بسم الله الرحمن الرحيم

# Basic Principles and Perspectives in Medical Chemistry and Biochemistry

## Chemistry of Carbohydrates

## Part-2

Medical and Biochemistry (BIQC-101) Lecture

by

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# Carbohydrates Chemistry

## Learning Objectives

1. Study the chemical structure of polysaccharides
2. Classify polysaccharides
3. Know the biochemical functions and differences between the various heteropolysaccharides
4. Be able to recognize the N and O linked polysaccharides
5. Know how dietary polysaccharides are digested by humans

# Polysaccharides

- Also known as *glycans:* Monosaccharides linked together by *glycosidic bonds* . There are two types of glycan:-

1. Homopolysaccharides (composed of a single type of sugar monomer i.e: cellulose is composed of glucose unit only)
2. Heteropolysaccharides (contain two or more different monosaccharide units heparin composed of D-glucosamine, D-glucoronic and l-iduronic acid).

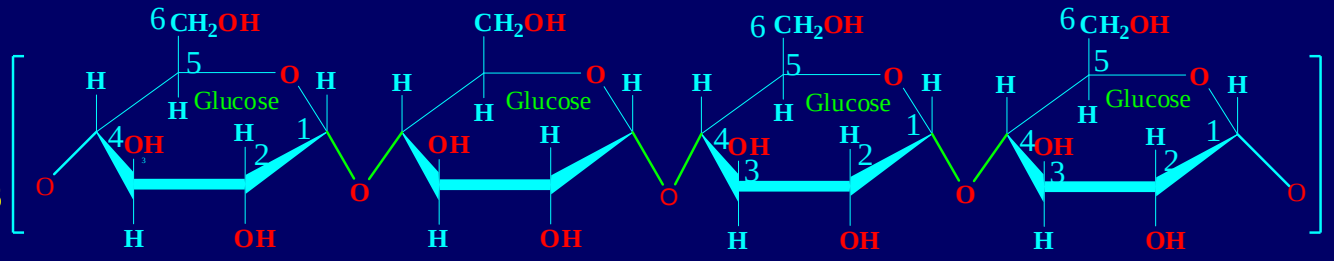
- Form both branched and linear polymers
- Two classes of polysaccharides .

1. Structural Polysaccharides i.e ( 1. Cellulose 2. Chitin)
2. Storage Polysaccharides i.e (1. starch (α-Amylose as straight chain and amylopectine as branched branched) 2. Glycogen its resembles amylopectin, but is more branched. It is degraded by glycogen phosphorylase (cleaves the α (1 - 4) bonds) and a glycogen debranching enzyme (cleaves the α (1 - 6) bonds).

# Homopolysaccharides

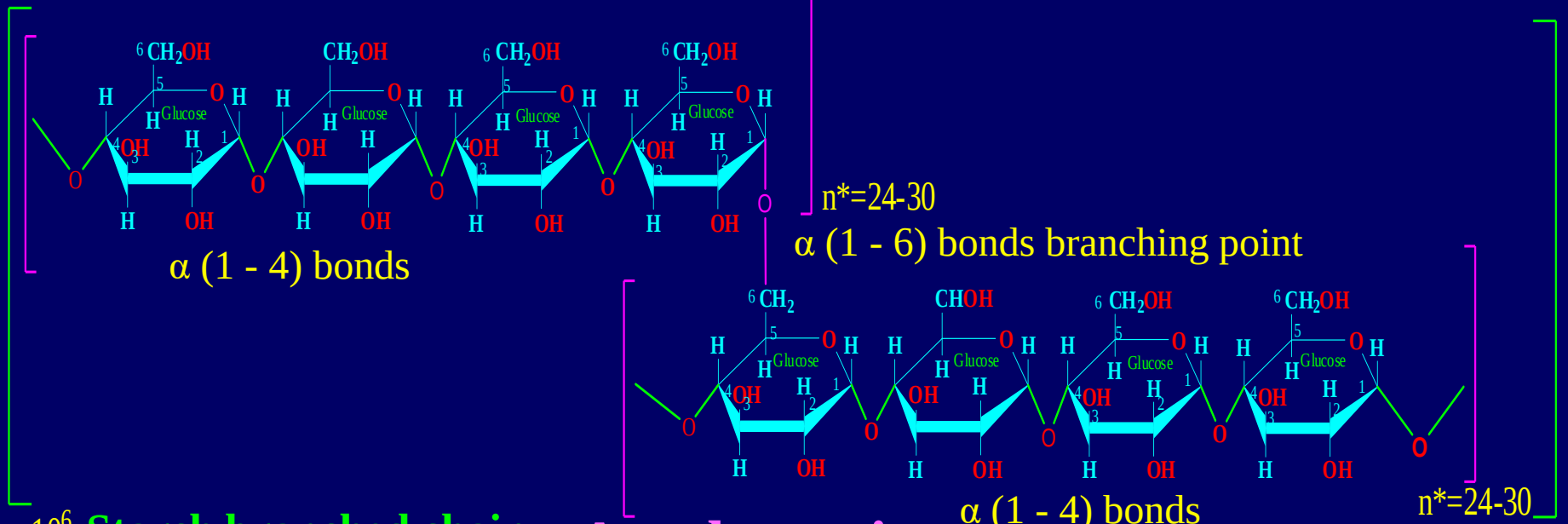
| Homopolysaccharides/ Glycans<br>( More than 10 Monosaccharide Units ) | |
|---|---|
| **Homopolysaccharides/ Homoglycans**<br>**( > 10 Same Repeating Units )** | |
| **Glucosans**<br>**(Repeating Unit of Glucose/Polymer of Glucose)**<br>Starch<br>Glycogen<br>Cellulose<br>Dextrin<br>Dextran | **Fructosans**<br>**(Repeating Unit of Fructose/Polymer of Fructose)**<br>Inulin<br>Used to measure kidney function |

