Memorize!

pH & Buffers:

Buffer Systems:

* Blood ⇒ H_2CO_3 / HCO_3^- system

* Inside cells (intracellular) ⇒ $H_2PO_3^-$ / HPO_3^{2-} . ATP . Glucose-6-phosphate . Biphosphoglycerate (RBCs). (anything with phosphate)

* Proteins ⇒ Hemoglobin ... (intracellular - RBCs) | proteins having histidine a.a. Both intracellular + extracellular
Albumin ... (extracellular - blood plasma)

Acidosis & Alkalosis

Respiratory Acidosis ⇒ Holding Breath. Choking. Asthma. Emphysema. (damage of alveoli walls. Air trapped.)

Why? $CO_2 \uparrow$. $\overset{\uparrow}{CO_2} + H_2O \rightleftharpoons H_2CO_3 \overset{\longrightarrow}{\rightleftharpoons} \uparrow HCO_3^- + \uparrow H^+$

Metabolic Acidosis ⇒ Impaired H^+ excretion. HCO_3^- Loss. Lactic acidosis. keto acids formation
- ↳ Starving... using fatty acids for energy
- ↳ Diabetes

Respiratory Alkalosis ⇒ Hyperventilation. High altitudes

Metabolic Alkalosis ⇒ Excessive salt intake. Alkali ingestion. Loss of H^+ in vomit

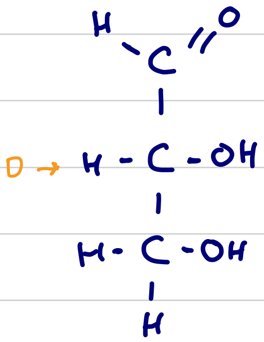
Metabolic Acidosis / Alkalosis ⇒ compensation with respiratory alkalosis / acidosis

Respiratory Acidosis / Alkalosis ⇒ compensation with metabolic alkalosis / acidosis

Carbohydrates:

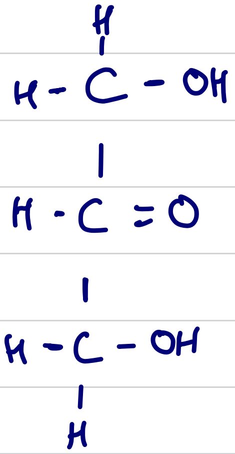
Monosaccharides:

3C - Aldotriose :



D-glyceroaldehyde

3C - ketotriose :

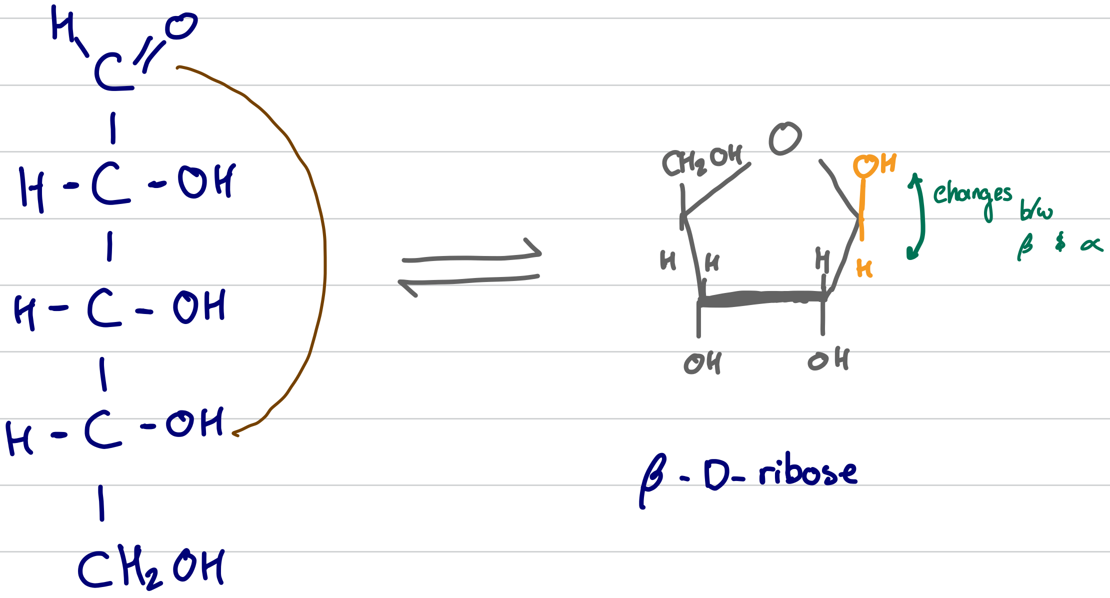


dihydroxyacetone

note: All are D-sugars. Before last -OH always to right.

