BIOMOLECULE II

CARBOHYDRATE AND LIPID

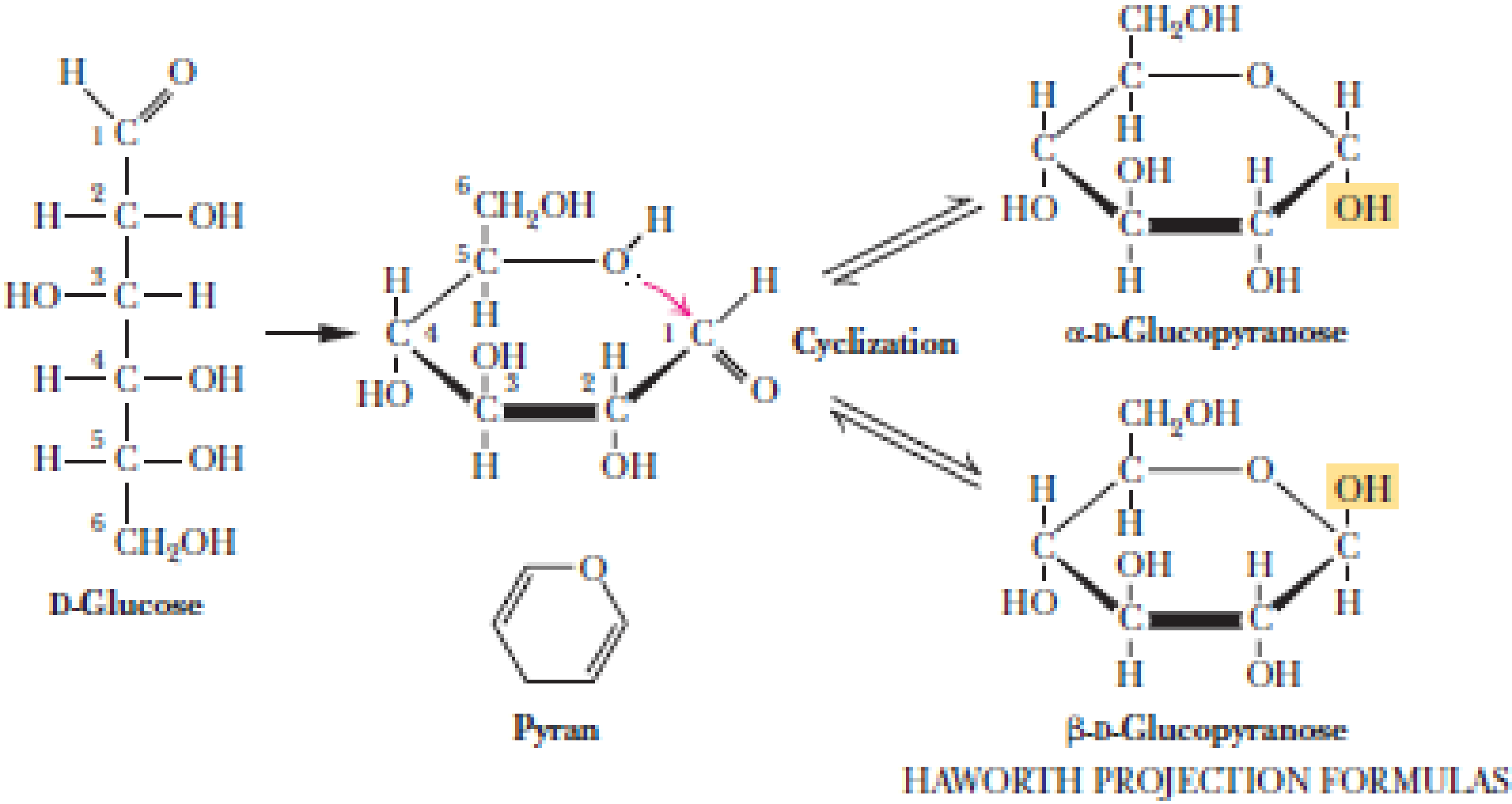
CARBOHYDRATE

- Energy sources
- Glucose – the most important –major metabolic fuel
  - ✓ precursor for other carbohydrate in body. E.g.
  - ✓ glycogen – storage
  - ✓ ribose, deoxyribose – nucleic acid
- Disease associated: diabetes, galactosemia, glycogen storage disease, lactose intolerance
- Oligosaccharides – in process that take place on the surface of cells – cell interactions and immune recognition
- Polysaccharides - structure component -e.g- cellulose of grass and trees, and component for bacterial cell wall

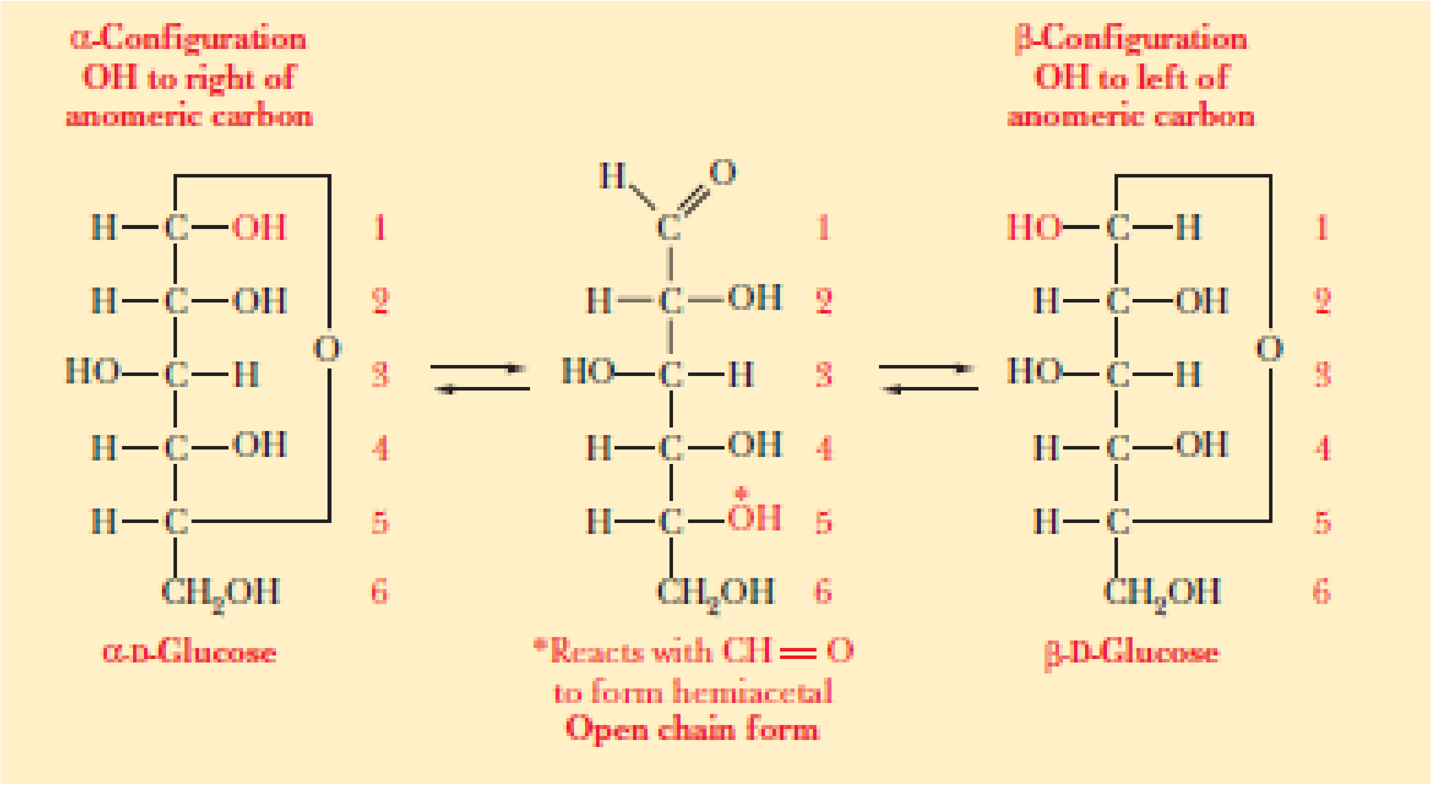
SUGAR: STRUCTURES AND STREOCHEMISTRY

- $C_n(H_2O)_n$
- Simple sugar – monosaccharide
- Oligosaccharide – formed when a few monosaccharide bonded together
- Polysaccharide – formed when many monosaccharide formed together

Glucose structure can be α or β

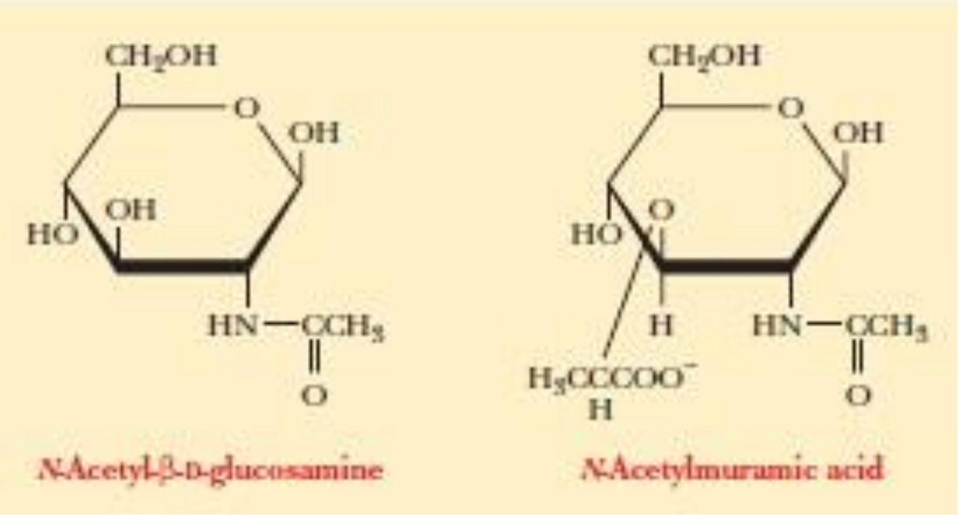


α and β configuration



Amino sugars

- Amino group (-NH2) or one of its derivatives is subtituted for the hydroxyl group (OH) of the parent sugar
- E.g – N-acetyl-β-D- glucoseamine and its derivative N-acetyl-β-D- muramic acid – components of bacterial cell walls



