

The background features a light gray gradient with several realistic water droplets of various sizes scattered across the surface. The droplets have highlights and shadows, giving them a three-dimensional appearance. The text is centered in the middle of the frame.

TOPIC NO 1

FOOD COMPOSITION

- **Food composition** is the detailed information about the nutritionally important components of foods.
- It provides information about protein, carbohydrates, fat, vitamins and minerals and for other important food components such as fibre.
- Food Composition data is presented in **food composition databases** (FCDBs).

TOPIC NO 2

WATER

- Water (moisture) is the predominant constituent in many foods.
- Water supports chemical reactions, and it is a direct reactant in hydrolytic processes.
- Water is a controlling factor in microbial spoilage, and also contributes to chemical and physical stability of foods.
- Water contributes significantly to the texture of food through physical interaction with proteins, polysaccharides, lipids and salts.

- Removal of water from food or binding it by increasing the concentration of common salt or sugar retards many reactions and inhibits the growth of microorganisms, thus improving the shelf lives of a number of foods.

Table: Moisture Content of some Foods

Food	Moisture content (weight-%)	Food	Moisture content (weight-%)
Meat	65–75	Cereal flour	12–14
Milk	87	Coffee beans, roasted	5
Fruits, vegetables	70–90	Milk powder	4
Bread	35	Edible oil	0
Honey	20		
Butter, margarine	16–18		

Topic no 3 Structure of water molecule

- Water is a simple molecule consisting of one oxygen atom bonded to two different hydrogen atoms.
- Because of the higher **electronegativity** of the oxygen atom, the bonds are polar covalent (**polar bonds**). The oxygen atom attracts the shared electrons of the covalent bonds to a significantly greater extent than the hydrogen atoms.
- As a result, the oxygen atom requires a partial negative charge (δ^-), while the hydrogen atoms each acquire a partial positive charge (δ^+).

- The molecule adopts a bent structure because of the two lone pairs of electrons on the oxygen atom. The H–O–H bond angle is about 105°

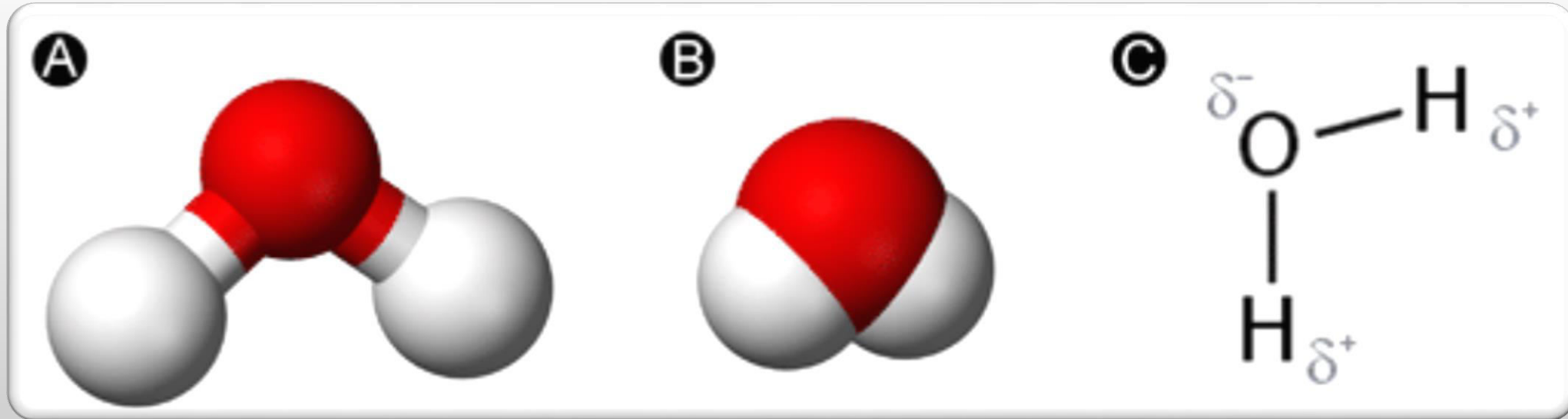


Fig. The water molecule, visualized three different ways: ball-and-stick model, space-filling model, and structural formula with partial charges.

- A single water molecule can participate in a maximum of four hydrogen bonds because it can accept two bonds using the lone pairs on oxygen and donate two hydrogen atoms.

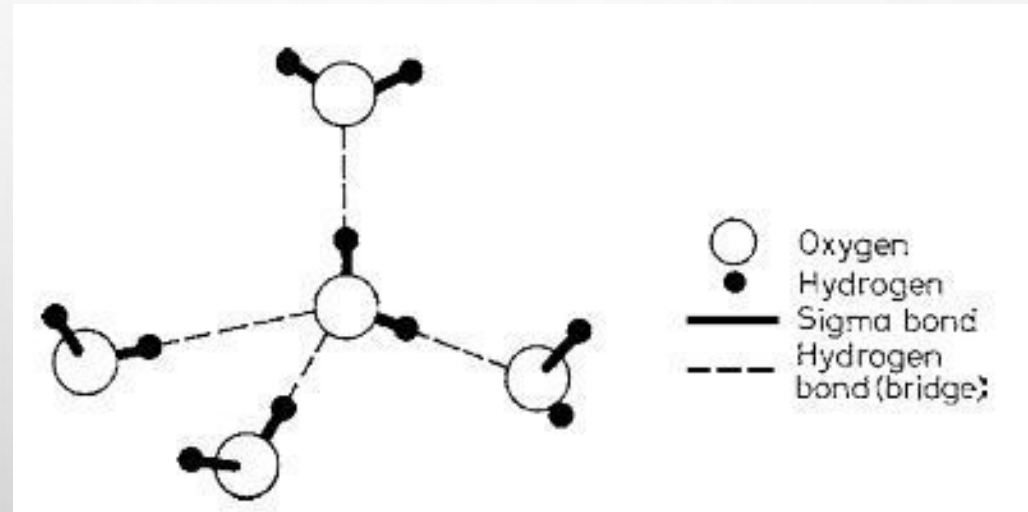
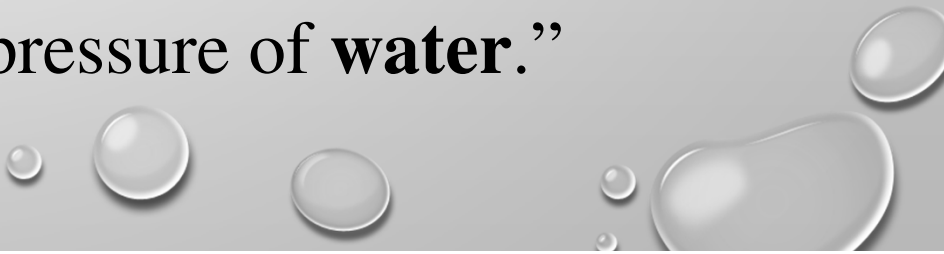


Fig. Tetrahedral Coordination of water molecules



Topic no 4

Water activity

- In 1952, scott came to the conclusion that the storage quality of food does not depend on the water content, but on water activity (aw), which is defined as follows:
 - “The partial vapor pressure of **water** in a substance divided by the standard state partial vapor pressure of **water**.”
- 

- With reference to food it is defined as

$$a_w = P/P_0$$

Where

P = partial vapor pressure of food moisture
at temperature T
P₀ = saturation vapor pressure of pure
water at T

- Pure distilled water has a water activity of exactly one.
- Higher a_w substances tend to support more microorganisms.
- Bacteria usually require at least 0.91, and fungi at least 0.7.

Table: Water activity values of foods

Food	Typical a_w
Fresh meat	0.98
Cheese	0.97
Preserves	0.88
Salami	0.83
Dried fruit	0.76
Honey	0.75
Pasta	0.50

The background of the slide is a light gray gradient with several realistic water droplets of various sizes scattered across it. The droplets have highlights and shadows, giving them a three-dimensional appearance.

TOPIC NO 5

FOOD COMPOSITION

AMINO ACIDS, PEPTIDES, PROTEINS

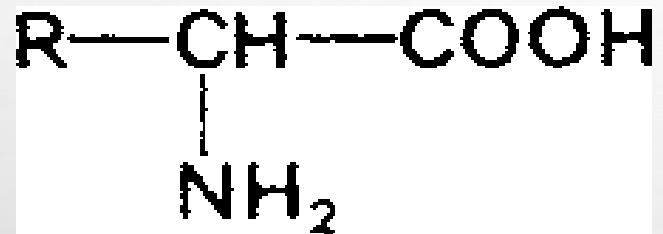
- Amino acids, peptides and proteins are important constituents of food.
- They supply the required building blocks for protein biosynthesis.
- In addition, they directly contribute to the flavor of food and are precursors for aroma compounds and colors formed during thermal or enzymatic reactions in production, processing and storage of food.

- Proteins also contribute significantly to the physical properties of food through their ability to build or stabilize gels, foams, emulsions and fibrillar structures.
- The nutritional energy value of proteins (17 kJ/g or 4 kcal/g) is as high as that of carbohydrates.
- The most important sources of protein are grain, oilseeds and legumes, followed by meat and milk.
- In addition to plants and animals, protein producers include algae (*Chlorella*, *Scenedesmus*, *Spirulina spp.*), Yeasts and bacteria (single-cell proteins [SCP]).

Topic no 6

Amino acids

- There are about 20 amino acids in a protein hydrolysate.
- The general structure of amino acids is



- In simplest case, r=h (glycine).
- In other amino acids, R is an aliphatic, aromatic or heterocyclic residue and may incorporate other functional groups

Classification

1. Classification on the basis of R-group

Group A : Hydrophobic amino acids

- Amino acids in which R-group is non-polar
- Glycine, alanine, valine, leucine, isoleucine, methionine, phenylalanine, proline, tryptophan

Group B: Hydrophilic, Uncharged amino acids

- Amino acids in which R-group is polar, hydrophilic but uncharged
- Cysteine, serine, threonine, glutamine, asparagine, tyrosine

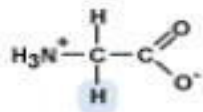
Group C: Acidic amino acids

- Amino acids in which R-group is acidic or negatively charged
- Glutamic acid and aspartic acid

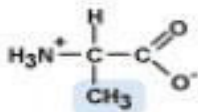
Group D: Basic amino acids

- Amino acids in which r-group is basic or positively charged
Lysine, arginine, histidine

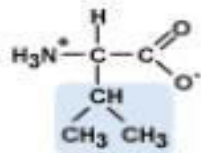
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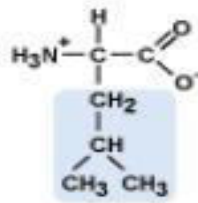
Glycine (Gly)



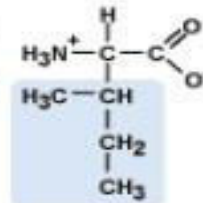
Alanine (Ala)



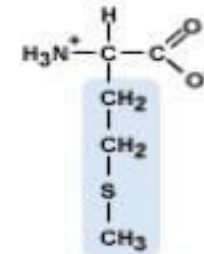
Valine (Val)



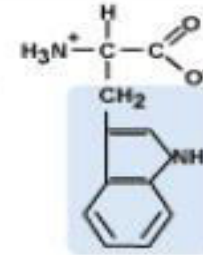
Leucine (Leu)



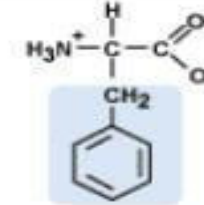
Isoleucine (Ile)



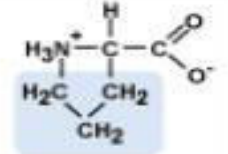
Methionine (Met)



Tryptophan (Trp)

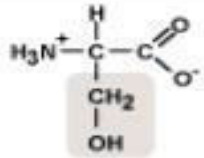


Phenylalanine (Phe)

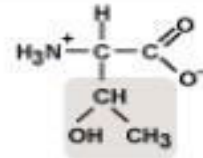


Proline (Pro)

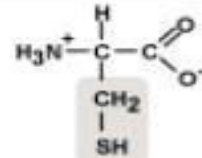
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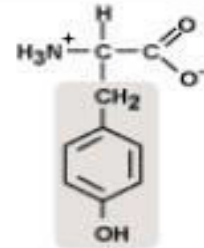
Serine (Ser)



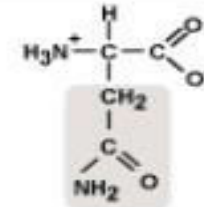
Threonine (Thr)



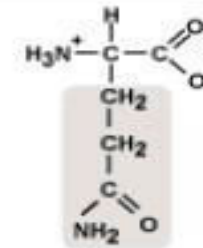
Cysteine (Cys)



Tyrosine (Tyr)

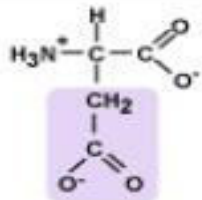


Asparagine (Asn)

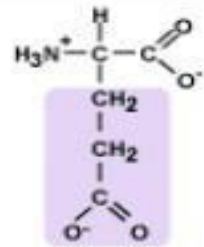


Glutamine (Gln)

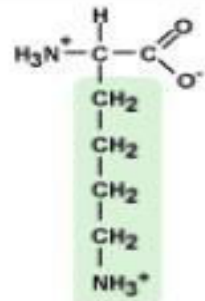
Electrically Charged



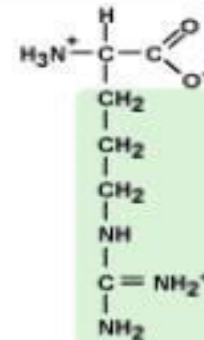
Aspartic Acid (Asp)



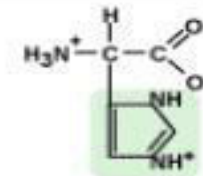
Glutamic Acid (Glu)



Lysine (Lys)



Arginine (Arg)



Histidine (His)

Acidic

Basic

Fig. Classification of amino acids on the basis of R-group

Topic no 7

- **Classification of amino acids on the basis of nutrition:**

1. Essential amino acids:

- These amino acids are not synthesized in cells of human beings, so these should be essentially present in diet.
- Phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, histidine, arginine, leucine, lysine
- Arginine is conditional amino acids (essential for infants, non essential for adults)

2. Non essential amino acids:

- These amino acids can be synthesized in body, so need not be included in diet.
- Glycine, alanine, serine, cysteine, asparagine, glutamine, aspartic acid, glutamic acid, tyrosine, proline

Table: Recommended daily amounts currently in use for essential amino acids in adult humans

Amino acid(s)	WHO mg per kg body weight	US mg per kg body weight
Histidine	10	14
Isoleucine	20	19
Leucine	39	42
Lysine	30	38
Methionine+ Cysteine	10.4 + 4.1 (15 total)	19 total
Phenylalanine+ Tyrosine	25 (total)	33 total
Threonine	15	20
Tryptophan	4	5
Valine	26	24

Topic no 8

Discovery and occurrence of amino acids

1. Alanine

- Isolated from silk fibroin by *Weyl* in 1888.
- Present in most proteins and is particularly enriched in silk fibroin (35%).
- Gelatin contain about 9% alanine, while its content in other proteins is 2–7%.