5C - Ribose:

Ribose ⇒ R R R
2 3 4



β - D- ribose

Glucose => R L R
2 3 4

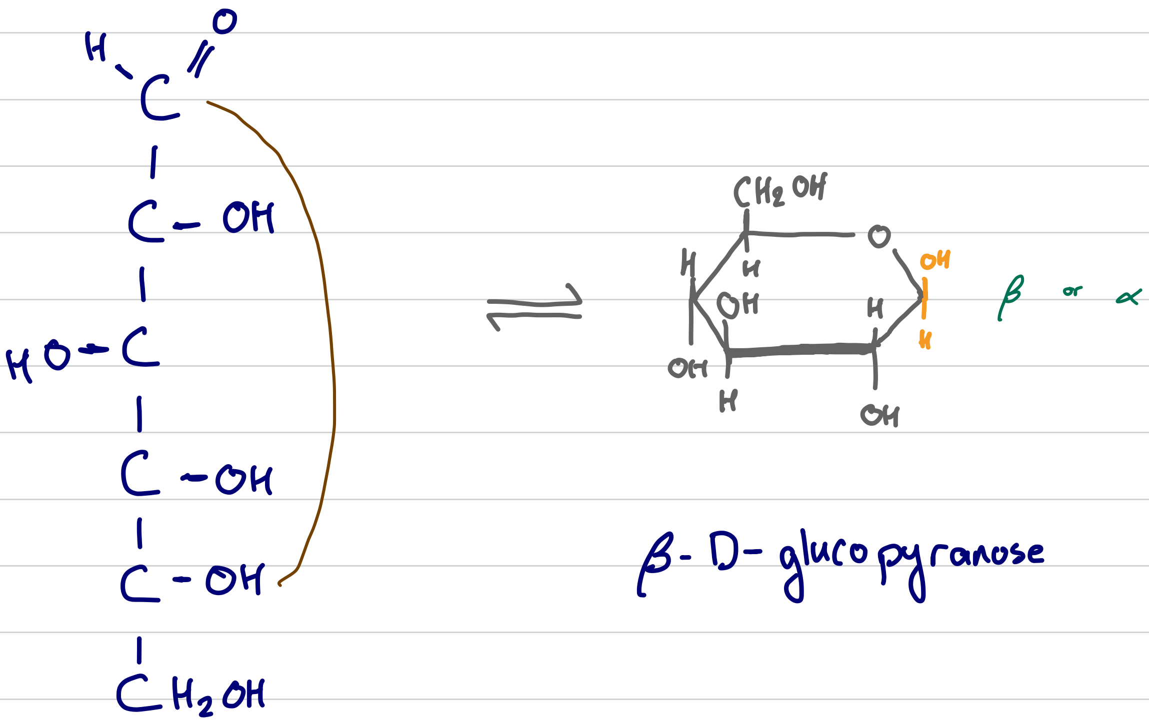
Galactose => R L L
2 3 4

Mannose => L L R
2 3 4

=> epimers. Different at only one carbon