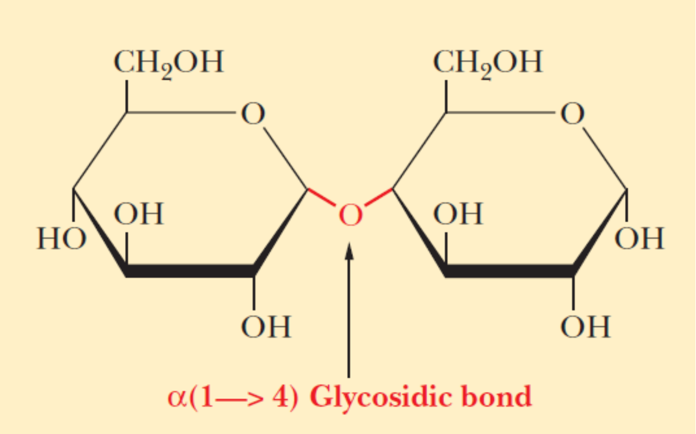
Reaction of monosaccharides

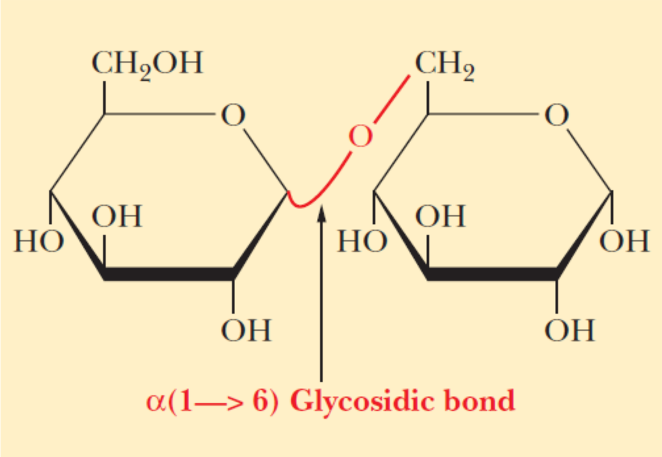
- Oxidation and reduction process of sugars:
- Oxidation – provides energy for organism, yield $C0_2$ and H_20 in aerobic processes
- Reduction – reverse process of oxidation – phostosythesis
- Oxidation reaction- important in lab practice – can identify sugars

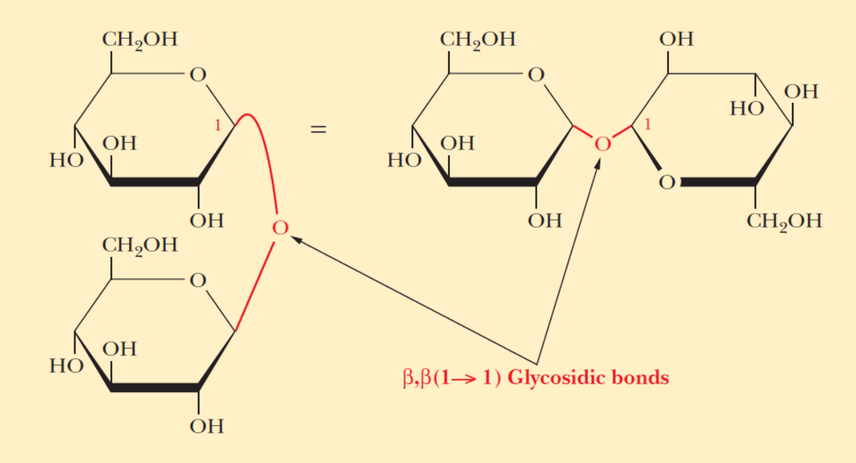
Sugar	Where Found	Biochemical Importance	Clinical Significance
D-Ribose	Nucleic acids.	Structural elements of nucleic acids and coenzymes, eg, ATP, NAD, NADP, flavoproteins. Ribose phosphates are intermediates in pentose phosphate pathway.	
D-Ribulose	Formed in metabolic processes.	Ribulose phosphate is an intermediate in pentose phosphate pathway.	
D-Arabinose	Gum arabic. Plum and cherry gums.	Constituent of glycoproteins.	
D-Xylose	Wood gums, proteoglycans, glycosaminoglycans.	Constituent of glycoproteins.	
D-Lyxose	Heart muscle.	A constituent of a lyxoflavin isolated from human heart muscle.	
L-Xylulose	Intermediate in uronic acid pathway.		Found in urine in essential pentosuria.

Sugar	Source	Importance	Clinical Significance
D-Glucose	Fruit juices. Hydrolysis of starch, cane sugar, maltose, and lactose.	The "sugar" of the body. The sugar carried by the blood, and the principal one used by the tissues.	Present in the urine (glycosuria) in diabetes mellitus owing to raised blood glucose (hyperglycemia).
D-Fructose	Fruit juices. Honey. Hydrolysis of cane sugar and of inulin (from the Jerusalem artichoke).	Can be changed to glucose in the liver and so used in the body.	Hereditary fructose intolerance leads to fructose accumulation and hypoglycemia.
D-Galactose	Hydrolysis of lactose.	Can be changed to glucose in the liver and metabolized. Synthesized in the mammary gland to make the lactose of milk. A constituent of glycolipids and glycoproteins.	Failure to metabolize leads to galactosemia and cataract.
D-Mannose	Hydrolysis of plant mannans and gums.	A constituent of many glycoproteins.	

Glycosidic Bond



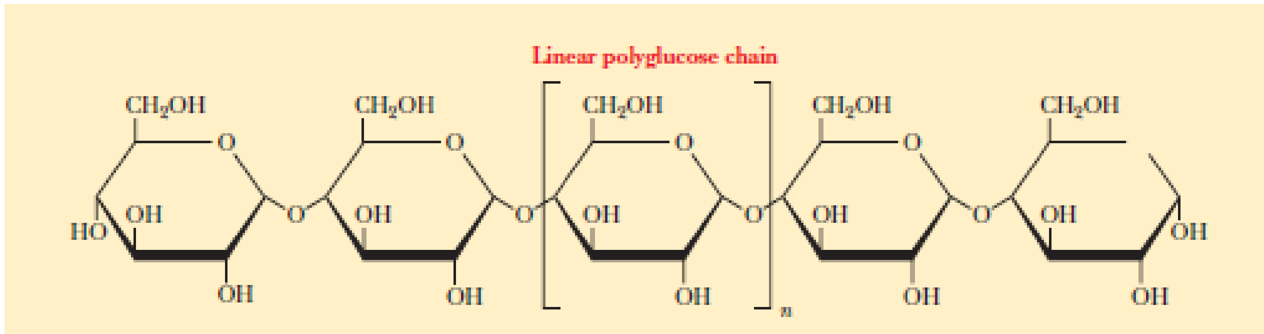




Linear and branch bonds

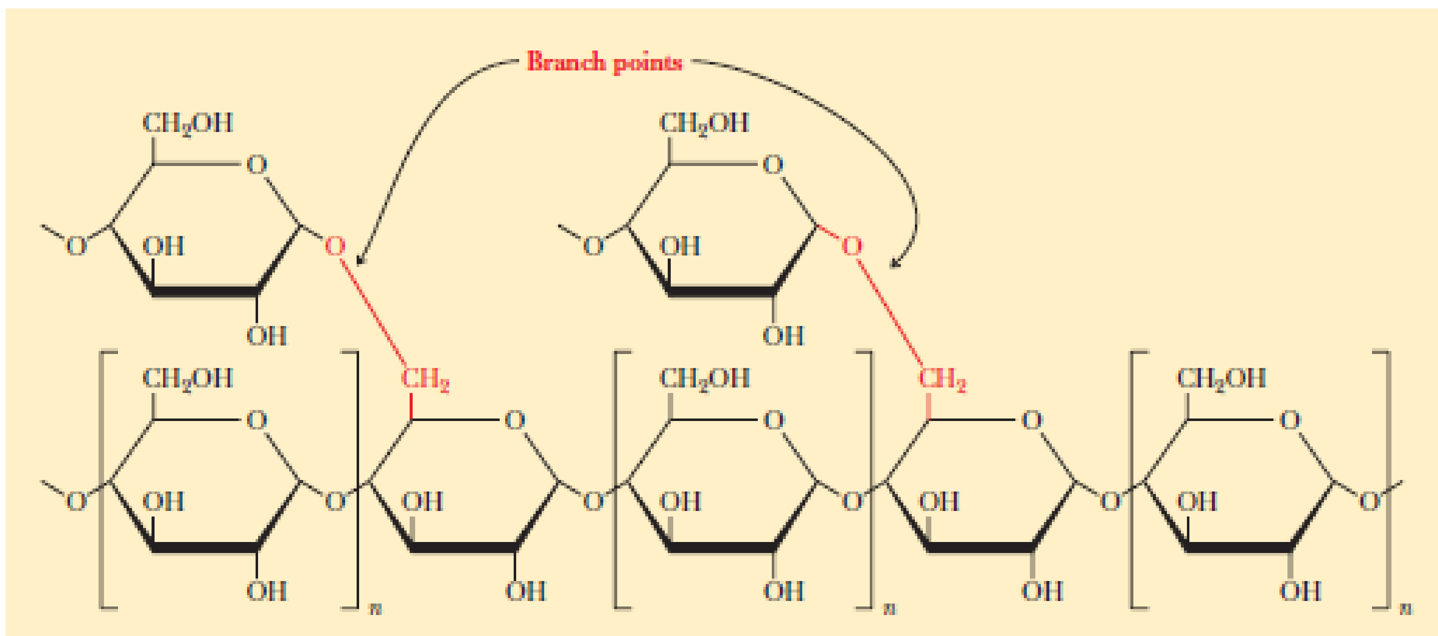
A

The linear polyglucose chain occurs in amylose. All glycosidic bonds are α(1→4).



B

The branched-chain polymer occurs in amylopectin and glycogen. Branched-polyglucose-chain glycosidic bonds are α(1→6) at branched points, but all glycosidic bonds along the chain are α(1→4).



Important Dissacharides

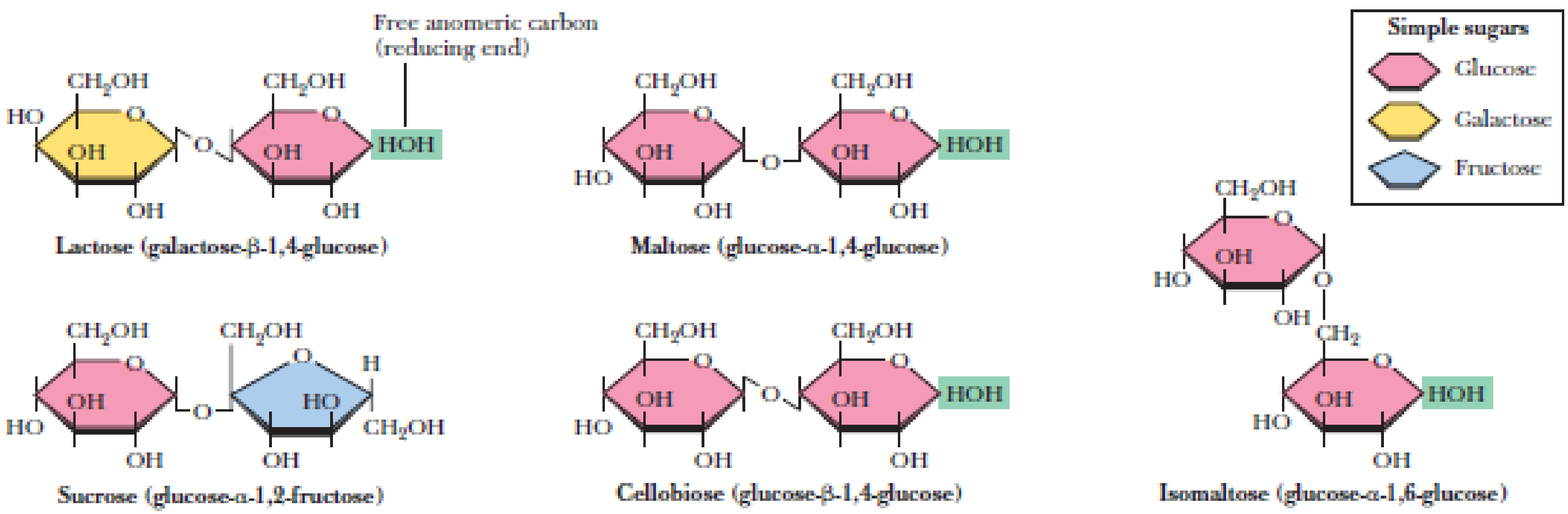
Table 13–4. Disaccharides.

