AGA 3201 Principles of Animal Nutrition

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About the course!

Duration: 15 weeks

- 3 Lecture hours per week
- 3 Laboratory hours per week

Assessment

- Continuous assessment (Tests, Assignments, Quizzes, Reports)

  40%

- Final Examination **60%**

- **Test 1 on 9th April, 2024**

Introduction

- Nutrition is the single major determinant of animal health, welfare, production and the economic viability of animal enterprises.
- Feed costs account for 50-70% of the costs of production in most animal production systems

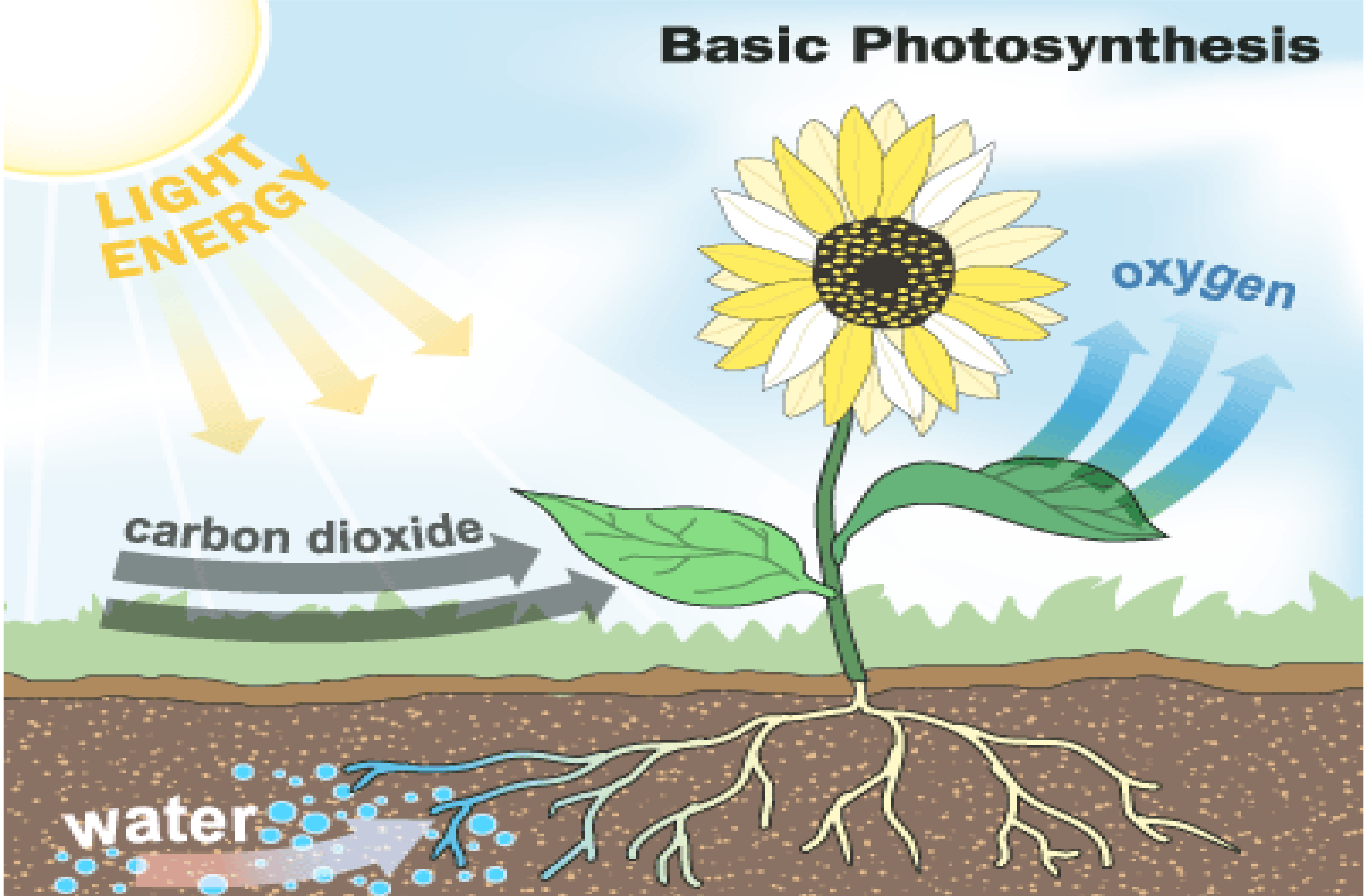
- Maximising output of animal products (pork, eggs, chicken meat) relative to the input of feed is therefore critical to the profitability of animal enterprises.
- Inefficient use of feed due to wastage or indigestibility can lead to economic losses in the animal enterprise

- All chemical processes in an animal body cells require the use of nutrients
- A nutrient is a compound or substance that is needed to support the maintenance, growth, development, lactation, reproduction, and health of the animals.

- Nutrients are required for maintenance first, and extra ones are for production (eggs, meat, and milk production)
- Tissues obtain these nutrients from ingested food or stored reserves (fat reserves or bones)

- Known nutrients required are;
  1) Carbohydrates
  2) Proteins
  3) Fats or lipids
  4) Vitamins
  5) Minerals
  6) Water
- Thy are needed in definite amounts varying with age, function, use etc.

Source of nutrients



- For wild animals, they eat a variety of foods to obtain a variety of these nutrients
- However, for farm animals they depend on the farmer to provide a balanced ration
- Hence, you should know what feed is good for them, and how this feed is digested and utilized by the animal

Feedstuffs and Nutrient Composition

- The economic importance of feeds in Monogastrics (like Poultry and Pigs) is clear; more than half of their total production cost is from feed.
- Therefore, the efficient use of feed is vital to monogastric animal production.

- The major objective of animal feeding is to convert feedstuffs into human food, and in this respect, monogastric animals are very efficient.
- A feedstuff is a material that contains nutrients necessary for maintenance and production

- Different feedstuffs contain different amounts and types of nutrients which can be accessed differently
- Thus, a feedstuff is usually not fed to animals by itself alone, but in combination with others

Feedstuffs Classification

- Livestock in general are fed various feedstuffs from various origins
- However, these are generally grouped into two categories;
    1) Roughages
    2) Concentrates

1. Roughages

- These are also called forages and have the following are their Characteristics;
  - Bulky but low in weight per unit volume
  - High content of cell wall material (25-30% CF)
  - Mostly for ruminant animals

- Generally low in energy but higher in fiber
- Higher in mineral content, and extremely palatable to ruminants especially when young
- Nutritive value can be extremely variable (species, age, parts)

- A wide variety of feedstuffs can be used in feeding monogastrics, which are broadly classified as;
  1) Energy feedstuffs (cereals, root tubers, and their grain by-products)
  2) Proteins supplements (mostly pulses[Leguminous seeds], and animal products)

3 Mineral supplements (DCP, MCP and LSF),
4 Vitamin supplements,
5 Non-nutritive feed additives (Antibiotics, coccidiostats, pellet binders, etc).
6 Specific feed grade amino acids supplements (DL-Methionine and Lysine)

- Feeds for monogastric animals are concentrated source of nutrients and therefore, they have higher nutritive value than roughages.
- They contain <18% CF and more than 60% TDN.
- Are less bulky, have higher digestibility, and form the bulk of feeds for monogastric animals

- The concentrates are further classified as:
  - **Energy Rich Concentrates** - e.g. Cereal grains, cereal grain by-products, roots and tubers.
  - **Protein Rich Concentrates**
    - ✓ Plant origin
    - ✓ Animal origin

ENERGY FEEDSTUFFS

- The major energy sources for Monogastric animals are
  - Cereal grains,
  - Cereal grain by-products,
  - Fats or Oils
  - Root and tubers

3. FEED SUPPLEMENTS

- Are compounds used to improve the nutritional value of the basal feeds so as to take care of any deficiency.
- Commonly used feed supplements are
  - Vitamin supplements
  - Mineral supplements

4. FEED ADDITIVES

- Are the non-nutritive substances usually added to basal feed in small quantity in order;
  - To improve feed efficiency,
  - Product quality,
  - Disease resistance,
  - Productive performance of the animals, etc.

- Some commonly used feed additives are as below:
  - Antibiotics e.g. Terramycin, Zinc bacitracin, Flavomycin etc.
  - Enzymes e.g. Amylase, lipase, protease, pepsin etc.
  - Hormones eg. Estrogen, progesterone, hexosterol etc.

- Probiotics e.g. Microbial species. Lactobacillus.
- Biostimulators e.g. Extracts of living organs like spleen, liver, ovary, chick embryo etc.
- Antioxidants e.g. Vitamin E (Tocopherols), BHT (Butylated hydroxy toluene).

- Mold inhibitors e.g. Propionic acid, acetic acid.
- Pellet binders e.g Gur, meal, molasses, sodium bentonite.
- Coccidiostats e.g. Amprolsol powder, Furasol powder

Chemistry Of Nutrients

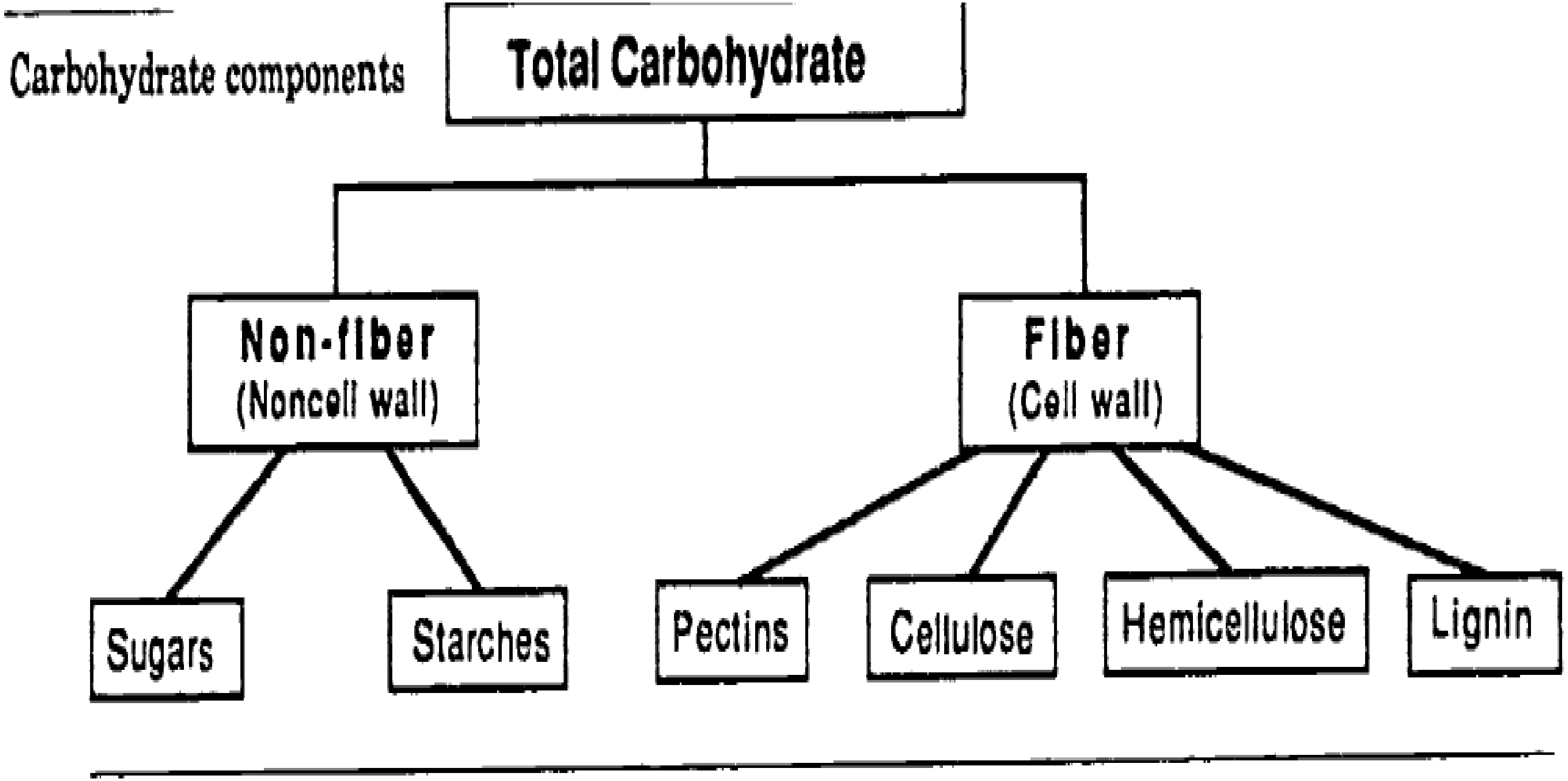
1. Carbohydrate

- Are macromolecules or polymers, built from monomers
- A polymer is a long molecule consisting of many similar building blocks
- These small building-block molecules are called monomers

- Carbohydrates consists of Carbon (C), Hydrogen (H) and Oxygen (O)
- These elements occur in a ratio of 1:2:1 (CH_2O), and are sometimes referred to as ‘hydrates’ of carbon
- Glucose, ($C_6H_{12}O_6$) is the most common monosaccharides in animal tissues

- In animals carbohydrates are converted into:
  - Body fat, milk fat, and lactose, blood sugar, muscle and liver glycogen, carbon units for synthesis of protein
  - Structural units of the animal's body

- In the analysis of feeds, carbohydrates are divided into two groups;
  - **Non-fiber** (non cell wall) carbohydrates (e.g. starches and sugars),
  - **Fiber** (cell wall) carbohydrates (pectins, cellulose, hemicellulose, and lignin)

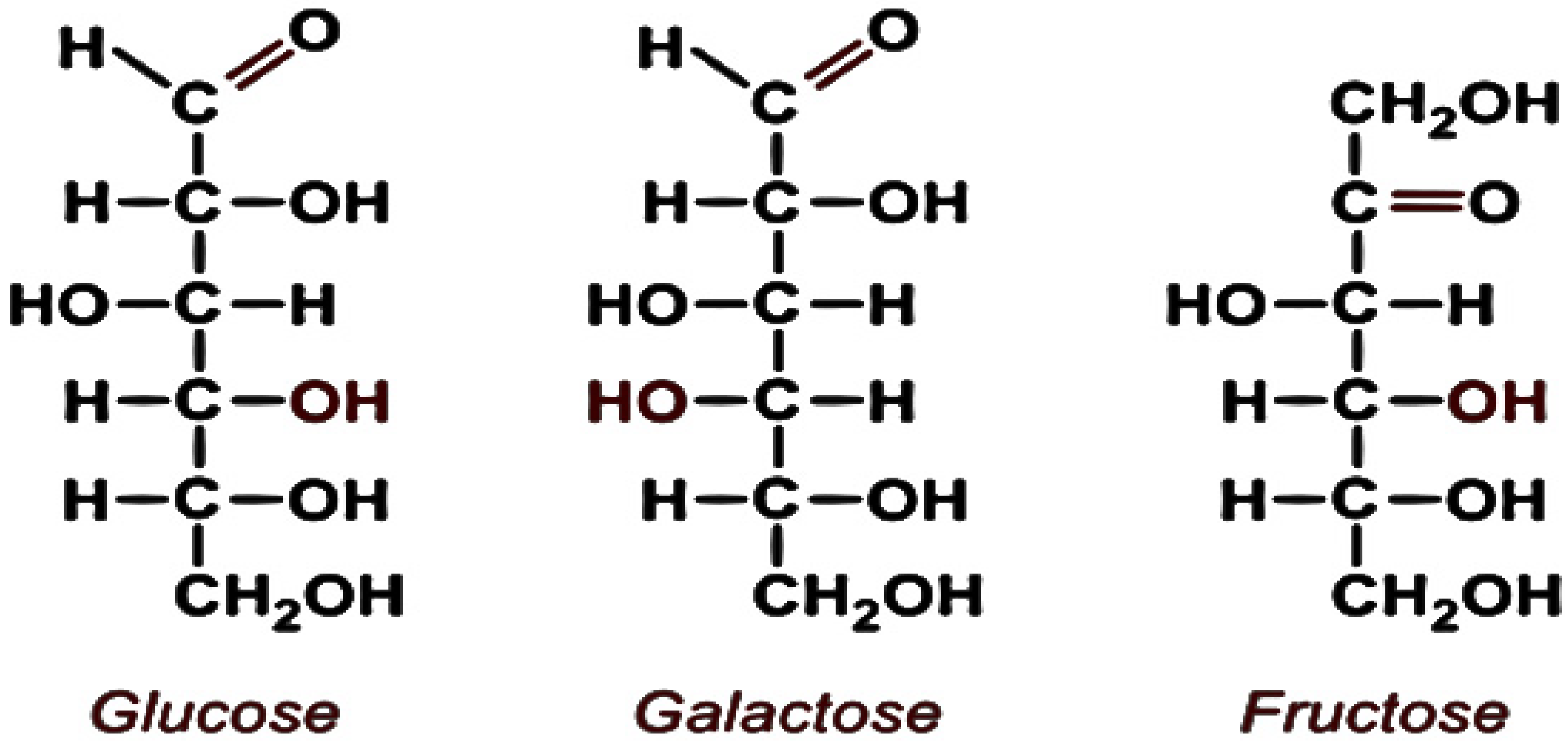

Carbohydrate components
Total Carbohydrate
Non-fiber
(Noncell wall)
Fiber
(Cell wall)
Sugars
Starches
Pectins
Cellulose
Hemicellulose
Lignin

Functions

1. Provide energy through oxidation
2. Supply carbon for the synthesis of cell components
3. Serve as a form of stored chemical energy
4. Form part of the structures of some cells and tissues

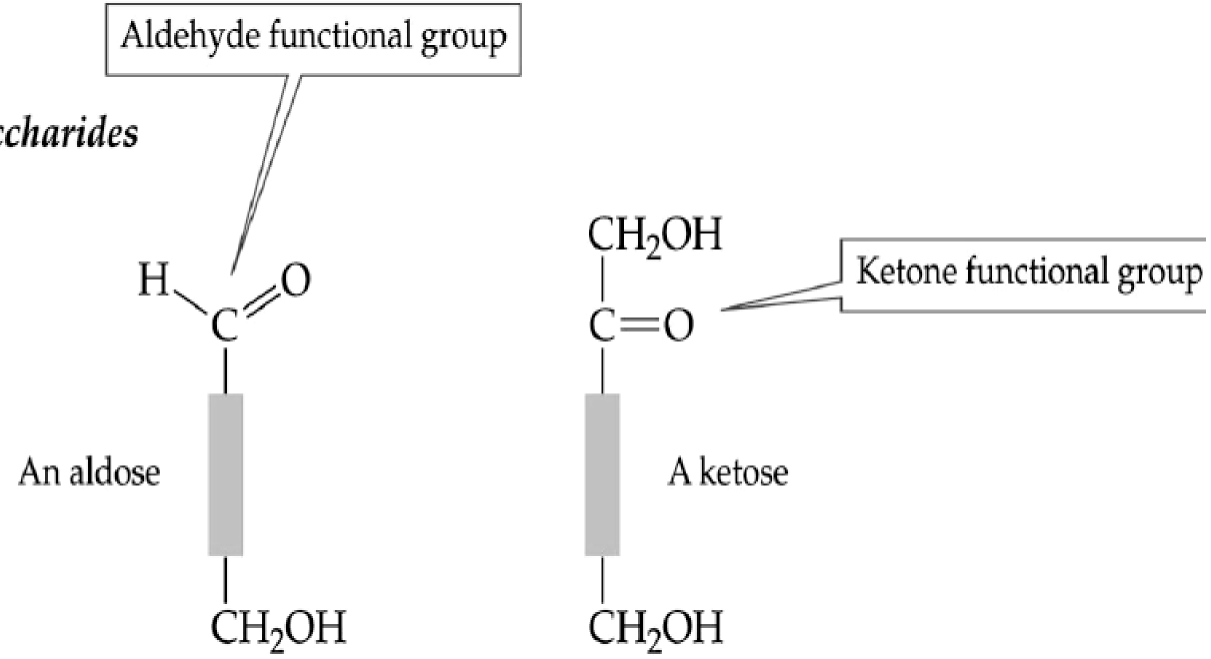
Classification of carbohydrates

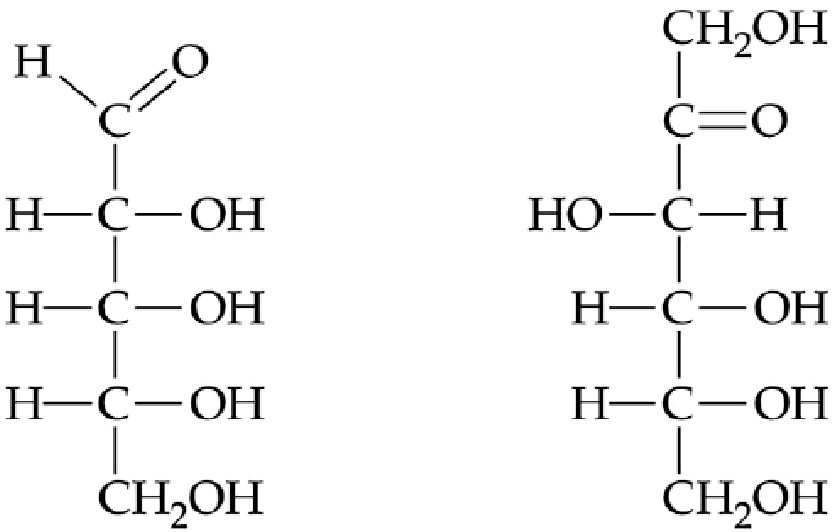
- (1) Monosaccharides (glucose, fructose and galactose)
- and (2) disaccharides (sucrose and lactose) are relatively small molecules, often called sugars
- (3) Oligosaccharides and (4) polysaccharides (cellulose, hemicellulose are larger molecules



- They have an aldehyde or ketone as the functional group at one end.