2. *Arginine*

- First isolated from lupin seedlings by Schulze and Steiger in 1886.
- Present in all proteins at an average level of 3–6%, but is particularly enriched in protamines.
- The arginine content of peanut protein is relatively high (11%).

3. *Asparagine*

- Isolated from Asparagus by Vauguelin and Robiquet in 1806.
- Its occurrence in proteins (Edestin) was confirmed by Damodaran in 1932.
- In glycoproteins the carbohydrate component may be bound N-glycosidically to the protein moiety through the amide group of asparagine.

4. *Aspartic acid*

- Isolated from legumes by Ritthausen in 1868.
- It occurs in all animal proteins, primarily in albumins at a concentration of 6–10%.
- Alfalfa and corn proteins are rich in aspartic acid (14.9% and 12.3%, respectively) while its content in wheat is low (3.8%).

Topic no 9

5. *Cysteine*

- Isolated from bladder calculi by Wolaston in 1810 and from horns by Mourner in 1899.
- Its content is high in keratins (9%).
- Cysteine is very important since the peptide chains of many proteins are connected by two cysteine residues, i.e. By disulfide bonds.
- Most proteins contain 1–2% cystine.

6. *Glutamine*

- First isolated from sugar beet juice by Schulze and Bosshard in 1883.
- Its occurrence in protein (Edestin) was confirmed by Damodaran in 1932.

• 7. *Glutamic acid*

- First isolated from wheat gluten by Ritthausen in 1866.
- It is abundant in most proteins, but is particularly high in milk proteins (21.7%), wheat (31.4%), corn (18.4%) and soya (18.5%).
- Molasses also contains relatively high amounts of glutamic acid.

8. *Glycine*

- First isolated from gelatin by Braconnot in 1820.
- Found in high amounts in structural protein.
- Collagen contains 25–30% glycine.

9. *Histidine*

- First isolated in 1896 independently by Kossel and by Hedin from Protamines occurring In fish.
- Most proteins contain 2–3% histidine.
- Blood proteins contain about 6%.

Topic no 10

14. Lysine

- Isolated from casein by Drechsel in 1889.
- Makes up 7–9% of meat, egg and milk proteins.
- Crab and fish proteins are the richest sources (10–11%).

ε- The processing of foods results in losses of lysine since its ϵ -amino group is very reactive (cf. *Maillard reaction*).

15. Methionine

- First isolated from casein by Mueller in 1922.
- Animal proteins contain 2–4% and plant proteins contain 1–2% methionine.
- Very sensitive to oxygen and heat treatment. Thus, losses occur in many food processing operations such as drying, kiln-drying, puffing, roasting or treatment with oxidizing agents.

16. *Phenylalanine*

- Isolated from lupins by Schulze in 1881.
- Occurs in almost all proteins (averaging 4–5%)

17. Proline

- Discovered in casein and egg albumen by Fischer in 1901.
- Present in numerous proteins at 4–7% and is abundant in wheat proteins (10.3%), gelatin (12.8%) and casein (12.3%).

18. Serine

- First isolated from sericin by Cramer in 1865.
- Most proteins contain about 4–8% serine.
- The carbohydrate component of glycoproteins may be bound O-glycosidically through the hydroxyl group of serine and/or threonine.

Topic no 11

19. Threonine

- Discovered by Rose in 1935.
- Present at 4.5–5% in meat, milk and eggs and 2.7–4.7% in cereals.
- Threonine is often the limiting amino acid in proteins of lower biological quality.
- The “bouillon” flavor of protein hydrolysates originates partly from a lactone derived from threonine

• *20. Tryptophan*

- First isolated from casein hydrolysates, prepared by hydrolysis using pancreatic enzymes, by Hopkins in 1902.
- Occurs in animal proteins in relatively low amounts (1–2%) and in even lower amounts in cereal proteins (about 1%).
- Exceptionally abundant in lysozyme (7.8%).

• *21. Tyrosine*

- First obtained from casein by Liebig in 1846.
- Found in almost all proteins at levels of 2–6%.
- Silk fibroin can have as much as 10% tyrosine.

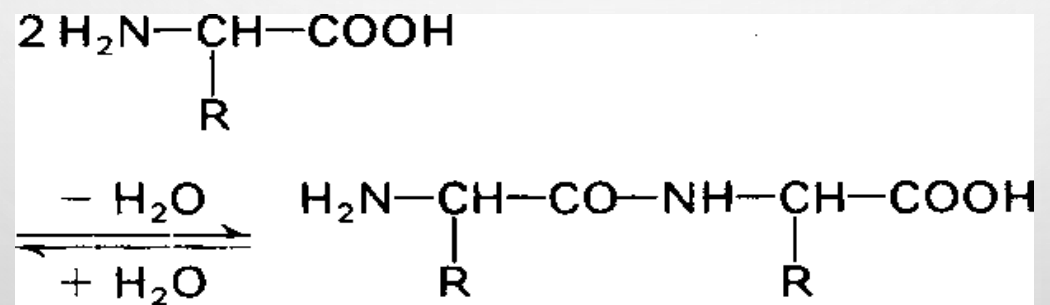
22. *Valine*

- First isolated by Schutzenberger in 1879.
- Present in meat and cereal proteins (5–7%) and in egg and milk proteins (7–8%).
- Elastin contains notably high concentrations of valine (15.6%).

Topic no 12

Peptides

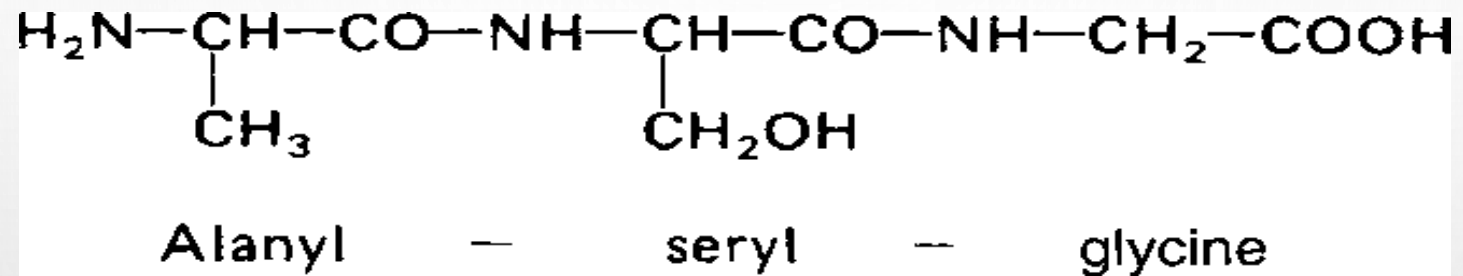
- Peptides are formed by binding amino acids together through an amide linkage.



- Peptide hydrolysis results in free amino acids.

- Peptides are denoted by the number of amino acid residues as di-, tri-, tetrapeptides, etc.,
- The term “oligopeptides” is used for those with 10 or less amino acid residues.
- Higher molecular weight peptides are called polypeptides.
- The transition of “polypeptide” to “protein” is rather undefined, but the limit is commonly assumed to be at a molecular weight of about 10 kdal, i.e., About 100 amino acid residues are needed in the chain for it to be called a protein.

- The first three letters of the amino acids are used as symbols to simplify designation of peptide.



- The peptide shown above can also be given as:

Ala - ser - gly or ASG

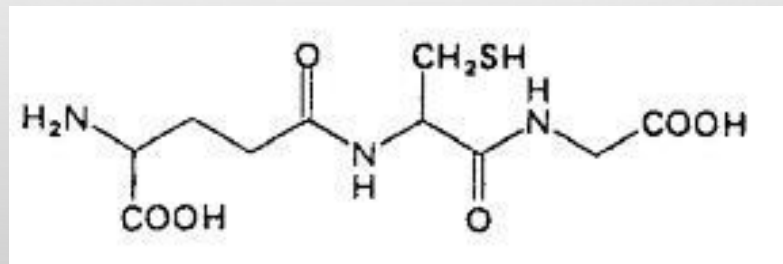
- One-letter symbols are used for amino acid sequences of long peptide chains.

- Peptides are widespread in nature.
- They are often involved in specific biological activities (peptide hormones, peptide toxins, peptide antibiotics).

Topic no 13

1. Glutathione

- Glutathione (γ -L-glutamyl-L-cysteinyl-glycine) is a tripeptide with a gamma peptide linkage between the carboxyl group of the glutamate side chain and the amine group of cysteine, and the carboxyl group of cysteine is attached by normal peptide linkage to a glycine.



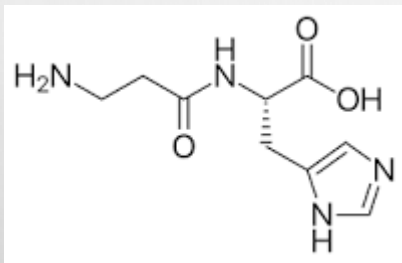
- It is widespread in animals, plants and microorganisms.

- Beef (200), broccoli (140), spinach (120), parsley (120), chicken (95), cauliflower (74), potatoes (71), paprika (49), tomatoes (49) and oranges (40) are especially rich in glutathione (mg/kg).
- The peptide is the coenzyme of glyoxalase.
- Involved in active transport of amino acids
- Also involved in many redox-type reactions.
- Influences the rheological properties of wheat flour dough through thiol-disulfide interchange with wheat gluten.
- Carnosine may act as a neurotransmitter for nerves involved in odor perception.

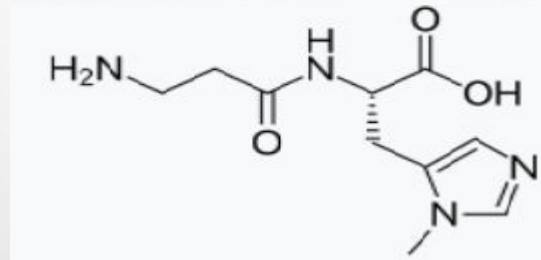
Carnosine, Anserine and Balenine

- These peptides contain a β -amino acid, β -alanine, bound to L-histidine or 1-methyl- or 3-methyl-L-histidine, and are present in meat extract and in muscle of vertebrates.
- Carnosine is predominant in beef muscle tissue, while anserine is predominant in chicken meat.

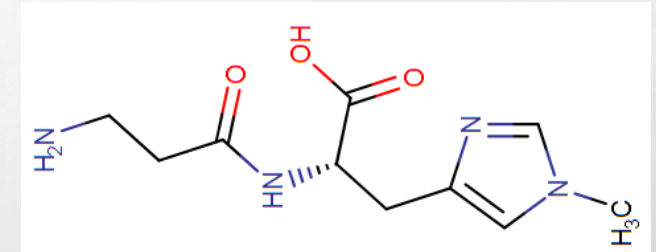
- Balenine is a characteristic constituent of whale muscle, although it appears that sperm whales do not have this dipeptide.



Carnosine



Anserine



Balenine

Table: Occurrence of carnosine, anserine and balenine (%) in meat

Meat	Carnosine	Anserine	Balenine
Beef muscle tissue	0.15–0.35	0.01–0.05	
Beef meat extract	3.1–5.7	0.4–1.0	
Chicken meat ^c	0.01–0.1	0.05–0.25	
Chicken meat extract	0.7–1.2	2.5–3.5	
Whale meat			
Whale meat extract a ^d	3.1–5.9	0.2–0.6	13.5–23.0
Whale meat extract b ^e	2.5–4.5	1.2–3.0	0–5.2

Topic no 14

Nisin

- Nisin is a polycyclic antibacterial peptide produced by the bacterium *Lactococcus lactis* that is used as a food preservative.
- It has 34 amino acid residues, including the uncommon amino acids lanthionine (Lan), methyllanthionine (MeLan), didehydroalanine (Dha), and didehydroaminobutyric acid (Dhb).
- These unusual amino acids are introduced by posttranslational modification of the precursor peptide.