Sugar	Source	Clinical Significance
Maltose	Digestion by amylase or hydrolysis of starch. Germinating cereals and malt.	
Lactose	Milk. May occur in urine during pregnancy.	In lactase deficiency, malabsorption leads to diarrhea and flatulence.
Sucrose	Cane and beet sugar. Sorghum. Pineapple. Carrot roots.	In sucrase deficiency, malabsorption leads to diarrhea and flatulence.
Trehalose[1]	Fungi and yeasts. The major sugar of insect hemolymph.	

[1] *O*-α-D-Glucopyranosyl-(1 → 1)-α-D-glucopyranoside.

Oligosaccharides

- Frequently occur as dissacharide
- Linking two monosaccharide units by glycosidic bonds
- Eg: sucrose, lactose, maltose, Isomaltose, cellobiose



Other **disaccharides** include:

- **Sucrose**, common table sugar, has a glycosidic bond linking the anomeric hydroxyls of glucose & fructose.

  Because the configuration at the anomeric C of glucose is α (O points down from ring), the linkage is α(1→2).

  The full name of sucrose is α-D-glucopyranosyl-(1→2)-β-D-fructopyranose.)

- **Lactose**, milk sugar, is composed of galactose & glucose, with β(1→4) linkage from the anomeric OH of galactose. Its full name is β-D-galactopyranosyl-(1→ 4)-α-D-glucopyranose

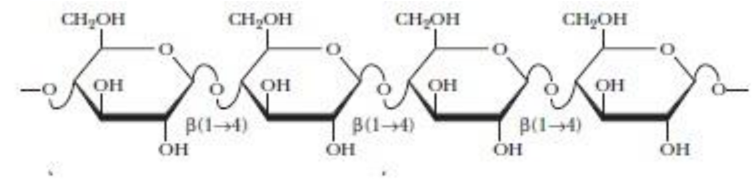
- Maltose – consist of two residues of D-glucose in **α(1→4)** linkages -

Polysaccharides

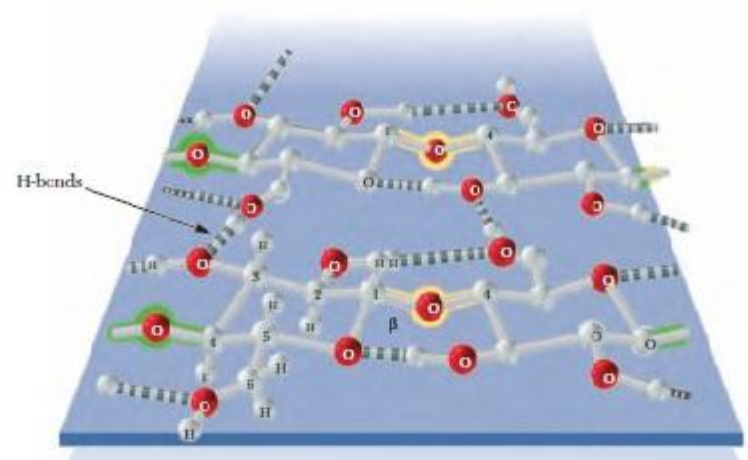
- Many monosaccharides that are linked together
- A polymer that consists of only one type of monosaccharide – homopolysaccharide
- More than one type of monosaccharide - heteropolysaccharide

Cellulose and starch

Cellulose



- Major structure of plants – wood and plants
- Linear homopolysaccharide of β-D-glucose, linked in β (1 4) glycosidic bonds
- Individual polysaccharide chains are hydrogen bonded together –machanical strenght to the plant fibers

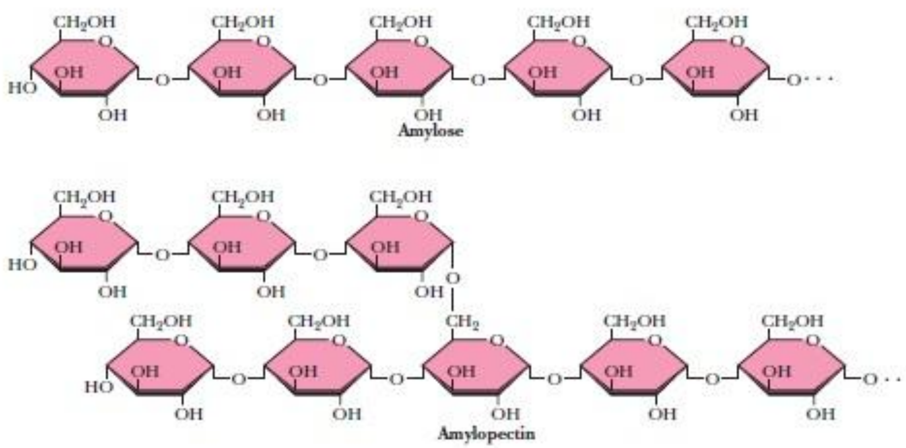


Cellulose

- Cellulase – enzyme that hydrolyze cellulose to glucose – attack β linkages
- Animal don’t have this enzyme
- Cellulase – found in bacteria that inhabit the digestive tract of termites and grazing animal (cattle and horses)

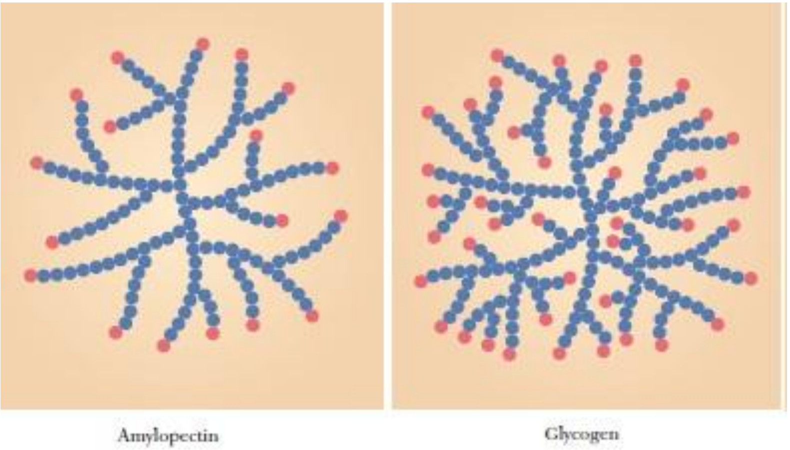
Starch

- Polymer of α-D-glucose, found as starch granules in the cytosoles
- Two forms: amylose and amylopectin
- Amylose – linear polymer of glucose – linked together by α (1 ⟶ 4) glycosidic bonds
- Amylopectin – branched chain polymer – brances starting at α (1 ⟶ 6) glycosidic bonds along the chain of at α (1 ⟶ 4) glycosidic bonds - branch point occur every 25 residue



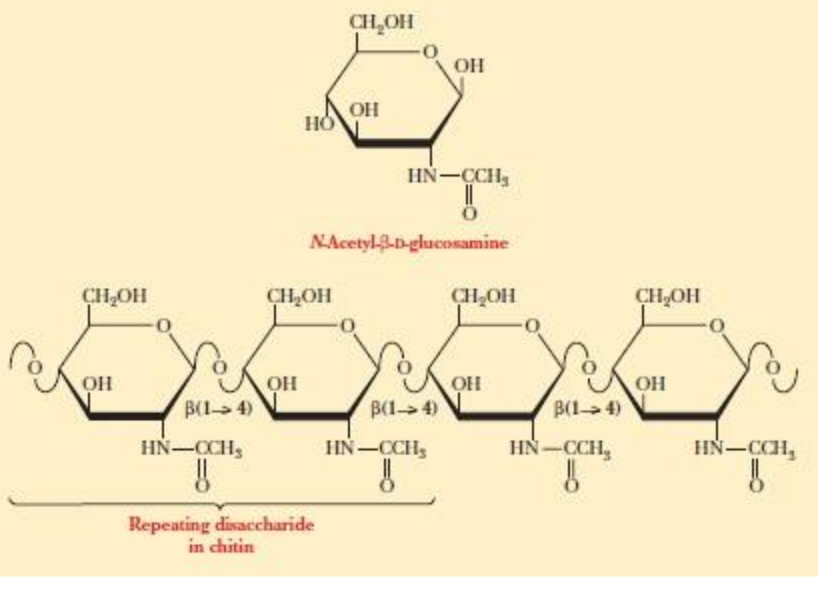
Glycogen

- Carbohydrate storage polymer in animals
- Almost similar to amylopectin – branched chain polymer of α-D-glucose
- Difference with amylopectin – glycogen more highly branced
- Branch point occur every 10 residue
- In animal cells found in granules – well fed liver and muscle cells, but not seen in brain and heart cell under normal condition
- Can be broken down using glycogen phosphorylase enzyme
- More branched – water soluble – important in the form of solution
- More branches – more target for enzymes - quicker mobilization of glucose to provide energy



Chitin

- Monomer – N- acetyl-β-D-glucoseamine
- Similar to cellulose in both structure and function
- Linear homoplysaccharide, all residue linked in β (1→ 4) glycosidic bonds .
- Major structure of exoskeletons of invertebrates – insects and crustaceans