**Starch straight chain** $n=10^6$




α (1 - 4) bonds

## α-Amylose




$n= 10^6$ **Starch branched chain**

## Amylopectine

Up to $10^6$ molecules of glucose residues mainly connected by α (1 - 4) glycisidic bond ,but has branched molecules via α (1 - 6) glycosidic bond every 24-30 glucose residues.

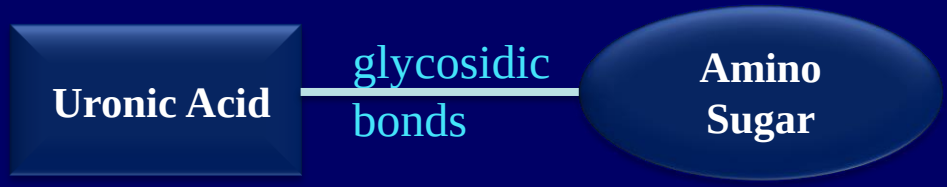
# Heteropolysaccharides

- In general, the most naturally occurring heteropolysaccharides (heteroglycans) contain two or more different monosaccharide units.
- Monosaccharide units or their derivatives repeatedly linked by glycosidic bonds.
- The most important heteropolysaccharides are found in the connective tissues.
- They have a structural role. for example, the major component of joint fluid , functions as a lubricating agent and shock absorber.
- The major heteropolysaccharides include:-

1. Mucopolysaccharides or Glycosaminoglycans
2. Mucoproteins or Proteoglycans

# Mucopolysaccharides Glycosaminoglycans

- Mucopolysaccharides chemically composed of more than 10 monosaccharide units and its derivatives repeatedly linked by glycosidic bonds.
- Mucopolysaccharides are complex, long, linear, unbranched, polyanionic.
- The glycosaminoglycans has disaccharide repeating unit linked by glycosidic bonds.
- GAG's are polyanionic and acidic due to presence of acid and sulfate groups
- GAG's are hydrophilic and attract water and helps in distributing water.

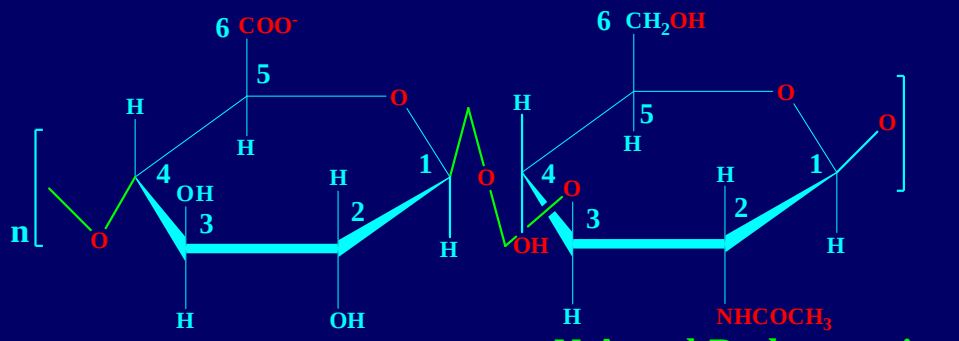



**Uronic Acid**
Glucuronic acid /Iduronic acid

**Amino Sugar**
Glucosamine / Galactosamine (Acetylated or sulfated or both)

- MPS/GAG's imparts following physical properties- high viscosity, high density, high buoyancy.