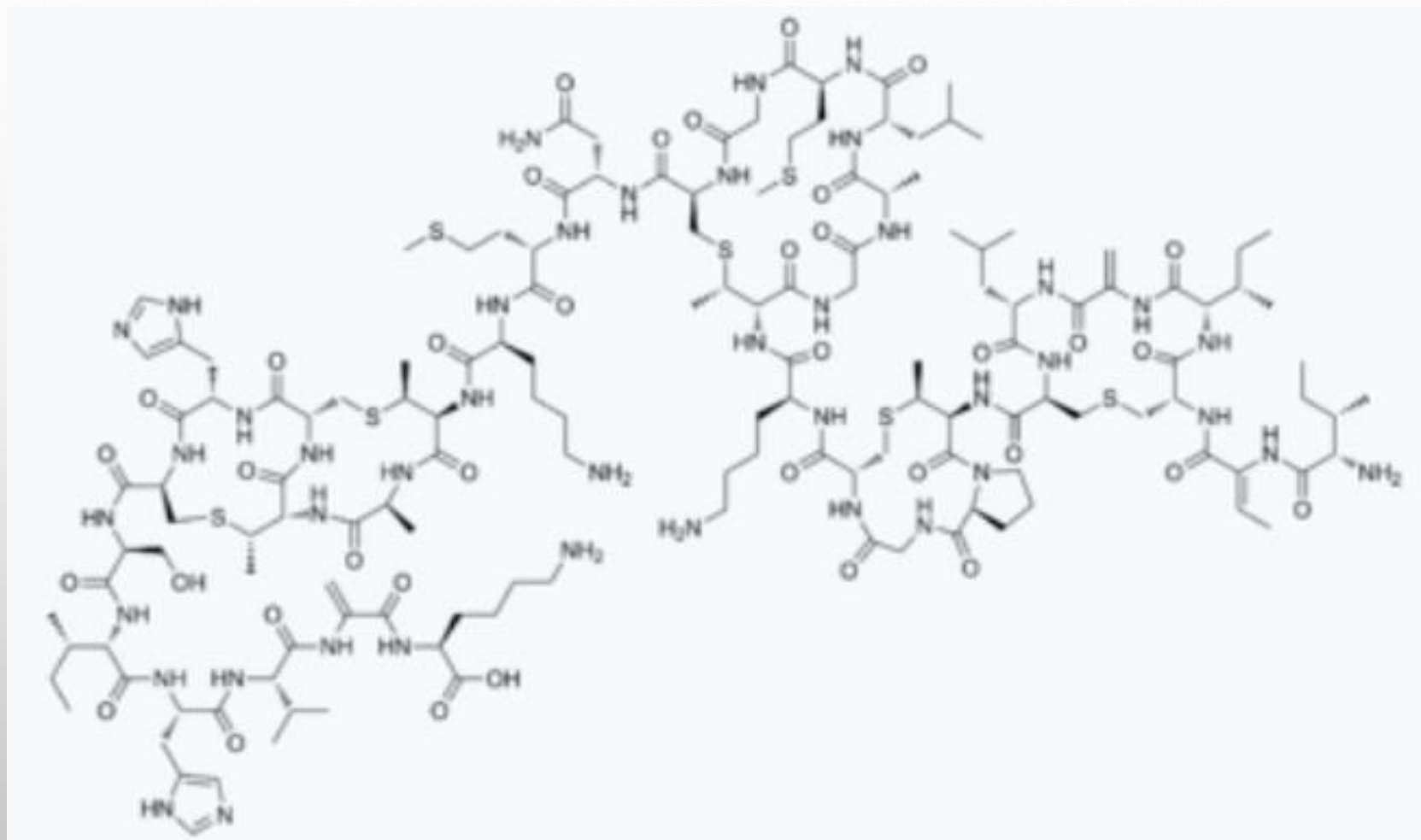


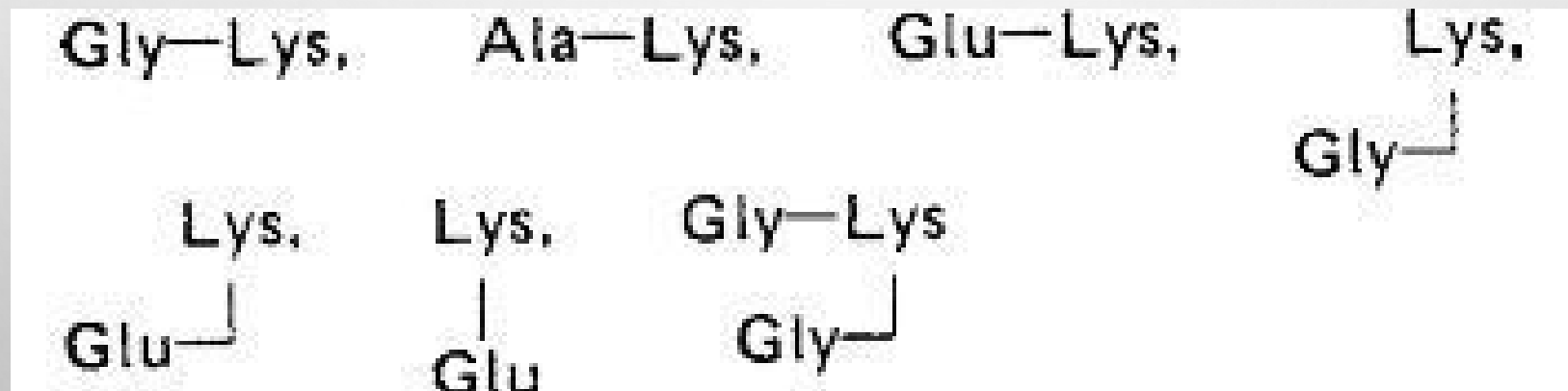
Fig. Nisin

- Nisin is effective against many Gram-positive organisms, including lactic acid bacteria (commonly associated with spoilage), *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus cereus*, *Clostridium botulinum*, etc. It is also particularly effective against spores.
- Gram-negative bacteria are protected by their outer membrane but may become susceptible to nisin action after a heat shock.

- It is used to suppress anaerobes in cheese and cheese products, especially in hard cheese and processed cheese to inhibit butyric acid fermentation.
- The use of nisin in the canning of vegetables allows mild sterilization conditions.
- Nisin is soluble in water and can be effective at levels nearing the parts-per-billion range.

Lysine peptides

- Substantially retard the browning reaction with glucose, hence they are suitable for lysine fortification of sugar-containing foods which must be heat treated.



Topic no 15

Proteins

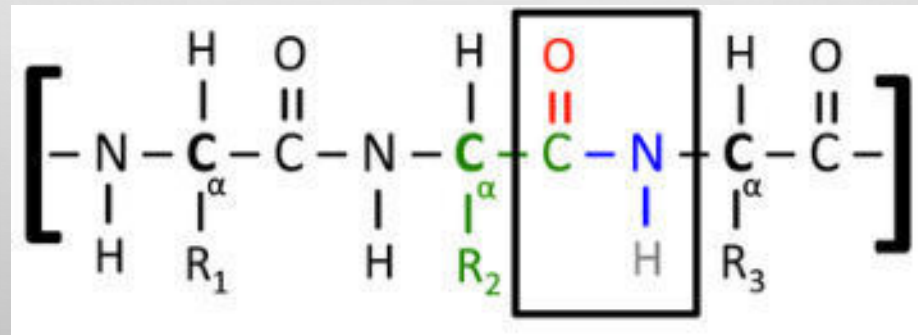
- **Proteins** are large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues.
- The structure of a protein is dependent on the amino acid sequence (the primary structure) which determines the molecular conformation (secondary and tertiary structures).

- Proteins sometimes occur as molecular aggregates which are arranged in an orderly geometric fashion (quaternary structure). Proteins differ from one another primarily in their sequence of amino acids, which is dictated by the nucleotide sequence of their genes, and which usually results in protein folding into a specific three-dimensional structure that determines its activity.
- The sequences and conformations of a large number of proteins have been elucidated and recorded in several data bases.

Levels of protein structure

Primary structure

- The primary structure of a protein refers to the sequence of amino acids in the polypeptide chain.
- The primary structure is held together by peptide bonds that are made during the process of protein biosynthesis.

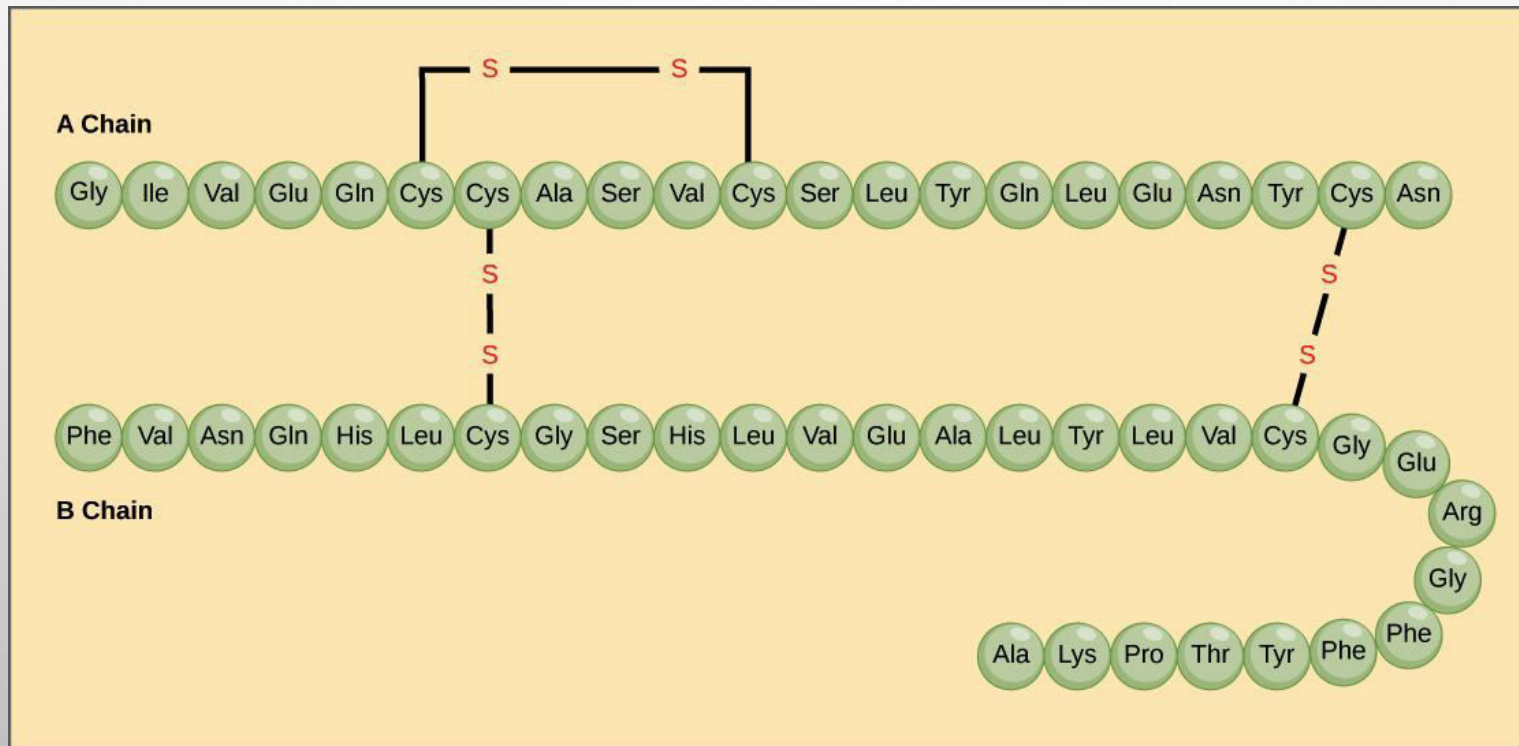


- The two ends of the polypeptide chain are referred to as the carboxyl terminus (C-terminus) and the amino terminus (N-terminus).
- Counting of residues always starts at the N-terminal end (NH_2 -group), which is the end where the amino group is not involved in a peptide bond.

- The primary structure of a protein is determined by the gene corresponding to the protein.
- A specific sequence of nucleotides in DNA is transcribed into mRNA, which is read by the ribosome in a process called translation.
- The sequence of a protein is unique to that protein, and defines the structure and function of the protein.

- The sequence of a protein can be determined by methods such as Edman degradation. Often, however, it is read directly from the sequence of the gene using the genetic code.
- Post-translational modification such as disulfide bond formation, phosphorylations and glycosylations are usually also considered a part of the primary structure.
- A change in the gene's DNA sequence may lead to a change in the amino acid sequence of the protein. Even changing just one amino acid in a protein's sequence can affect the protein's overall structure and function.

- For example, insulin is composed of 51 amino acids in 2 chains. One chain has 31 amino acids, and the other has 20 amino acids.



Insulin Structure

Topic no 16

Secondary structure

- The primary structure gives the sequence of amino acids in a protein chain while the secondary structure reveals the arrangement of the chain in space.
- The most common types of secondary structures are the α helix and the β pleated sheet.
- Both structures are held in shape by hydrogen bonds, which form between the carbonyl O of one amino acid and the amino H of another.

• **Alpha helix**

- In an **α helix**, the carbonyl (C=O) of one amino acid is hydrogen bonded to the amino H (N-H) of an amino acid that is four down the chain.
- This pattern of bonding pulls the polypeptide chain into a helical structure that resembles a curled ribbon, with each turn of the helix containing 3.6 amino acids.

- The R groups of the amino acids stick outward from the α helix, where they are free to interact.
- The hydrogen bonds make this structure especially stable.
- The most common secondary structure is the α -helix and for polypeptides from L-amino acids, it is exclusively the Right-handed α -helix.
- The left-handed α -helix is energetically unfavorable for L-amino acids.

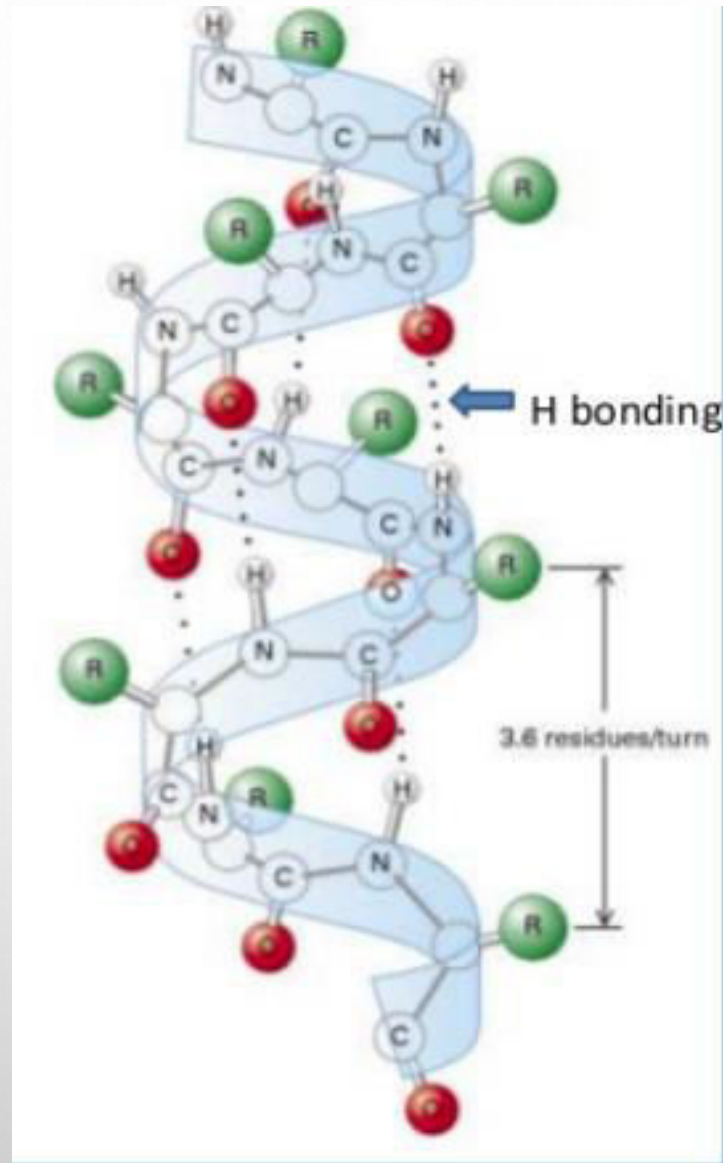


Fig. Alpha Helix

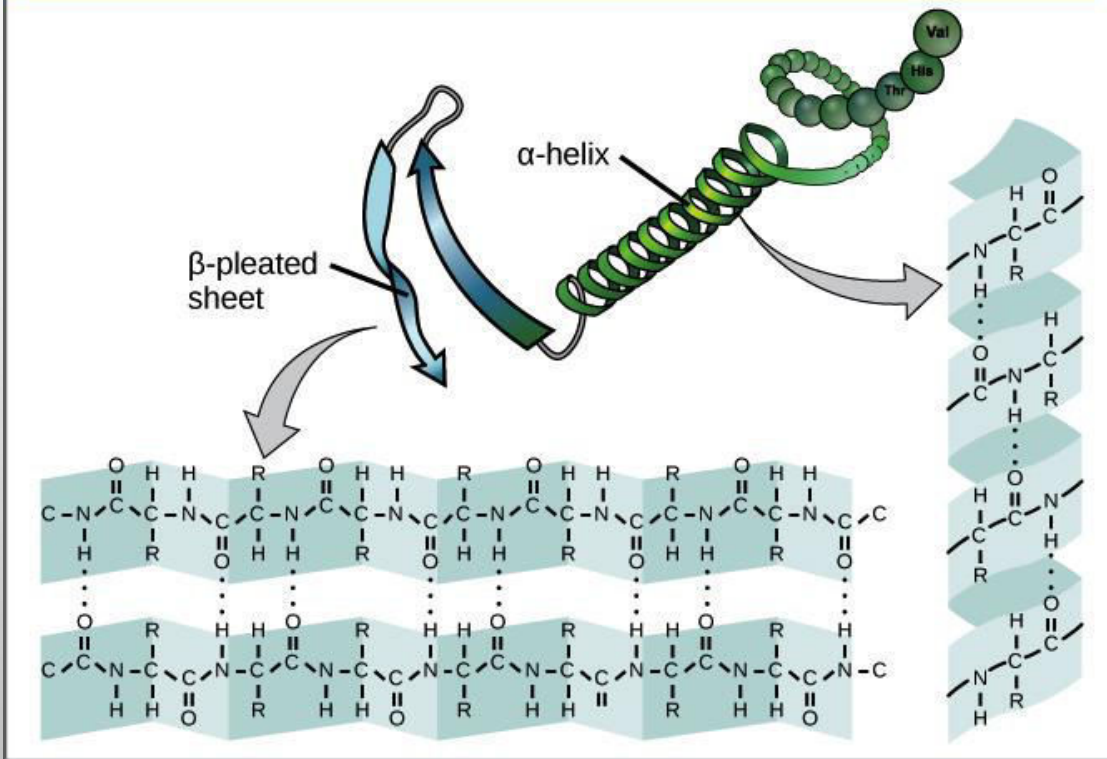
Topic no 17

β pleated sheet

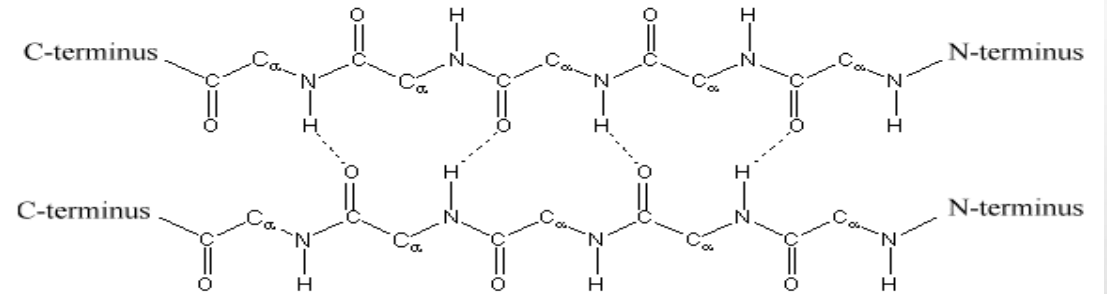
- In a **β pleated sheet**, two or more segments of a polypeptide chain line up next to each other, forming a sheet-like structure held together by hydrogen bonds.
- The hydrogen bonding in a β -sheet is between strands (inter-strand) rather than within strands (intra-strand).
- The hydrogen bonds form between carbonyl and amino groups of backbone, while the R groups extend above and below the plane of the sheet.