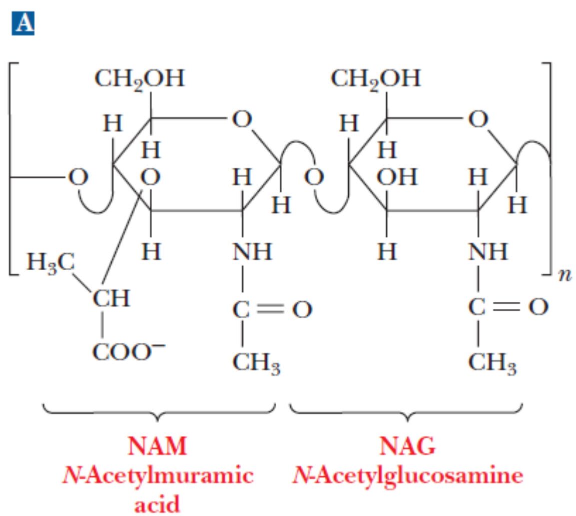


Role of polysaccharide in the structure of cell walls

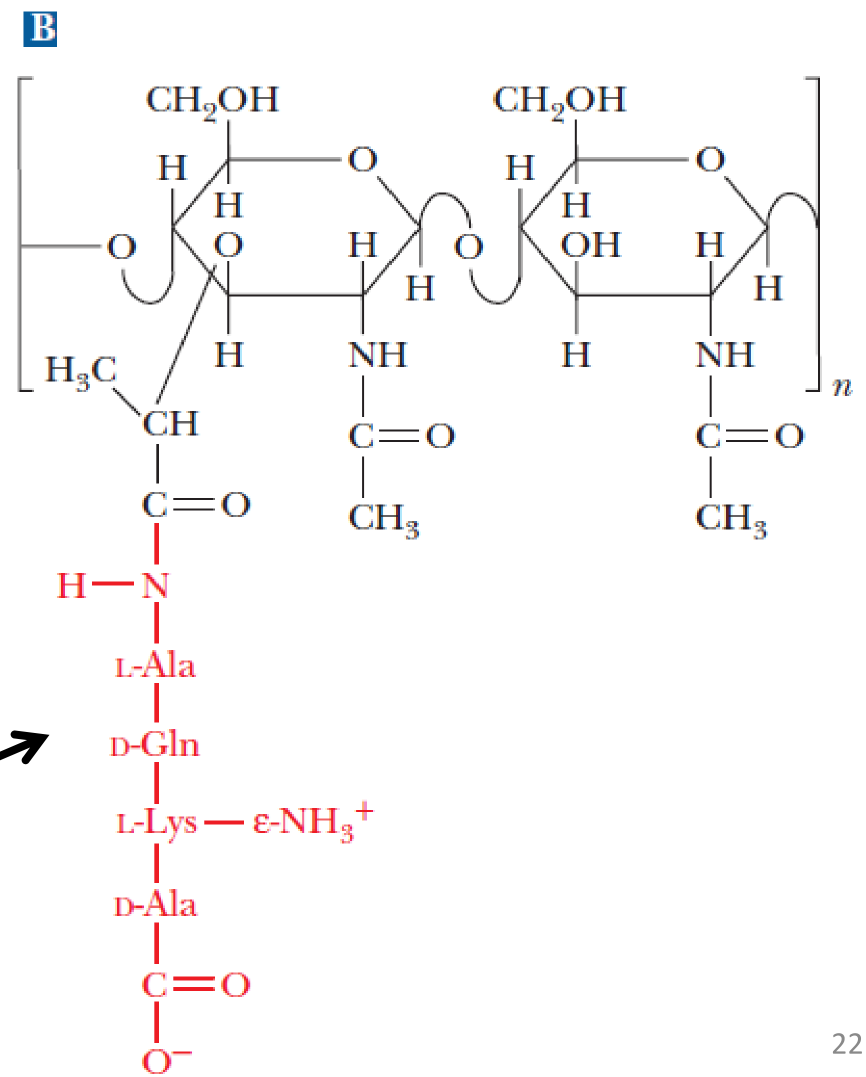
Bacteria cell walls

- Consist of heteropolysaccharide
- Monomers are N-acetyl-β-D- glucoseamine and N-acetyl-β-D- muramic acid
- N-acetyl-β-D- muramic acid found only in prokaryotic cells
- 2 residues held by β (1→ 4) glycosidic bonds
- Cross link with peptide

E.g. Cell wall of Staph aureus

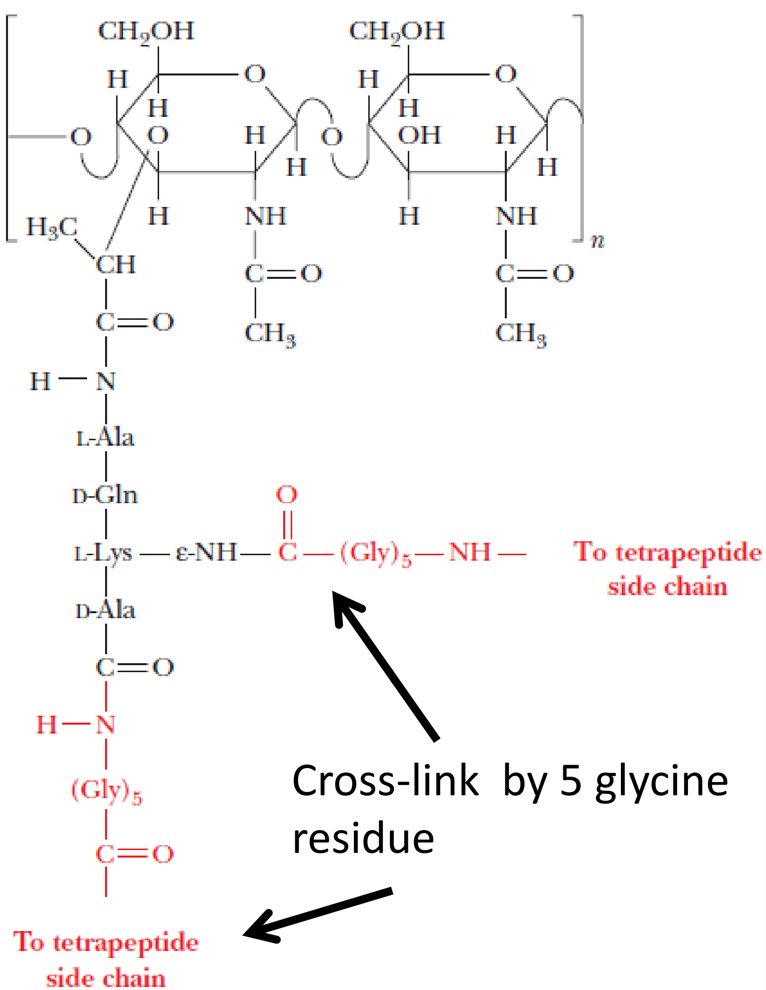


Repeating dissacharide



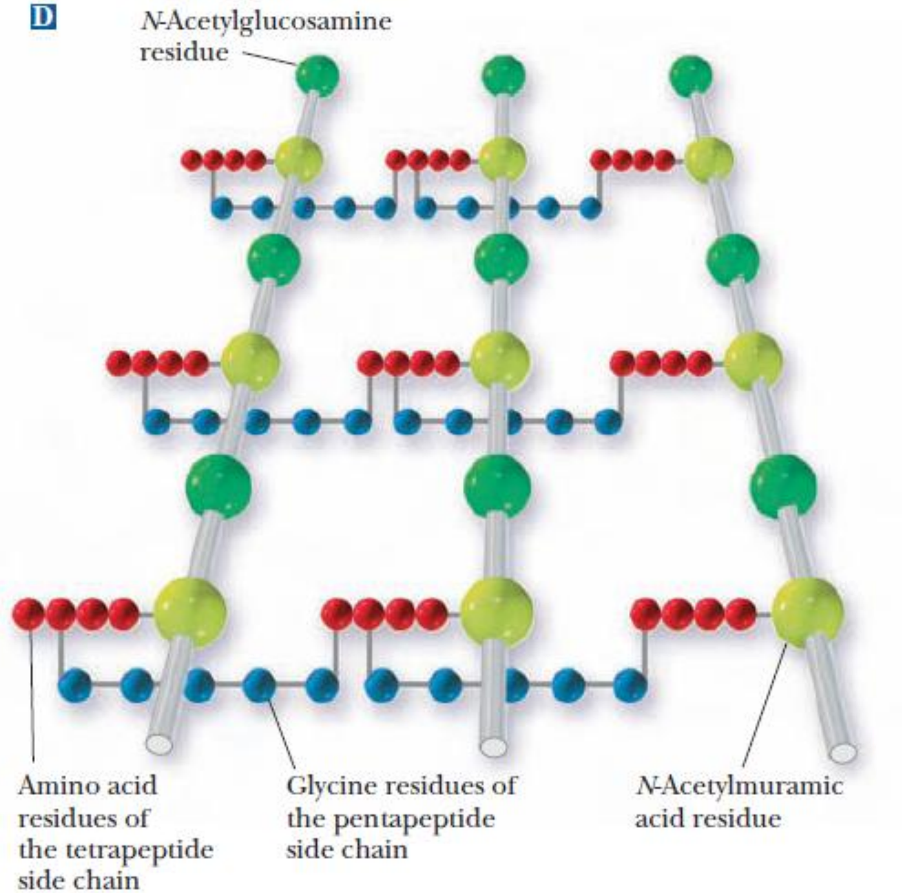
4 amino acids is bonded (tetramer)

C



Cross-link by 5 glycine residue

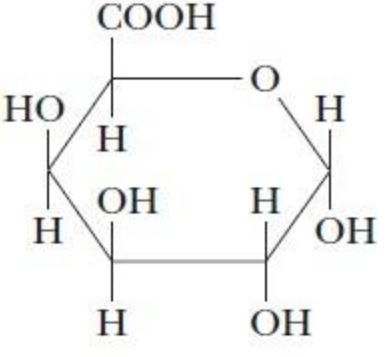
D



Peptidoglycan structure – have both peptide and carbohydrate components

Plant cell walls

- Consist largey of cellulose
- Other component found - Pectin (polymer of D-galacturonic acid)
- Major non-polysaccharide component found in woody plants – lignin –tough and durable material
- Contain little peptide or protein



D-Galacturonic acid

Glycoproteins

- Protein that contain oligosaccharide chains covalently attached to the polypeptide side chain
- Important role in cell membrane
- Major part in mucus that is secreted by epithelial cells – role as lubrication and in protection of tissues lining the respiratory and GIT system
- The amount of carbo in glycoprotein vary – eg.
  - IgG- 4% of carbo from total weight
  - Glycophorin – 60% carbo
- Few hormons: follicle stimulating hormon, luteinizing hormone
- Exist as plasma protein: immunoglobulin (antibody) and antigen

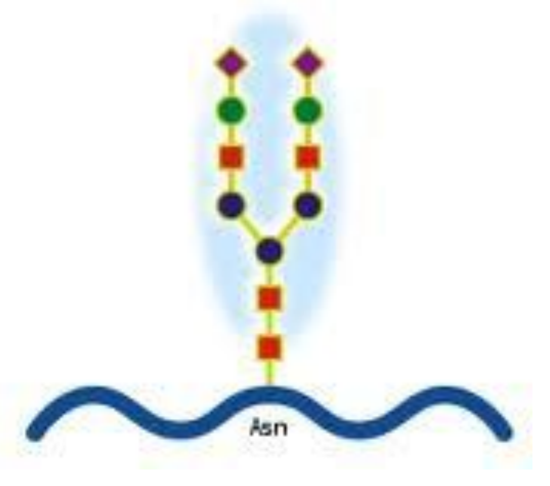


Table 13–5. Carbohydrates found in glycoproteins.