- Two common example are Hyaluronate and Hyparin
- Hyaluronate made up of repeating units of sugar derivatives glucuronate (glucuronic acid) and *N*-acetylglucosamine.
- Hyaluronic acid is present as ground substance /cementing substance in extra cellular spaces of connective tissue.
- Hyaluronic acid in synovial fluid of joints and vitreous humor of eye serve as lubricant and shock absorbent.



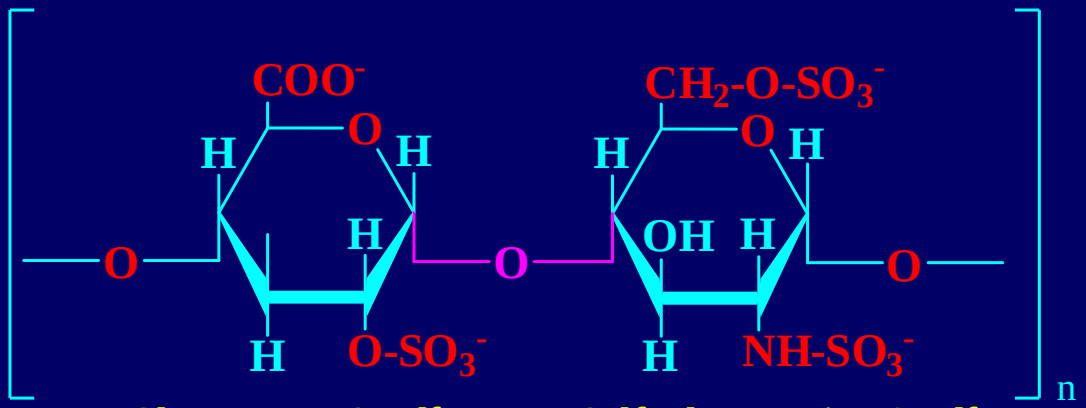

**Hyaluronate**

Glycosidic linkages in Hyaluronate is β (1-3) glycoisidic bond

- Enzyme "Hyaluronidase " hydrolyses hyaluronic acid. hyaluronidase present in head of sperm , hydrolyzes the hyaluronic acid present on ovum which facilitates its penetration and fertilization.

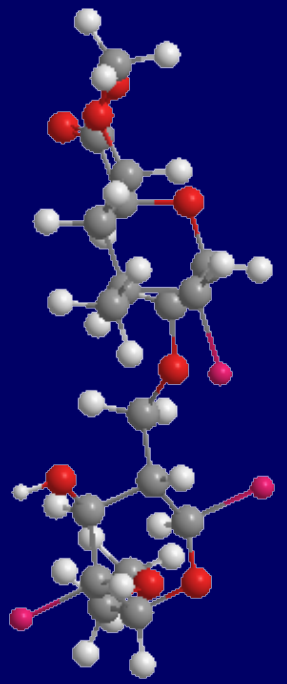
# Hyparin

- The discovery of heparin was announced in 1916.
- Heparin, a soluble glycosaminoglycan found in granules of mast cells and is highly sulfated.
- Heparin has an extended helical conformation.
- Heparin is an anticoagulant (blood thinner) that prevents the formation of blood clots.
- Heparin is used to treat and prevent blood clots caused by certain medical conditions or medical procedures. It is also used before surgery to reduce the risk of blood clots.