- The strands of a β pleated sheet may be **parallel**, pointing in the same direction (meaning that their n- and c-termini match up), or **antiparallel**, pointing in opposite directions (meaning that the n-terminus of one strand is positioned next to the c-terminus of the other).
- The anti-parallel β -sheet is more stable due to the more well-aligned hydrogen bonds.

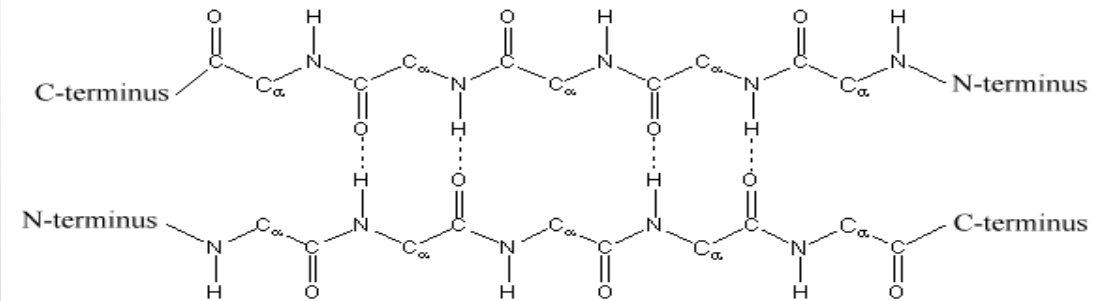
Secondary Protein Structure



Parallel β Sheet



Antiparallel β Sheet



β -Pleated Sheets

- Certain amino acids are more or less likely to be found in α -helices or β pleated sheets.
- The amino acid proline is sometimes called a “helix breaker” because its unusual R group (which bonds to the amino group to form a ring) creates a bend in the chain and is not compatible with helix formation.
- Proline is typically found in bends, unstructured regions between secondary structures.

- Amino acids such as tryptophan, tyrosine, and phenylalanine, which have large ring structures in their R groups, are often found in β pleated sheets, perhaps because the β pleated sheet structure provides plenty of space for the side chain.
- Many proteins contain both α helices and β pleated sheets, though some contain just one type of secondary structure (or do not form either type).

Topic no 18

β Turns

- Also known as β -bends, tight turns, reverse turns
- Are a type of non-regular secondary structure in proteins that cause a change in direction of the polypeptide chain.
- They occur at hairpin corners where the peptide chain changes direction abruptly.
- Such corners involve four amino acid residues often including proline and glycine.

- Several types of turns are known; of greatest importance are
 - Type I (42% of 421 examined turns)
 - Type II (15%)
 - Type III (18%)

Type I β -turns

- All amino acid residues are allowed, with the exception of proline in position 3.

Type II β -turns

- In type II, glycine is required in position 3.

Type III β -turns

- In type III, all amino acids are allowed.

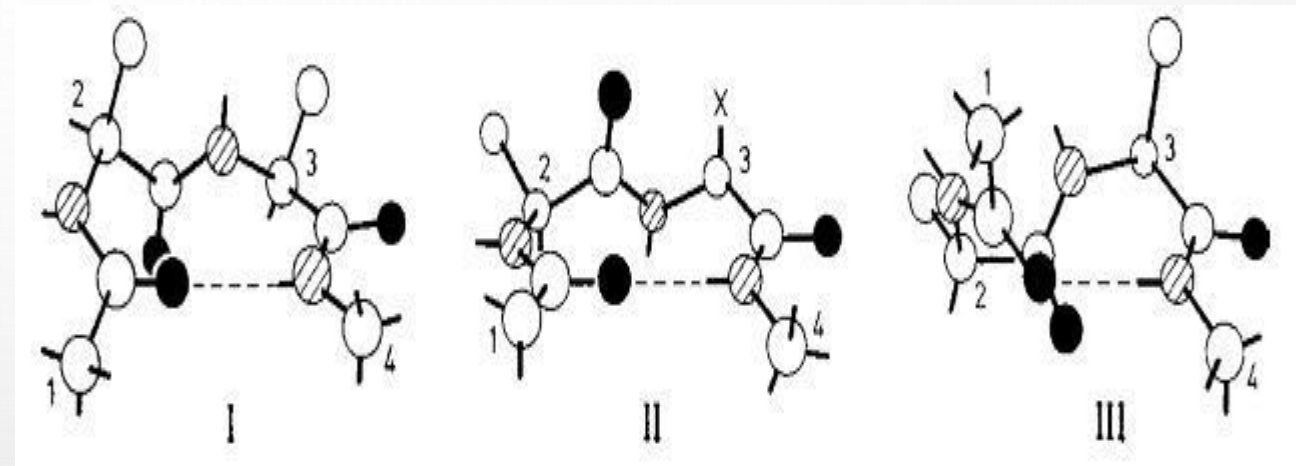
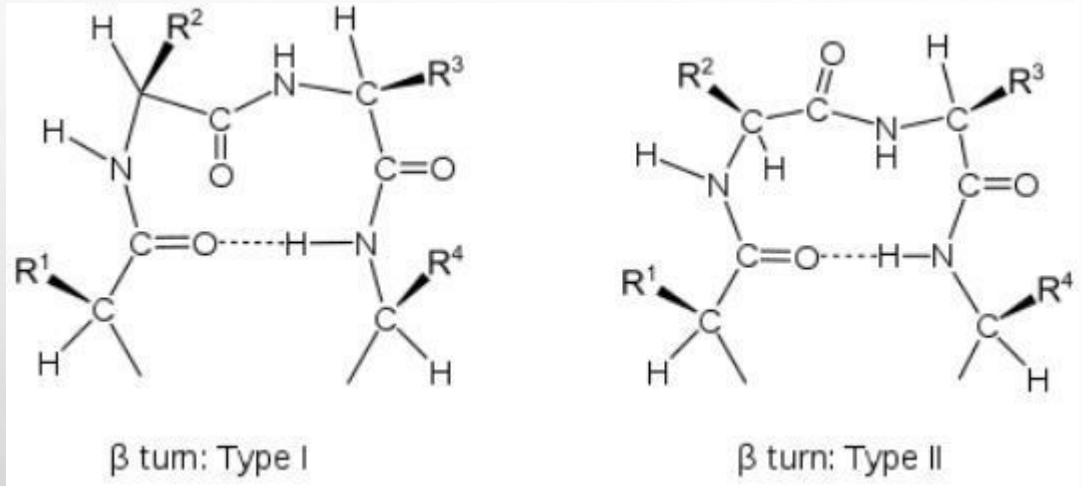


Fig. Type I and Type II β Turn

Fig. Turns of the peptide chains (β -turns), types I–III.
 :○ = carbon, ⊗ = nitrogen, ● = oxygen
 The α -C atoms of the amino acid residues are marked 1–4. X = no side chain allowed

Super-secondary structures

- Analysis of known protein structures has demonstrated that regular elements can exist in combined forms.
- Examples are the coiled-coil α -helix, chain segments with antiparallel β -structures (β -meander structure) and combinations of α -helix and β -structure (e.g., $\beta\alpha\beta\alpha\beta$)

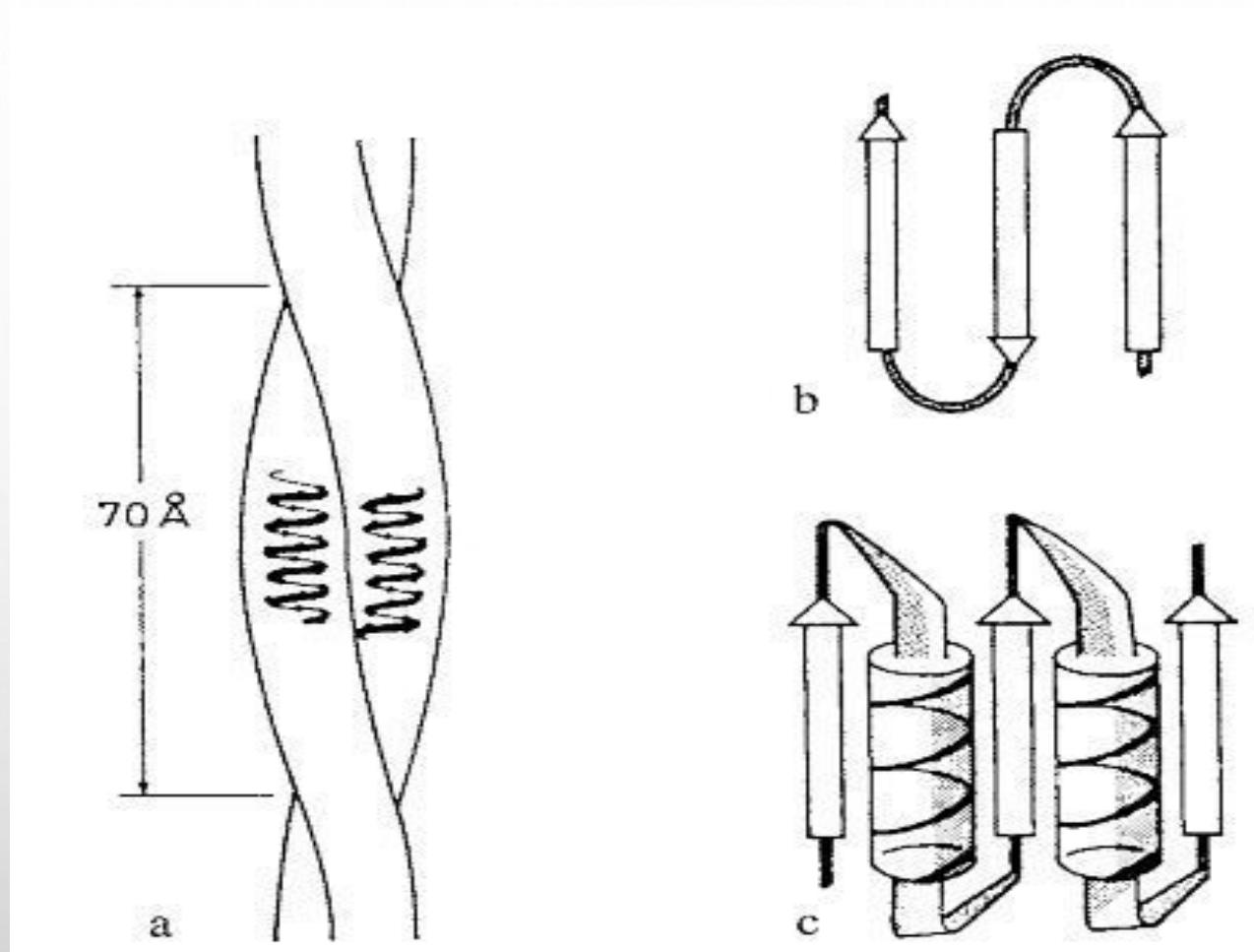


Fig. Superhelix secondary structure (according to Schulz and Schirmer, 1979). a coiled-coil α -helix, b β -meander, c β α β α β -structure

Topic no 19

Tertiary structure of proteins

- The overall three-dimensional shape of an entire protein molecule is the **tertiary structure**.
- The protein molecule will bend and twist in such a way as to achieve maximum stability or low

• The forces that give rise to the tertiary structure of a protein are

- Ionic bonding
- Hydrogen bonding
- Hydrophobic interaction
- Disulfide bonds

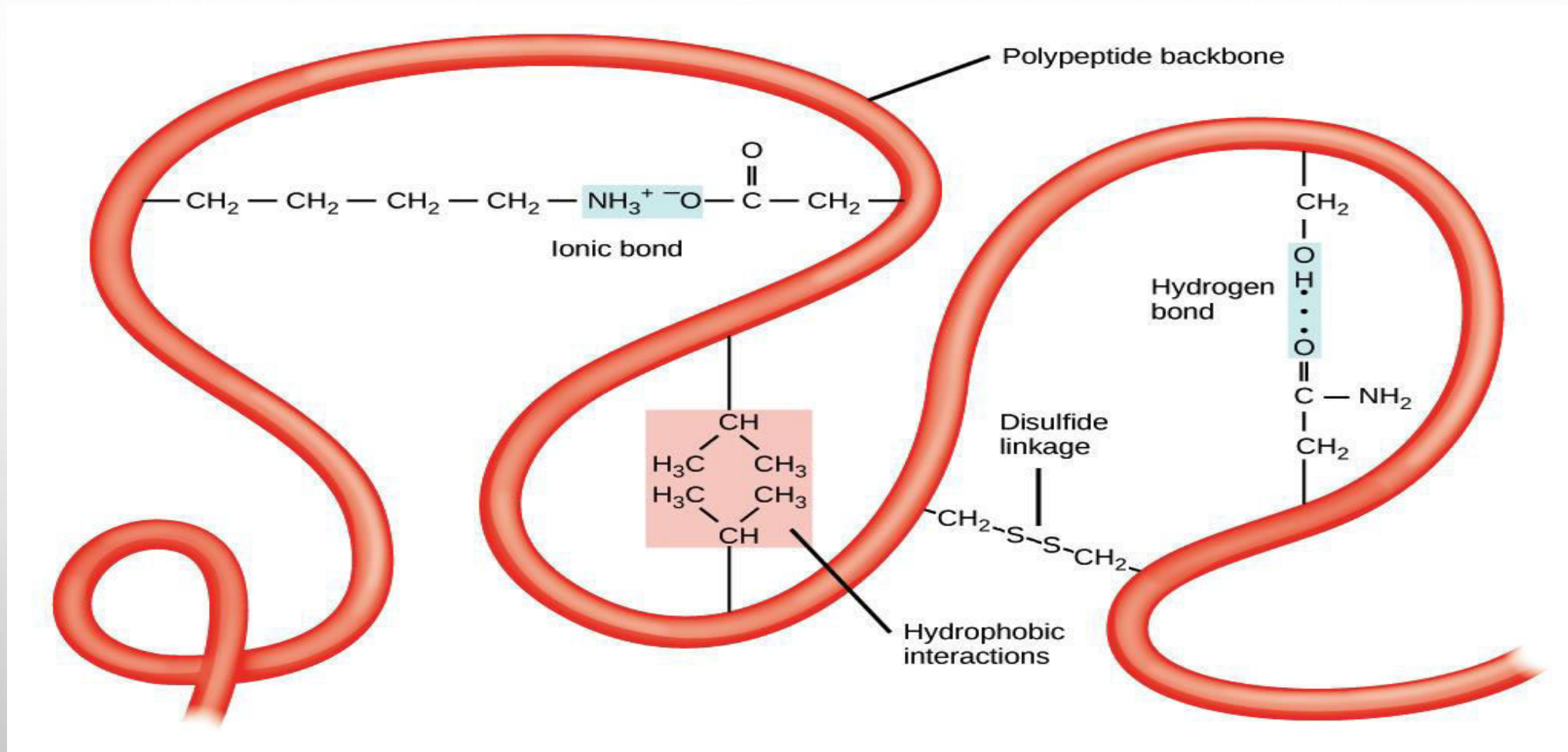


Fig: Forces that give rise to the tertiary structure of a protein

• **Ionic bonds**

- Some amino acids contain side chains that carry positive or negative charges.
- If an amino acid with a positive charge comes close enough to an amino acid that carries a negative charge, they can form a bond that helps to stabilize the protein molecule.