Hexoses	Mannose (Man) Galactose (Gal)
Acetyl hexosamines	*N*-Acetylglucosamine (GlcNAc) *N*-Acetylgalactosamine (GalNAc)
Pentoses	Arabinose (Ara) Xylose (Xyl)
Methyl pentose	L-Fucose (Fuc; see Figure 13–15)
Sialic acids	N-Acyl derivatives of neuraminic acid, eg, *N*-acetylneuraminic acid (NeuAc; see Figure 13–16), the predominant sialic acid.

e.g. role of carbohydrates in the immune response

- Blood groups – A, B, AB, O
- Distinction between groups – depend on the oligosaccharide of glycoprotein on the surface of the blood cells

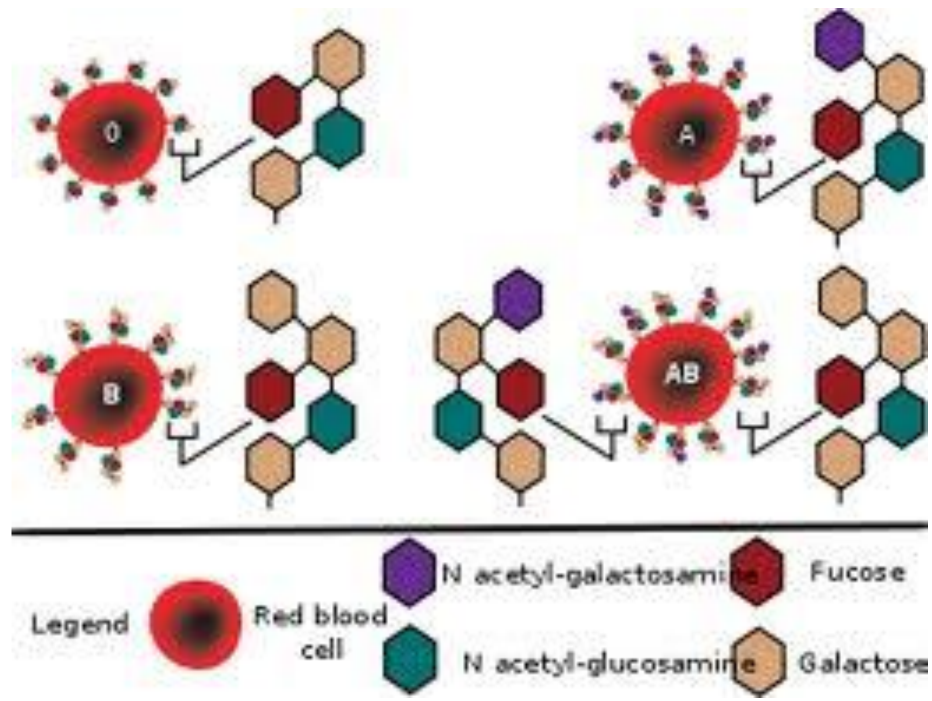
✓ All blood type – contain L-sugar fructose

✓ A – N-acetylgalactoseamine is found attached to the sugar

✓ B- α-D- galactose attached to the sugar

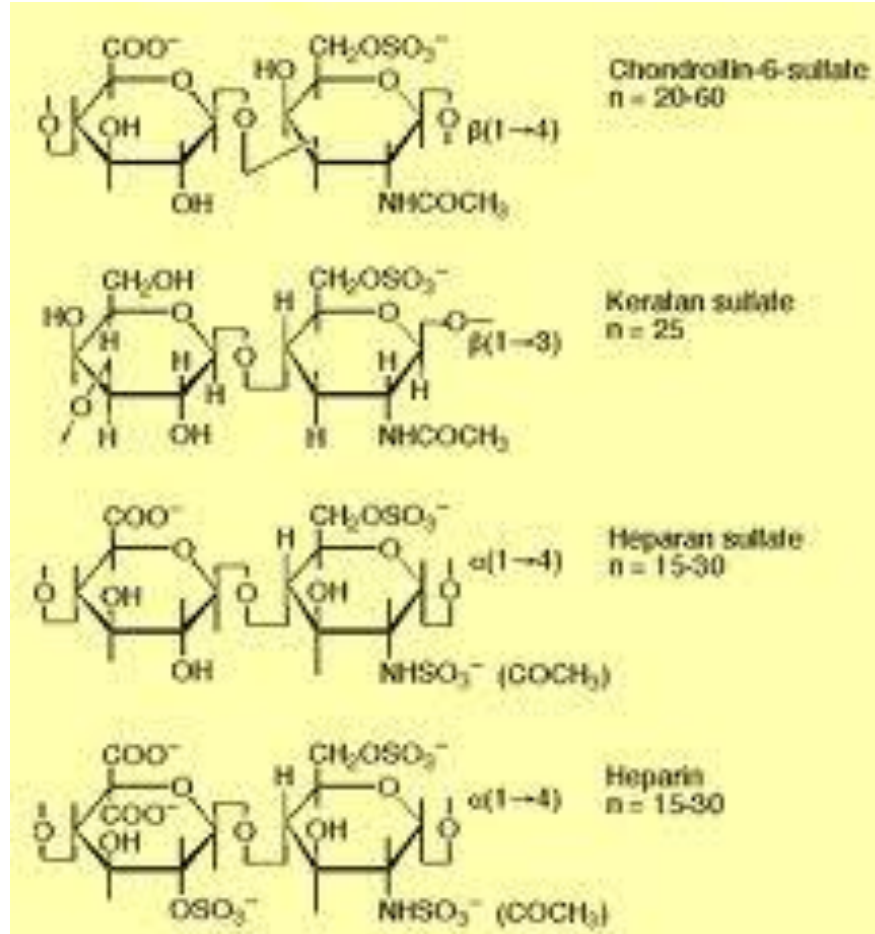
✓ O- Non of these 2 present

✓ AB – both present



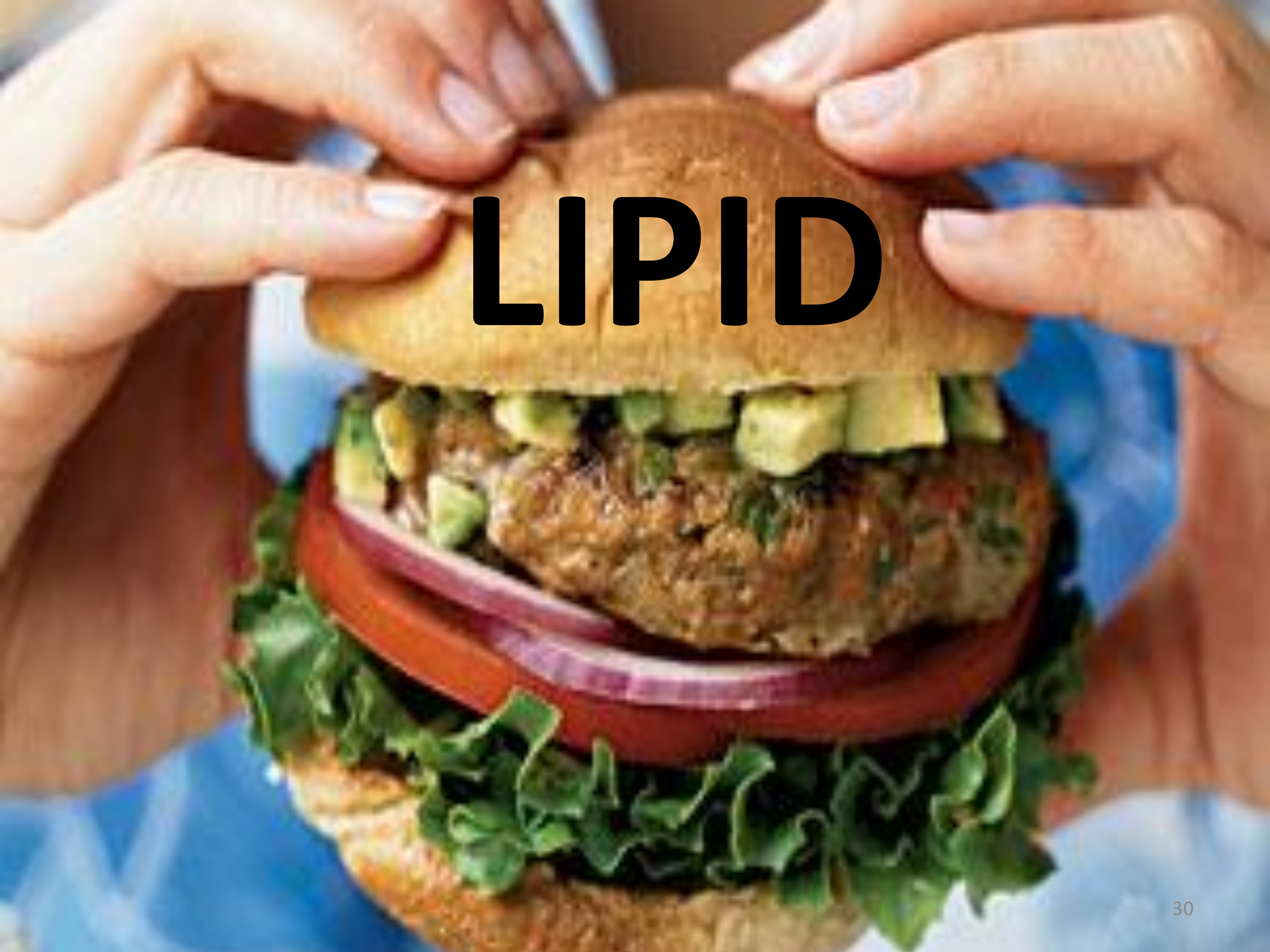
Proteoglycans

- Contain as much as 95% of polysaccharide
- Carbohydrate chain - glycosaminoglycan
- Consist of many different glycoaminoglycan chain linked to covalently to protein core
- Glycoseaminoglycans – polysaccharide based on dissacharide that consist of amino sugar and monomer that have negative charge (sulfate or carboxyl group)
- Sulfate group may attached to the glycoaminoglycan



Proteoglycans

- Their property of holding large quantities of water and occupying space -Role as lubricants/cushioning and support elements in connective tissue
- E.g: hyaluronic acid, chondroitin sulfate and heparin
- Heparin – anticoagulant
- Hyaluronic acid – components of the vitreous humor of eye and lubricating fluid of joints
- Chondroitin sulfate and keratan sulfate – connective tissue


LIPID

Lipids

- **Lipids:** a heterogeneous class of naturally occurring organic compounds classified together on the basis of common solubility properties
  - insoluble in water, but soluble in aprotic organic solvents including diethyl ether, chloroform, methylene chloride, and acetone
  - Contain or derived from fatty acids

- Lipids include
  - fatty acids, triacylglycerols, sphingolipids, phosphoacylglycerols, glycolipids,
  - lipid-soluble vitamins
  - prostaglandins, leukotrienes, and thromboxanes
  - cholesterol, steroid hormones, and bile acids

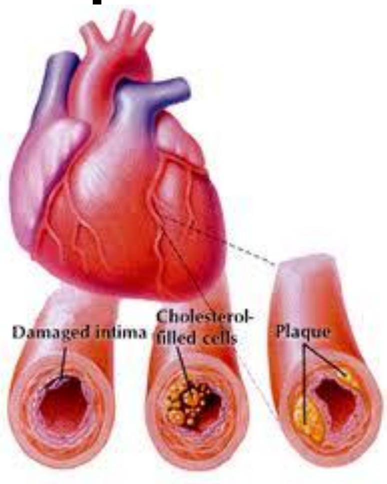
Biomedical importance of lipid

- Important dietary constituents – high energy value
- Fat soluble vitamins and the essential fatty acids contained in the fat of natural food
- Fat is stored in adipose tissue – also serves as a thermal insulator in the subcutaneous tissues around certain organs
- Non polar lipids- electrical insulator – allow rapid propagation and depolarization waves along myelinated nerves

Biomedical importance of lipid

- Combination of lipid and protein –lipoprotein – important in cell membrane structure and in mitochondria
- Also serve as means of transporting lipids in the blood