D-Glucuronate-2-sulfate N-Sulfoglucosamine-6-sulfate

**Heparin**



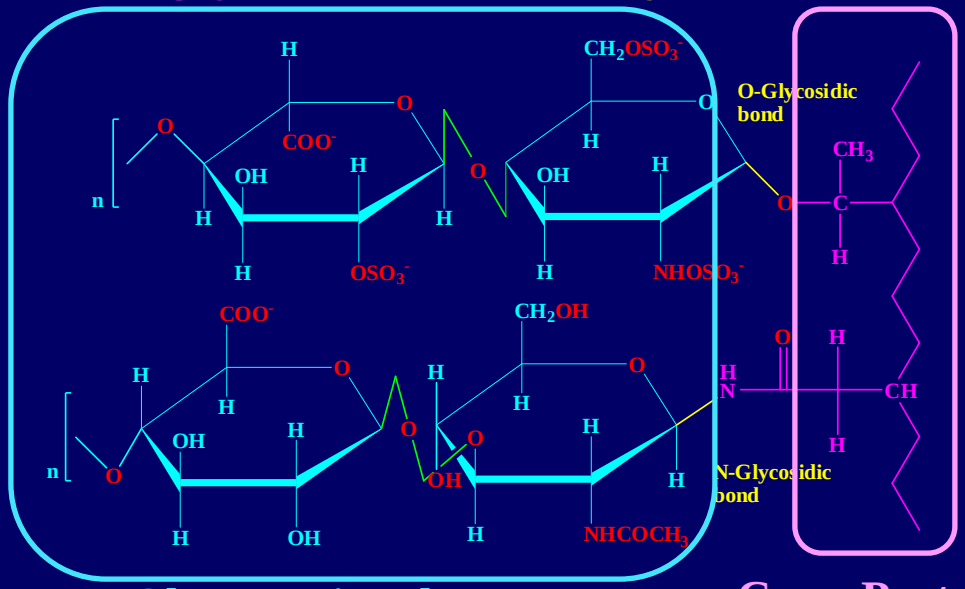
# Mucoproteins or Proteoglycans

- Some mucopolysaccharides found in the combination with proteins to form mucoproteins or mucoids or proteoglycans.
- Mucoproteins may contain up:-

1. Carbohydrate 95%
2. Protein 5%

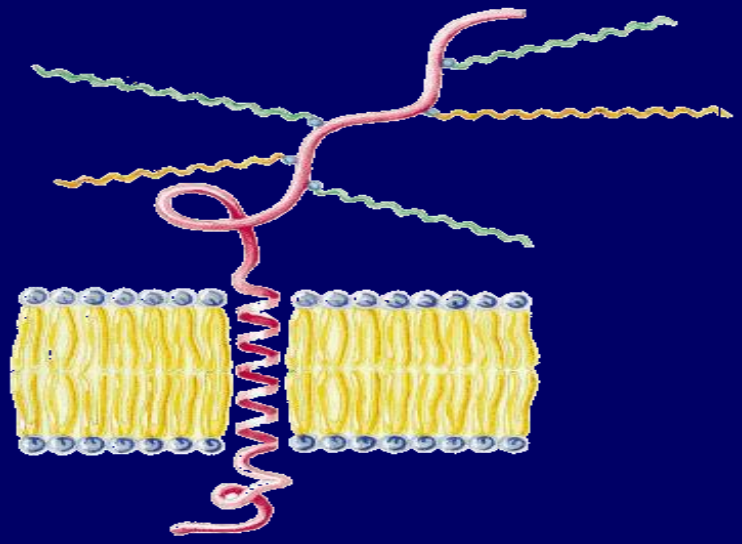
- Mucopolysaccharides linked to proteins by :

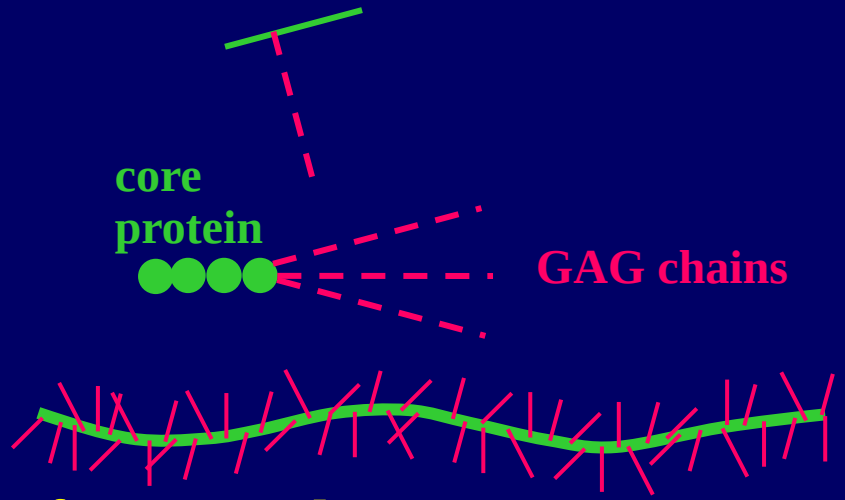
1. O-glycosidic bonds by OH of serine and threonine.
2. N-glycosidic bonds by amide nitrogen of asparagine residue