Hydrogen bonds

- These bonds are formed between water molecules in the solution and the hydrophilic amino acid side chains on the surface of the molecule.
- Hydrogen bonds also occur between polar side chains and help in stabilizing the tertiary structure.
- Hydrogen bonds can bring together two parts of a chain that are some distance away in terms of sequence. Bonds also occur between polar side chains and help in stabilizing the tertiary structure.

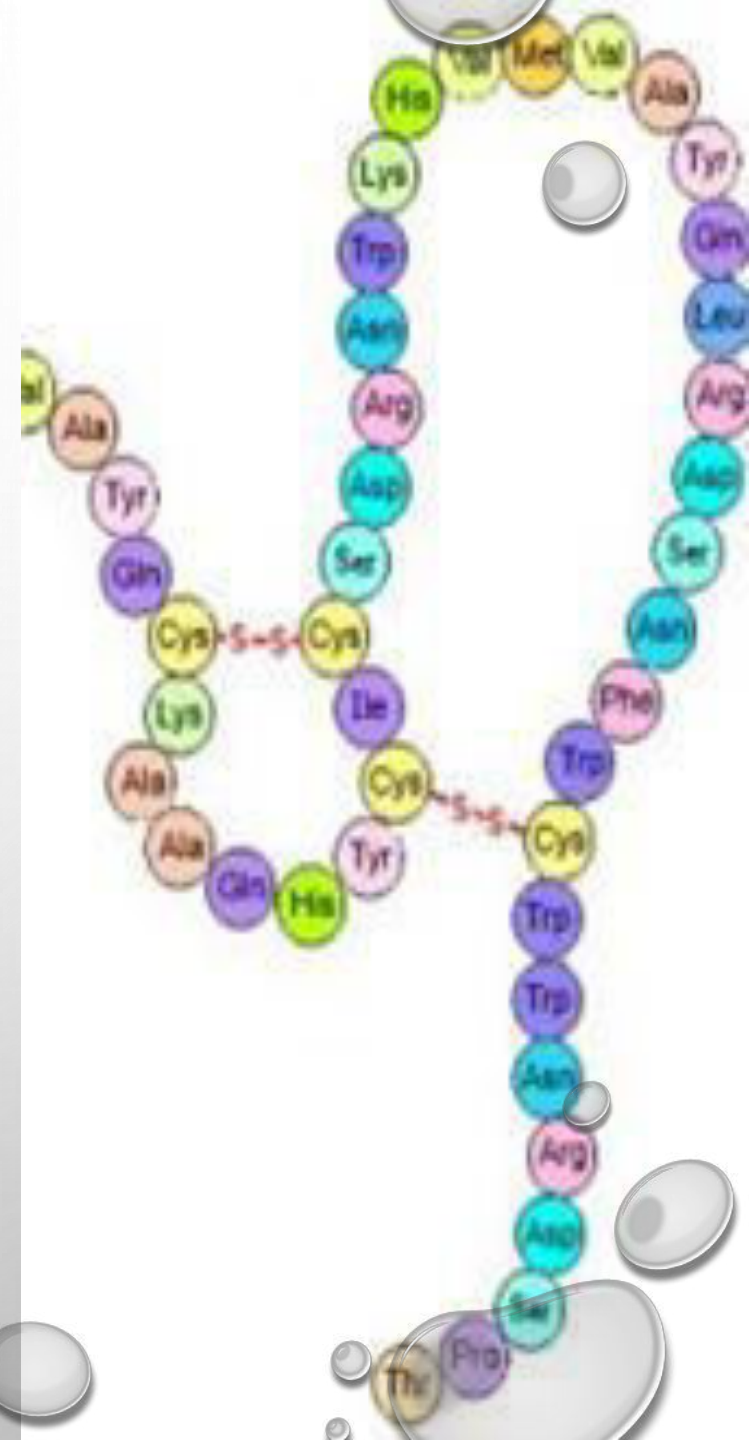
Hydrophobic interactions

- Amino acids with nonpolar, hydrophobic R groups cluster together on the inside of the protein, leaving hydrophilic amino acids on the outside to interact with surrounding water molecules.
- Under physiologic conditions, the hydrophobic side-chains of neutral, non-polar amino acids such as phenylalanine or isoleucine tend to be buried on the interior of the protein molecule thereby shielding them from the aqueous medium.

- The alkyl groups of **alanine**, **valine**, **leucine** and **isoleucine** often form hydrophobic interactions between one-another, while aromatic groups such as those of **phenylalanine** and **tryosine** often stack together.
- Acidic or basic amino acid side-chains will generally be exposed on the surface of the protein as they are hydrophilic.

Disulfide bonds

- Covalent linkages between the sulfur-containing side chains of cysteines, are much stronger than the other types of bonds that contribute to tertiary structure.
- The formation of disulfide bridges is an important aspect of the stabilization of protein tertiary structure, allowing different parts of the protein chain to be held together covalently.



Topic no 20

Types of Tertiary Structures

1. Globular proteins

- Most proteins fall into this category.
- Globular proteins form a compact ball shape, where hydrophobic amino acids are found in the center of the structure and hydrophilic amino acids are found on the surface, forming a molecule that is soluble in water.



- **Role of globular proteins**

- Globular proteins can act as:

- Enzymes

- Transporters of other molecules through membranes

- Regulatory roles are also performed by globular proteins

Examples



- Alpha, beta and gamma (IgA, IgD, IgE, IgG and IgM) globulin.
- Nearly all enzymes with major metabolic functions are globular in shape, as well as many signal transduction proteins.
- Albumins are also globular proteins, although, unlike all of the other globular proteins, they are completely soluble in water. They are not soluble in oil

2. Fibrous proteins

- Entire peptide chain is packed or arranged within a single regular structure for a variety of fibrous proteins.
- Stabilization of these structures is achieved by intermolecular bonding (electrostatic interaction and disulfide linkages, but primarily hydrogen bonds and hydrophobic interactions).

Examples

- wool keratin (α -helix), silk fibroin (β -sheet structure) and collagen (a triple helix)

Topic no 21

Quaternary Structure

- Quaternary structures are reserved for proteins composed of two or more polypeptide chains.
- The quaternary structure of a protein is the overall structure that is the result of the addition of these polypeptide subunits.
- The individual polypeptides are called protein subunits, which means different polypeptides folded separately. Subunits may be identical polypeptides or they may be different.

- When proteins consist of more than one polypeptide chain, they are said to have quaternary structure and are also known as multimeric proteins, meaning proteins consisting of many parts.

- Hemoglobin is an example of a quaternary structure that is composed of two alpha subunits and two beta subunits.

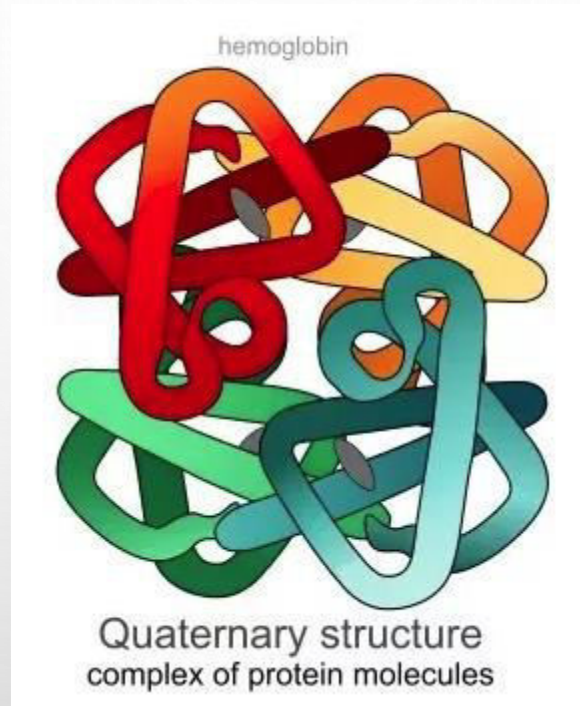
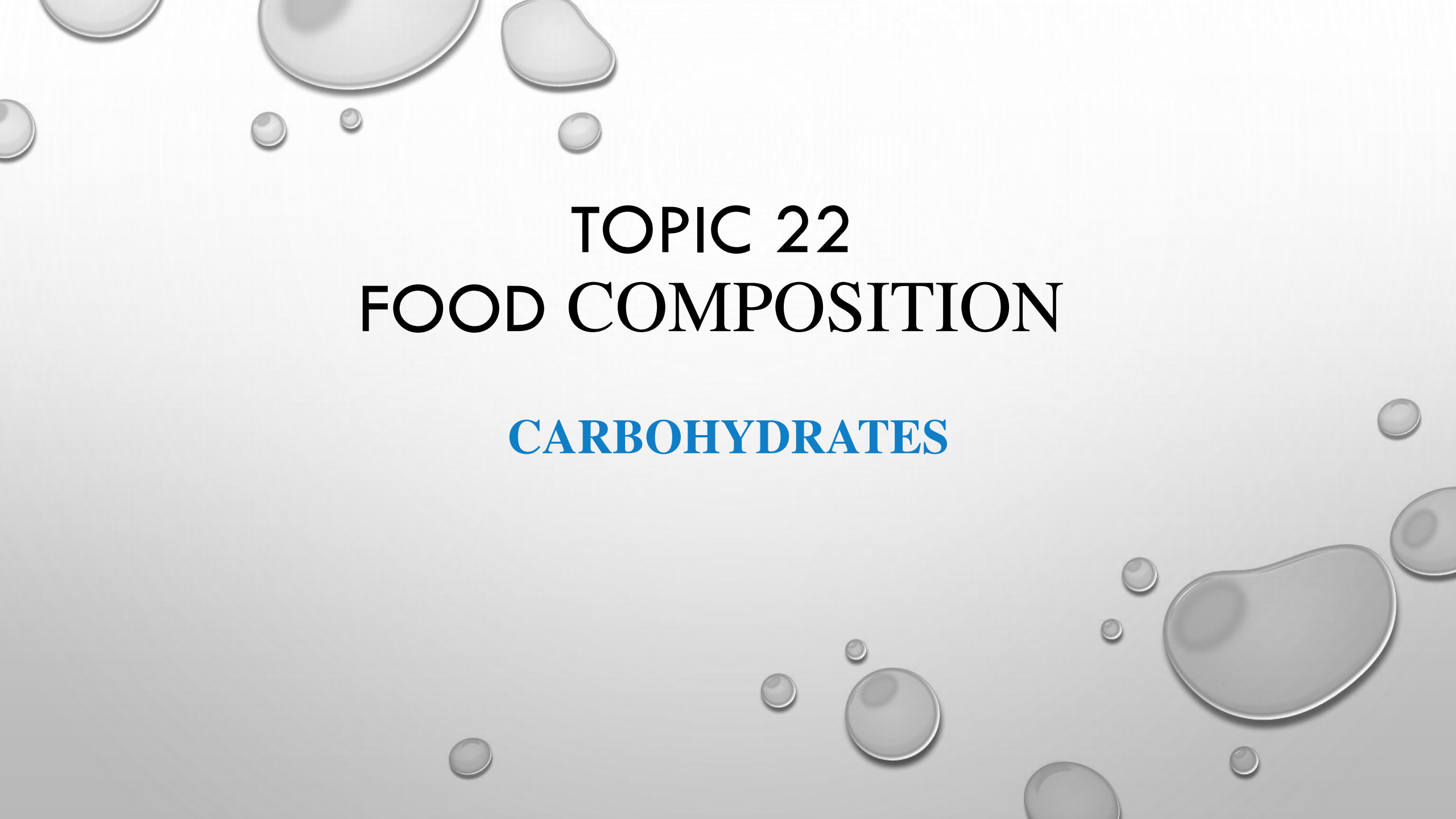


Fig. Quaternary structure of Proteins

The background of the slide is a light gray gradient with several realistic water droplets of various sizes scattered across it. The droplets have highlights and shadows, giving them a three-dimensional appearance.

TOPIC 22

FOOD COMPOSITION

CARBOHYDRATES

- Carbohydrates are the most widely distributed and abundant organic compounds on earth.
- They have a central role in the metabolism of animals and plants.
- Carbohydrate biosynthesis in plants starting from carbon dioxide and water with the help of light energy, i. E., Photosynthesis, is the basis for the existence of all other organisms which depend on the intake of organic substances with food.

- Carbohydrates represent one of the basic nutrients and are quantitatively the most important source of energy.
- Their nutritional energy value amounts to 17 kJ/g or kcal/g.
- Even the non-digestible carbohydrates, acting as bulk material, are of importance
- In a balanced daily nutrition.
- Other important functions in food are fulfilled by carbohydrates.

- They act for instance as sweetening, gel or paste-forming and thickening agents, stabilizers and are also precursors for aroma and coloring substances, especially in thermal processing.
- Carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield such compounds on hydrolysis
- Many of the carbohydrates have the empirical formula $(\text{CH}_2\text{O})_n$.
- Some carbohydrates also contain phosphorus, nitrogen or sulfur.




Some of the important functions are

1. Carbohydrates along with being the chief energy source, in many animals, they are instant source of energy. Glucose is broken down by glycolysis/ kreb's cycle to yield ATP.

