenzyme in FMN & FAD in carbohydrate, lipid & protein metabolism in oxidation and reduction reactions.

Deficiency Symptoms of Water Soluble Vitamins

- Thiamine-(B1)-- Beri-Beri– two types
- Wet Beri-Beri--- Edema of legs,face,trunk,Breathlessness and palpitation (Cardiovascular Beri-Beri)
- Dry Beri – Beri-Beri--- Neurological manifestations, The muscles become weak, walking difficult

- Riboflavin (B2)-- Cheilosis(fissures at the corners of mouth)
- --- Glossitis(tongue smooth & purplish)
- ---- Dermatitis

Deficiency Symptoms of Water Soluble Vitamins

- Niacin--- Pellagra characterized by ---- Dermatitis, Diarrhea and Dementia.
- Pantothenic acid– Burning feet syndrome (pain & numbness in toes) ,fatigue.
- Pyridoxine (B6) – Neurological symptoms, Hypochromic microscopic anemia, Reduction in heme synthesis, Drug induced B6 deficiency (Isonizid used in treatment of tuberculosis)
- Folic acid--- Macrocytic anemia

Deficiency Symptoms of Water Soluble Vitamins

- Vitamin B12---Pernicious Anaemia,Neuronal degeneration and demyelination of nervous system

- L-Ascorbic acid-----Scurvy
- Characterized by spongy and sore gums,loose teeth,swollen joints, fragile blood vessels , delayed wound healing, hemorrhage& osteoporosis