Glycosaminoglycans

Core Protein






- Examples of proteoglycans are Aggrecan and Biglycan
- Proteoglycans are composed of as many as 200 GAG chains. Molecular weight range: 105 – 107 Daltons ($1.660 \times 10^{-27}$ kg).
- Mucoproteins widely distributed in extracellular matrix of connective tissues ( bone and cartilage).
- Mucoproteins provide structural framework and mechanical support to those tissues which constitute them.

## Representative Heteropolysaccharides

| Heteropolysaccharide | Component sugars | Functions | Distribution |
|---|---|---|---|
| **Hyaluronic acid Mucopolysaccharides** | D-glucuronic acid and N-acetyl-D-glucosamine | lubricant, shock absorber, water binding | connective tissue, skin |
| **Chondroitin-4-sulfate Proteoglycans** | D-glucuronic acid and N-acetyl-D-galactosamine-4-O-sulfate | calcium accumulation, cartilage and bone formation | cartilage |
| **Heparin Proteoglycans** | D-glucuronic acid, L-iduronic acid, N-sulfo-D-glucosamine | anticoagulant | mast cells, blood |
| **Gamma globulin Proteoglycans** | N-acetyl-hexosamine, D-mannose, D-galactose | antibody | blood |
| **Blood group substance Proteoglycans** | D-glucosamine, D-galactosamine, L-fucose, D-galactose | blood group specificity | cell surfaces, especially red blood cells |

# Mucopolysaccharidoses

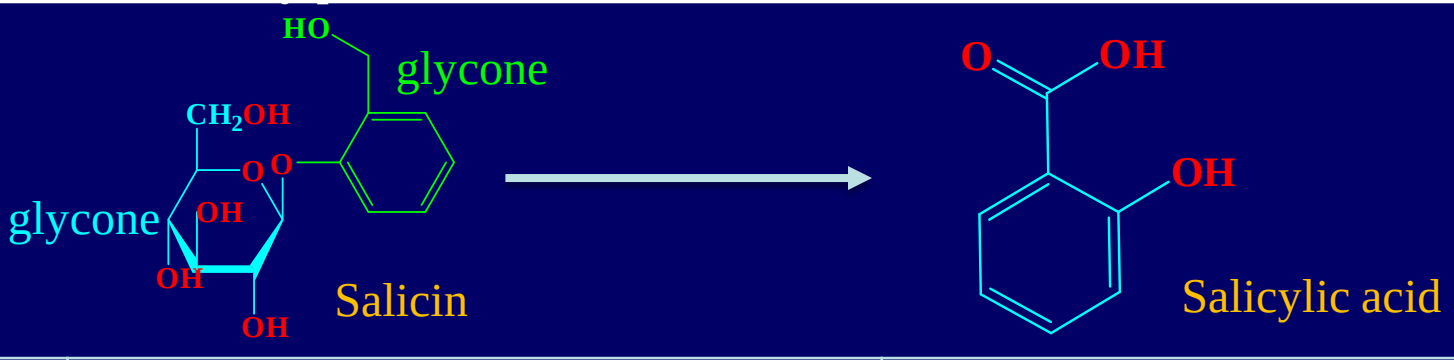
- Mucopolysaccharidoses are metabolic disorders caused by the absence or malfunctioning of **lysosomal enzymes** needed to break down molecules called glycosaminoglycans
- Individuals with mucopolysaccharidosis either do not produce enough of lysosomal enzymes required to break down these sugar chains into simpler molecules, or they produce enzymes that do not work properly.
- Over time, these GAGs collect in the cells, blood and connective tissues. The result is permanent, progressive cellular damage which affects appearance, physical abilities, organ and system functioning.

# Glycoside

A glycoside is any molecule in which a sugar group is bonded through its anomeric carbon to another group via a glycosidic bond.

Classification of Glycoside : Glycosides can be classified by the glycone, by the type of glycosidic bond, and by the aglycone.