Monosaccharides



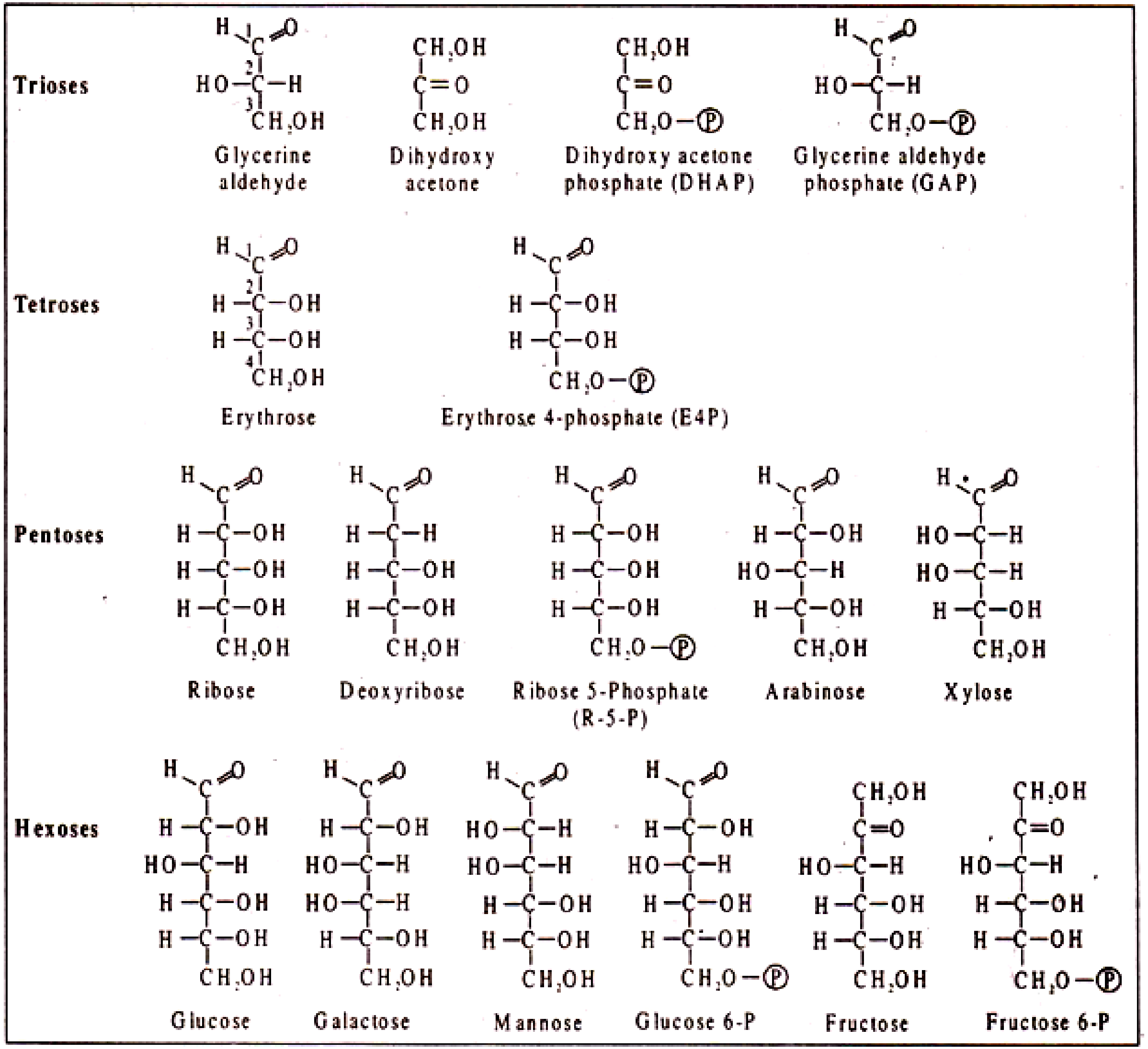


Ribose, an aldopentose (a component of ATP, coenzymes, and RNA)

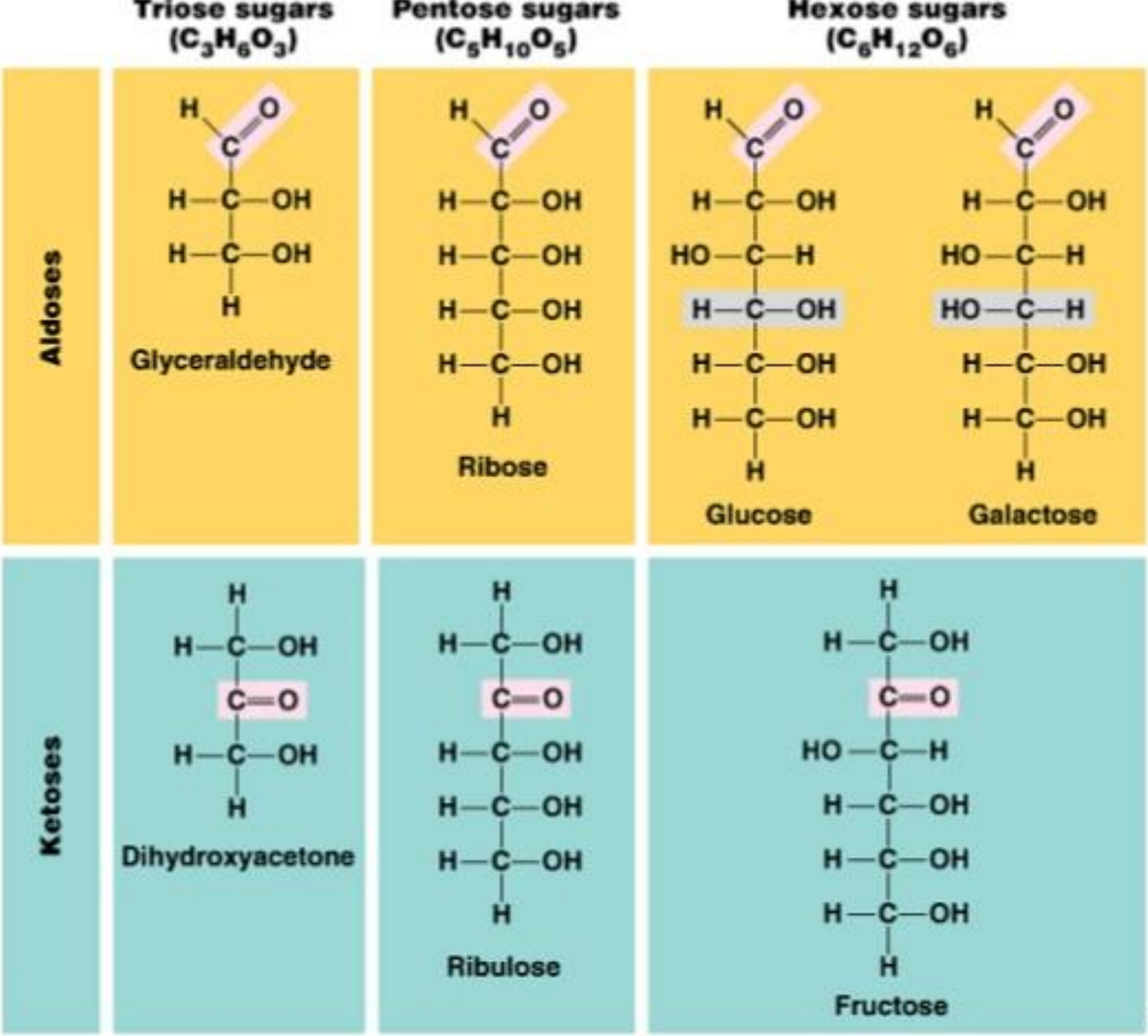
Fructose, a ketohexose (present in corn syrup and fruit)

- Monosaccharides are classified by
  - The location of the carbonyl group
  - The number of carbons in the carbon skeleton
- Their names can be derived from these two methods of classifications

- Based on the number of carbons in the backbone
  - Trioses; **3** carbons
  - Tetroses; **4** carbons
  - Pentoses; **5** carbons
  - Hexoses; **6** carbons


Trioses
Glycerine aldehyde
Dihydroxy acetone
Dihydroxy acetone phosphate (DHAP)
Glycerine aldehyde phosphate (GAP)
Tetroses
Erythrose
Erythrose 4-phosphate (E4P)
Pentoses
Ribose
Deoxyribose
Ribose 5-Phosphate (R-5-P)
Arabinose
Xylose
Hexoses
Glucose
Galactose
Mannose
Glucose 6-P
Fructose
Fructose 6-P

- Based on location of the carbonyl group (-C=O) in the chain;
  - Aldose; Carbonyl group (-C=O) is at the end aldehydes)
  - Ketose; Carbonyl group (-C=O) is on the middle (ketones)


Triose sugars
($C_3H_6O_3$)
Pentose sugars
($C_5H_{10}O_5$)
Hexose sugars
($C_6H_{12}O_6$)
Aldoses
Glyceraldehyde
Ribose
Glucose
Galactose
Ketoses
Dihydroxyacetone
Ribulose
Fructose
Fig. 5.3

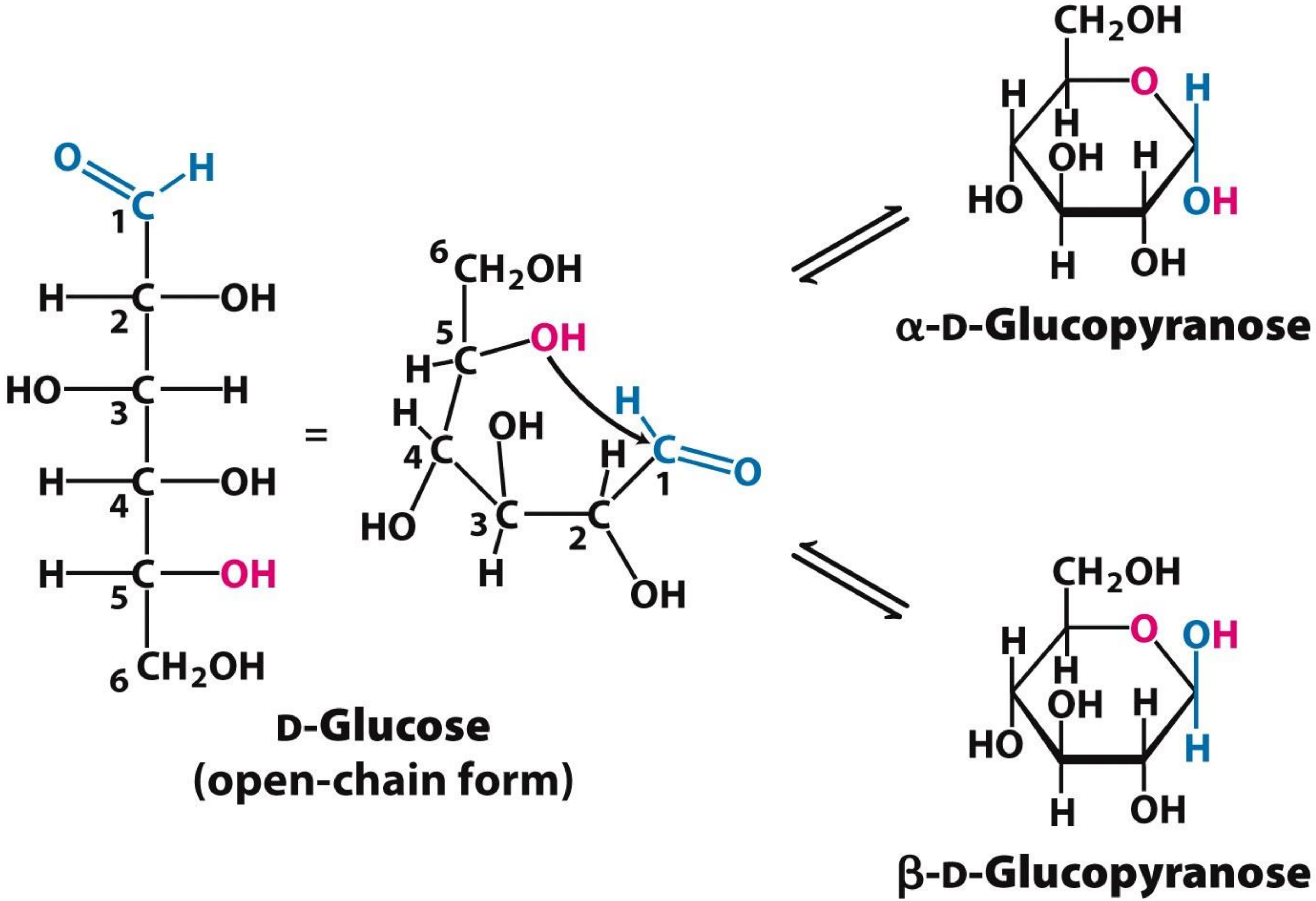
Linear and ring forms

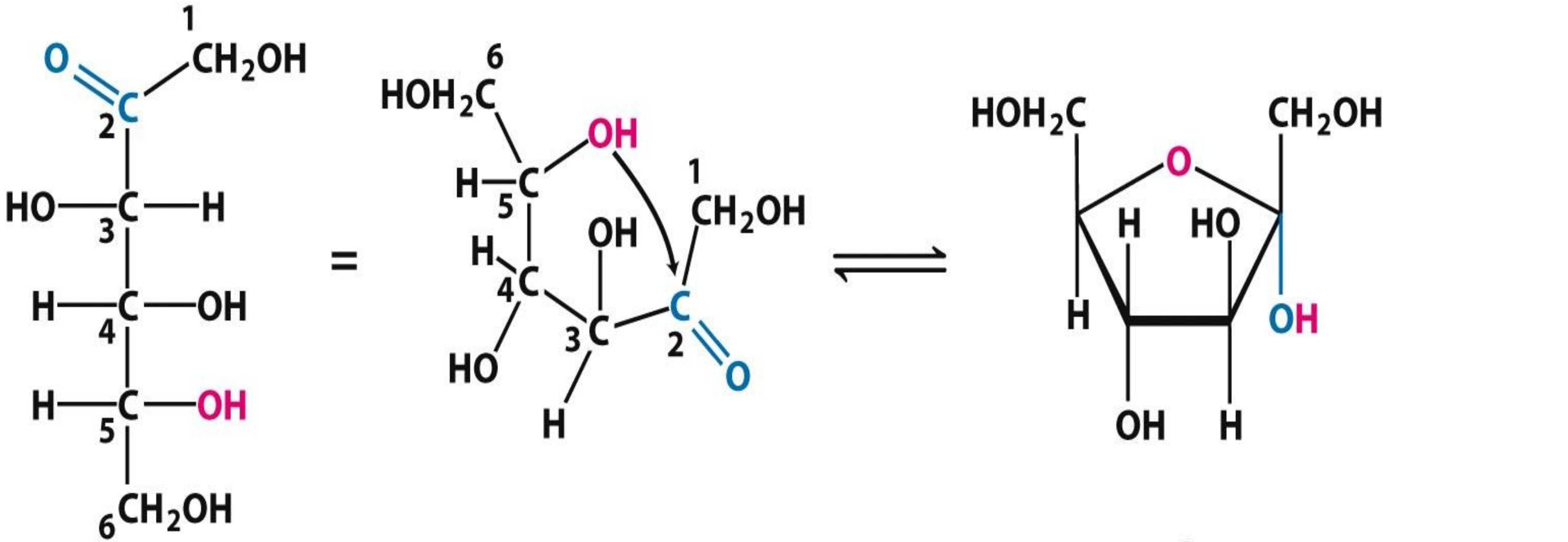
- In aqueous solutions, hexoses sugars forms rings
- -C=O group reacts with OH on a chiral carbon that is furthest away from it to form a stable 5 or 6 sided ring structure
- The number C in the ring is same as in the linear structure

- The C of the -C=O group is known as an anomeric carbon
- Depending on if the OH group attaches on the -C=O from the top or bottom, a different ring structure, with an α, or β configuration, is formed

Remember!

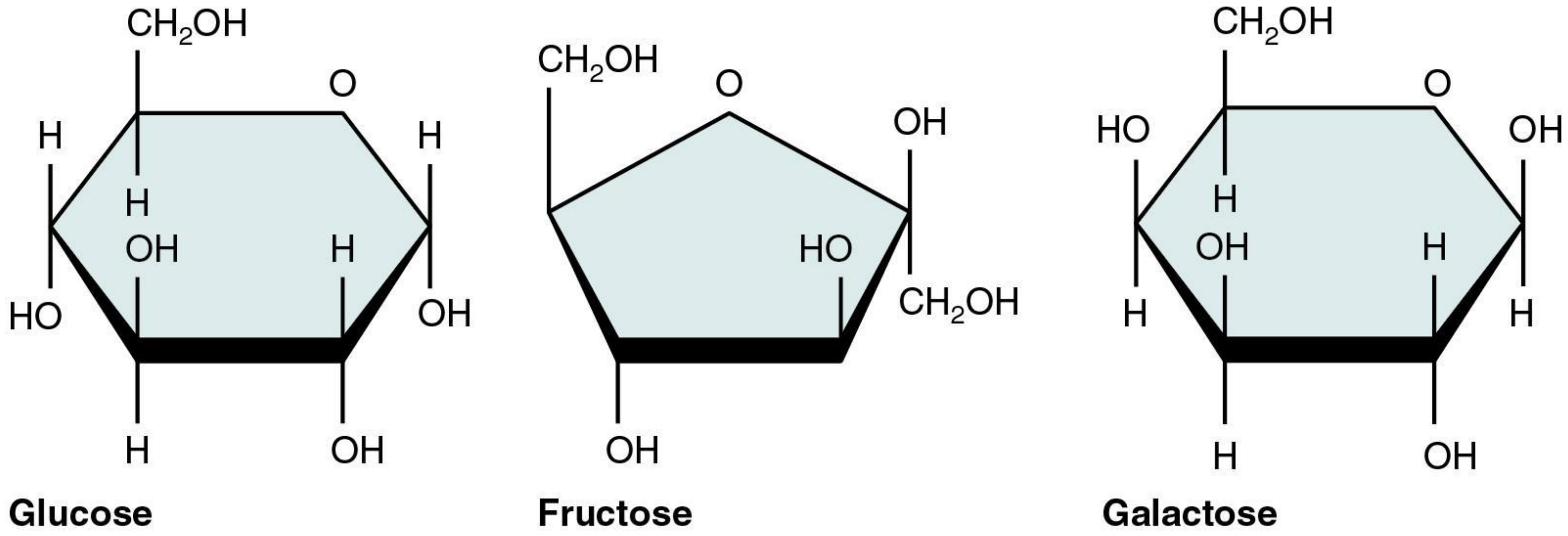
- The different orientation of the resulting OH group have different names
- Alpha (α) = OH group below ring or on the opposite side of CH_2OH group
- Beta (β) = OH group above the ring or same side as that of CH_2OH group


D-Glucose
(open-chain form)
α-D-Glucopyranose
β-D-Glucopyranose

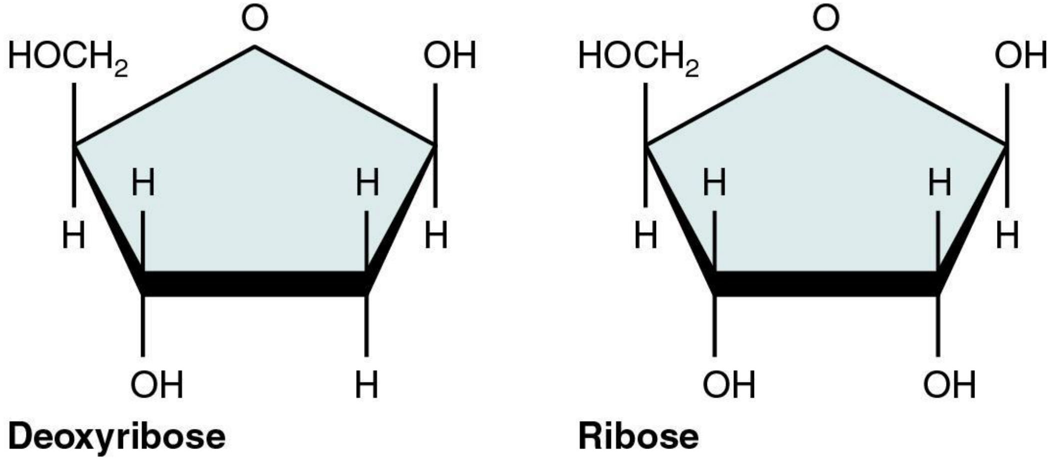


D-Fructose
(open-chain form)

α-D-Fructofuranose
(a cyclic form of fructose)



(a) Hexoses

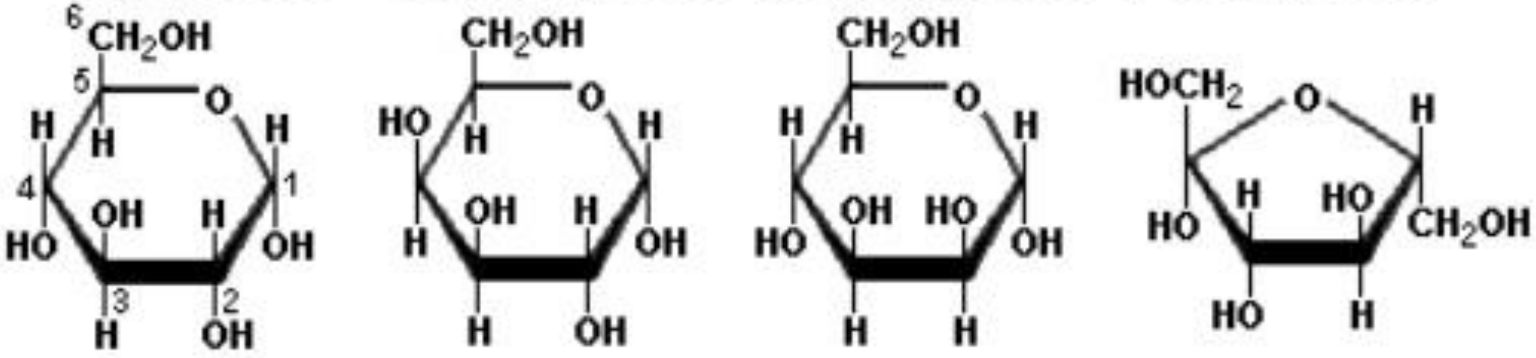


(b) Pentoses

Ring forms of hexose sugars

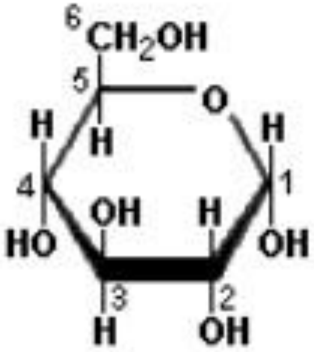
- Question: How do you distinguish galactose, mannose and fructose from glucose? Refer to specific carbon numbers.