Importance of knowledge lipid biochemistry



- To understand in the area of:
  - Obesity
  - Diabetis mellitus
  - Atherosclerosis
  - Role of polyunsaturated f.a in nutrition and health

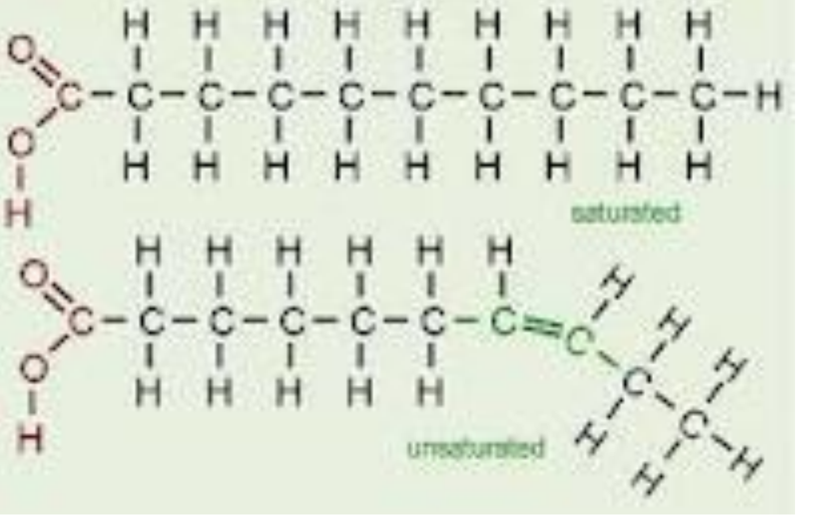
Chemical nature of lipids

Amphiphatic

- ❖ Has carboxyl group at polar end - hydrophilic
- ❖ Hydrocarbon chain at non polar tail – hyrophobic
- Contain even number of carbon atom – usually unbranched

Two types:

- ❖ Unsaturated – contain double bonds – lower melting points- plant oil
- ❖ saturated - there are only single bonds – higher melting points, eg. Animal fats



LIPIDS

Complex lipids:

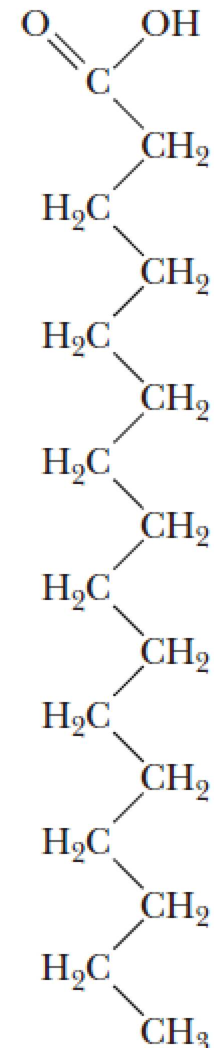
Non polar – triacylglycerols, and cholesterol esters

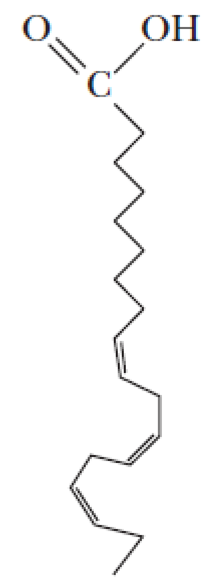
Polar lipids- phospholipids, sphingolipids, and eicasanoids

Our discussion on lipids will be based on these complex lipids

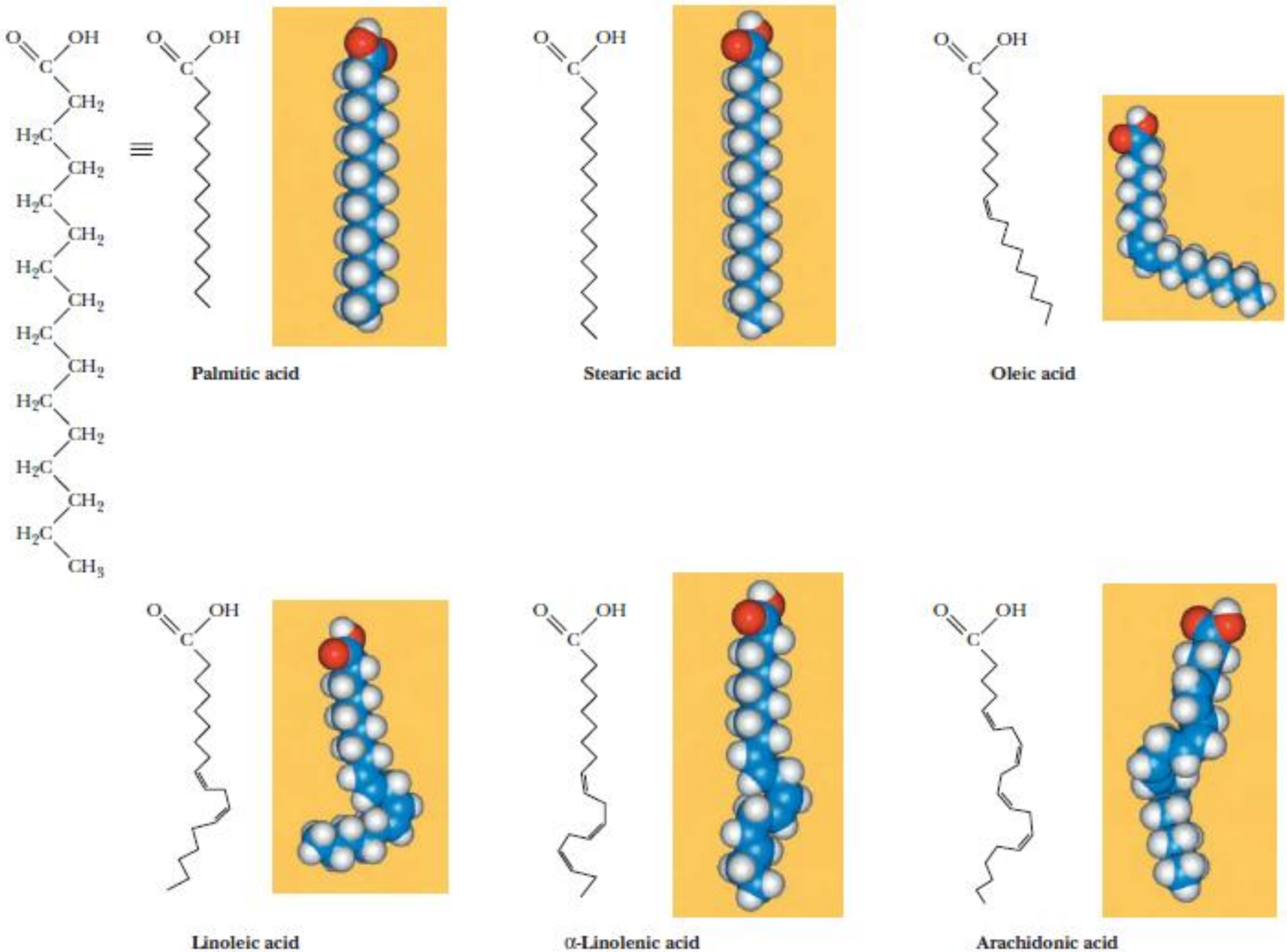
Fatty Acids

- **Fatty acid:** an unbranched-chain carboxylic acid, most commonly of 12 - 20 carbons, derived from hydrolysis of animal fats, vegetable oils, or phosphodiacylglycerols of biological membranes



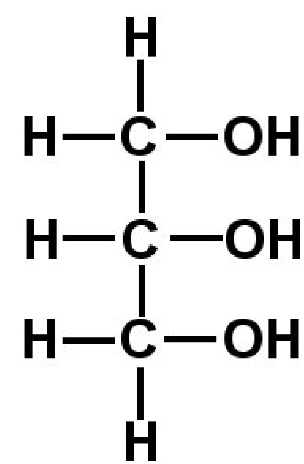


Fatty acid


O
OH
C
CH2
H2C
CH3
Palmitic acid
Stearic acid
Oleic acid
Linoleic acid
α-Linolenic acid
Arachidonic acid

Fatty acids

- Fatty acids occur primarily as esters of glycerol and stored for future use
- Most fatty acid in mammalian exist as triacylglycerols – 3 OH group of glycerol are esterified with fa



Glycerol structure

Saturated Fatty Acid

Table 8.1

Typical Naturally Occurring Saturated Fatty Acids

Acid	Number of Carbon Atoms	Formula	Melting Point (°C)
Lauric	12	$CH_3(CH_2)_{10}CO_2H$	44
Myristic	14	$CH_3(CH_2)_{12}CO_2H$	58
Palmitic	16	$CH_3(CH_2)_{14}CO_2H$	63
Stearic	18	$CH_3(CH_2)_{16}CO_2H$	71
Arachidic	20	$CH_3(CH_2)_{18}CO_2H$	77

Unsaturated Fatty Acid

Table 8.2

Typical Naturally Occurring Unsaturated Fatty Acids

Acid	Number of Carbon Atoms	Degree of Unsaturation*	Formula	Melting Point (°C)
Palmitoleic	16	$16{:}1\text{—}\Delta^{9}$	$CH_3(CH_2)_5CH{=}CH(CH_2)_7CO_2H$	–0.5
Oleic	18	$18{:}1\text{—}\Delta^{9}$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$	16
Linoleic	18	$18{:}2\text{—}\Delta^{9,12}$	$CH_3(CH_2)_4CH{=}CH(CH_2)CH{=}CH(CH_2)_7CO_2H$	–5
Linolenic	18	$18{:}3\text{—}\Delta^{9,12,15}$	$CH_3(CH_2CH{=}CH)_3(CH_2)_7CO_2H$	–11
Arachidonic	20	$20{:}4\text{—}\Delta^{5,8,11,14}$	$CH_3(CH_2)_4CH{=}CH(CH_2)_4(CH_2)_2CO_2H$	–50

*Degree of unsaturation refers to the number of double bonds. The superscript indicates the position of double bonds. For example, Δ9 refers to a double bond at the ninth carbon atom from the carboxyl end of the molecule.