2. Serve as energy stores, fuels, and metabolic intermediates. It is stored as glycogen in animals and starch in plants.

3. Stored carbohydrates acts as energy source instead of proteins.



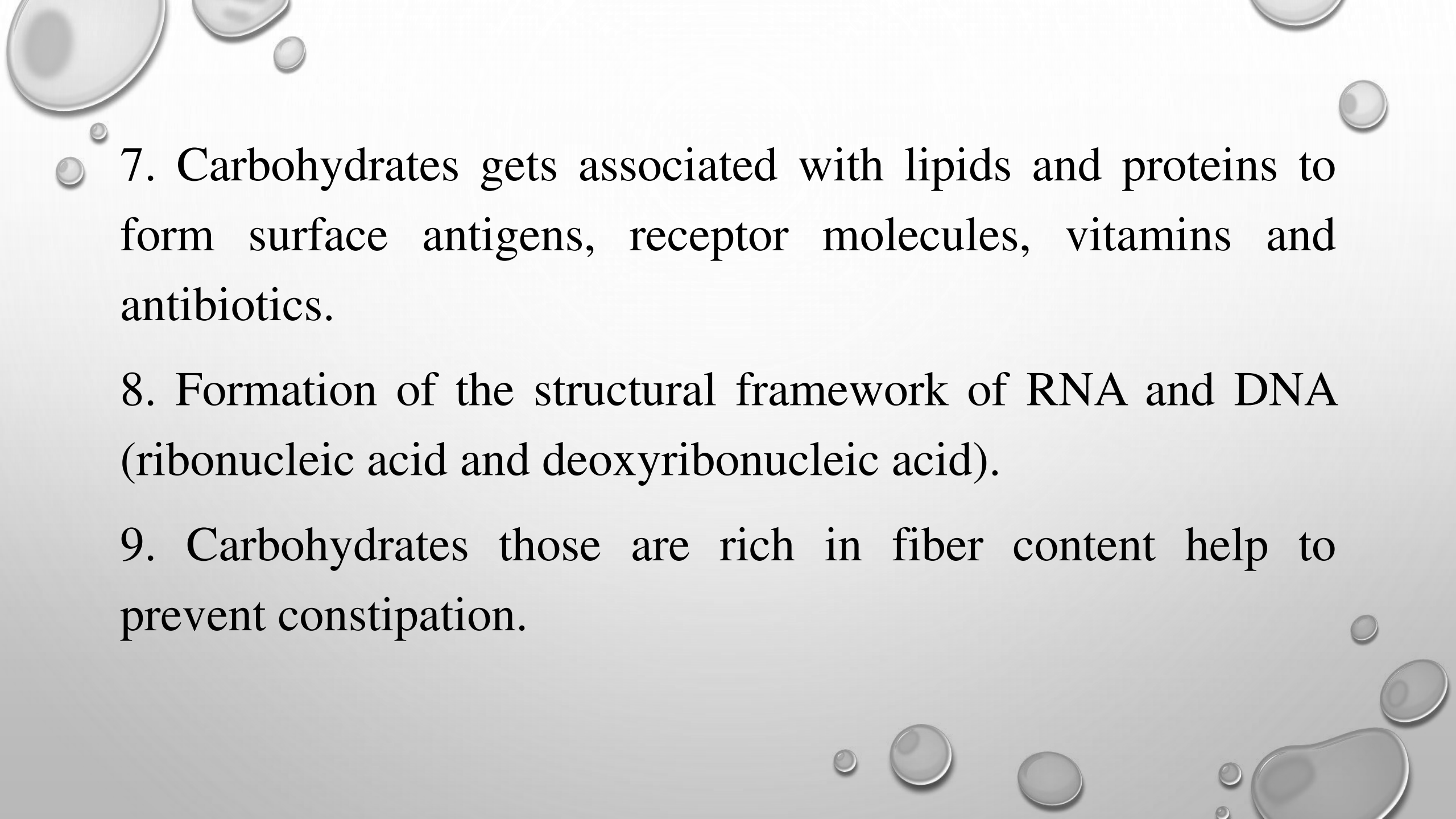


4. They form structural and protective components, like in cell wall of plants and microorganisms. Structural elements in the cell walls of bacteria (peptidoglycan or murein), plants (cellulose) and animals (chitin).

5. Carbohydrates are intermediates in biosynthesis of fats and proteins.

6. Carbohydrates aid in regulation of nerve tissue and is the energy source for brain.



- 
7. Carbohydrates gets associated with lipids and proteins to form surface antigens, receptor molecules, vitamins and antibiotics.
 8. Formation of the structural framework of RNA and DNA (ribonucleic acid and deoxyribonucleic acid).
 9. Carbohydrates those are rich in fiber content help to prevent constipation.

TOPIC 23

CLASSIFICATION OF CARBOHYDRATES

Carbohydrates are classified into four major groups:

1. Monosaccharides
2. Disaccharides
3. Oligosaccharides
4. Polysaccharides

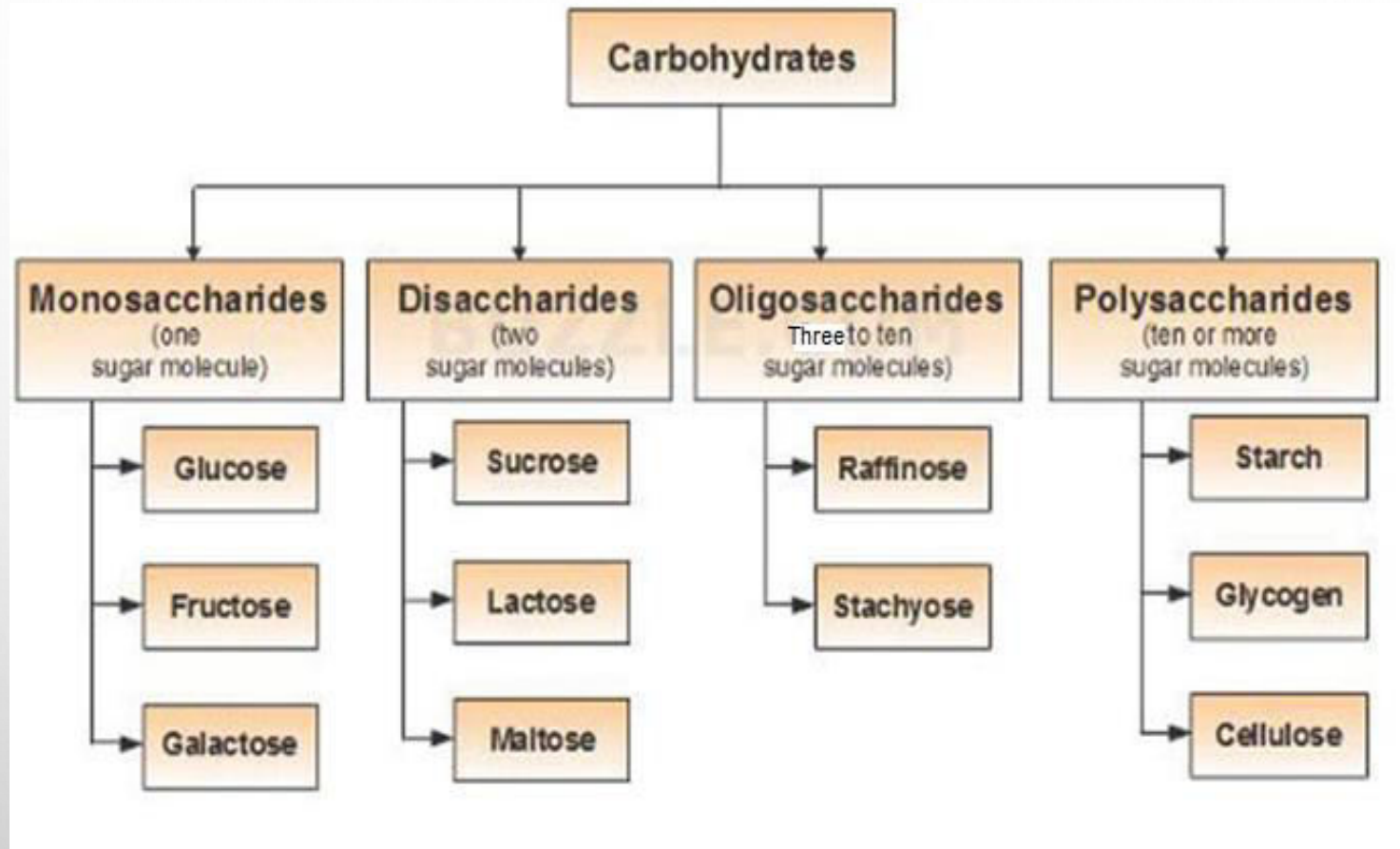


Fig. Classification of Carbohydrates

TOPIC 24

Monosaccharides

- Monosaccharides are simplest group of carbohydrates and often called simple sugars since cannot be further hydrolyzed.
- They are colorless, crystalline solid which are soluble in water and insoluble in non-polar solvent.
- These are compound which possess a free aldehyde or ketone group. The general formula is $C_n(H_2O)_n$ or $C_nH_{2n}O_n$.

Structure and nomenclature

- They are classified according to the number of carbon atoms they contain and also on the basis of the functional group present.
- The monosaccharides thus with 3,4,5,6,7... carbons are called trioses, tetroses, pentoses, hexoses, heptoses etc., And also as aldoses or ketoses depending upon whether they contain aldehyde or ketone group.

• **Linear-chain monosaccharides**

Simple monosaccharides have a linear and unbranched carbon skeleton with one carbonyl ($\text{C}=\text{O}$) functional group, and one hydroxyl (OH) group on each of the remaining carbon atoms.

- If the carbonyl is at position 1, the molecule begins with a formyl group $\text{H}(\text{C}=\text{O})-$ and is technically an aldehyde. In that case, the compound is termed an aldose. Otherwise, the molecule has a keto group, a carbonyl $-(\text{C}=\text{O})-$ between two carbons; then it is formally a ketone, and is termed a ketose. Ketoses of biological interest usually have the carbonyl at position 2.

- Depending upon the total number of carbon atoms in monosaccharides and aldehyde and ketone functional groups present they are classified using terms shown in the below table.

Table: Classification of Monosaccharides

Carbon Atoms	General terms	Aldehydes	Ketones
3	Triose	Aldotriose	Keto triose
4	Tetrose	Aldotetrose	Ketotetrose
5	Pentose	Aldopentose	Ketopentose
6	Hexose	Aldohexose	Ketohexose
7	Heptose	Aldoheptose	Ketoheptose

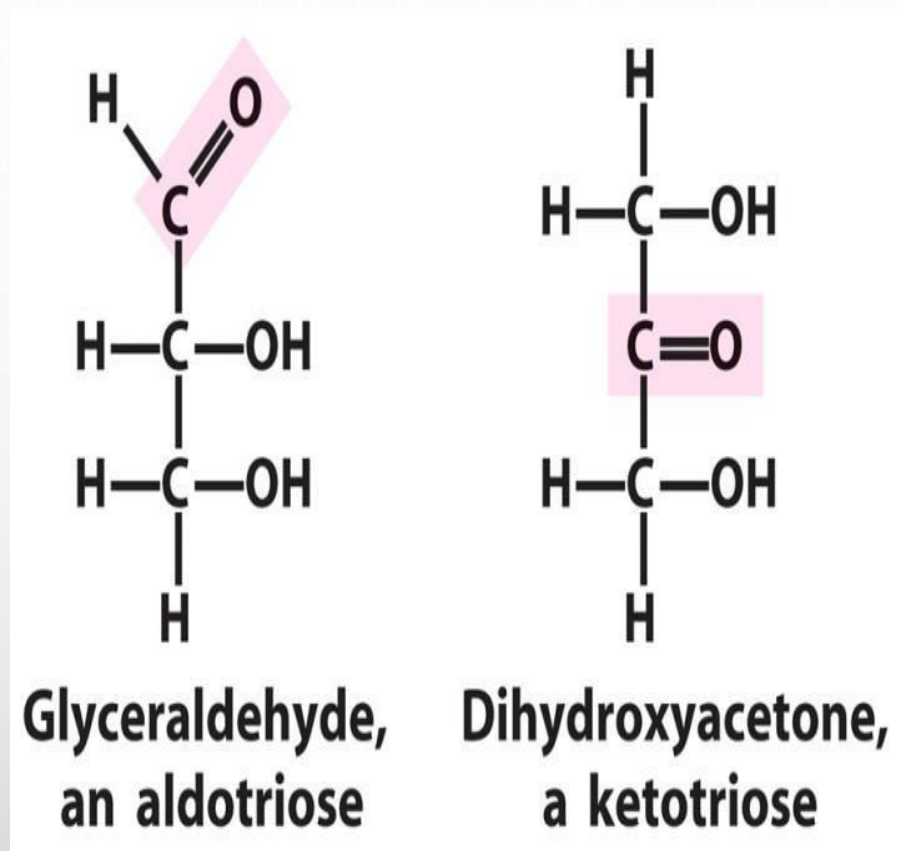


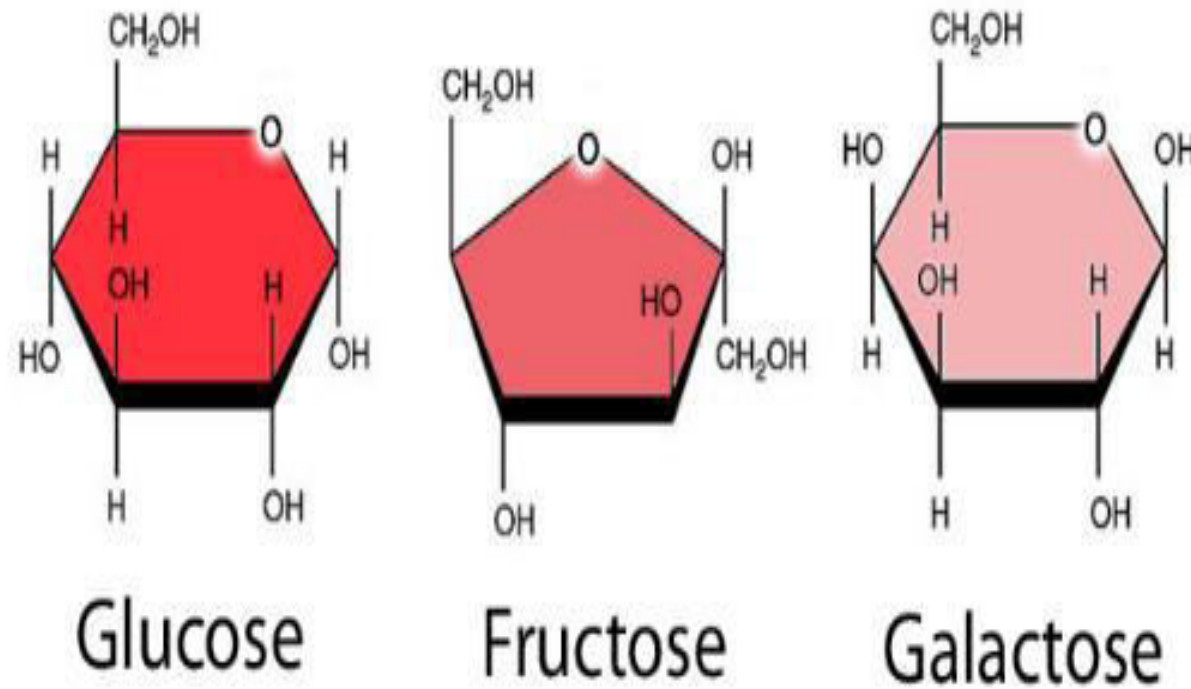
Fig. Structure of Glyceraldehyde and Dihydroxyacetone

TOPIC 25

Cyclisation of monosaccharides

- A monosaccharide often switches from the acyclic (open-chain) form to a cyclic form, through a nucleophilic addition reaction between the carbonyl group and one of the hydroxyls of the same molecule.
- The reaction creates a ring of carbon atoms closed by one bridging oxygen atom.
- The resulting molecule has an hemiacetal or hemiketal group, depending on whether the linear form was an aldose or a ketose. The reaction is easily reversed, yielding the original open-chain form.