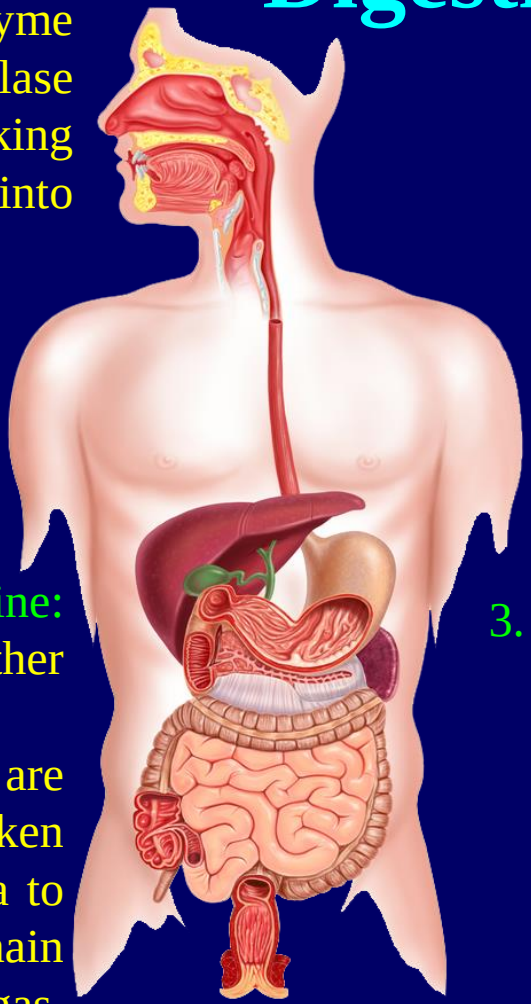
1. By glycone/presence of sugar: If the glycone is glucose, the glycoside is a glucoside; if it is fructose, the glycoside is a fructoside ; if it is glucuronic acid, the molecule is a glucuronide; etc. In the body, toxic substances are often bonded to glucuronic acid to increase their water solubility; the resulting glucuronides are then excreted.
2. By type of glycosidic bond: Glycosides can be linked by an O- (an *O-glycoside*), N- (a glycosylamine), S-(a thioglycoside), or C- (a C-glycoside) glycosidic.
3. By aglycone: Glycosides are also classified according to the chemical nature of the aglycone. An example of an alcoholic glycoside is salicin.




| G.No | Examples of Glycosides | Therapeutic Use |
|---|---|---|
| 1 | Cardiac Glycosides Digoxin /Digitonin Ovabain | In treatment of cardiac insufficiency. |
| 2 | Phlorizin (Glucose Transporter Inhibitor) | In treatment of Diabetes mellitus. |
| 3 | Streptomycin | Antibiotic used to treat bacterial infections. |
| 5 | Salicin is converted in the body into salicylic acid | Analgesic, antipyretic, and anti-inflammatory |

# Digestion of Carbohydrates

1. Mouth: The enzyme salivary amylase begins breaking down starch into shorter polysaccharides



2. Stomach: Salivary amylase is inactivated in acidic media so, no further carbohydrate digestion occurs

3. Small intestine: Majority of starch digestion and breakdown of disaccharides occurs here. The enzyme pancreatic amylase breaks down starch into monosaccharides ,disaccharides and oligosaccharides. The digestion of carbohydrates. Is completed by the enzymes lactase, sucrase and maltase attached to the border of the villi. The disaccharides, and oligosaccharides are broken down into monosaccharides ( glucose , fructose, galactose).

4. Large intestine: Fiber and other indigestible carbohydrates are partially broken down by bacteria to form short chain fatty acids and gas. The remaining fiber is excreted in the feces

| Enzyme | Produced By | Site of Action | Substrate Acting On | End Products |
|---|---|---|---|---|
| Salivary amylase | Salivary glands | Mouth | Polysaccharides (Starch) | Disaccharides (maltose), oligosaccharides |
| Pancreatic amylase | Pancreas | Small intestine | Polysaccharides (starch) | Disaccharides (maltose), monosaccharides |
| Oligosaccharidases | Lining of the intestine; brush border membrane | Small intestine | Disaccharides | Monosaccharides (e.g., glucose, fructose, galactose) |
| Sucrase | Lining of the intestine; brush border membrane | Small intestine | Disaccharides Sucrose | Monosaccharide Sucrose |
| Lactase | Lining of the intestine; brush border membrane | Small intestine | Disaccharides Lactose | Monosaccharide Lactose |
| Maltase | Lining of the intestine; brush border membrane | Small intestine | Disaccharides Maltose | Monosaccharide Maltose |

# Thank You For Your Attention