Fatty acids

- Long hydrocarbon chain – will not form hydrogen bonding – thus hydrophobic
- Fatty acid in unesterifed or sterified – have more tendency to associate with each other or other hydrophobic structure, such as sterol and hydrophobic chain of aa
- This hydrophobic character – essential for construction of biological membrane

Fatty acids

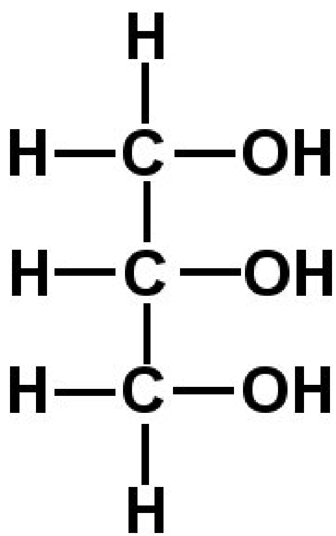
- Hydrophobic nature – make it efficient compound for energy storage compare to glycogen
  - Will yield 2 and half times amount of ATP produced on complete oxidation compare to pure glycogen
  - Can be stored as without associated water where as glycogen is very hydrophilic and binds about twice its weight of water when stored in tissues. Thus recovered energy from TA is 4 times higher than the same amount of glycogen stored

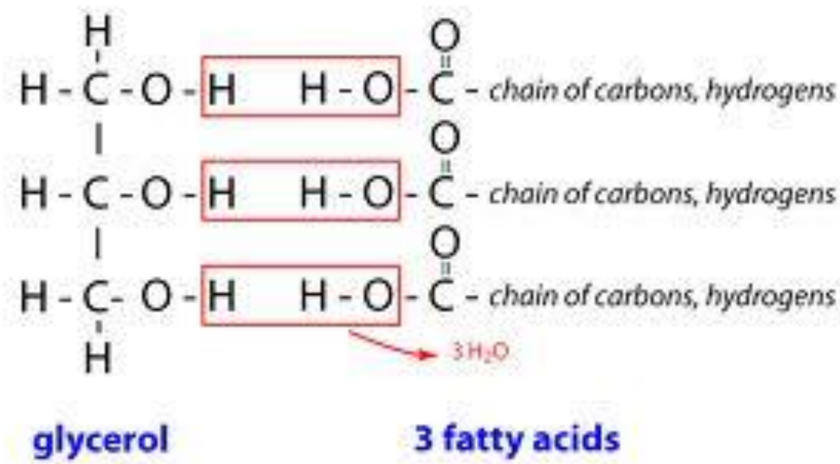
Sources of fatty acids

- Diet and biosythesis supply for the fatty acids needed by body
- Excess protein and carbohydrate are readily converted to f.a and triacylglycerol
- Most fatty acids are supplied in the diet
- Many higher mammals include human are unable to synthesize fatty acids with double bonds (unsaturated) near the methyl end of molecule
- Polyunsaturated fatty acids (PUFA) essential for specific functions, eg. Precursor for prostaglandins

Triacylglycerols

- Glycerol – compound that have 3 OH group
- Triacylglycerol – 3 alcohol group form ester linkages with fatty acid

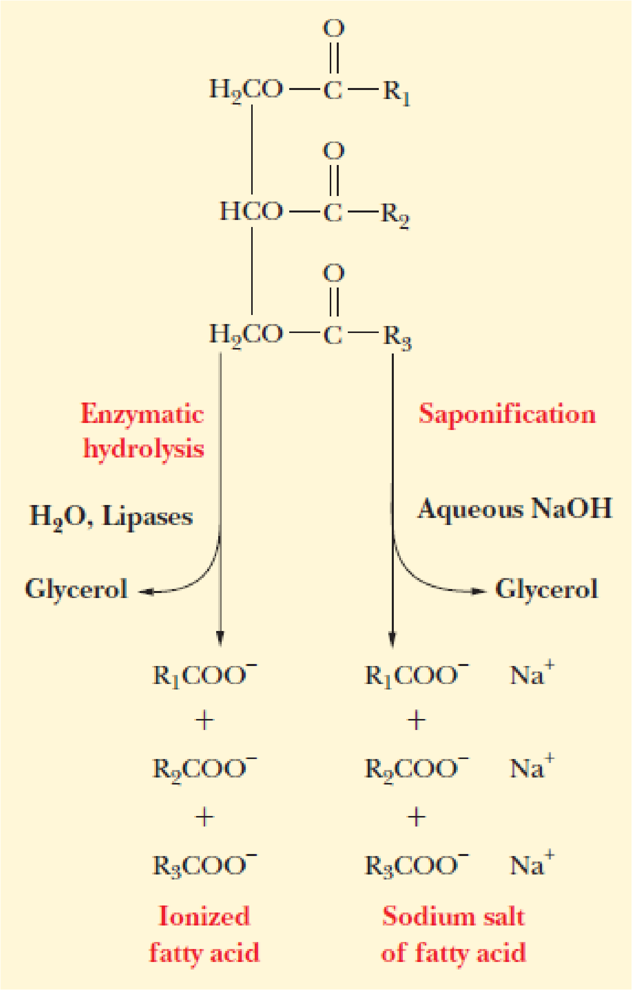




Triacylglycerols (TG)

- Concentrated stores of metabolic energy
- Is synthesized in most tissue, but synthesis in liver is primarily for production of **blood lipoprotein**
- Is stored as lipid droplets in cytoplasm in adipose tissue
- Continues synthesis and breakdown of TG occur to supply for energy demand in body
- Some storage also in skletal and cardiac for local consumption

Hydrolisis of triacylglycerols



- Lipases –enyzme that hydrolyze ester linkages
- Outside organism, the same reaction can occur with the presence of NaOH – saponification process

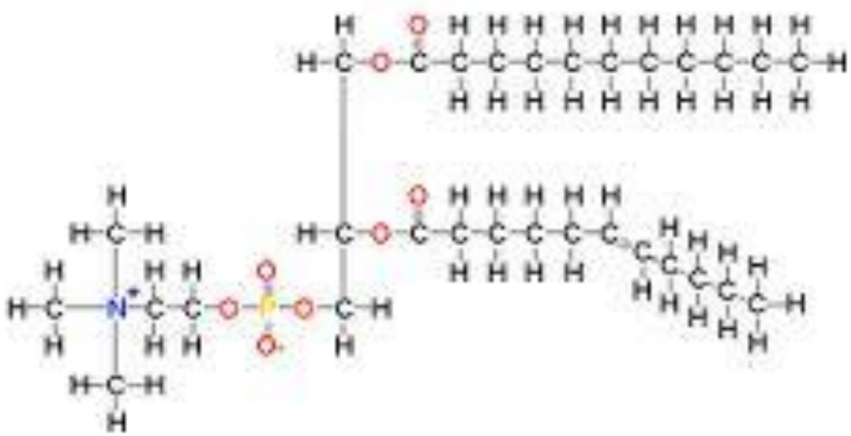
Transportation of lipid

- Energy available in f.a needs to be transported throughout the site of f.a absorption, biosynthesis or storage to functioning tissues that consume them
- Three types of substance are used as vehicles:
  1. chylomicrons and other lipoprotein (VLDL, HDL, LDL) – TG are carried in protein-coated lipid droplets
  2. f.a bound to serum albumins
  3. Ketone bodies, acetoacetate and β-hydroxybutyrate

- TASK – DESCRIBE IN DETAIL THE FUNCTION OF LIPOPROTEIN, HDL, LDL AND VLDL AND CORRELATE WITH ATHEROSCLEROSIS

Phospholipids

- Polar, ionic lipids composed of 1,2-diacylglycerol and phosphodiester bridge that links the glycerol backbone to some base, usually nitrogenous one; eg. Choline, serine, ethanolamine



Phospholipid

Phospholipids

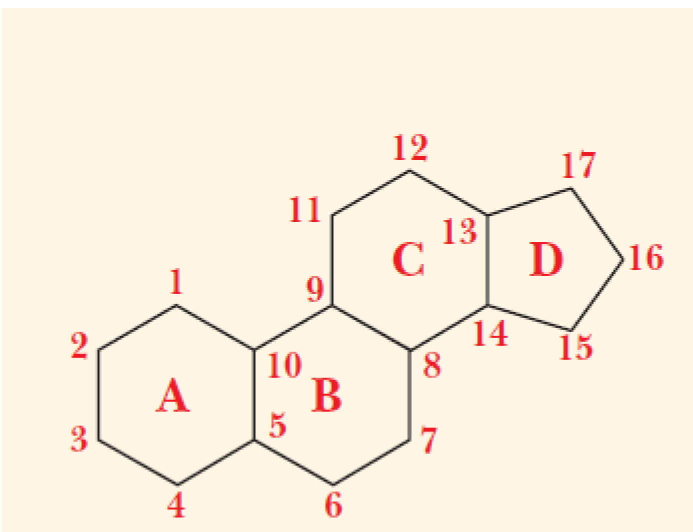
- The most abundant in mammal tissue:
  - ✓Phosphatidyl choline
  - ✓Phosphatidylethanolamine
  - ✓Phosphatidylserine
  - ✓Phosphatidylinositol
  - ✓Phosphatidylglycerol

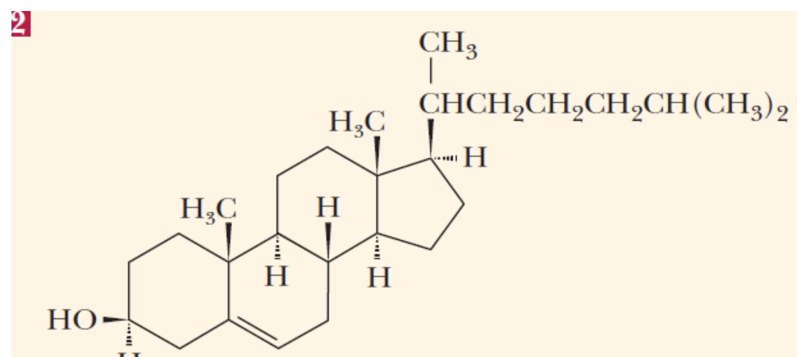
TASK : STATE THE ROLE FOR ALL PHOSPHOLIPID ABOVE

- Detergent properties of phospholipids- phosphatidyl choline – fx to solubilize cholesterol
- Impairment of phospholipid production and secretion into bile – formation of cholesterol stone and bile pigment gallstone

CHOLESTEROL

- Classified under steroid group:
- Structure : fused ring system consist of 3 six-membered ring (A,B, C) and 1 five-membered ring (D ring)
- Sex hormones also include in steroid group





Cholesterol

Cholesterol

- Is a lipid with a very solubility in water
- The high solubility in blood is due to LDL and VLDL
- Major sterol in mammal and component of virtually all plasma and intracellular membranes
- Abundant in mylienated structure of brain and central nerveous system
- Small amount in mitochondria
- Immediate precursor of bile acids that are synthesized in liver – fx to facilitate absorption of dietary TG and fat soluble vit
- Excretion of cholesterol is through intestine in the form of bile acids
- precursor of various steroid hormone –corticostiroids, deoxycorticostirone, corticostirone, corticostirone, cortisol and cortisone

Waxes

- Waxes – complex mixture of esters of long chain carboxylic acid and long chain alcohols
- Protective coatings for plants and animals
- Coat stems, leaves and fruits
- On fur, feathers and skin
- Sphingolipids – do not contain glycerol, but contain amino alcohol sphingosine