- In these cyclic forms, the ring usually has 5 or 6 atoms. These forms are called furanoses and pyranoses, respectively.
- For example, the aldohexose glucose may form a hemiacetal linkage between the hydroxyl on carbon 1 and the oxygen on carbon 4, yielding a molecule with a 5-membered ring, called glucofuranose. The same reaction can take place between carbons 1 and 5 to form a molecule with a 6-membered ring, called glucopyranose.



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Fig. Cyclic Structures of some Monosaccharides

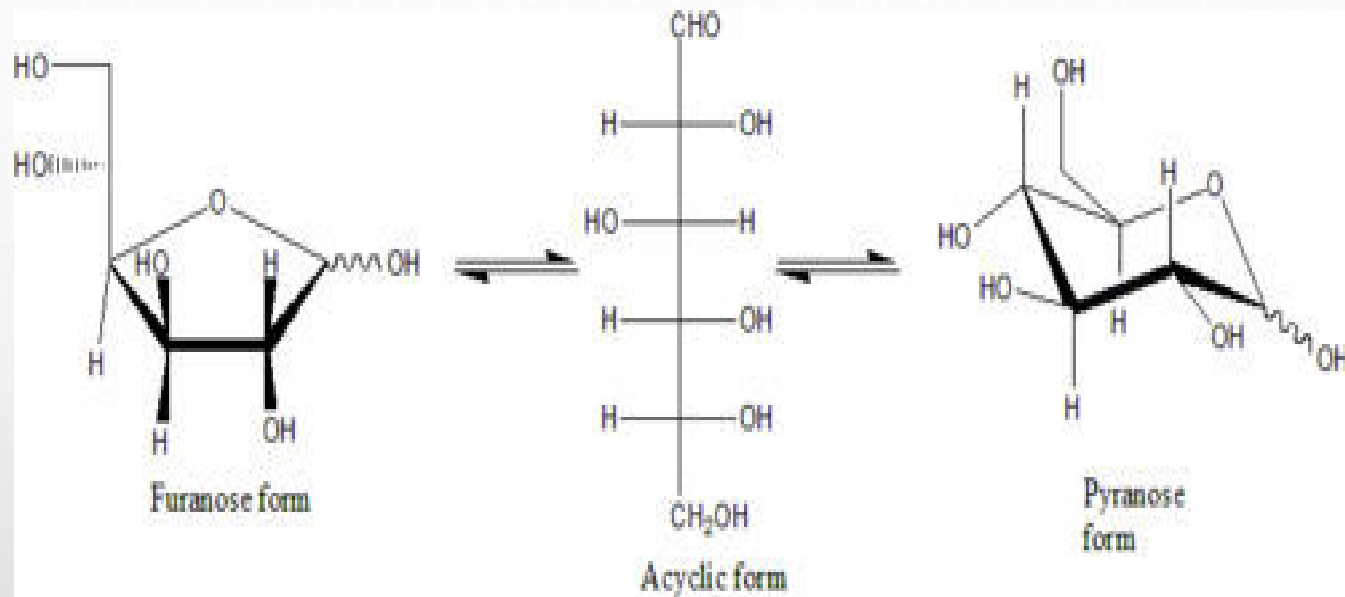
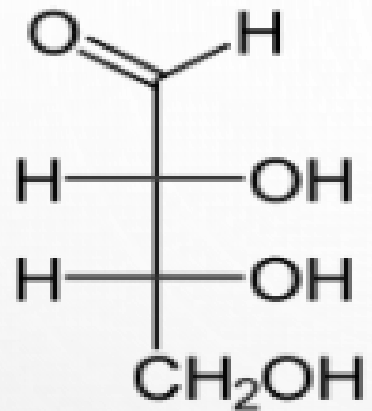


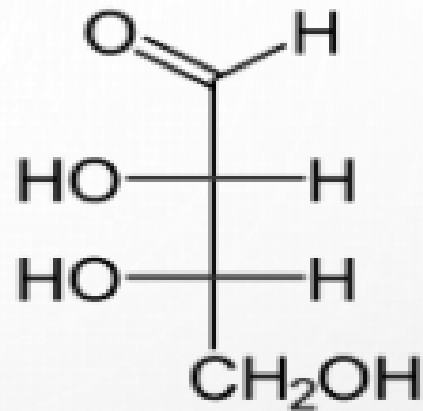
Fig. Furanose and Pyranose form of Glucose

D- and L- forms

Monosaccharides can appear in either **D- (dextro)** or **L- (levo)** form, which are the mirror images of each other. Most naturally occurring monosaccharides are in the d-form and most synthetically produced are in the l-form. D- and L-forms have different properties.



D-Erythrose



L-Erythrose

Fig: D- and L-erythrose with a mirror arrangement of atoms

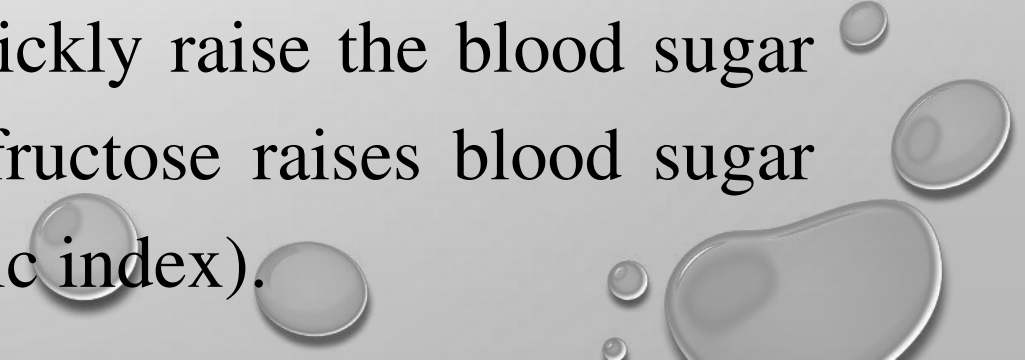
TOPIC 26

Functions of monosaccharides

- Monosaccharides are an energy source; most of them provide about 4 calories (kilocalories) per gram, just like other carbohydrates.
- Glucose is the main fuel for the body cells.
- Fructose participates in metabolism.
- Galactose is found in erythrocytes of individuals with b-type of blood.
- Ribose is part of deoxyribonucleic acid (dna) in the chromosomes.




- **Absorption of monosaccharides and their effect on blood sugar levels**

- Monosaccharides, are absorbed in the small intestine.
 - They can be absorbed without previously being broken down by the intestinal enzymes.
 - Glucose and galactose are absorbed easily, completely and faster than other carbohydrates, while fructose can be absorbed slowly and incompletely.
 - After ingestion, glucose and galactose quickly raise the blood sugar (they have high glycemic index), while fructose raises blood sugar only mildly and slowly (it has low glycemic index).
- 



Common naturally occurring monosaccharides

- Glucose or dextrose
 - Fructose
 - Galactose
 - Mannose
 - Ribose and deoxyribose
- 

Examples of foods that contain a lot of free monosaccharides

- Fruits and fruit juices (glucose, fructose)
- Honey (glucose, fructose)
- Candies (glucose)
- Syrups: liquid glucose; corn syrup and invert sugar (glucose and fructose); fructose syrup, high fructose corn syrup (HFCS), agave nectar and blackstrap molasses (high in fructose)
- Sweet wines (glucose, fructose)
- Foods with added simple sugars: soft drinks, energy drinks, chocolate, sweetened dairy products, desserts (mainly glucose)



• **Added sugars**

- Sugars added to commercial foods are usually simple sugars: glucose (often named dextrose), fructose, high fructose corn syrup and invert sugar (a mixture of glucose and fructose).



TOPIC 27

DISACCHARIDES

- A disaccharide (also called a double sugar) is the sugar formed when two monosaccharides (simple sugars) are joined by glycosidic linkage.
- Disaccharides are soluble in water. The general formula of disaccharides is $C_n(H_2O)_{n-1}$.

- Three common examples are sucrose, lactose, and maltose.
- They have twelve carbon atoms, with the general formula $C_{12}H_{22}O_{11}$.
- The joining of simple sugars into a double sugar happens by a condensation reaction, which involves the elimination of a water molecule from the functional groups only.
- Breaking down a disaccharide consumes a water molecule. These reactions are vital in metabolism. Each disaccharide is broken down with the help of a corresponding disaccharidase (sucrase, lactase, and maltase).

Classification

There are two functionally different classes of disaccharides:

- 1. Reducing disaccharides** in which one monosaccharide, the reducing sugar of the pair, still has a free hemiacetal unit that can perform as a reducing aldehyde group

Examples

- Cellobiose
- Maltose

• **2. Non-reducing disaccharides**

The component monosaccharides bond through an acetal linkage between their anomeric centers. This results in neither monosaccharide being left with a hemiacetal unit that is free to act as a reducing agent.

Examples

- Sucrose
- Trehalose

Formation

- The formation of a disaccharide molecule from two monosaccharide molecules proceeds by displacing a hydroxyl radical from one molecule and a hydrogen nucleus (a proton) from the other, so that the now vacant bonds on the monosaccharides join the two monomers together.
- The vacant bonds on the hydroxyl radical and the proton unite in their turn, forming a molecule of water, that then goes free. Because of the removal of the water molecule from the product, the term of convenience for such a process is "dehydration reaction" (also "condensation reaction" or "dehydration synthesis").

- For example, milk sugar (lactose) is a disaccharide made by condensation of one molecule of each of the monosaccharides glucose and galactose.

TOPIC 28

COMMON DISACCHARIDES

Disaccharide	Unit 1	Unit 2	Bond
Sucrose (table sugar)	Glucose	Fructose	$\alpha(1\rightarrow2)\beta$
Lactulose	Galactose	Fructose	$\beta(1\rightarrow4)$
Lactose (<i>milk sugar</i>)	Galactose	Glucose	$\beta(1\rightarrow4)$
Maltose (<i>malt sugar</i>)	Glucose	Glucose	$\alpha(1\rightarrow4)$
Trehalose	Glucose	Glucose	$\alpha(1\rightarrow1)\alpha$
Cellobiose	Glucose	Glucose	$\beta(1\rightarrow4)$
Chitobiose	Glucosamine	Glucosamine	$\beta(1\rightarrow4)$

Sucrose

- This is the most important disaccharide. It is popularly known as *table sugar*. Sucrose is found in all photosynthetic plants. It is commercially obtained from sugarcane and sugar beets via an industrial process.
- The molecular formula of sucrose is $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.
- If sucrose goes through acid catalysed hydrolysis it will give one mole of D-glucose and one mole of D-fructose.
- Sucrose is a non-reducing sugar

- The chemical structure of sucrose comprises of α form of glucose and β form of fructose. The glycosidic linkage is α linkage because the molecule formation is in α orientation.

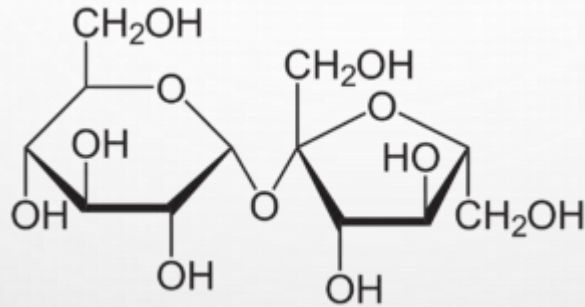


Fig. Structure of sucrose

- Sucrose is a non-reducing sugar.

Lactose

- Lactose is the primary ingredient found in the milk of all mammals. Unlike the majority of saccharides, lactose is not sweet to taste. Lactose consists of one galactose carbohydrate and one glucose carbohydrate. These are bound together by a 1-4 glycosidic bond in a beta orientation.

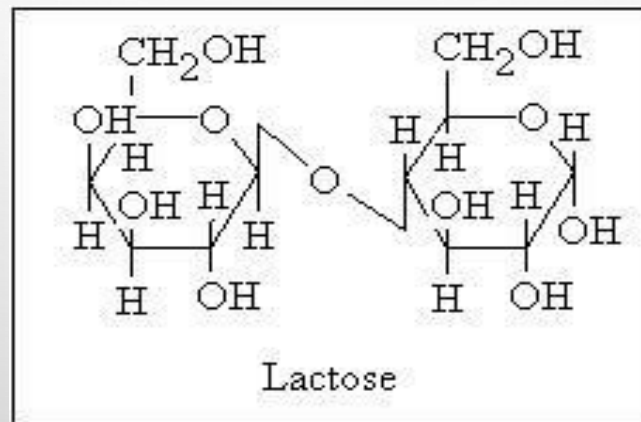


Fig. Structure of lactose

- Lactose is a reducing sugar since it has one free hemiacetal hydroxide.

Maltose

- It has two monosaccharide glucose molecules bound together, the link is between the first carbon atom of glucose and the fourth carbon of another glucose molecule.

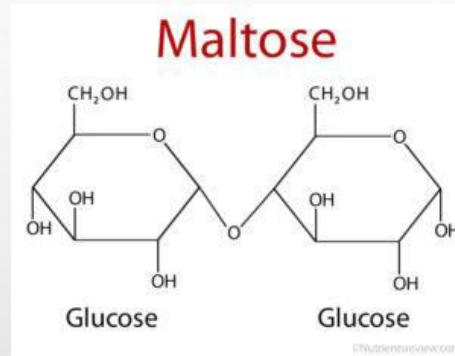


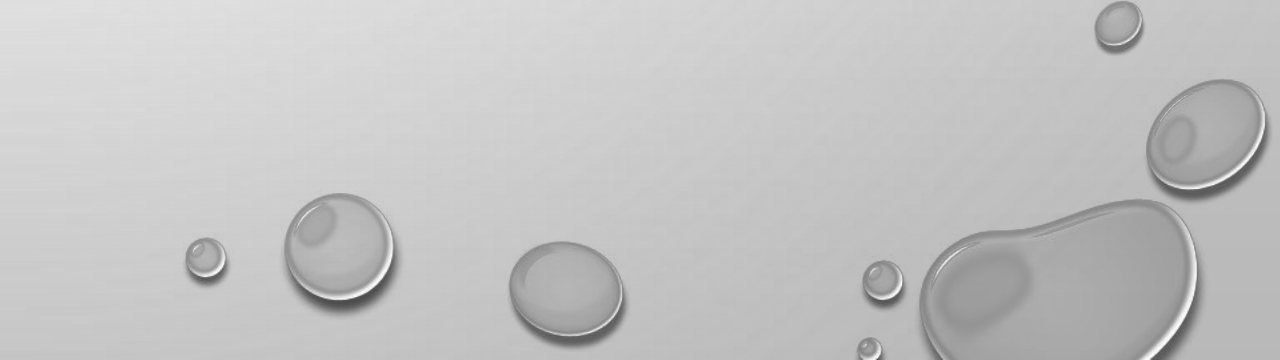
Fig. Structure of maltose

- On acid catalysed hydrolysis one mole of maltose gives two moles of D-glucose.
- Maltose is a reducing sugar.