Glucose Galactose Mannose Fructose

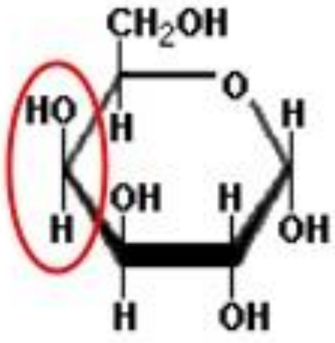


Ring forms of hexose sugars

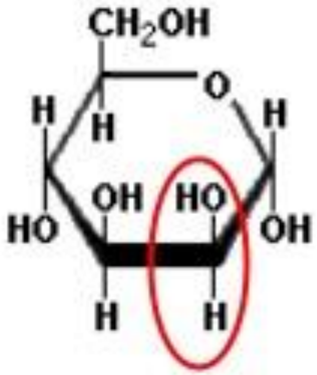
Glucose



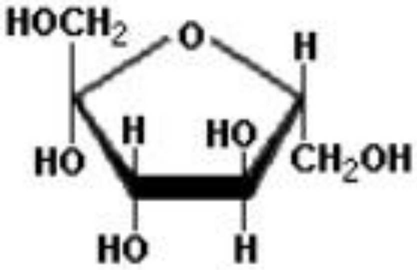
Galactose



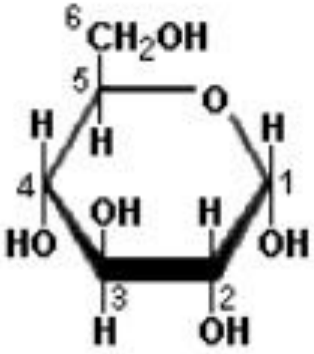
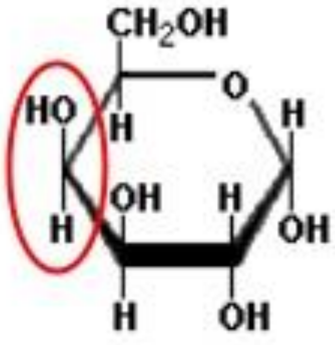
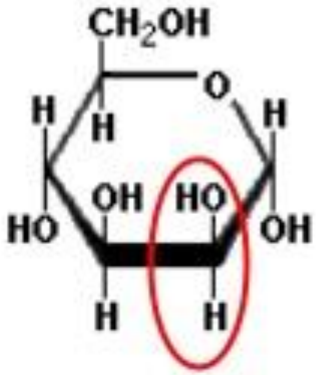
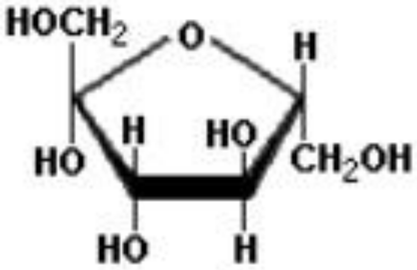
Mannose



Fructose

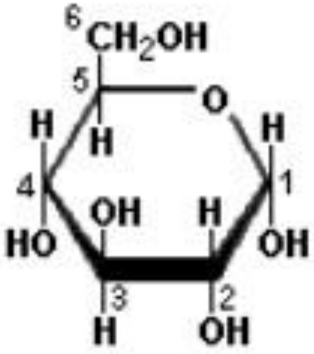


Ring forms of hexose sugars

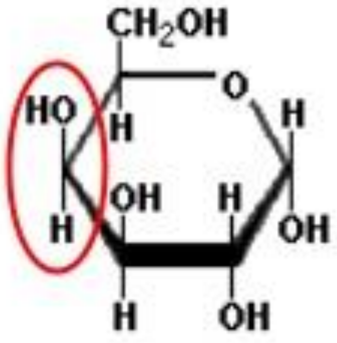
Glucose	Galactose	Mannose	Fructose
			
	Carbon 4 – OH is up	Carbon 2 – OH is up	

Ring forms of hexose sugars

Glucose

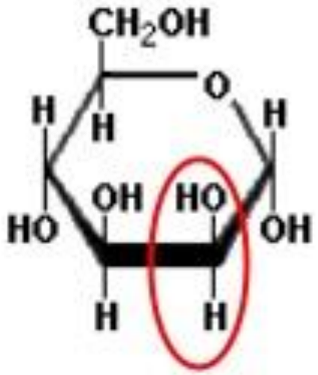


Galactose



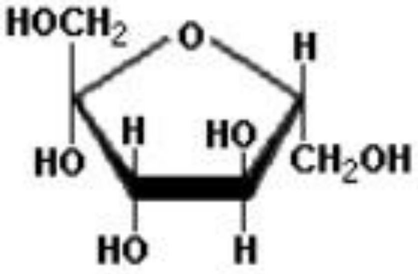
Carbon 4 – OH is up

Mannose



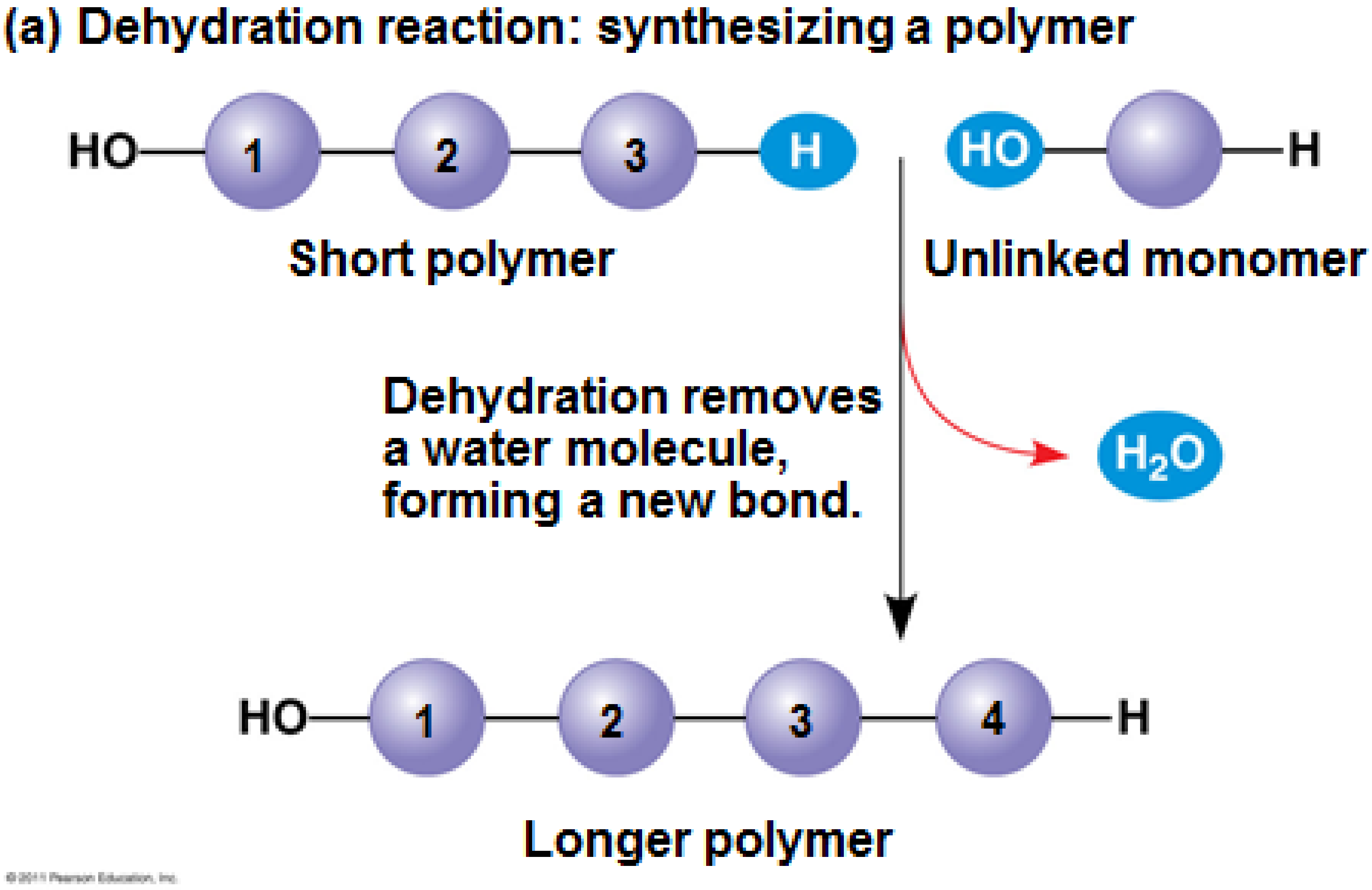
Carbon 2 – OH is up

Fructose



5 sided ring

- A dehydration reaction occurs when two monomers bond together through the loss of a water molecule
- Polymers are disassembled to monomers by hydrolysis, a reaction that is essentially the reverse of the dehydration reaction


(a) Dehydration reaction: synthesizing a polymer
HO
1
2
3
H
HO
H
Short polymer
Unlinked monomer
Dehydration removes a water molecule, forming a new bond.
H_2O
HO
1
2
3
4
H
Longer polymer
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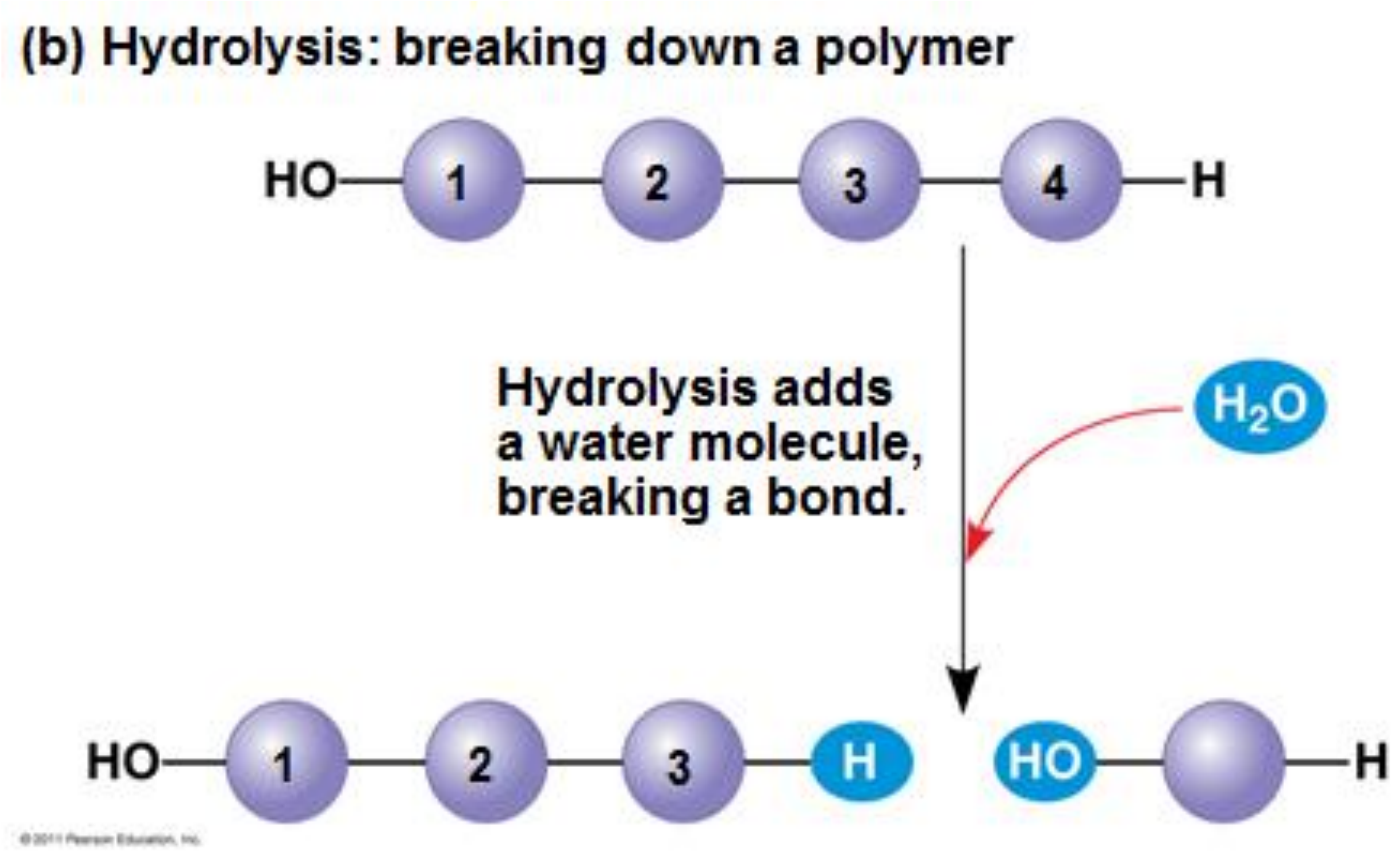
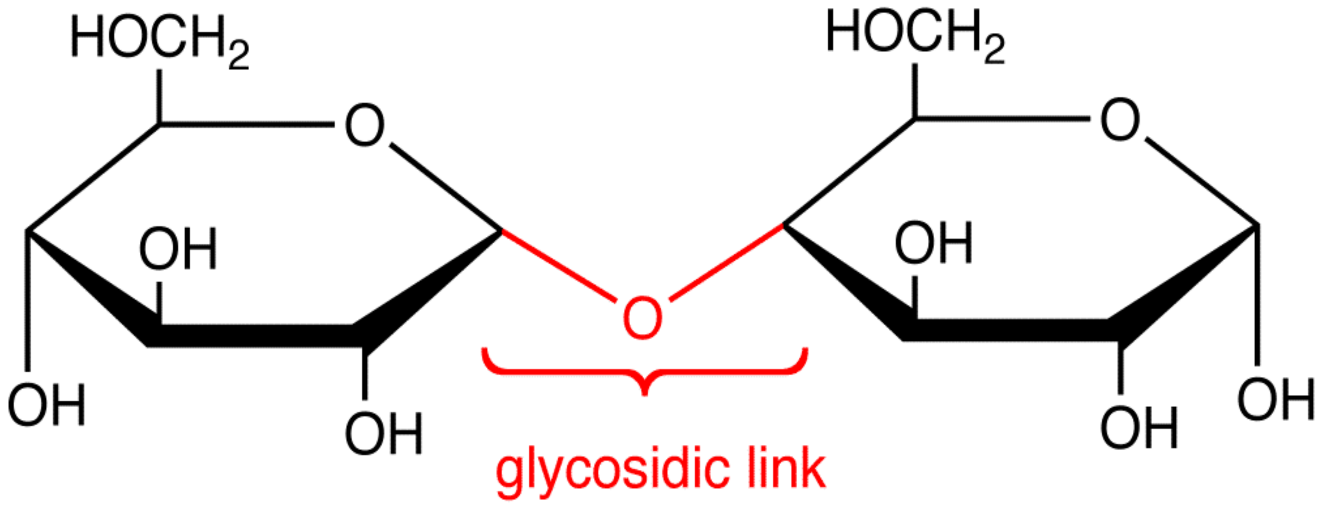

(b) Hydrolysis: breaking down a polymer
HO
1
2
3
4
H
Hydrolysis adds
a water molecule,
breaking a bond.
H_2O
HO
1
2
3
H
HO
H

Dissaccharide

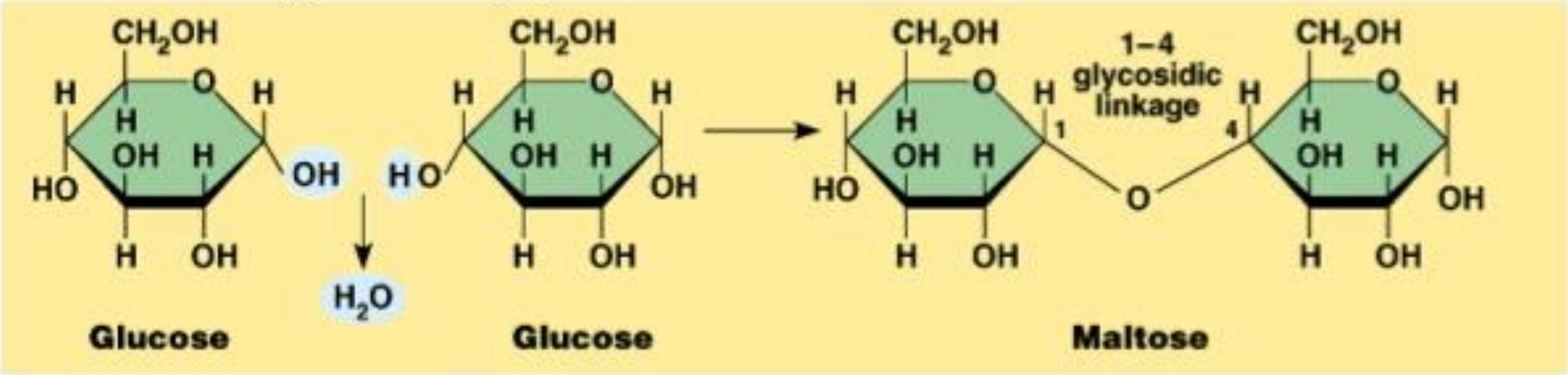
- Di = two
- Condensation reaction of 2 monosaccharides forming an ether bond known in carbohydrates as a glycosidic bond
- 3 dissaccharides that all involve glucose:
  - Maltose = glucose + glucose
  - Lactose = glucose + galactose
  - Sucrose = glucose + fructose

- A disaccharide is formed when a dehydration reaction joins two monosaccharides
  This covalent bond is called a glycosidic linkage



Dissaccharide: Maltose

- Glucose + Glucose = Maltose + H2O
- Produced in malted products (e.g. beer)
- Linkage: α-1,4

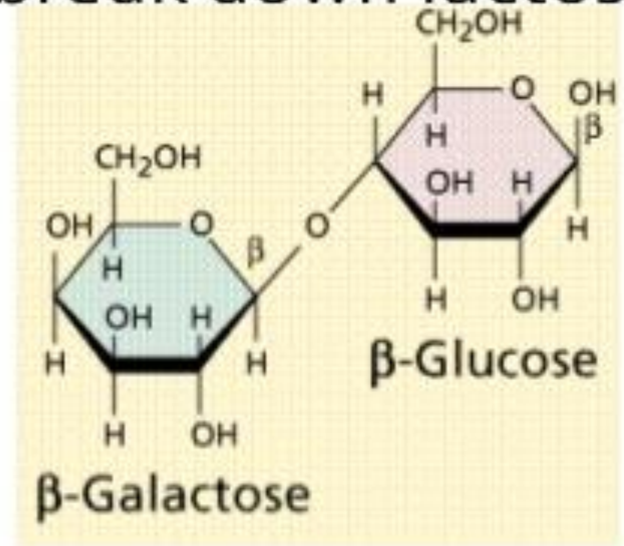


(a) Dehydration synthesis of maltose

Fig. 5.5a

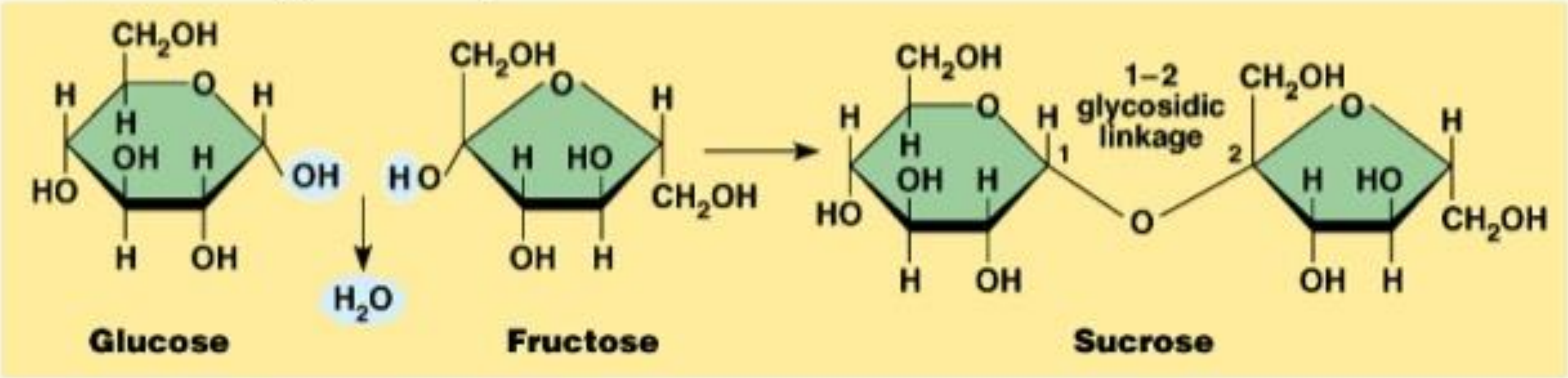
Dissaccharide: Lactose

- Glucose + Galactose = Lactose + H_2O
- the major form of sugar in milk
- People with lactose intolerance lack the enzyme needed to break down lactose
- Linkage: β-1,4



Dissaccharide: Sucrose

- Glucose + Fructose = Sucrose + H_2O
- table sugar
- the major transport form of sugars in plants
- Linkage: α-1,2

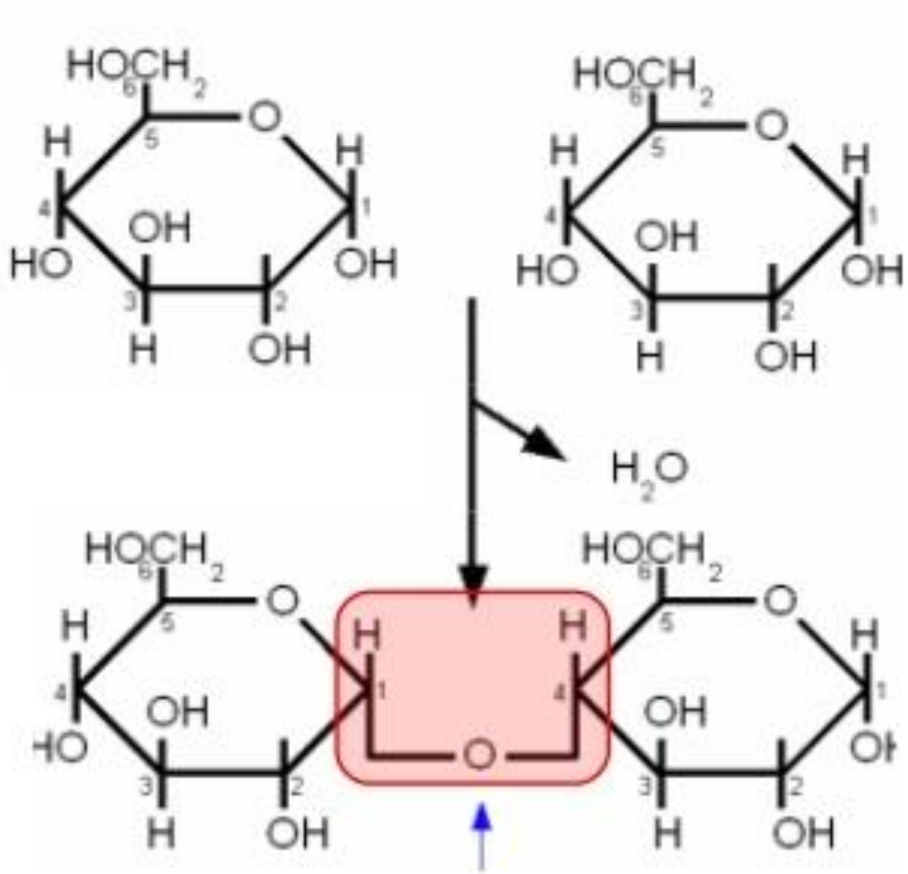


(b) Dehydration synthesis of sucrose

Fig. 5.5b

Saccharide Condensation Reaction

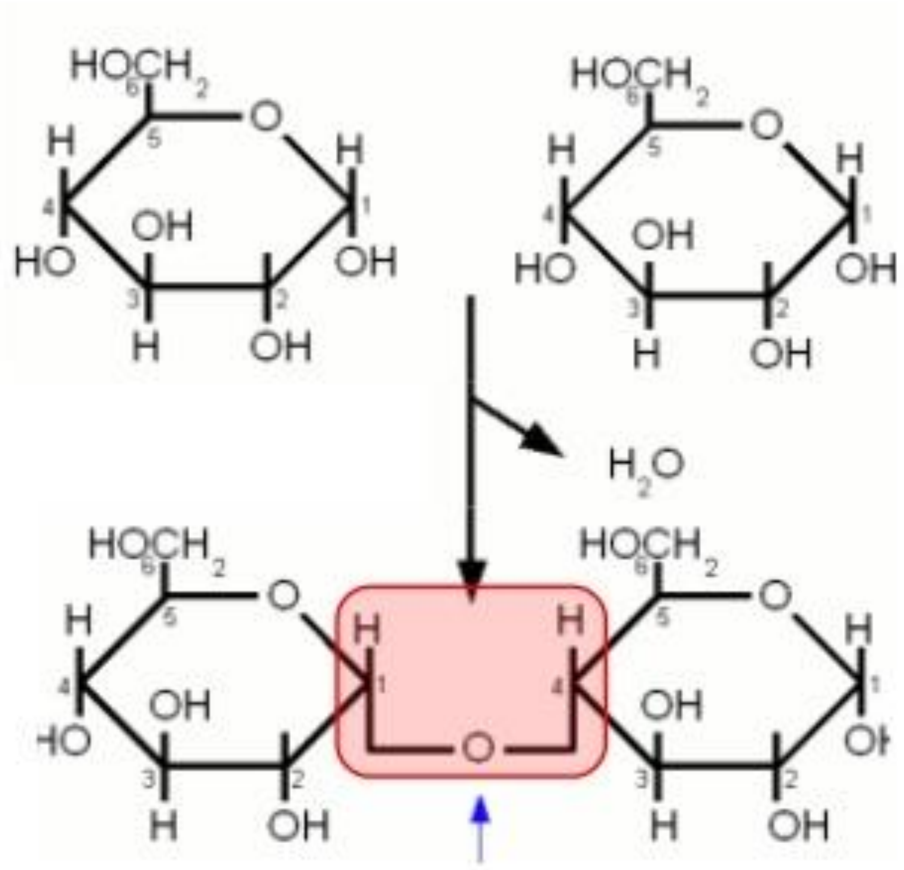
- Which functional group(s) participates in this reaction?
- What is the name of the new functional group formed (red box)?