Waxes

- An ester of a long-chain fatty acid and alcohol
  - from the Old English word *weax* = honeycomb

$$CH_3(CH_2)_{14}\overset{\overset{\displaystyle O}{\|}}{C}O(CH_2)_{29}CH_3$$

A major component of beeswax (honeycombs)

$$CH_3(CH_2)_{30}\overset{\overset{\displaystyle O}{\|}}{C}O(CH_2)_{33}CH_3$$

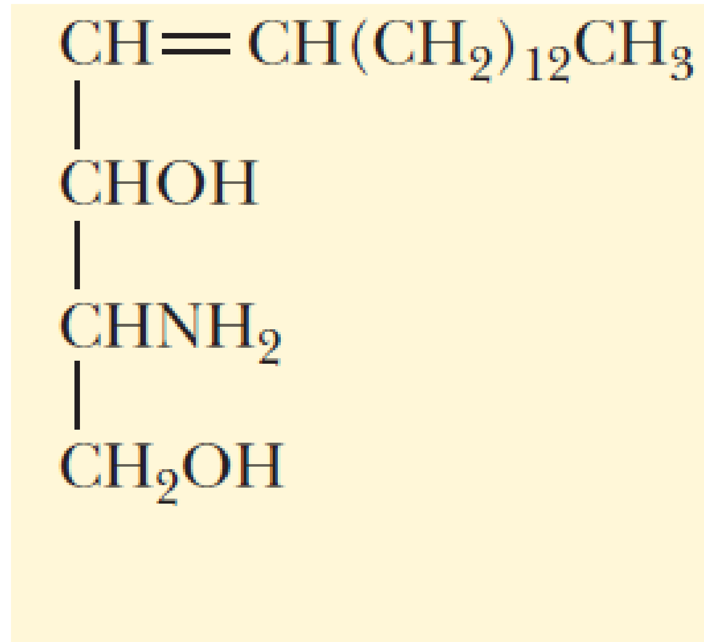
A major component of carnauba wax (the Brazilian wax palm)

$$CH_3(CH_2)_{14}\overset{\overset{\displaystyle O}{\|}}{C}O(CH_2)_{15}CH_3$$

A major component of spermacetti wax (head of the sperm whale)

Sphingolipids

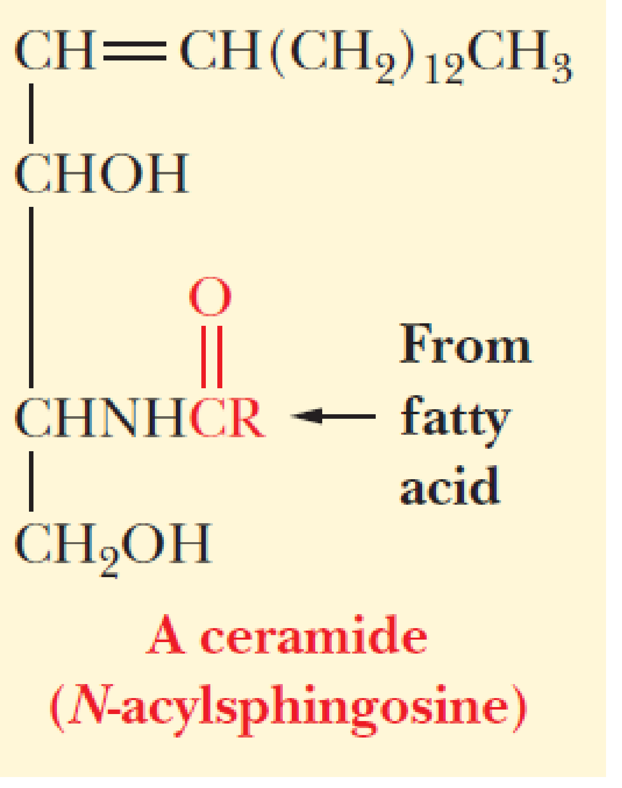
- Complex lipids whose core structure is provided by long-chain amino alcohol sphingosine
- Sphingolipids are present in blood and nearly all blood tissue – highest in CNS
- Components of cell membrane



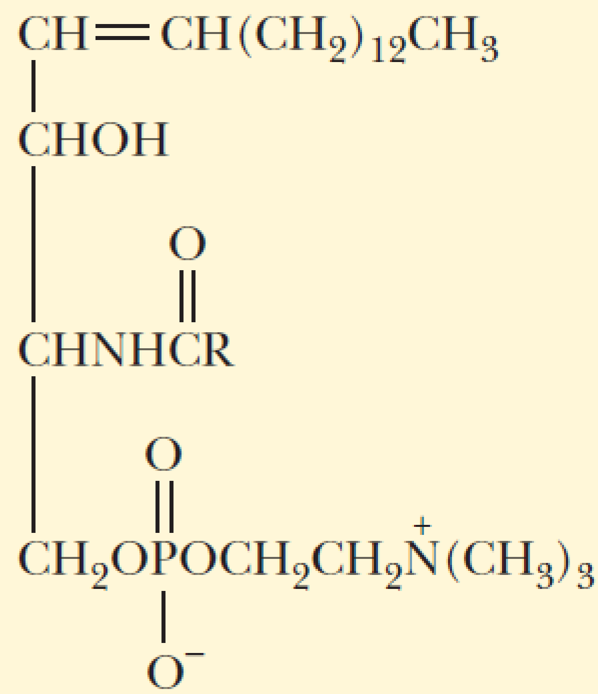
Sphingosine

Sphingolipids

- The simplest compund – CERAMIDE – fatty acid linked to the amino group of sphingosine
- Ceramide is not component of membrane lipids but an intermediate in synthesis of sphingomyline



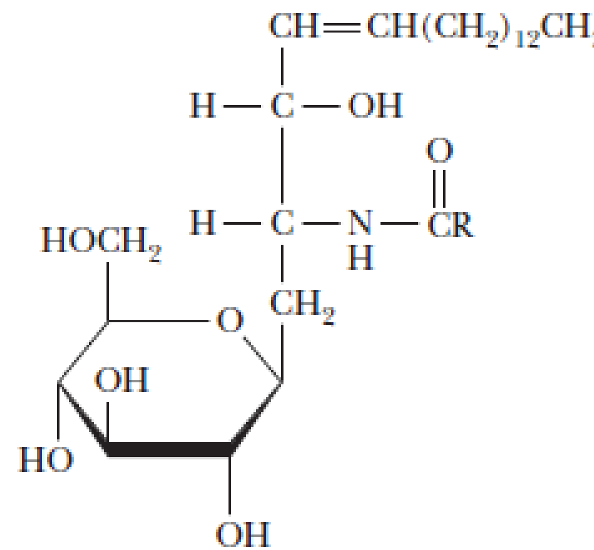
- Sphingomyline – primary alcohol group of sphingosine is esterified to phosphoric acid, which in turn esterfied to amino alcohol, choline
- Sphingomyline – in cell membranes in nerveous system



A sphingomyelin

Glycolipids

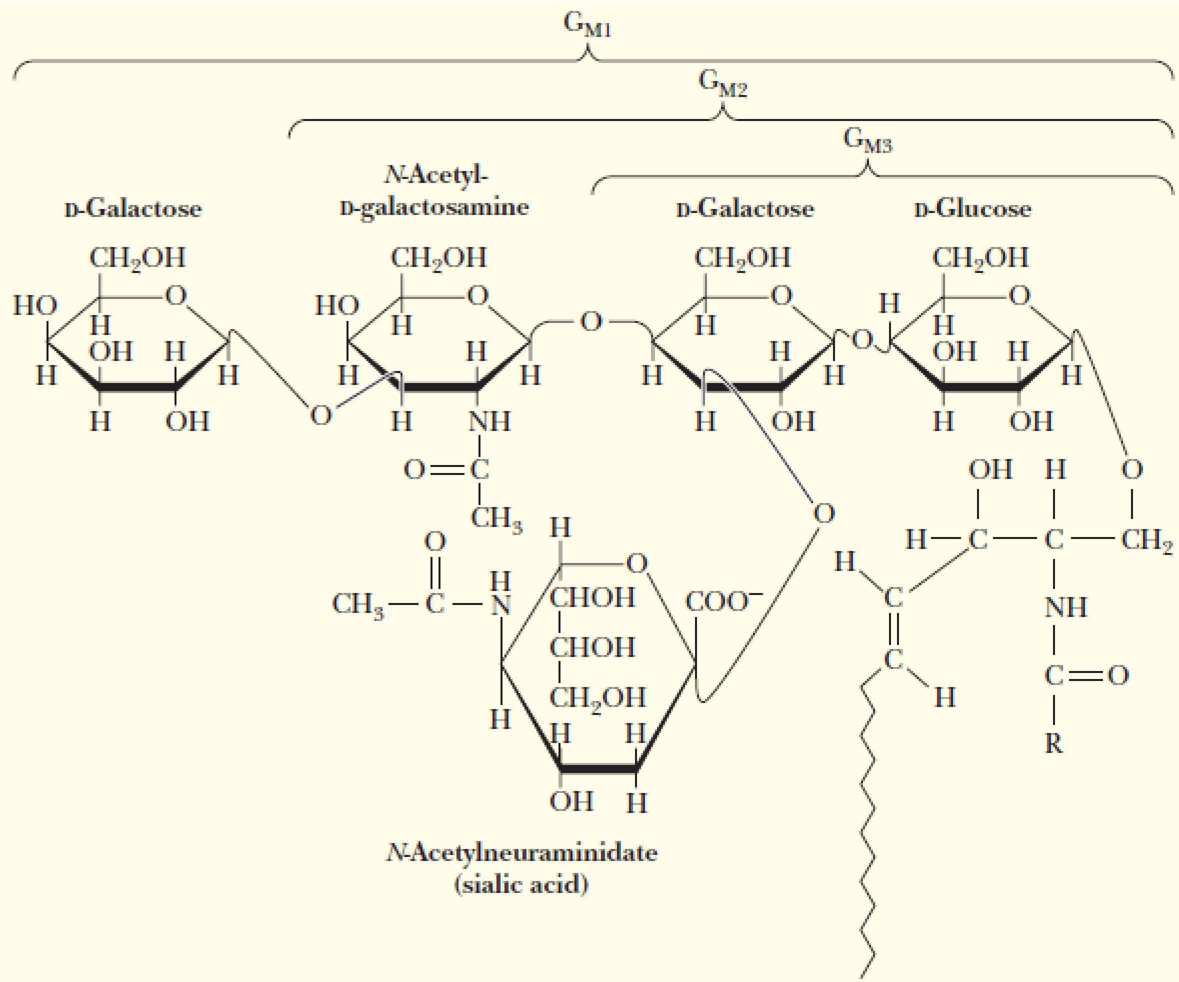
- Carbohydrate bound to lipid
- Ceramides are the parent compound – sugar is attached to the primary alcohol group of ceramide through glycosidic bonds – forming cerebroside
- Sugar residue; glucose or galactose
- Found in nerve and brain membrane cells
- Glycolipids often found as markers on cell membranes
- Example of glycolipids: ganglioside



A Glucocerebroside

Ganglioside

- Molecule composed of glycosphingolipid (ceramide and oligosaccharide) with one ore more sialic acid compound (N-neuriminic acid, NeuAc)
- Large quantity in nerve tissue-modulates cell signal transduction
- Simplest – GM3 (Ceramide,glucose, galactose and NeuAc)



Gangliosides G_{M1}, G_{M2}, and G_{M3}

EICOSANOIDS

- Derived from Eicosa (20 carbon) polyenoic fatty acid
- Consist of: Prostanoids, Leukotriens (LTs) and Lipoxins (LXs)
- Prostanoids include: Prostaglandin (PG), Prostacyalins and Thromboxanes

- TASK: LIST DOWN THE ROLE OF PROSTAGLANDIN, THROMBOXANE AND LEUKOTRIEN


REEZE!
HOMICIDE? BURGLARY?
WORSE. TRANS FAT.
RAISE YOU HANDS AN STEP AWA FROM TH CHICKE

Introduction to Serum Protein Electrophoresis

Video Lesson - Janaki Silva

voice-over – Dilru Silva