TOPIC 29

OLIGOSACCHARIDES

- Compound sugars that yield 3 to 10 molecules of the same or different monosaccharides on hydrolysis
 - Found naturally, at least in small amounts, in many plants.
- 

Examples

1. Fructo-oligosaccharides (FOS)

- Found in many vegetables
- Consist of short chains of fructose molecules
- Soluble dietary fibre

2. Galactooligosaccharides (GOS)

- Occur naturally
- Short chains of galactose molecules
- Cannot be digested in the human small intestine and instead pass through to the large intestine
- Promote the growth of *Bifidobacteria*, beneficial to gut health

3. Mannan oligosaccharides (MOS)

- Widely used in animal feed
- Normally obtained from the yeast cell walls of *Saccharomyces cerevisiae*
- Differ from other oligosaccharides in that they are not fermentable

4. Raffinose

- A trisaccharide composed of galactose, glucose, and fructose
- Found in beans, cabbage, brussels sprouts, broccoli, asparagus, other vegetables
- Raffinose can be hydrolyzed to d-galactose and sucrose by the enzyme α -galactosidase (α -gal)

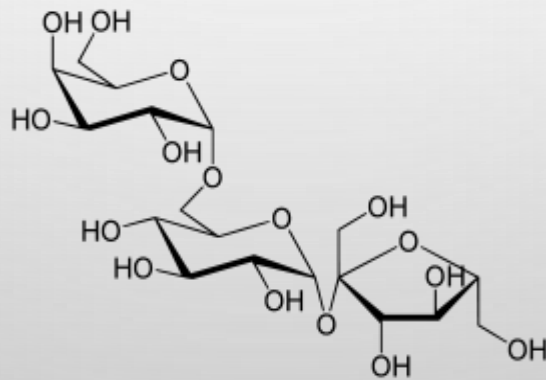


Fig raffinose

Sources

- Oligosaccharides are a component of fibre from plant tissue
- FOS are present in jerusalem artichoke, burdock, chicory, leeks, onions, and asparagus
- GOS is naturally found in soybeans and can be synthesized from lactose
- FOS and GOS are also sold as nutritional supplements.

Topic 30

Polysaccharides

- Also called as “glycans”
- **Polysaccharides** are polymeric carbohydrate molecules composed of long chains of monosaccharide units bound together by glycosidic linkages.
- Yield more than 10 molecules of monosaccharides on hydrolysis.



Differ from each other in

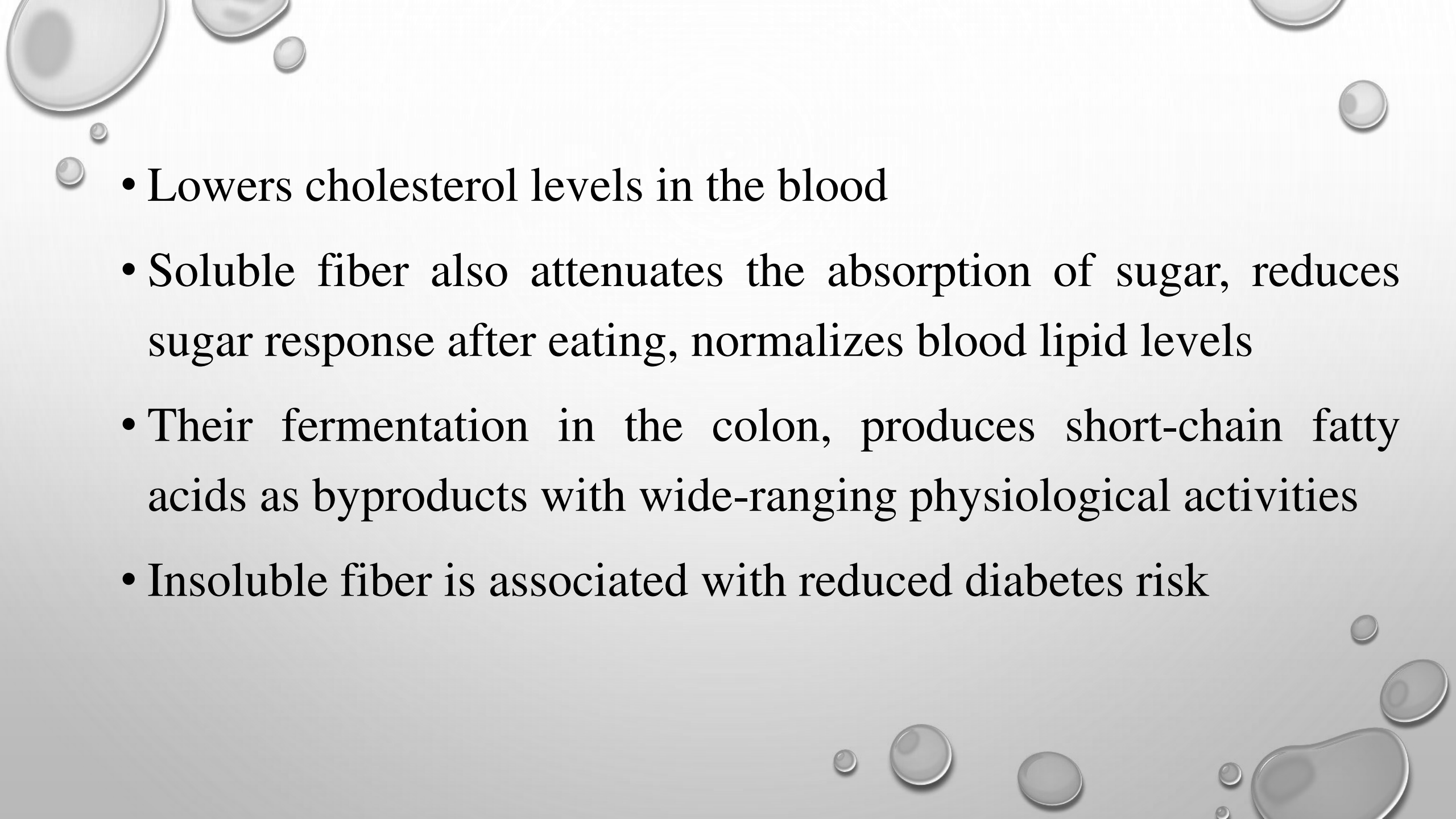
- The identity of their recurring monosaccharide units
- In the length of their chains
- In the types of bond linking units and in the degree of branching.

They range in structure from linear to highly branched



Function

- Primarily concerned with two important functions
 - Structural functions and the storage of energy
- Nutrition polysaccharides are common sources of energy
- Provide important dietary elements for humans called dietary fibres, these carbohydrates enhance digestion among other benefits

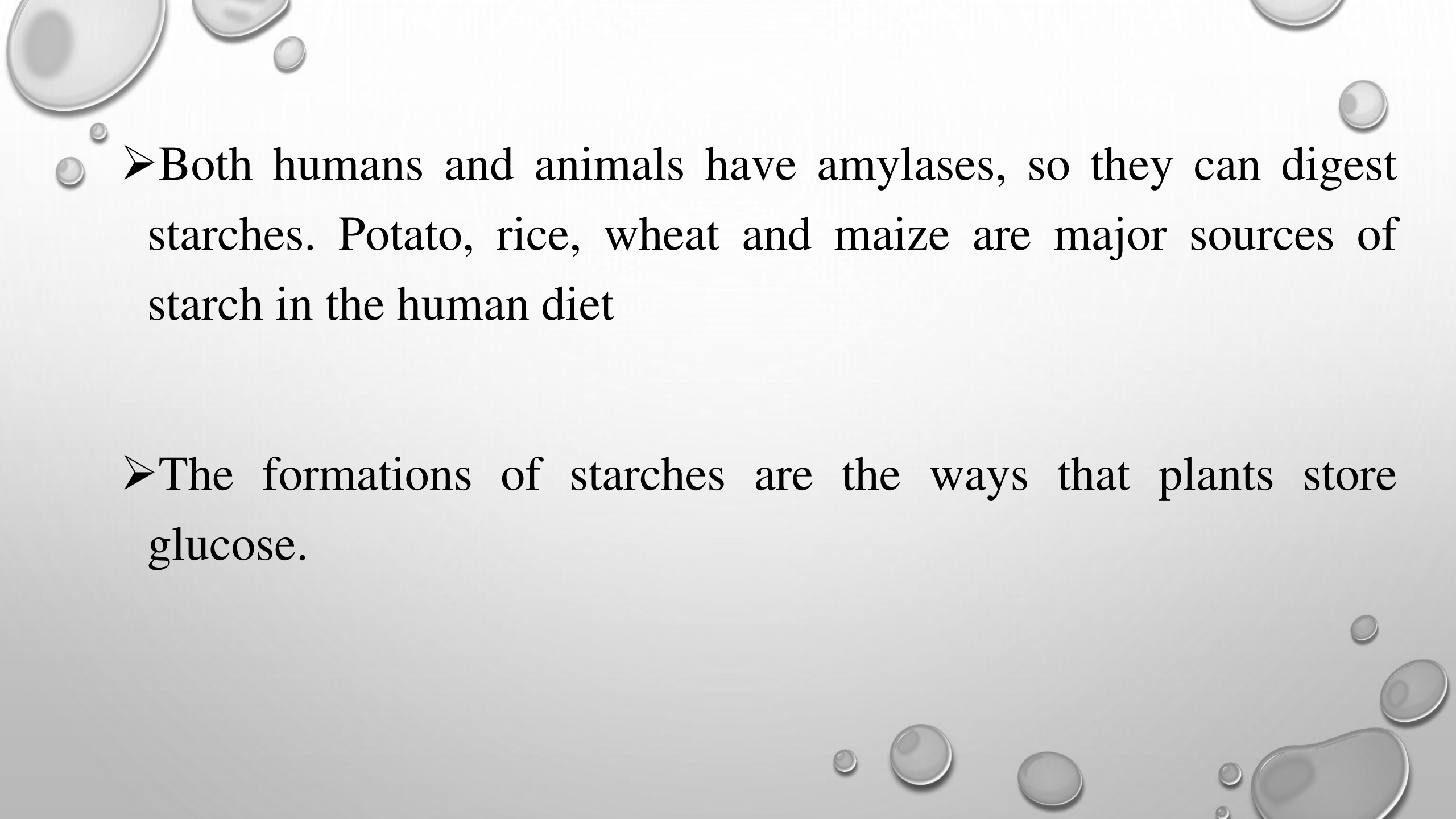
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- Lowers cholesterol levels in the blood
 - Soluble fiber also attenuates the absorption of sugar, reduces sugar response after eating, normalizes blood lipid levels
 - Their fermentation in the colon, produces short-chain fatty acids as byproducts with wide-ranging physiological activities
 - Insoluble fiber is associated with reduced diabetes risk

Topic 31

Storage polysaccharides

Starch

- A glucose polymer in which glucopyranose units are bonded by alpha-linkages.
- Made up of a mixture of amylose (15–20%) and amylopectin (80–85%)
- Amylose consists of a linear chain of several hundred glucose molecules and amylopectin is a branched molecule made of several thousand glucose units

- 
- Both humans and animals have amylases, so they can digest starches. Potato, rice, wheat and maize are major sources of starch in the human diet
 - The formations of starches are the ways that plants store glucose.

Glycogen

- Serves as the secondary long-term energy storage in animal and fungal cells
- Made primarily by the liver and the muscles, but can also be made by glycogenesis within the brain and stomach.
- Analogous to starch
- Glycogen is a polymer of $\alpha(1\rightarrow4)$ glycosidic bonds linked, with $\alpha(1\rightarrow6)$ -linked branches
- Found in the form of granules in the cytosol/cytoplasm in many cell types, and plays an important role in the glucose cycle

- Glycogen is composed of a branched chain of glucose residues.
 - It is stored in liver and muscles.
- It is an energy reserve for animals.
- It is the chief form of carbohydrate stored in animal body.
- It is insoluble in water. It turns brown-red when mixed with iodine.
- It also yields glucose on hydrolysis

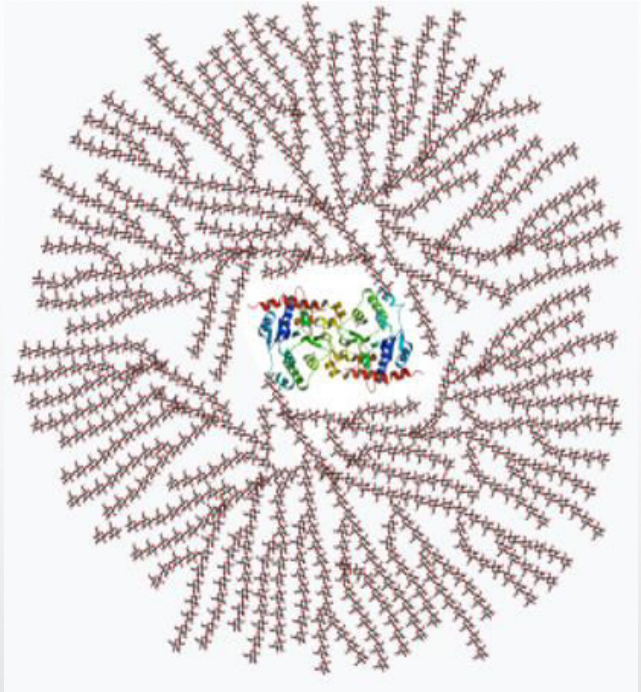


Fig. Structure of maltose

Topic 32

Structural polysaccharides

Arabinoxylans

- Found in both the primary and secondary cell walls of plants
- Copolymers of two sugars: arabinose and xylose

Have beneficial effects on human health.

Cellulose

- Structural components of plants are formed primarily from cellulose
- Wood is largely cellulose and lignin, while paper and cotton are nearly pure cellulose
- It is a polymer made with repeated glucose units bonded together by beta-linkages
- Insoluble in water
- Does not change color when mixed with iodine
- Most abundant carbohydrate in nature.

Chitin

- Chitin is one of many naturally occurring polymers
 - Forms a structural component of many animals, such as exoskeleton
 - It is bio-degradeable in the natural environment
 - Breakdown may be catalyzed by enzymes called chitinases
 - Chemically, chitin is closely related to chitosan (a more water-soluble derivative of chitin).

Pectins

- Pectins are a family of complex polysaccharides that contain 1,4-linked α -d-galactosyl uronic acid residues
- Present in most primary cell walls and in the non-woody parts of terrestrial plants

Classification of pectins

- Classified depending on the type of molecules produced as a result of hydrolysis
- **Homopolysaccharides/Homoglycan**
- When all the monosaccharides in a polysaccharide are of same type.
- **Example** starch, glycogen, cellulose, pectin.



- **Heteropolysaccharides/ Heteroglycan**

- When more than one type of monosaccharide is present, examples of heteropolysaccharides are hyaluronic acid, chondrotin.