Linkage Naming

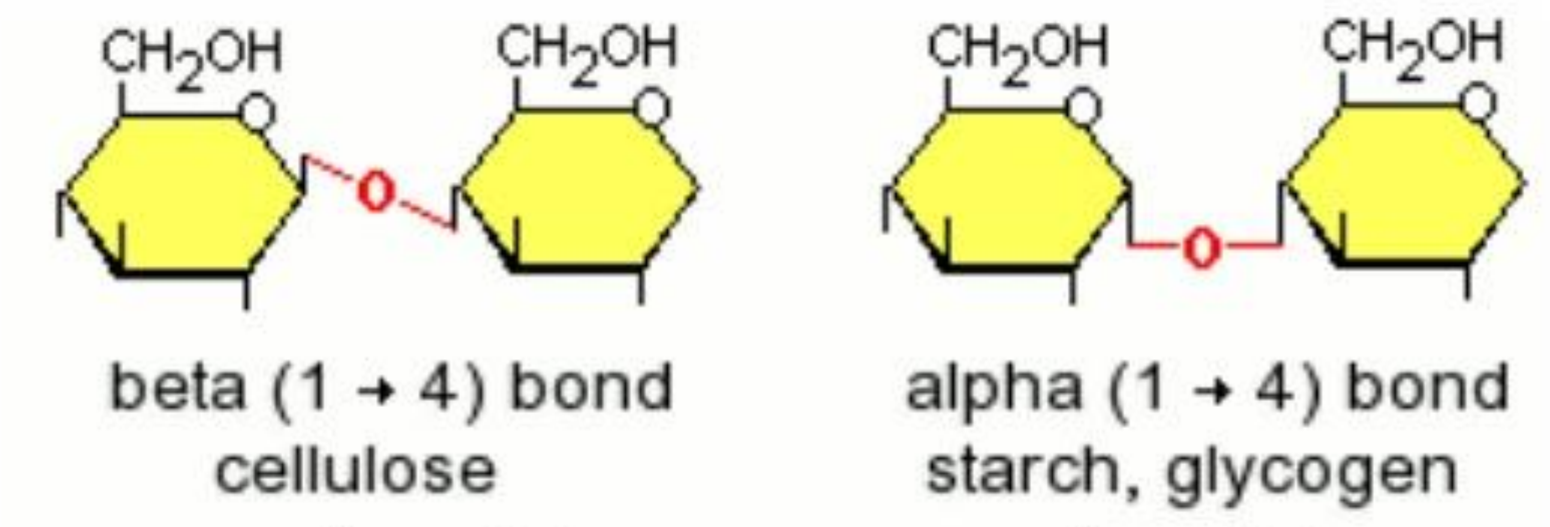
To name the linkage:

- Identify whether the anomeric carbon in the link is α or β
- Number the carbons and determine which two carbons are involved in the linkage
- Example: α-1,4 linkage



Linkage: Anomeric Carbon

- α and β orientation of the anomeric carbon result in the formation of different types of bonds in polymers

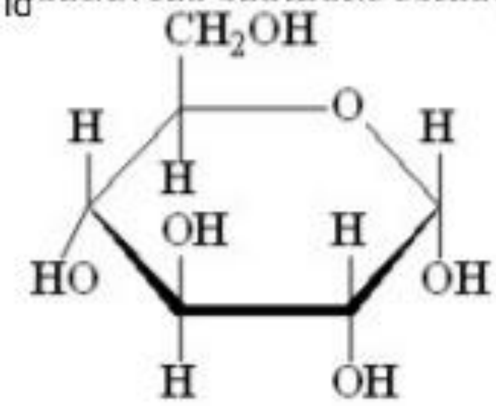


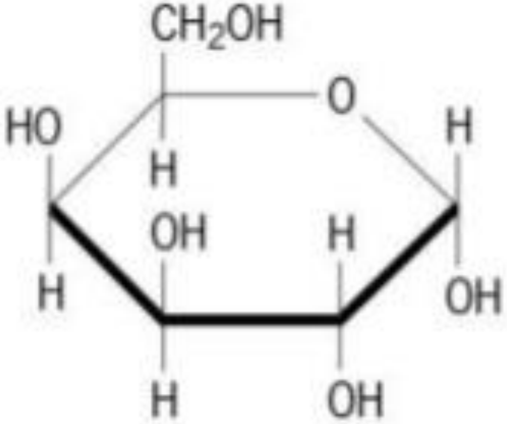
non-digestible

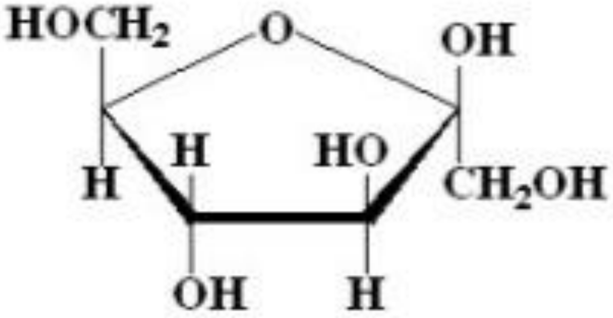
digestible

Reducing Sugars

- In a chemical reaction, when the anomeric carbon has an OH group, it is considered a reducing sugar.
- All monosaccharides are reducing sugars

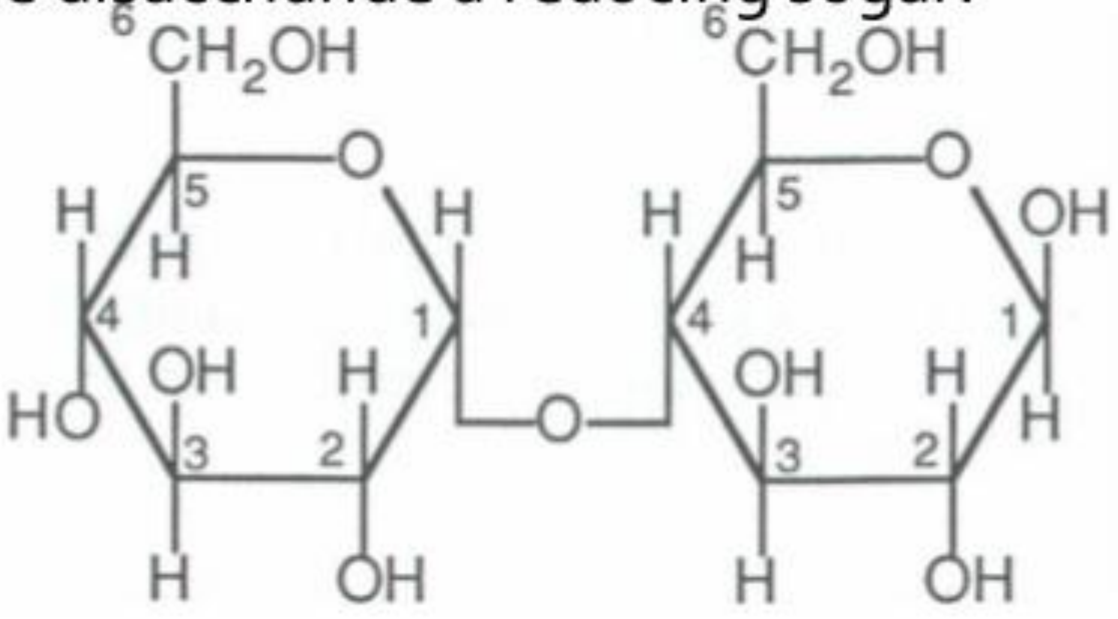




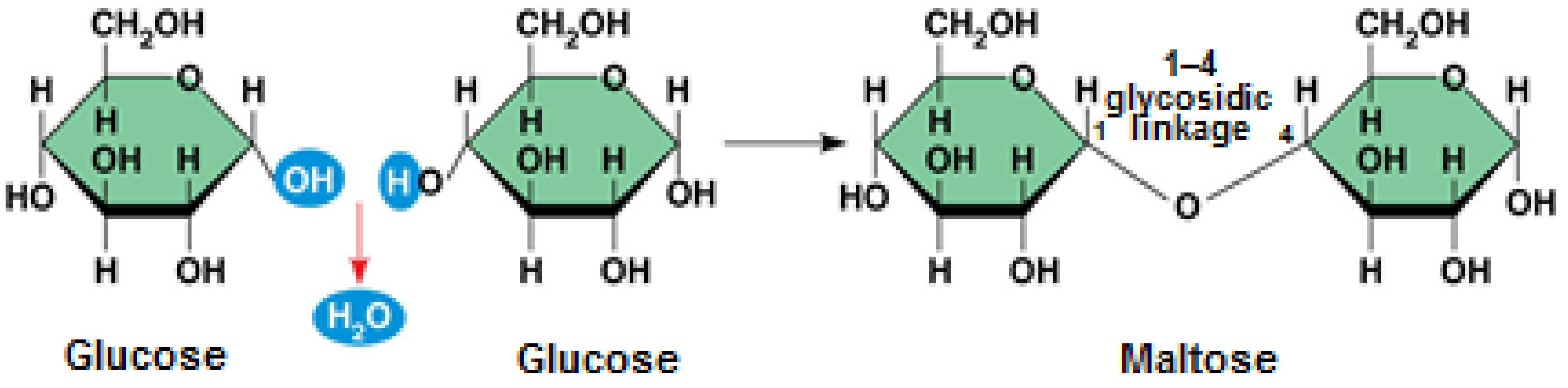


Disaccharides: Reducing?

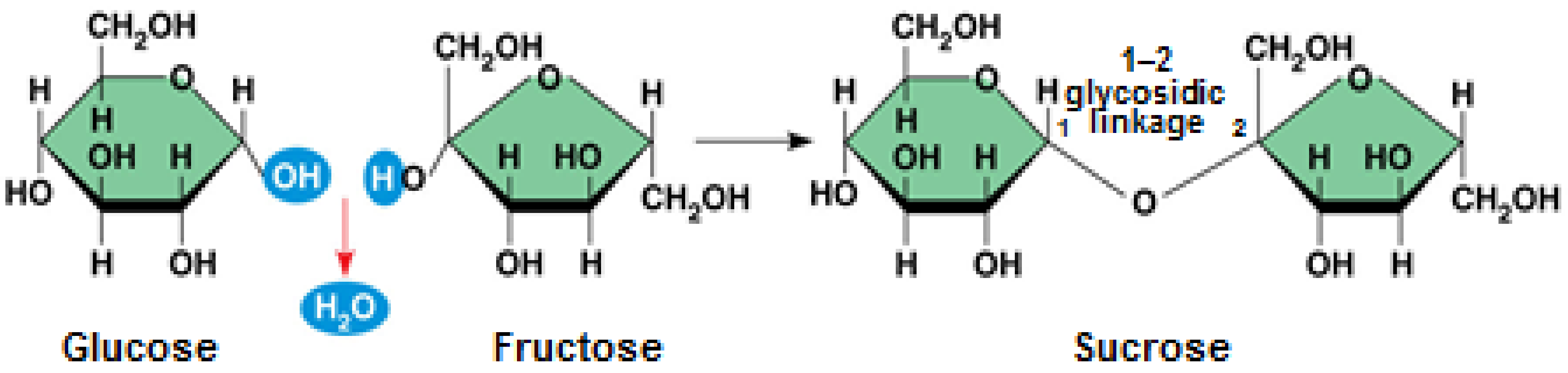
- Name the monosaccharides
- Name the disaccharide
- Name the linkage
- Is the disaccharide a reducing sugar?



Synthesizing Maltose & Sucrose



(a) Dehydration reaction in the synthesis of maltose



(b) Dehydration reaction in the synthesis of sucrose

POLYSACCHARIDES

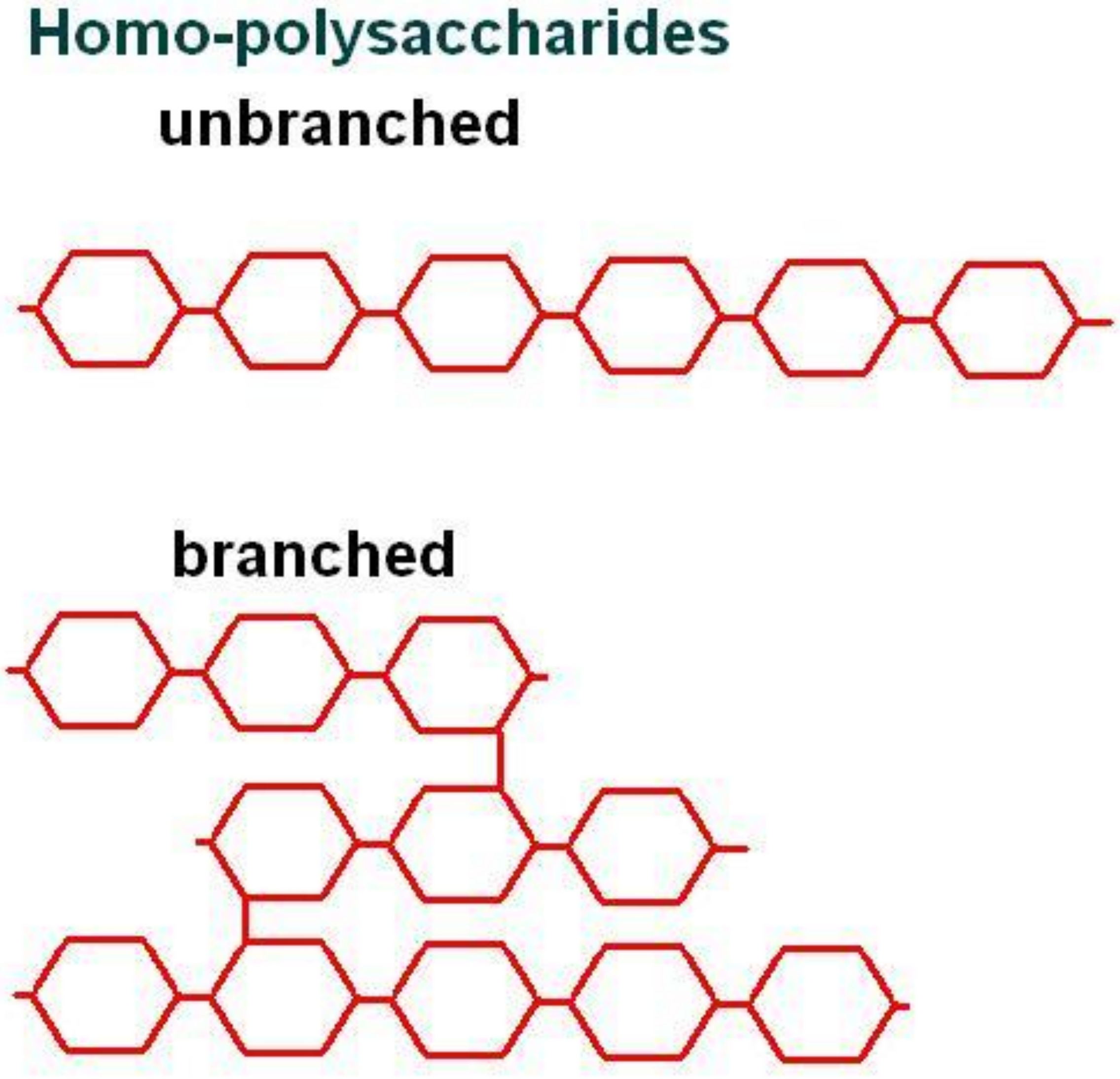
- are complex carbohydrate polymers consisting of more than 2 monosaccharides linked together covalently by glycosidic linkages in a condensation reaction.
- Being comparatively large macromolecules, polysaccharides are most often insoluble in water.

- Polysaccharides, the polymers of sugars, have storage and structural roles.
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages

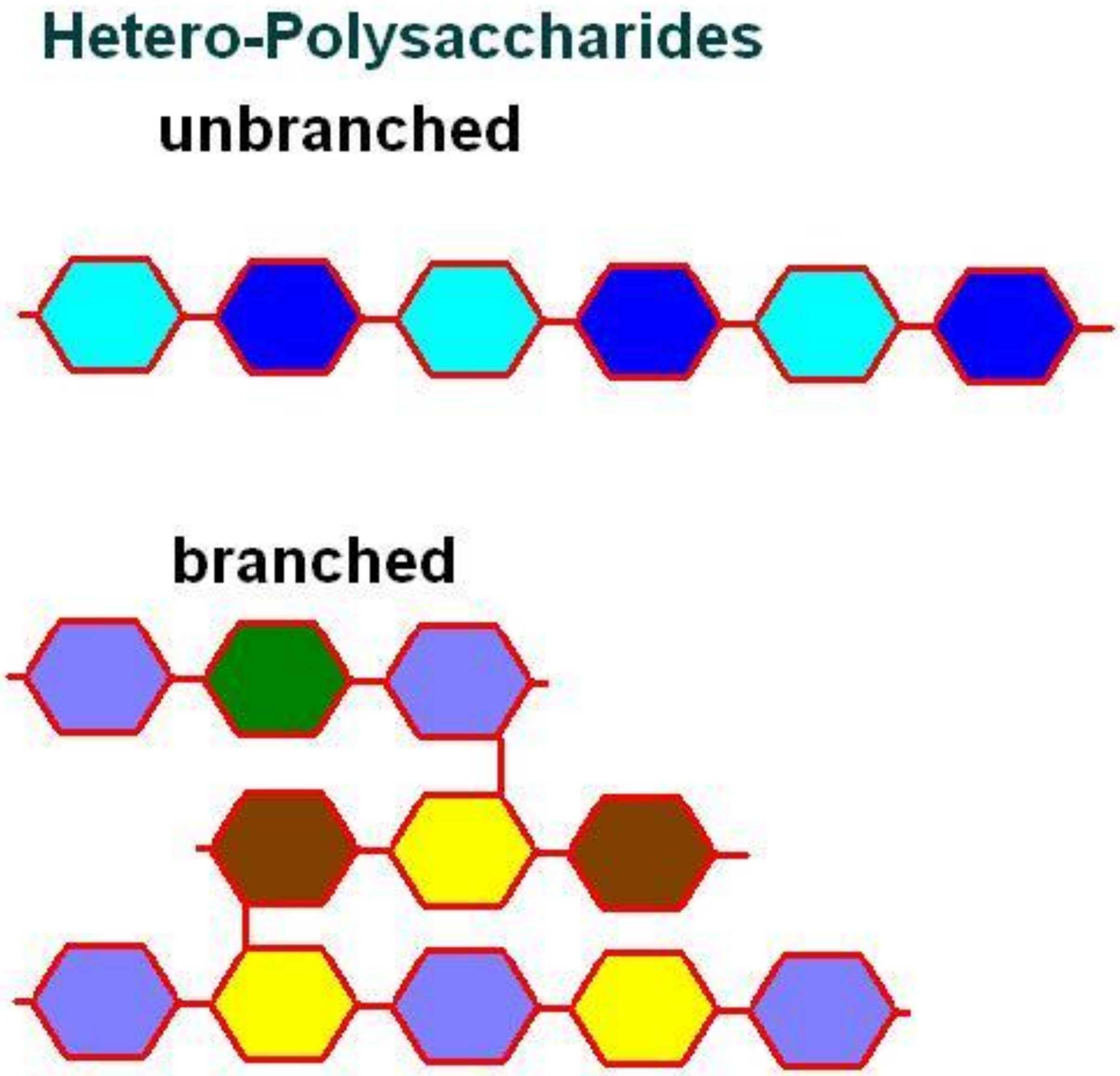
- Polysaccharides are very important in organisms for the purposes of energy storage and structural integrity.
- There are two types;
  - Homo-polysaccharides
  - Hetero-polysaccharides.

- A homo-polysaccharide has only one type of monosaccharide repeating in the chain;
- a hetero-polysaccharide is composed of two or more types of monosaccharides.
- In both types, the monosaccharide can link in a linear fashion or they can branch out into complex formations.

Homopolysaccharides



Heteropolysaccharides

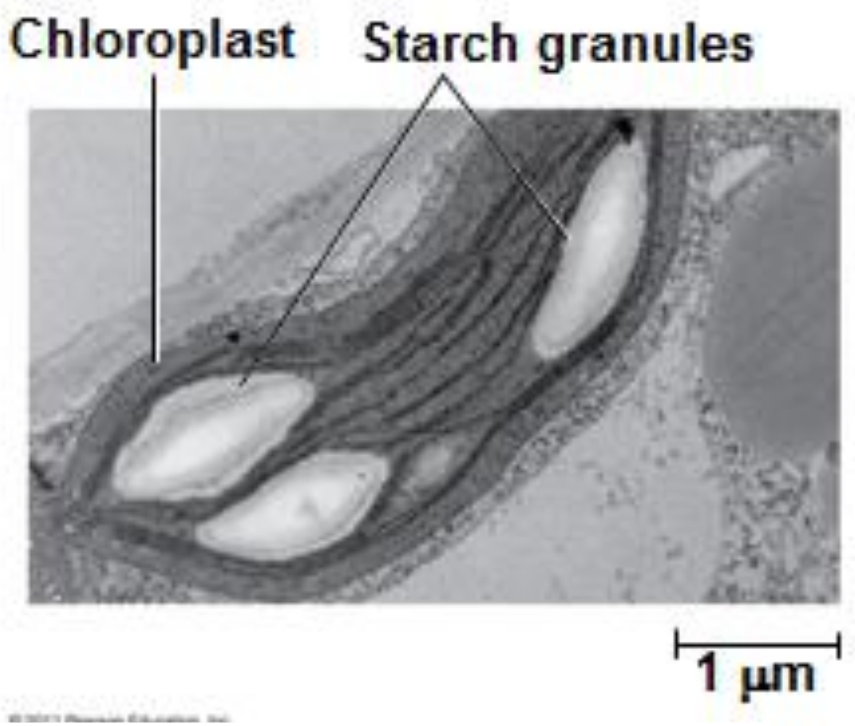


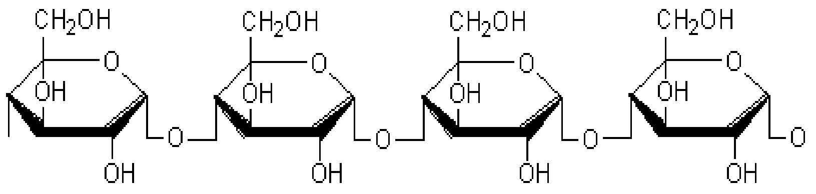
Use of Polysaccharides

- Have several roles;
- Polysaccharides such as starch, glycogen, and dextrans are all stored in the liver and muscles to be converted to energy.
- Amylose and Amylopectin are polysaccharides of starch.

Polysaccharides: Storage forms

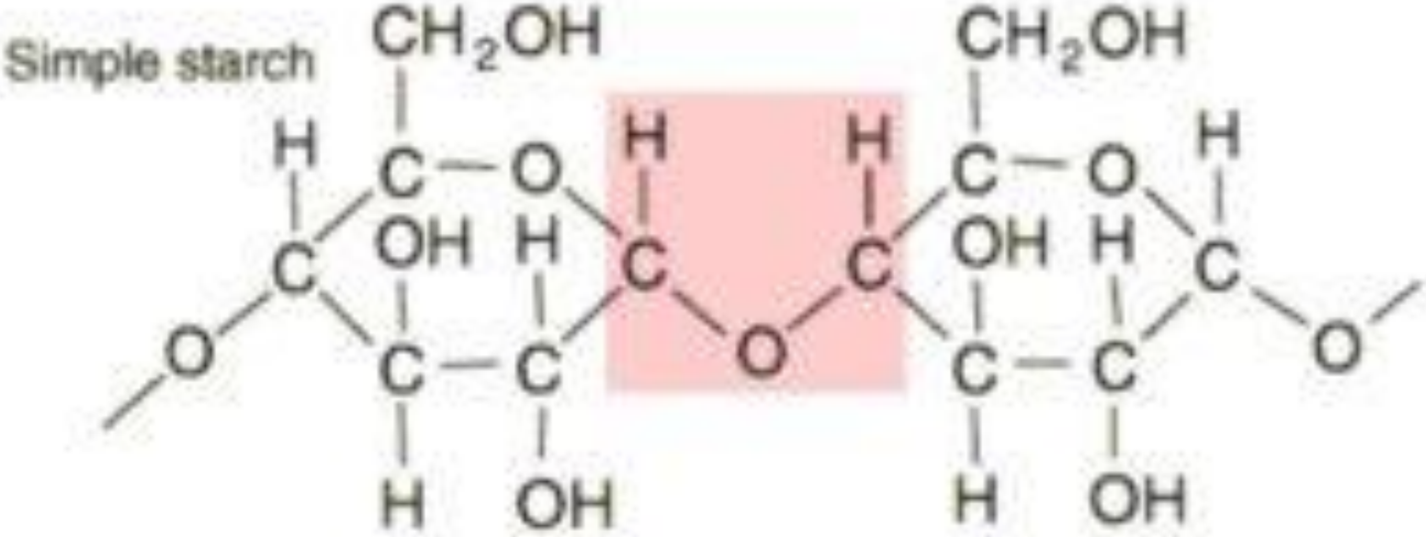
- 1. **Starch**, a storage polysaccharide of plants, consists entirely of glucose monomers
- Plants store surplus starch as granules within chloroplasts and other plastids
- The simplest form of starch is amylose

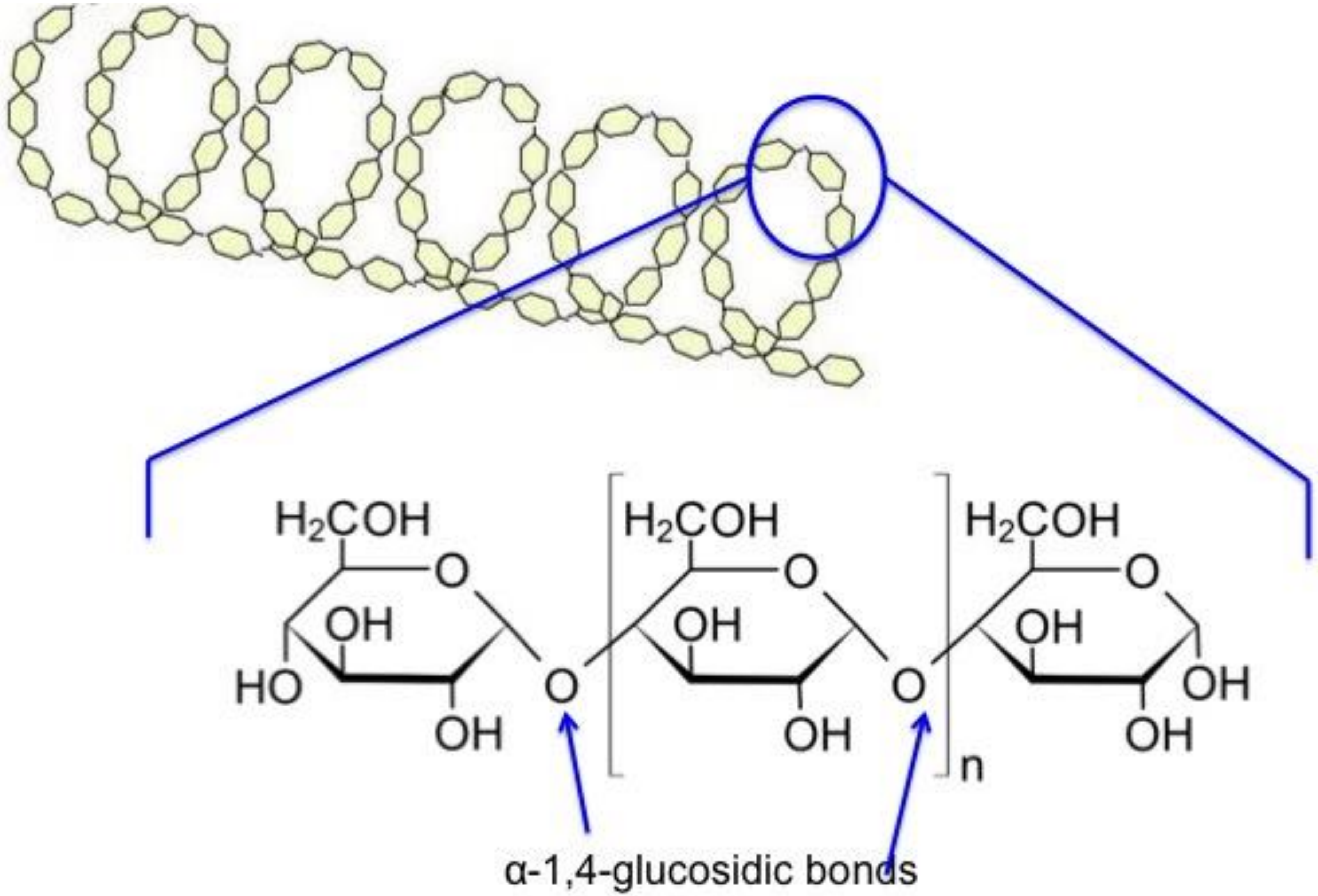


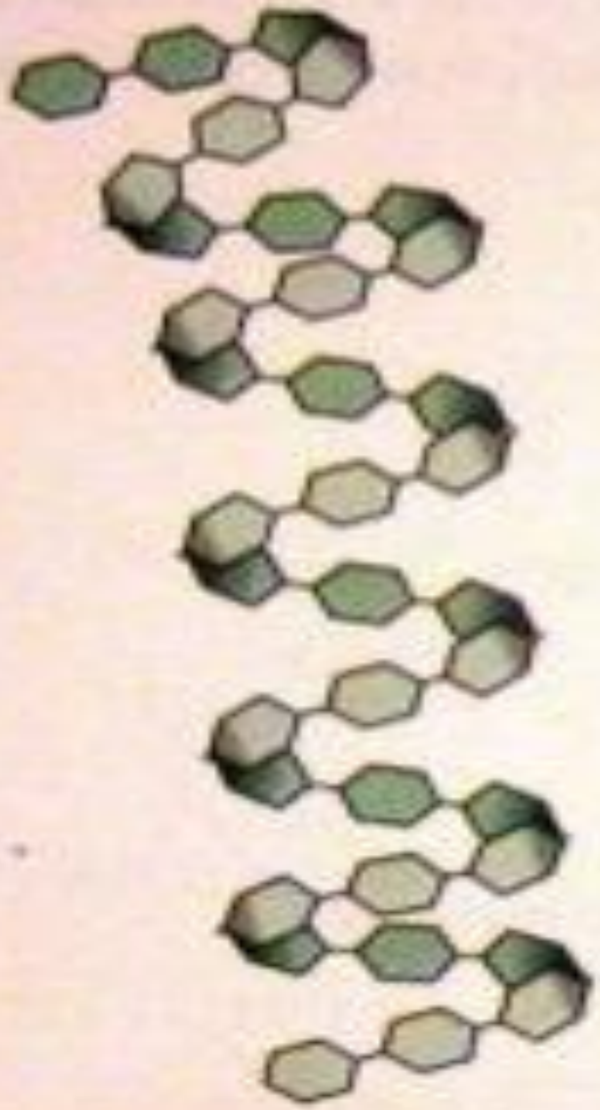


- Amylose has a linear chain structure made up of hundreds of glucose molecules that is linked by a alpha 1,4 glycosidic linkage.
- Due to the nature of these alpha 1,4 bonds, the macromolecule often assumes a bent shape.
- The starch molecules form a hollow helix that is suitable for easy energy access and storage.

Structure of Starch

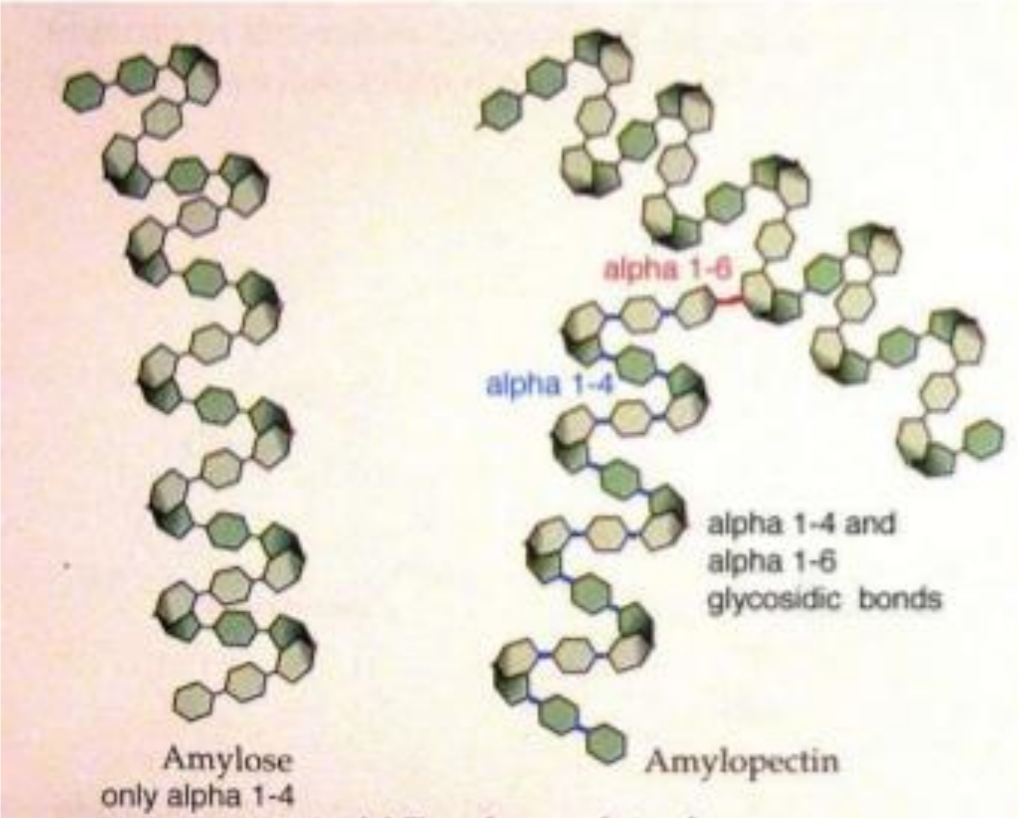



H2COH
O
OH
HO
OH
O
H2COH
O
OH
OH
O
n
H2COH
O
OH
OH
OH
α-1,4-glucosidic bonds

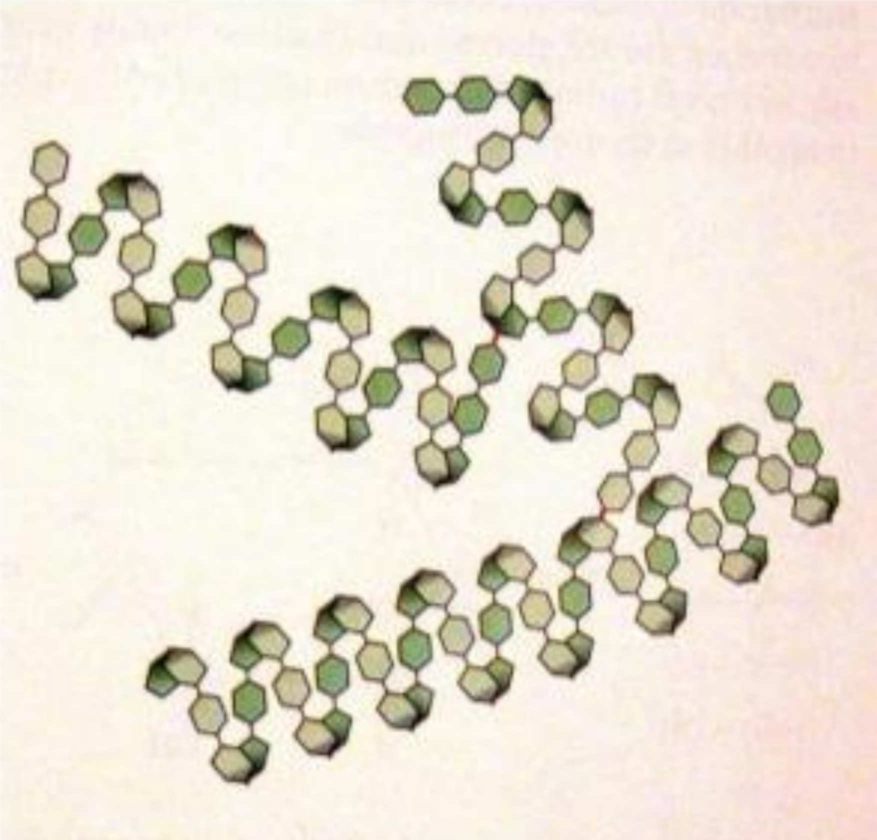


Amylose
only alpha 1-4
glycosidic bonds (a

Starch Vs Glycogen…



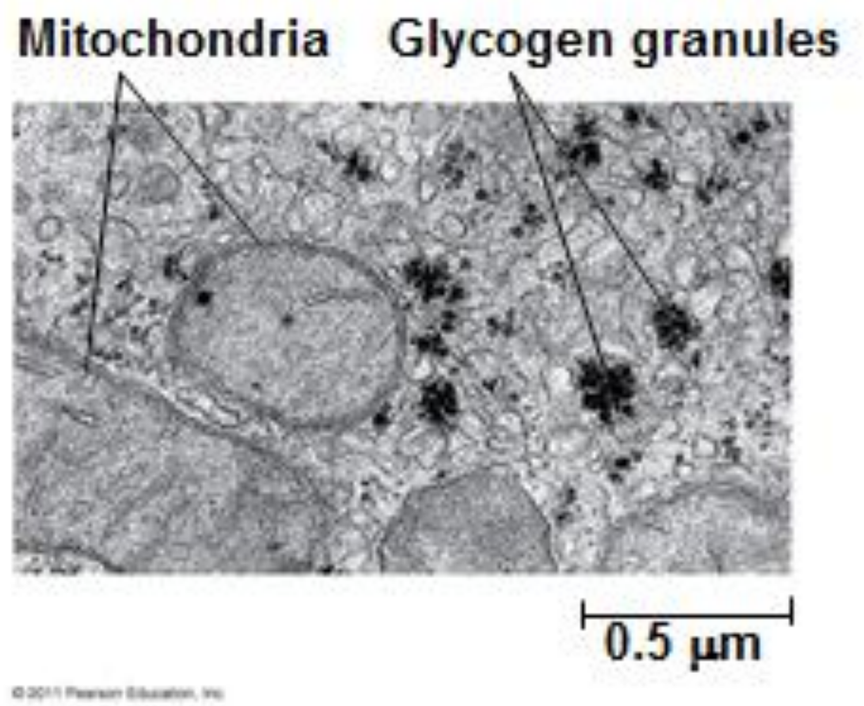
(a) Two forms of starch

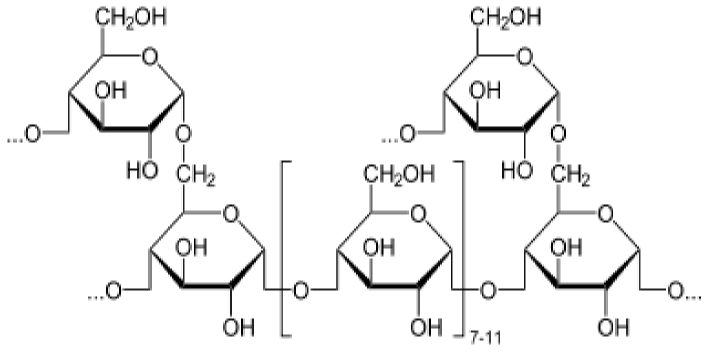


(b) Glycogen

- This gives starch a less fibrous quality and a more granule-like shape which is better suited for storage.
- Unlike the linear structure of Amylose, the Amylopectin starches are branched containing an alpha 1,6 glycosidic linkage about every 30 glucose units.
- Like amylose it is a homopolymer composed of many glucose units.

- 2. Glycogen is a storage polysaccharide in animals
- Humans and other vertebrates store glycogen mainly in liver and muscle cells





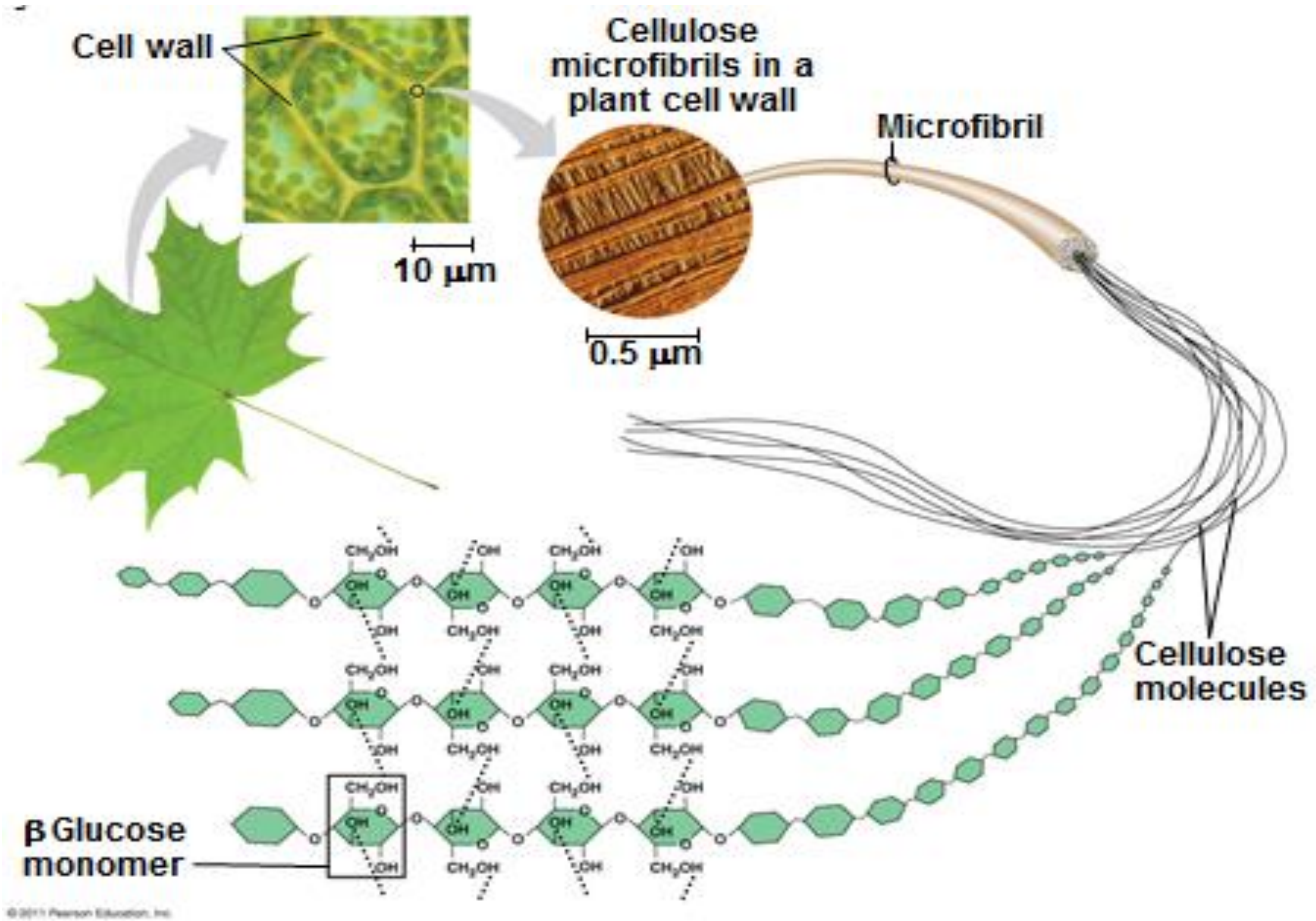
- Glycogen is found in animals, and it is branched like amylopectin.
- It is formed by mostly alpha 1,4 glycosidic linkages but branching occurs more frequently than in amylopectin as alpha 1,6 glycosidic linkages occur about every ten units.
- Other polysaccharides have structural functions.

Structural polysaccharides

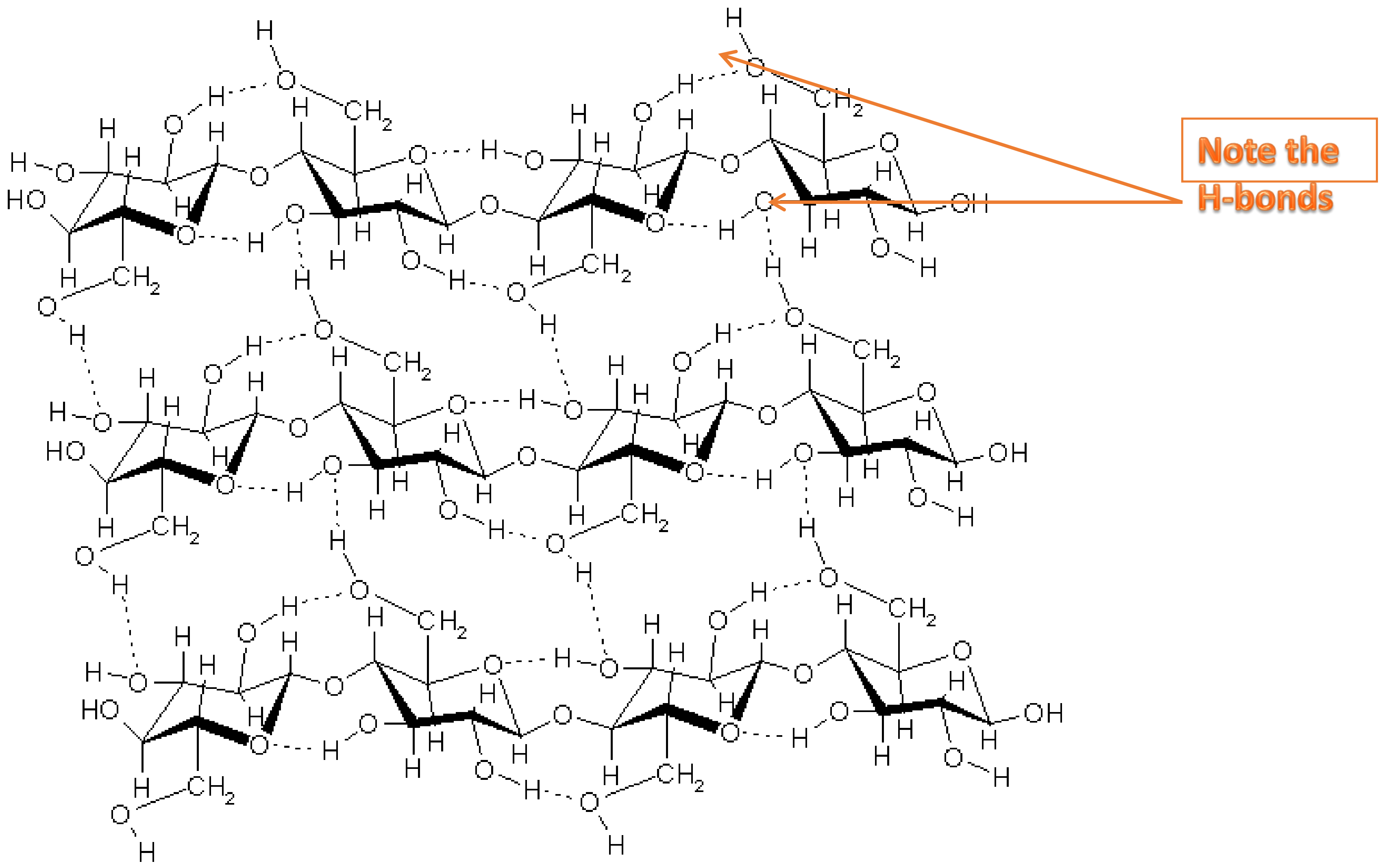
- Cellulose is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ
- The difference is based on two ring forms for glucose: alpha (α) and beta (β)

- Cellulose is a major component in the structure of plants.
- Cellulose is made of repeating beta 1,4-glycosidic bonds.
- These beta 1,4-glycosidic bonds, unlike the alpha 1,4 glycosidic bonds, force celullose to form long and sturdy straight chains that can interact with one another through hydrogen bonds to form fibers.

Such Elegance!



Cellulose: A termite's best friend!

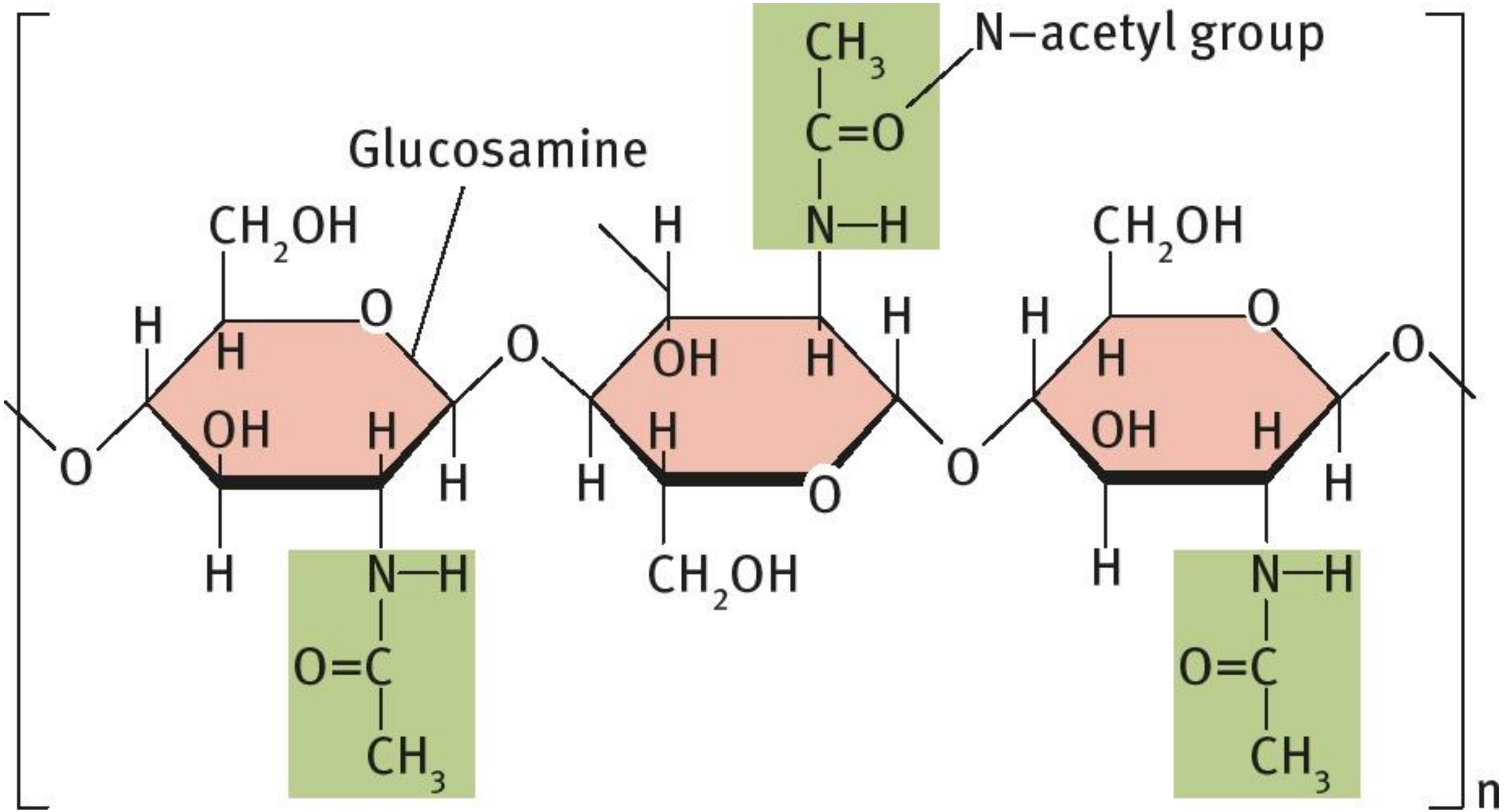


Polysaccharide Random Acts of Biology

- **Cellulose** in human food passes through the digestive tract as insoluble fiber
- Some microbes use enzymes to digest cellulose
- Many herbivores, from cows to termites, have symbiotic relationships with these microbes

- **Chitin**, another structural polysaccharide, is found in the exoskeleton of arthropods (crunch!)
- Chitin is a large, structural polysaccharide made from chains of modified glucose.
- **Chitin** also provides structural support for the cell walls of many fungi

STRUCTURE OF CHITIN



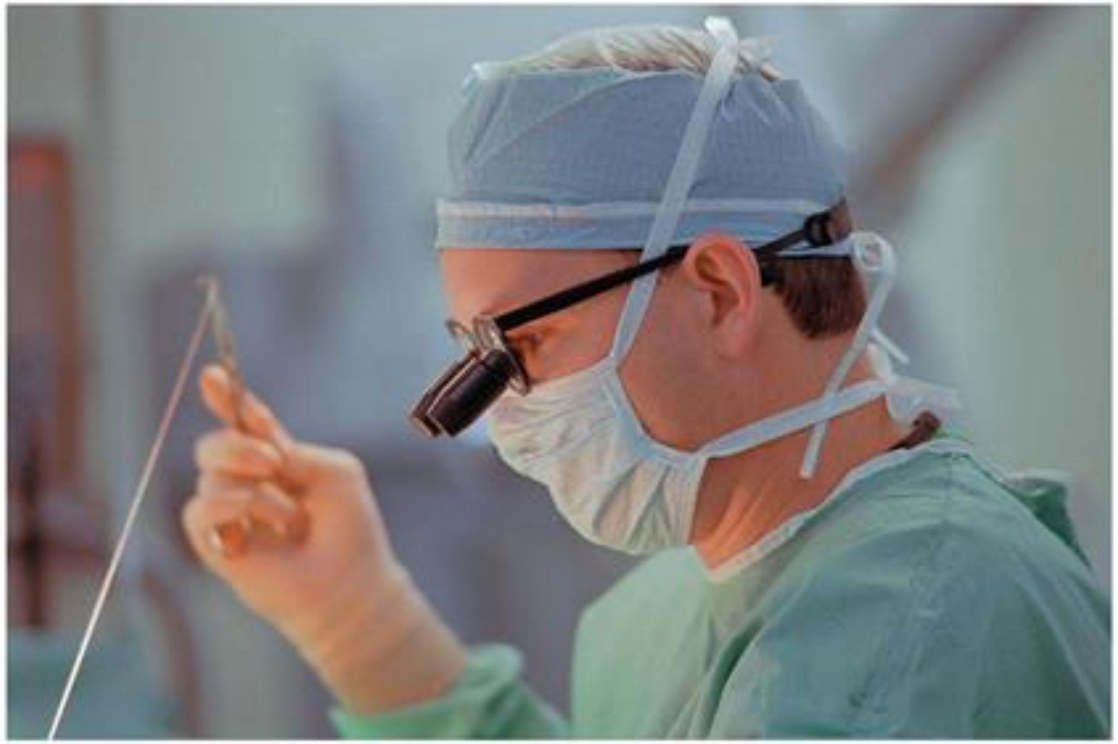
- Chitin is found in the exoskeletons of insects, the cell walls of fungi, and certain hard structures in invertebrates and fish.
- In terms of abundance, chitin is second to only cellulose.
- Like cellulose, no vertebrate animals can digest chitin on their own.

- Animals that eat a diet of insects often have symbiotic bacteria and protozoa which can break down the fibrous chitin into the glucose molecules that compose it.

- However, because chitin is a biodegradable molecule that dissolves over time, it is used in a number of industrial applications, such as surgical thread and binders for dyes and glues.

Who knew?

▲ Chitin forms the exoskeleton of arthropods.



▲ Chitin is used to make a strong and flexible surgical thread that decomposes after the wound or incision heals.

Chemistry of Proteins

Introduction

- A **protein**, made of **C,H,O,N/S**, is a naturally occurring, extremely complex substance that consists of amino acid residues joined by peptide bonds.
- They are present in all living organisms and include many essential biological compounds such as enzymes, hormones, and antibodies.

- They perform many functions within organisms, including
  - ✓ Catalyzing metabolic reactions,
  - ✓ DNA replication
  - ✓ Responding to stimuli
  - ✓ Providing structure to cells, tissues and organisms

- ✓Transporting molecules from one location to another.

- They differ from one another primarily in their sequence of amino acids, dictated by the Nucleotide sequence the DNA, which usually results in protein folding to a specific 3D picture determining its activity.

Protein sources

- Animal origin (slaughterhouse by products) and dried fish meals
- Plant origin (cottonseed meal,
- soybean meal, linseed meal, peanut meal, corn meal)

Feed Protein content

- Total amount of protein in a feed is calculated by multiplying the nitrogen % content with a constant factor of 6.25
- This measures the crude protein content of the feed

Digestible Protein

- Is the protein in a feed that can be digested and used by the animal
- It is usually about 50-80% of crude protein depending on the feedstuff carrying it

Protein requirement

- Some animals need more protein than others
- Young animals require more proteins than adults
- Lactating animals need more protein than a dry cow

Functions of proteins

- Some amino acids and their derivatives function as neurotransmitters and other as regulators
- Examples include L-dopamine, Epinephrine, Thyroxine and Histidine

- Proteins are generally the building blocks of life
- Are used for tissue development and muscle production
- Enzymes are composed of proteins
- They can also be used to supply energy

Essential amino acids

- Of the 20 amino acids that make up proteins, 10 of them can be synthesized by the animal's body
- The other 10 amino acids must be acquired from food sources.
- These amino acids are known as **essential amino acids**

10 essential amino acids

1. Arginine
2. Histidine
3. Isoleucine
4. Leucine
5. Lysine
6. Methionine
7. Phenylalanine
8. Threonine
9. Tryptophan
10. Valine

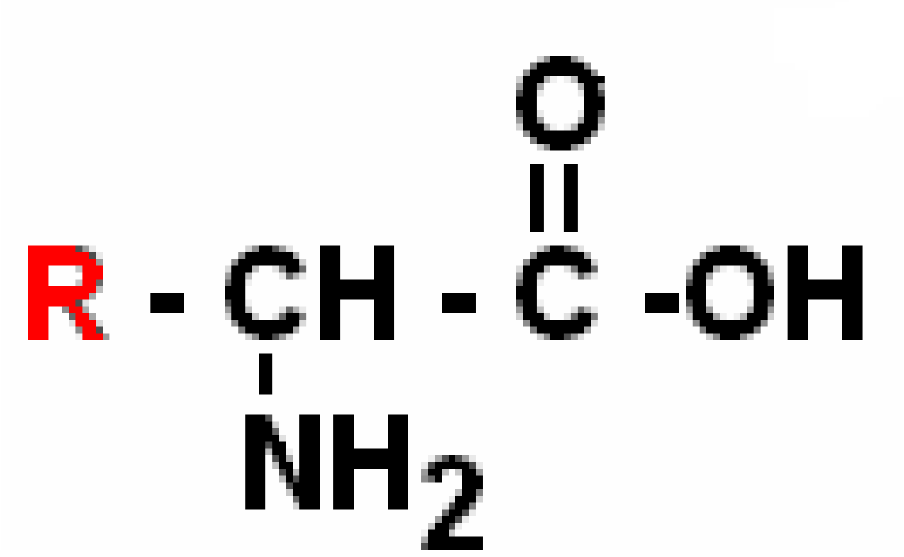
PVT
TIM
HALL

Non essential amino acids

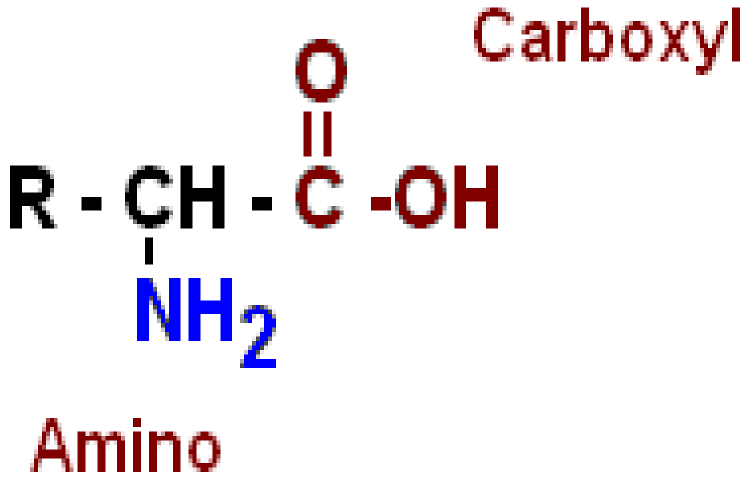
1. Alanine
2. Asparagine
3. Aspartic Acid
4. Cysteine
5. Glutamic Acid
6. Glutamine
7. Glycine
8. Proline
9. Serine
10. Tyrosine

Amino Acid Structure

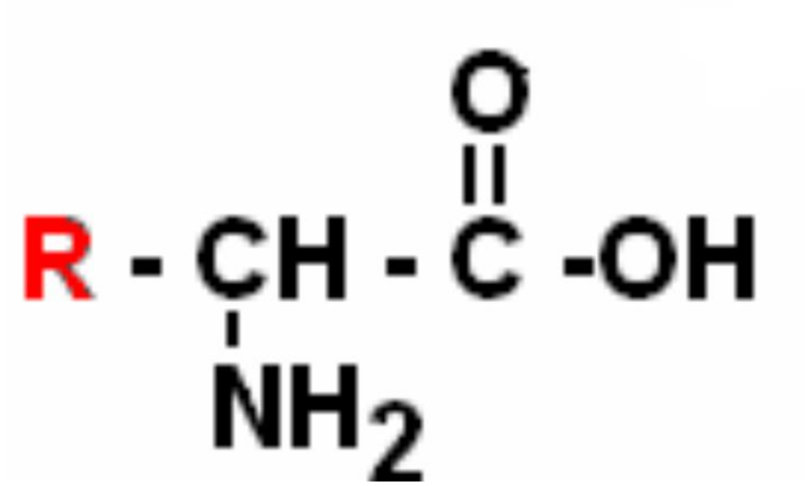
- The general formula of an amino acid is shown here:



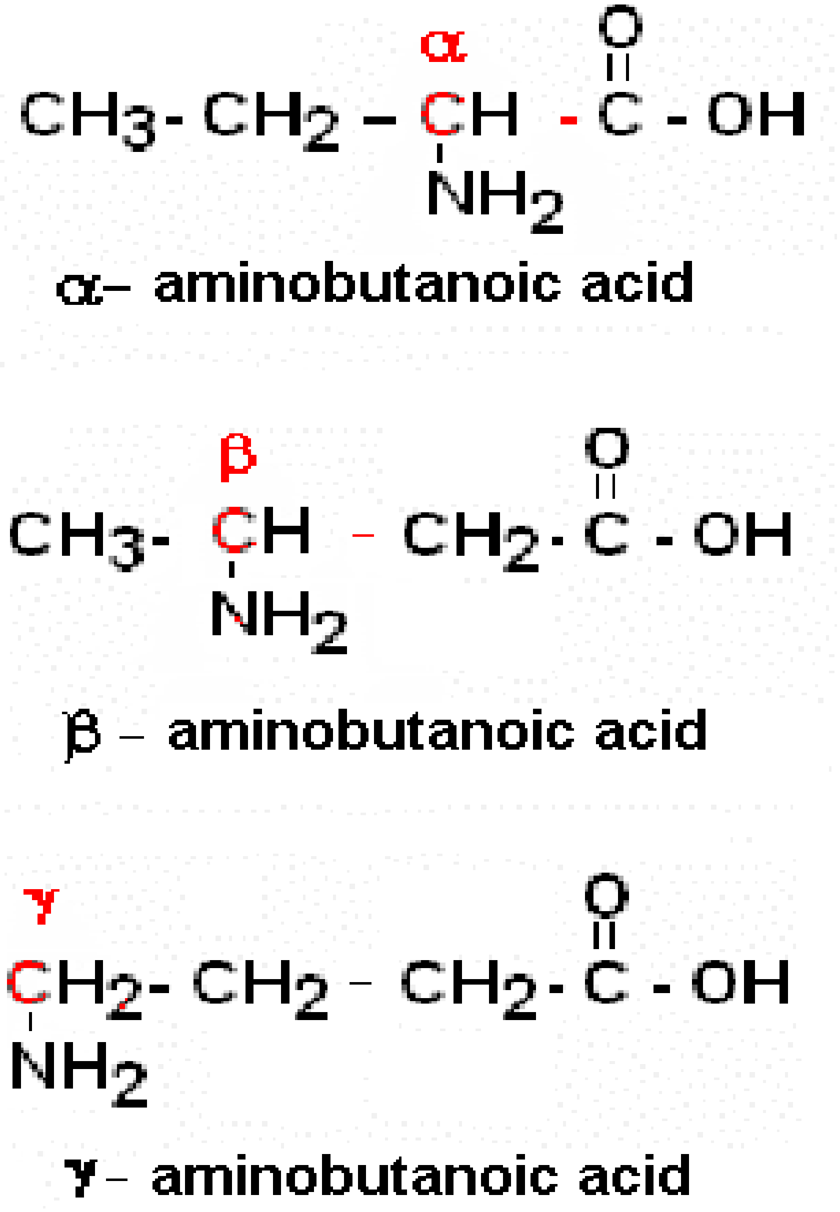
- Amino acids have both a carboxyl group (-COOH) and an amino group (-NH2) in the same molecule.



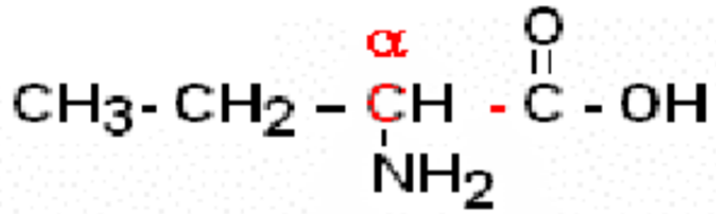
- The group designated by **R** is usually a carbon chain but other structures are also possible



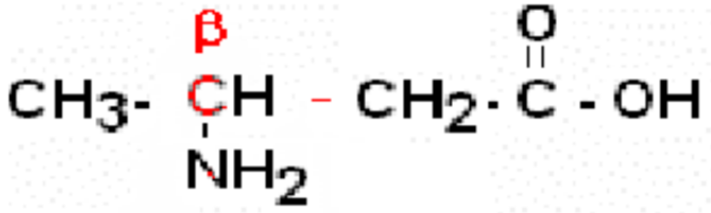
- Amino acids may be characterized as α, β , or γ amino acids depending on the location of the amino group in the carbon chain.



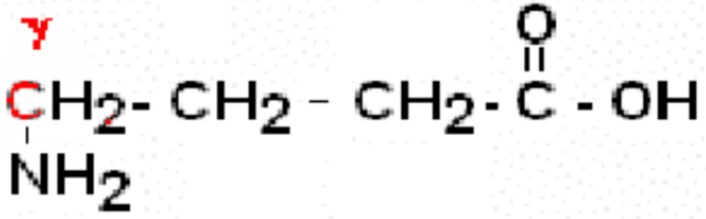
- α are on the carbon adjacent to the carboxyl group.
- β are on the second carbon after the carboxyl group
- γ on the third carbon from the carboxyl group



α– aminobutanoic acid

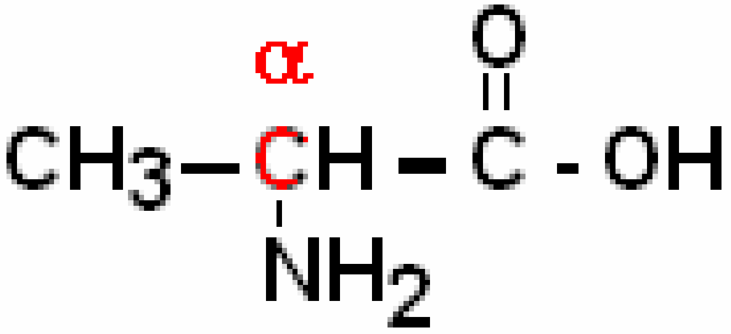


β – aminobutanoic acid



γ – aminobutanoic acid

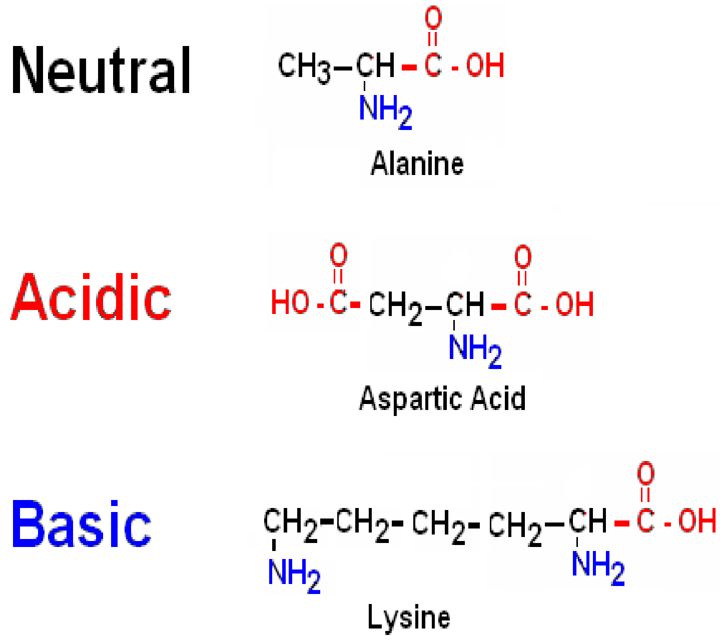
- Most Amino acids found in proteins are α amino acids because the amino group is always found on the carbon adjacent to the carboxyl group



Alanine is an α amino acid

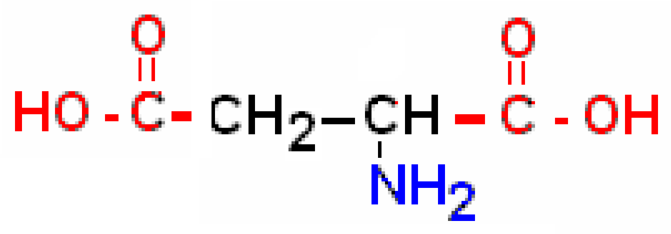
Amino acid classification

- Amino acids may be characterized as Acidic, Basic, or **Neutral** depending on the character of the side chain attached.

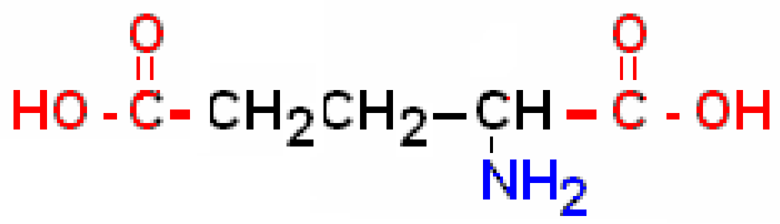


Acidic Amino Acids

- There are two acidic amino acids.
- In their structures, there are two carboxyl groups but only one amino group per molecule



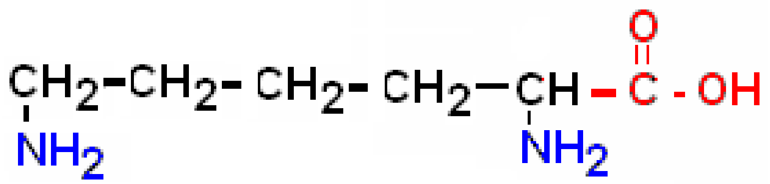
Aspartic Acid



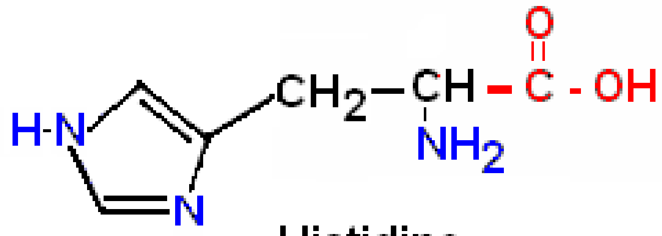
Glutamic Acid

Basic Amino Acids

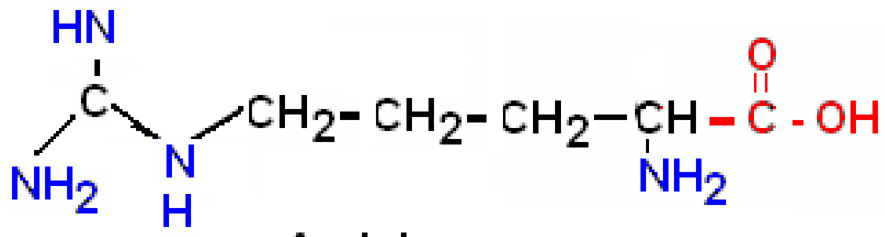
- These amino acids are basic because they have more amino groups than carboxyl groups



Lysine

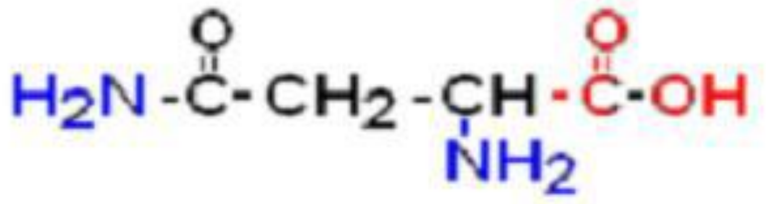


Histidine

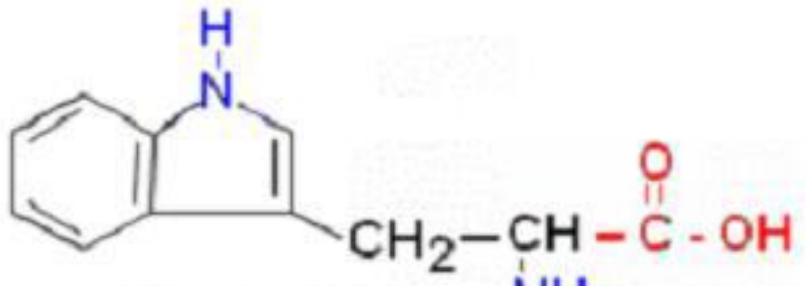


Arginine

- These amino acids are also basic.
- They have more amino groups than carboxyl groups



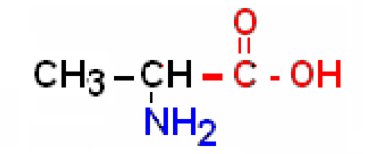
Asparagine



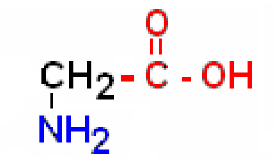
Tryptophan

Neutral amino acids

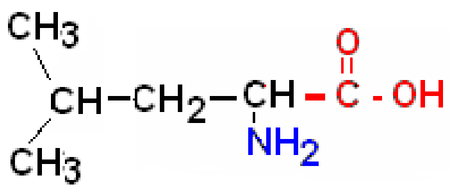
- These amino Acids are considered neutral because there is one carboxyl group per amino group



Alanine

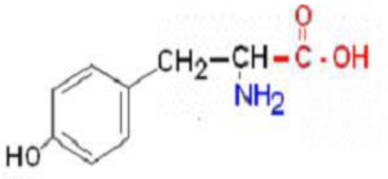


Glycine

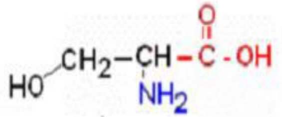


Leucine

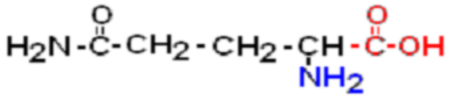
Neutral Amino acids



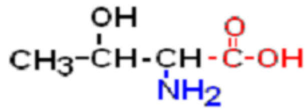
Tyrosine



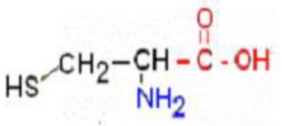
Serine



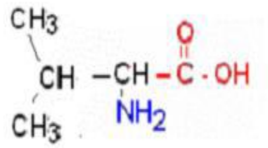
Glutamine



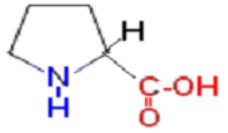
Threonine



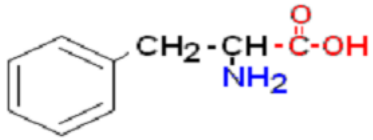
Cysteine



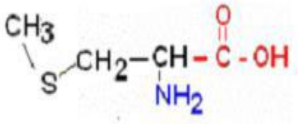
Valine



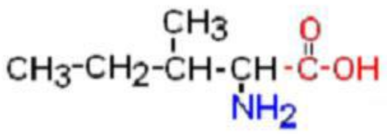
Proline



Phenylalanine



Methionine



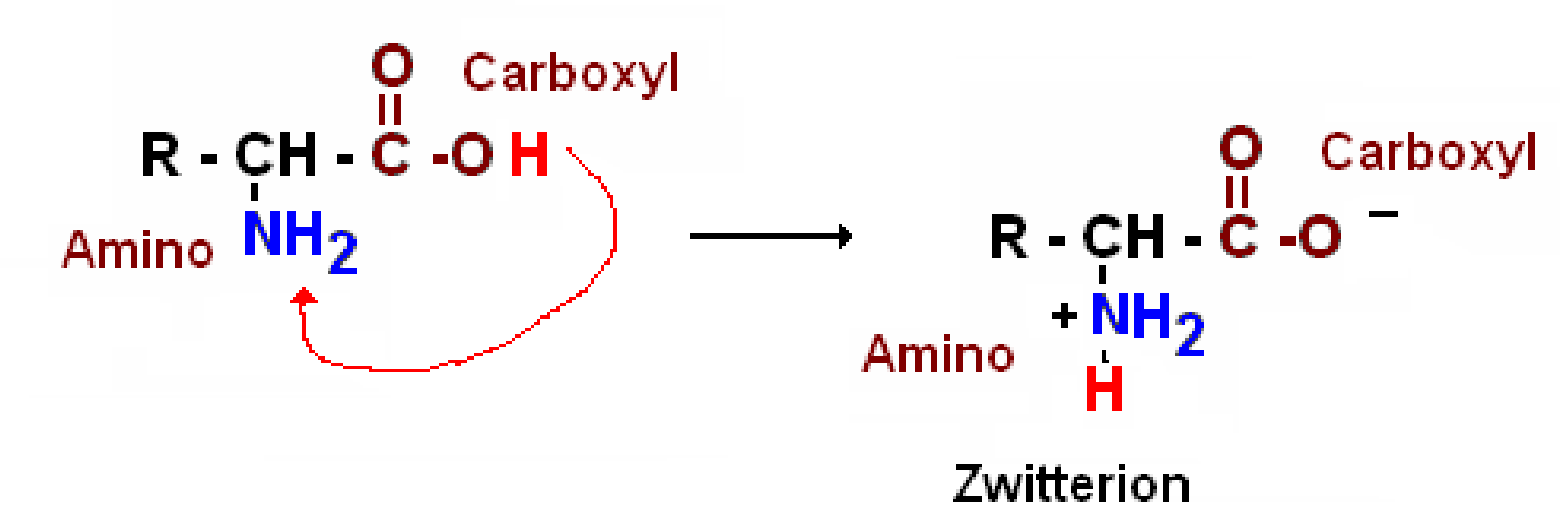
Isoleucine

- There are equal numbers of carboxyl groups and amino groups.

- Amino acids are amphoteric

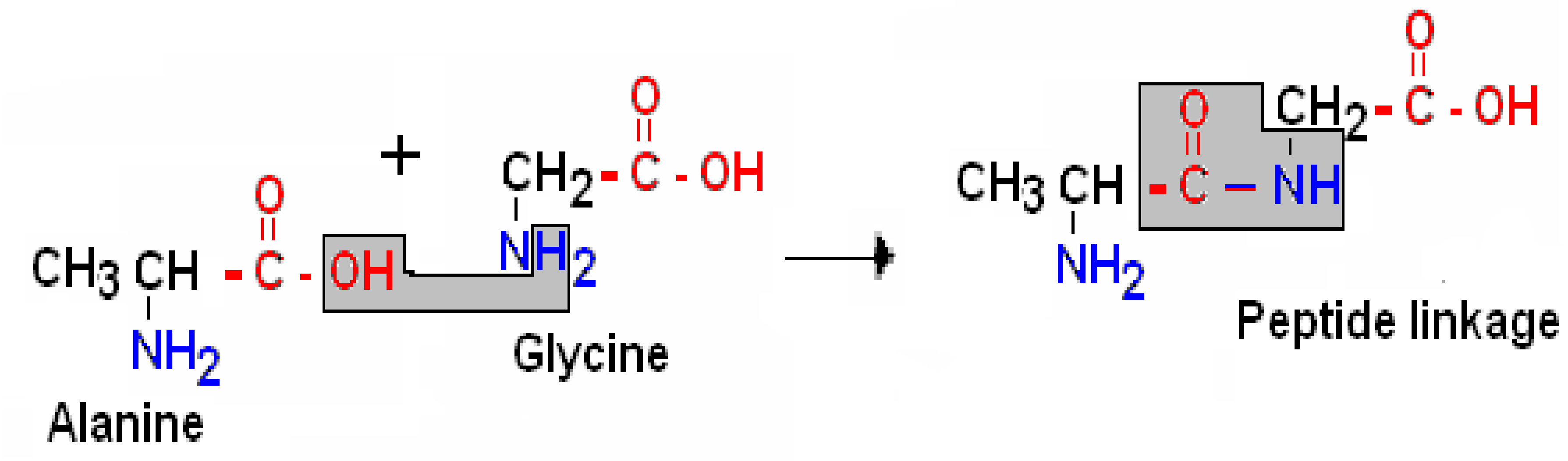
- They are capable of behaving as both an acid and a base, since they have both a proton donor group and a proton acceptor group

- In neutral aqueous solutions the proton typically migrates from the carboxyl group to the amino group, leaving an ion with both a (+) and a (-) charge.



Peptide bonds

- When two amino acids combine, there is a formation of an amide and a loss of a water molecule



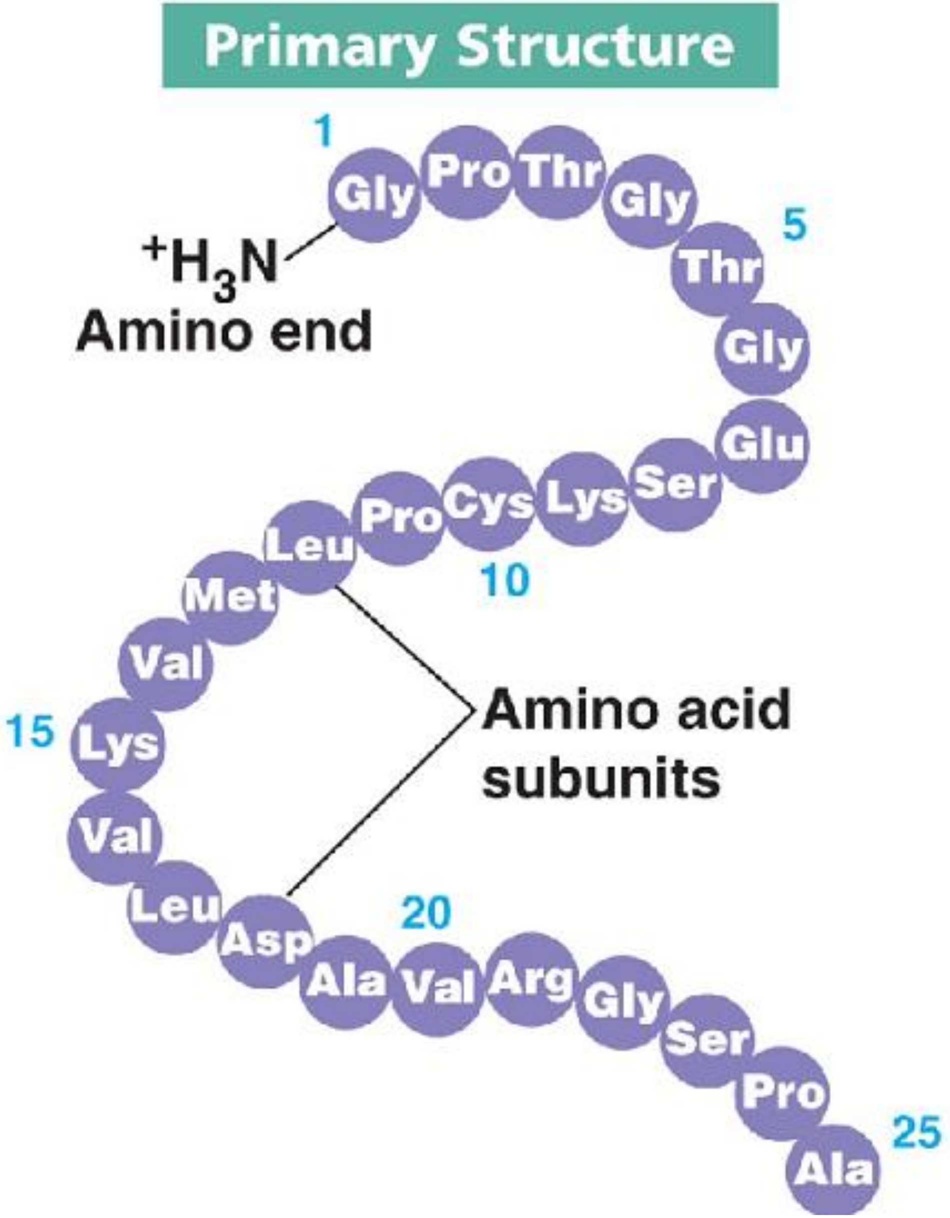
Levels of structures

- Amino acids can undergo condensation reactions in any order, thus making it possible to form large numbers of proteins.

- Structurally, proteins can be described in four ways
  1. Primary
  2. Secondary
  3. Tertiary
  4. Quaternary structure

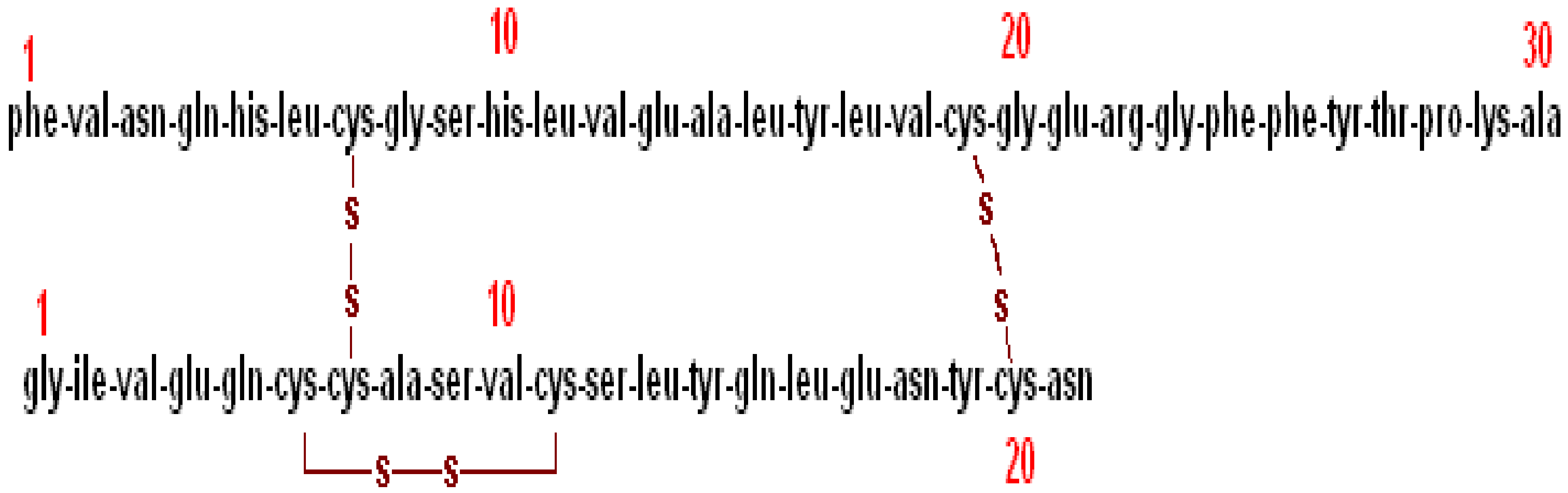
1. Primary structure

- The primary structure of a protein is defined by the sequence of amino acids, which form the protein.
- This sequence is determined by the base pair sequence in the DNA used to create it.



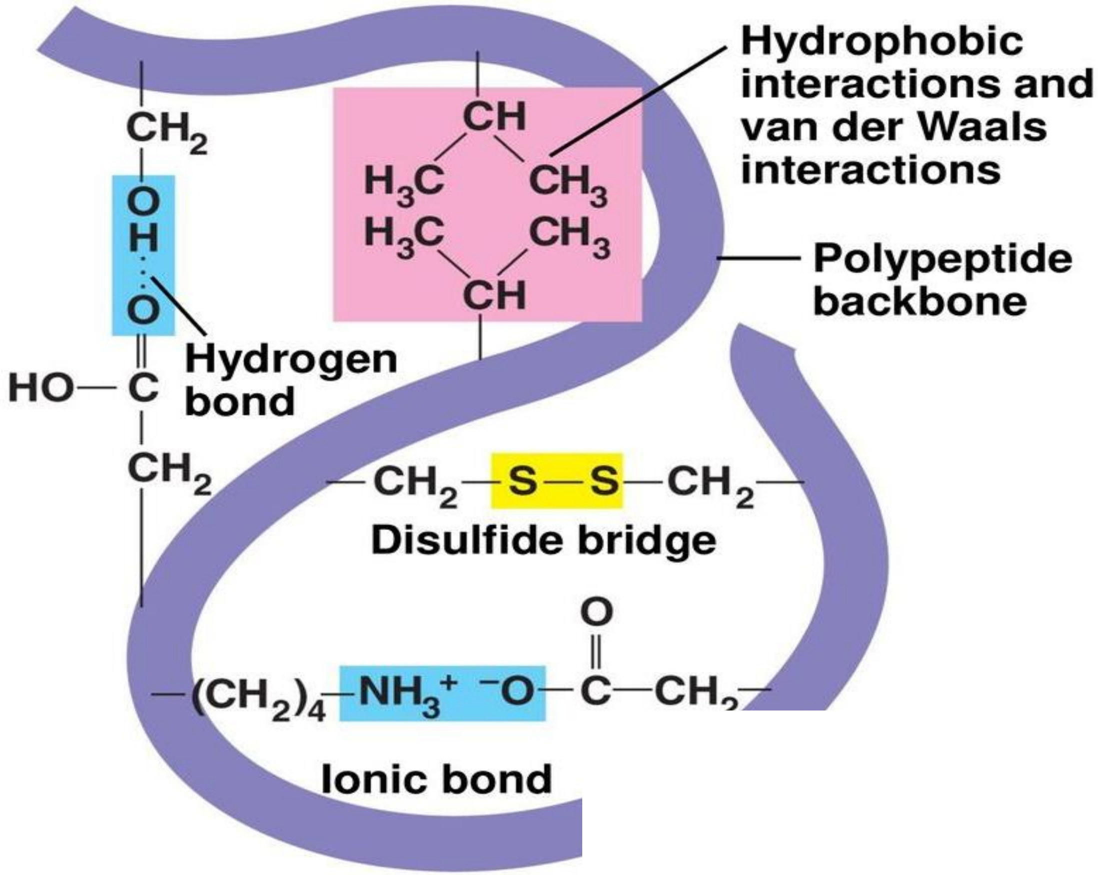
Primary Structure
1
Gly
Pro
Thr
Gly
5
Thr
Gly
Glu
Ser
Lys
Cys
Pro
Leu
10
Met
Val
15
Lys
Val
Leu
Asp
20
Ala
Val
Arg
Gly
Ser
Pro
25
Ala
$^{+}H_3N$
Amino end
Amino acid
subunits

- The sequence for bovine insulin is shown below

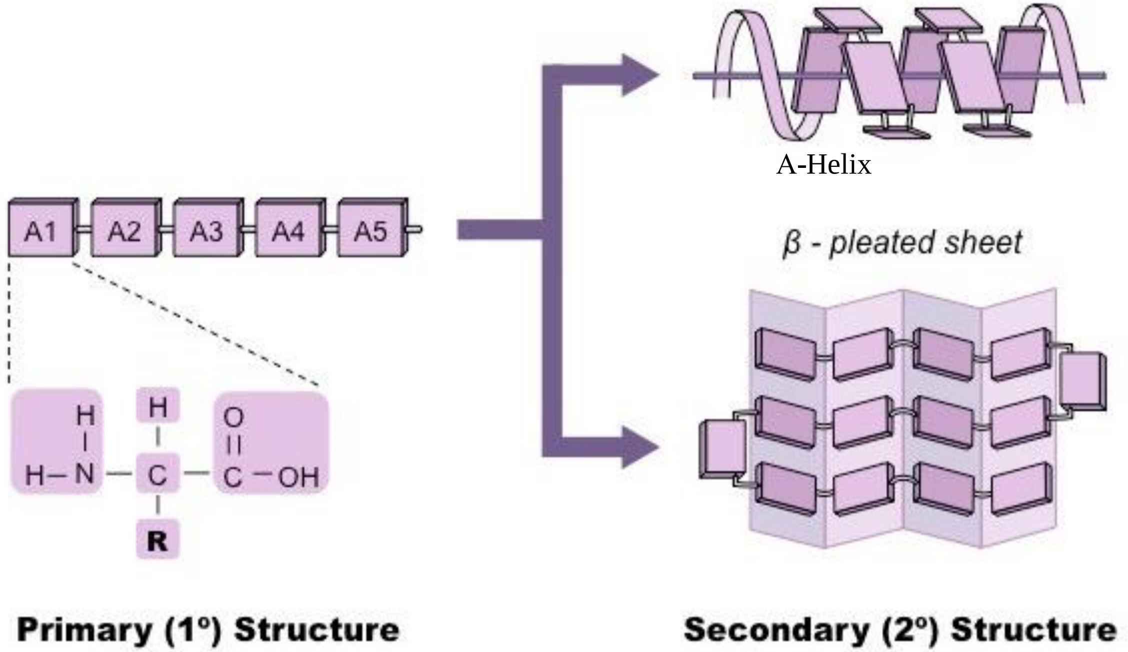


2. Secondary structure

- The secondary structure describes the way that the chain of amino acids folds itself due to intramolecular hydrogen bonding
- Two common secondary structures are;



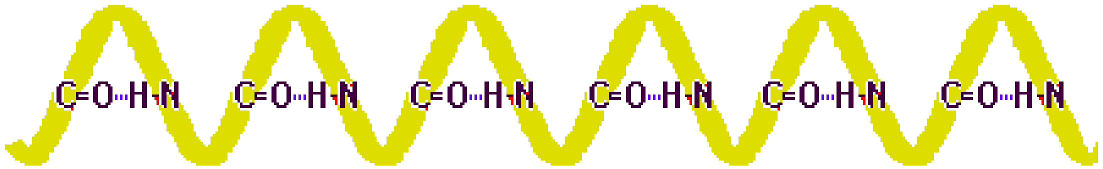
Hydrophobic interactions and van der Waals interactions
Polypeptide backbone
Hydrogen bond
Disulfide bridge
Ionic bond



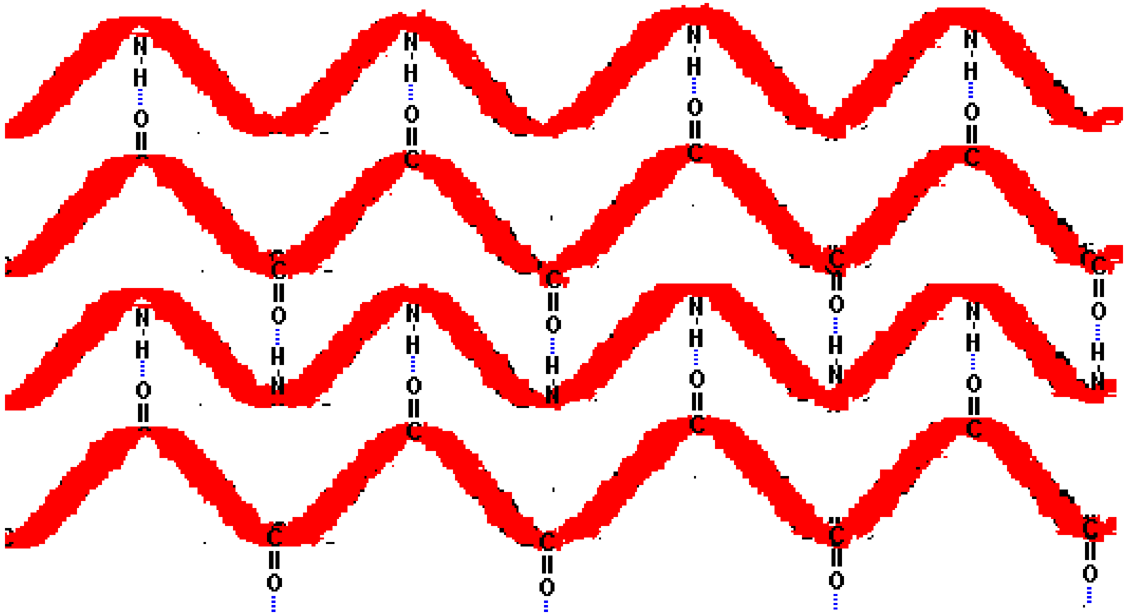
A-Helix
β - pleated sheet
A1 A2 A3 A4 A5
Primary (1°) Structure
Secondary (2°) Structure

- Follows localized comformation of the chain; the folding exhibited by the protein

The α-Helix



The β sheet



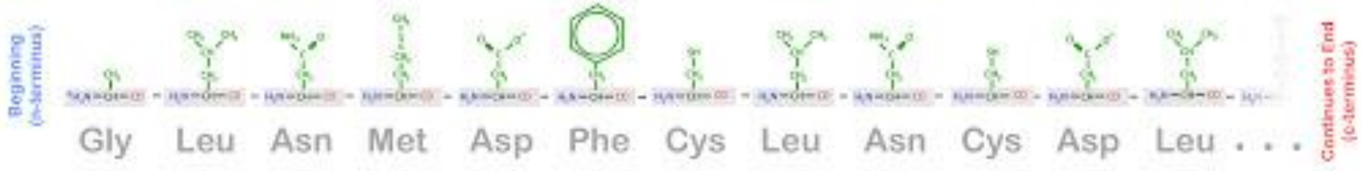
3. Tertiary structure

- Is the arrangement of the secondary structures into this final 3-dimensional shape.
- The sequence of AA in a protein will determine where α-helices and β-sheets (the secondary structures) will occur.

- These secondary structure motifs then fold into an overall arrangement that is the final 3-dimensional fold of the protein (the tertiary structure).
- Each unique sequence of amino acids gives rise to a unique protein type, with a unique shape and function.

Primary Structure

The Sequence of Amino Acids in a Protein

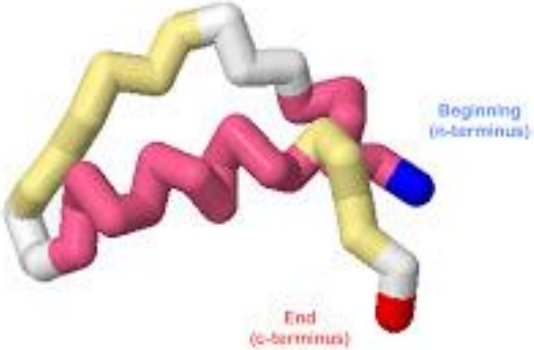


Secondary Structure

Alpha Helix and Beta Sheet Motifs in a Protein

Tertiary Structure

The Overall
3-Dimensional Shape
of a Protein



Note: For visual clarity, the R-groups (sidechains) are not shown in the secondary and tertiary structure illustrations.

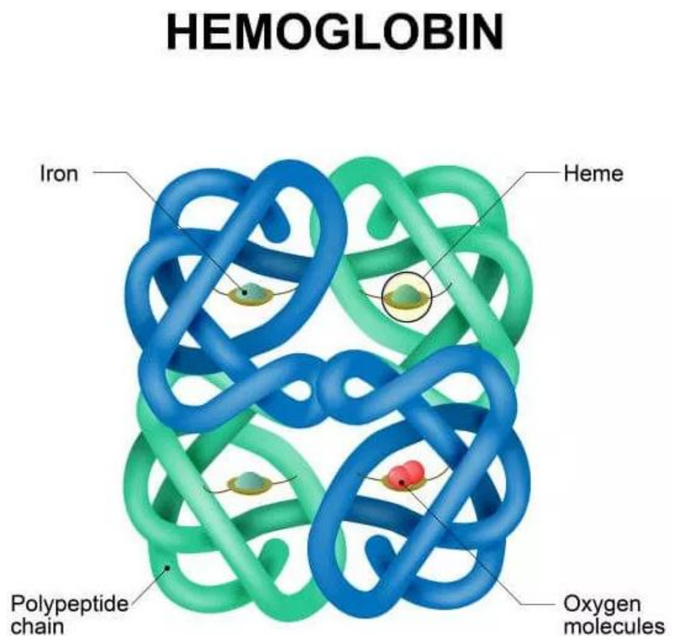
4. Quaternary structure

- Quaternary structure is the association of several protein chains or subunits into a closely packed arrangement.
- Each of the subunits has its own primary, secondary, and tertiary structure.

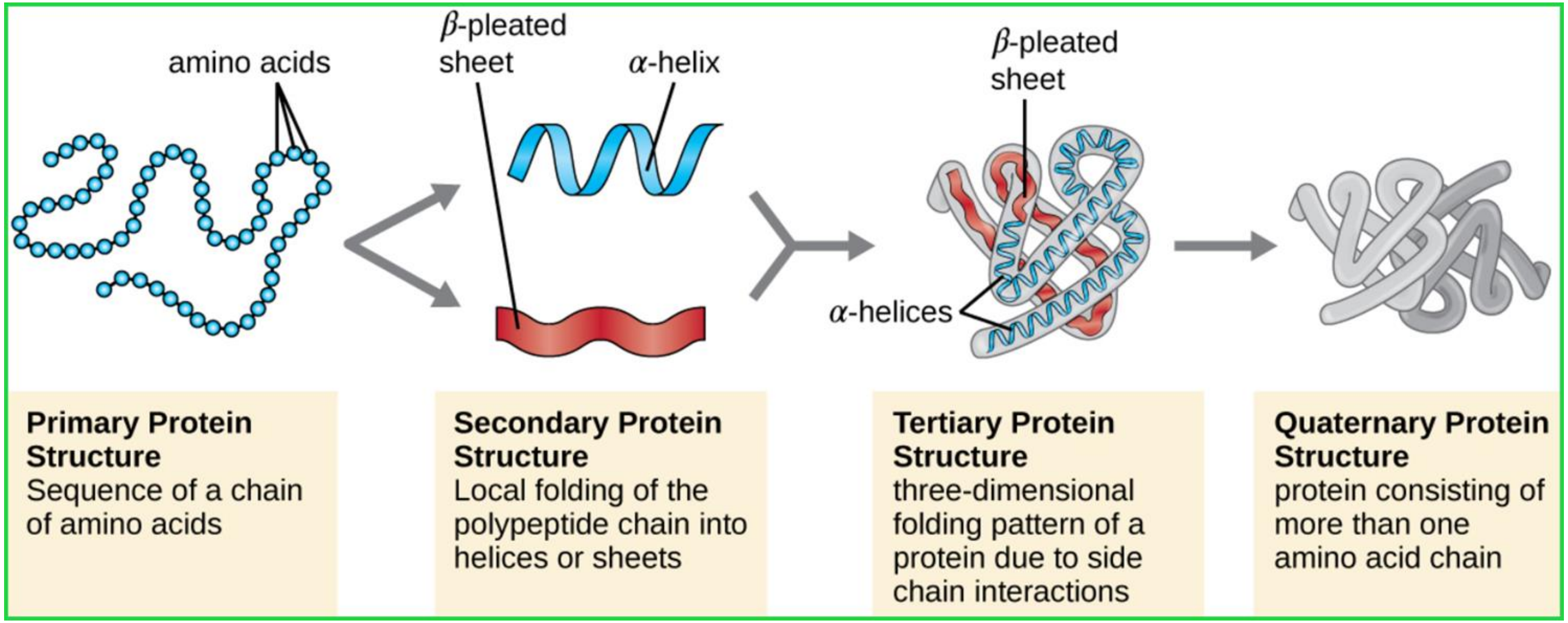
- The subunits are held together by hydrogen bonds and van der Waals forces between nonpolar side chains

Quaternary Protein Structure
protein consisting of more than one amino acid chain

- One example of a quaternary protein structure is *hemoglobin.*
- Hemoglobin is made up of four polypeptide chains, and is specially adapted to bind oxygen in the blood



Summary of structures

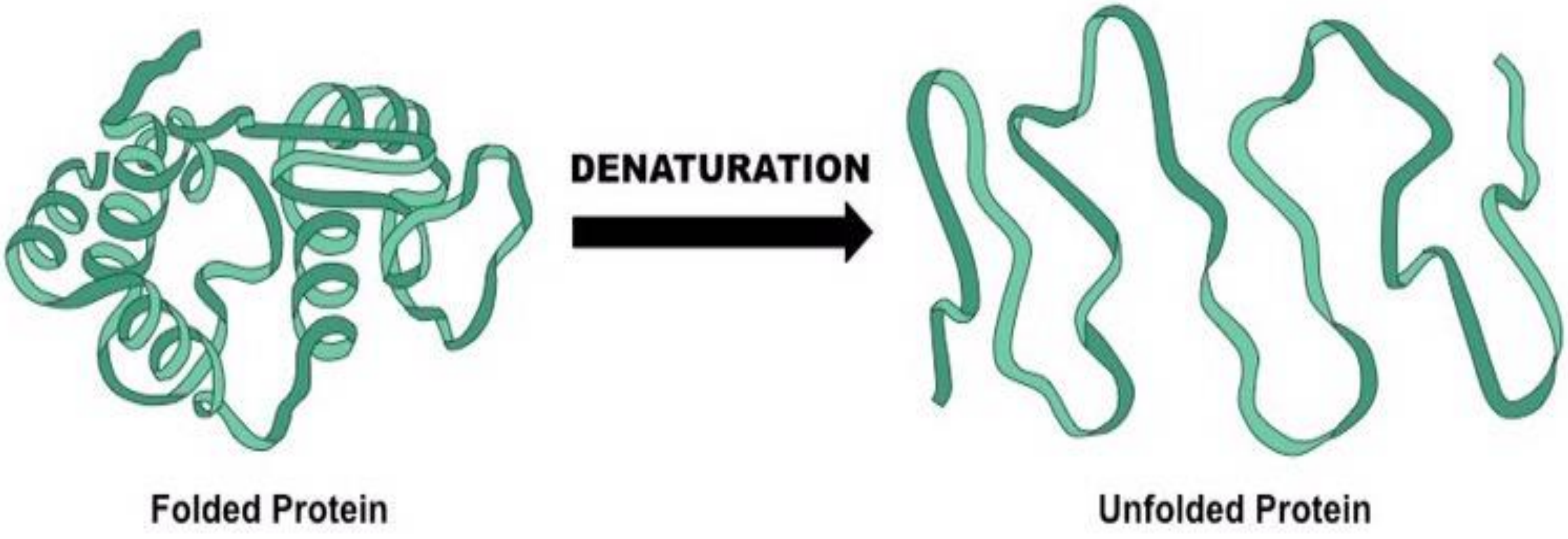


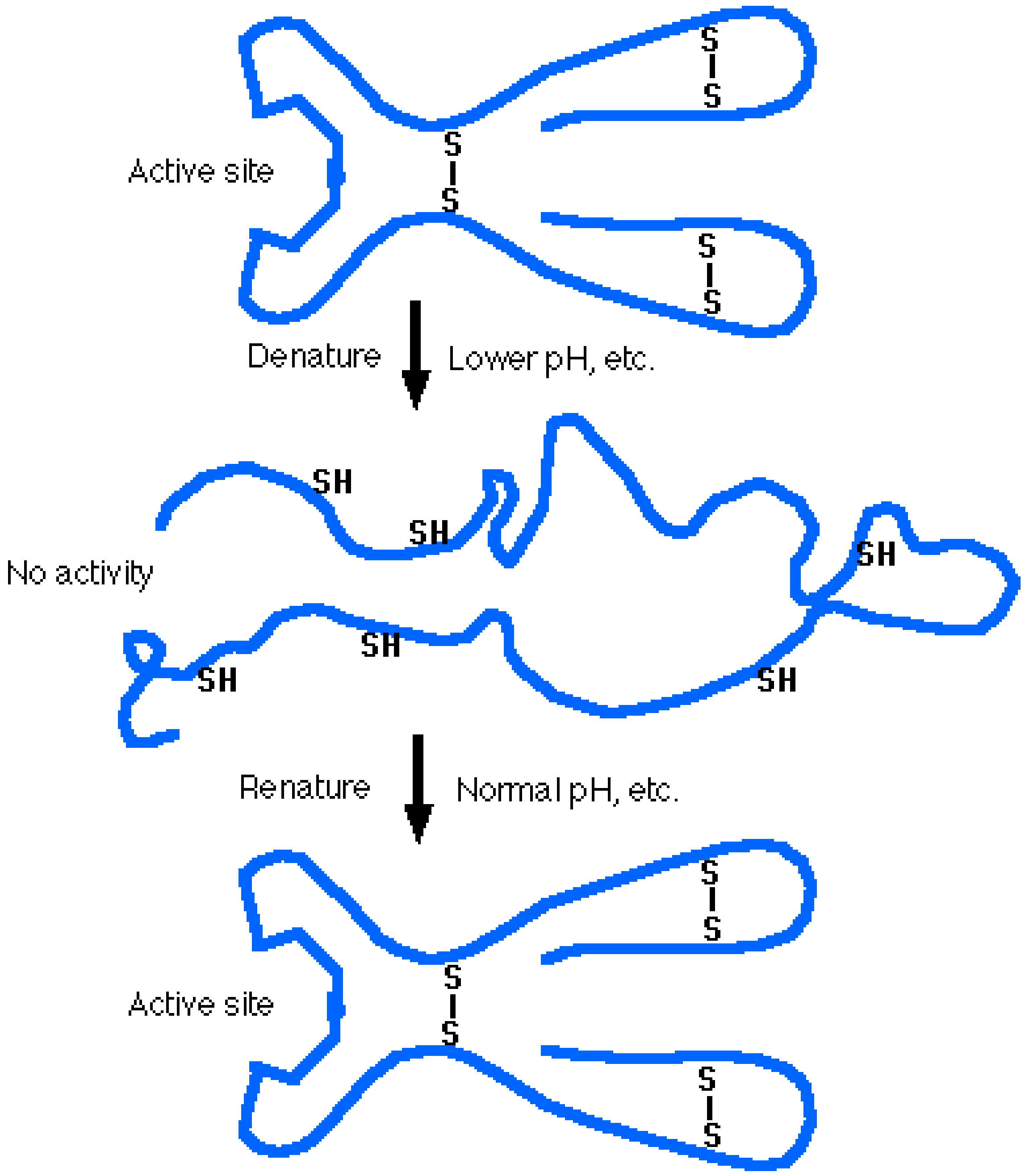
Denaturing Proteins

- Denaturation is a process in which a protein losses its native shape due to the disruption of weak bonds and interactions, thereby becoming biologically inactive.

- Denaturation involves transformation of a well-defined folded structure of a proteins formed under physiological conditions, to an unfolded state under non-physiological conditions is called protein denaturation.

- In case of proteins,
  - A loss of 3D structure is sufficient to cause loss of function
  - Loss of secondary, tertiary and quaternary structure
  - Change in physical, chemical and biological properties of proteins

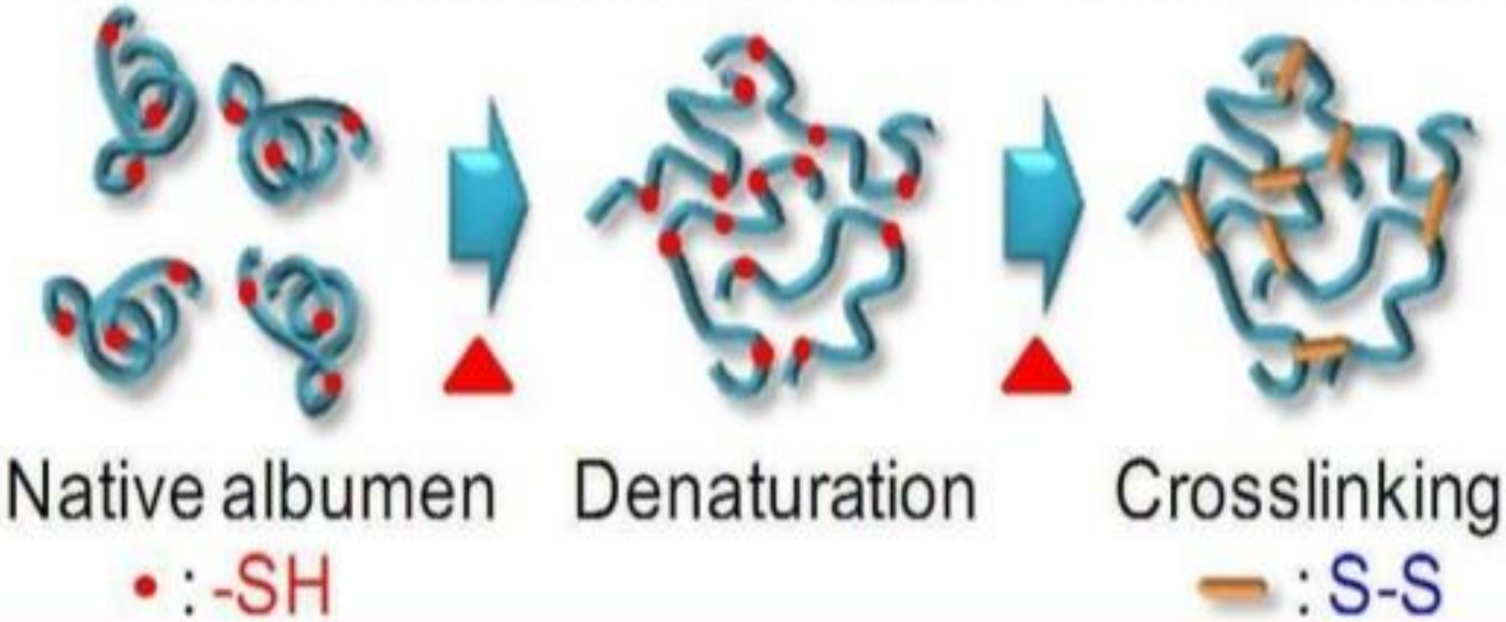

DENATURATION
Folded Protein
Unfolded Protein



Active site
S
S
S
S
S
S
Denature
Lower pH, etc.
No activity
SH
SH
SH
SH
SH
SH
Renature
Normal pH, etc.
Active site
S
S
S
S
S
S

(a) Denaturation of egg protein:

(b) Protein Thermal Irreversible Denaturation



- Changing pH denatures proteins because it changes the charges on many of the side chains which disrupts electrostatic attractions and H bonds.
- Certain reagents such as urea and guanidine hydrochloride denature proteins by forming hydrogen bonds formed between the groups

- Detergents such as sodium dodecyl sulphate denature proteins by associating with the non-polar groups of protein, thus interfering with the normal hydrophobic interactions.
- Organic solvents such as acetone alcohols denature proteins by disrupting hydrophobic interactions

- Proteins can also be denatured by heat. Heat increase molecular motion which can disrupt the attractive forces.
- None of these agents breaks the peptide bonds, so the primary structure of proteins remains intact when it is denatured.

- A denatured enzyme ceases/stops its function.
- A denatured antibody no longer binds to its antigen.
- A denatured milk proteins losses its biological activity

- The denatured state does not necessarily mean that complete unfolding or denaturation of protein and randomization of confirmation.
- Under some of the conditions these proteins exhibit both properties such as denaturation and renaturation

- Unfolding of native proteins occurs both at higher temperature (heat denaturation or thermal denaturation) and at at lower temperature (cold denaturation).
- In both the cases there is breakage of hydrogen bonds, disulfide bonds, hydrophobic interactions, vanderwalls forces, but not peptide bonds

Causes of Denaturation

- Denaturation occurs when proteins are exposed to an extreme environment conditions such as;
  - high level of salt,
  - higher level of acidity,
  - higher temperature etc.

Agents causing denaturation

- Physical agents:
  - ➢ Heat
  - ➢ Violent shaking or agitation
  - ➢ Hydrostatic pressure, UV radiation Chemical agents:
  - ➢ Acids and alkalis, Organic solvents, Salts of heavy metals
  - ➢ Detergents
  - ➢ Altered pH

Denaturation by heat

- Heat affects the weak interactions in a protein (primarily H-bonds) in a complex manner.
- If temp is increased slowly, a protein’s conformation generally remains intact until an abrupt loss of structure and function occurs over a narrow temperature range.

- During cooking, this stress causes denaturation which is typically as heat and ultimately proteins gets coagulated.