* Galactose & mannose are diastereomes but NOT epimers

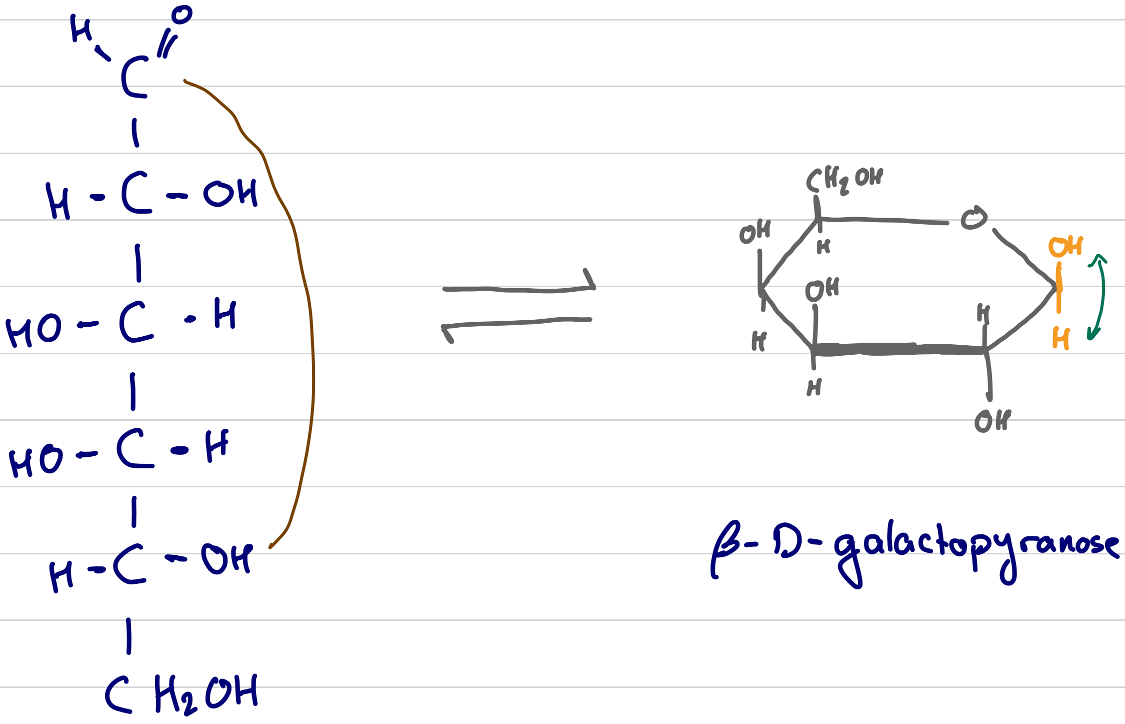
6C - Glucose:



β or α

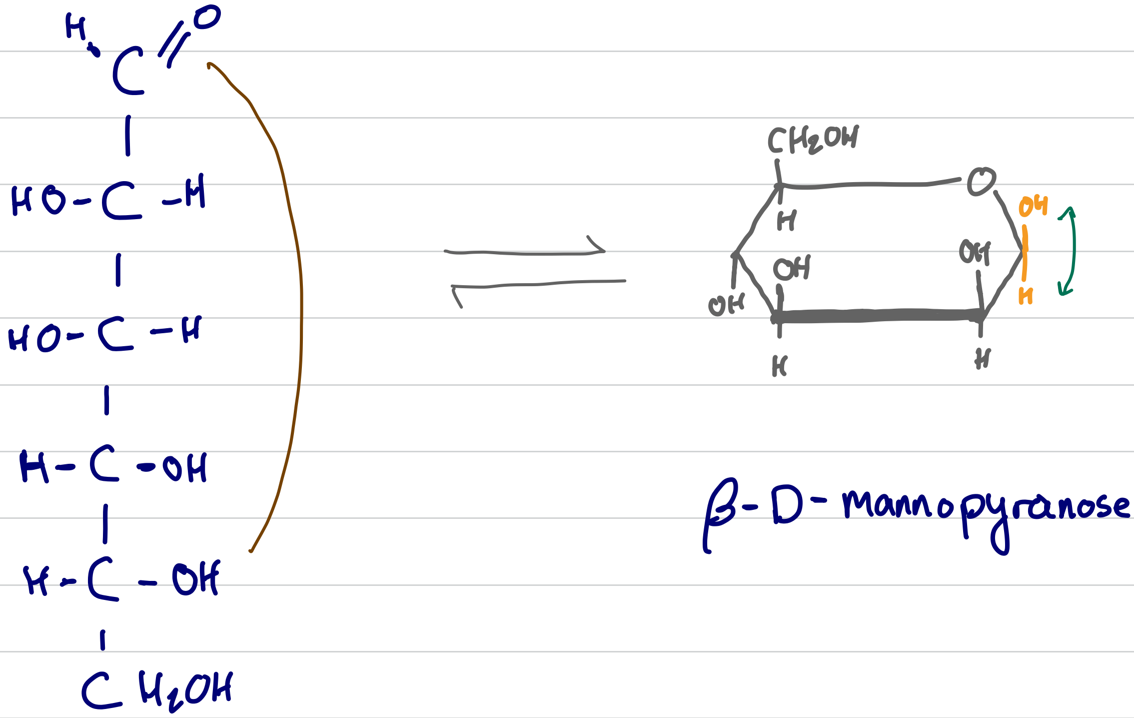
β- D- glucopyranose

6C - Galactose:



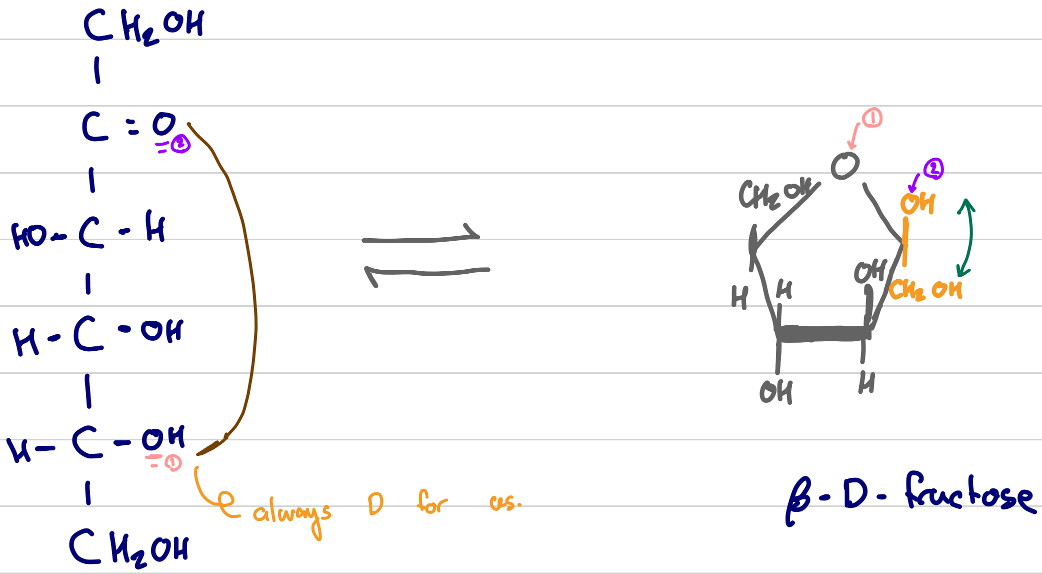
β-D-galactopyranose

6C - Mannose:

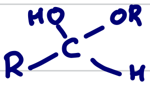


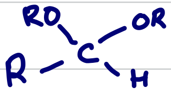
β-D-mannopyranose

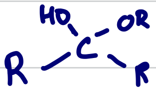
6C - Fructose: Ketose ... NOT aldose | / ⇒ L R
3 4

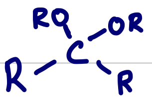


β - D - fructose

* Hemiacetal ⇒  cyclic aldose anomeric

* Acetal ⇒  cyclic aldose disaccharide anomeric

* Hemiketal ⇒  cyclic ketose anomeric

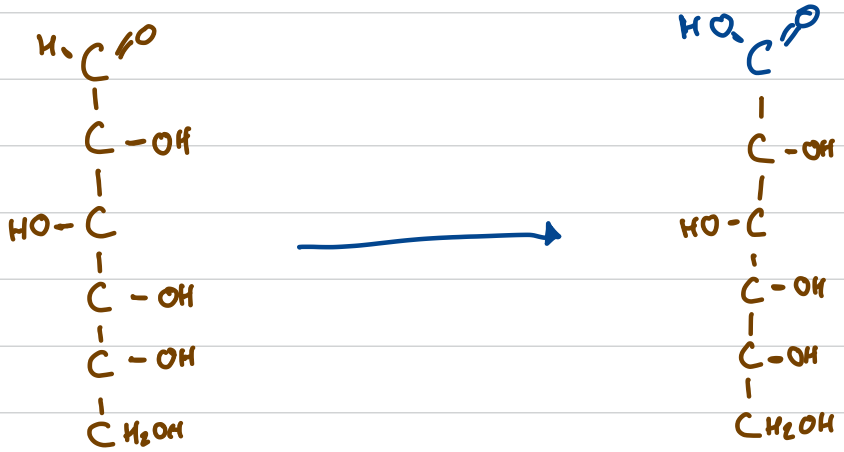
* ketal ⇒  cyclic ketose disaccharide anomeric

Glucose Oxidation:

Oxidation at C1: Linear gluconate

Glucose ⟶ Gluconic Acid / Gluconate

Conditions: Weak oxidizing agent



Glucose

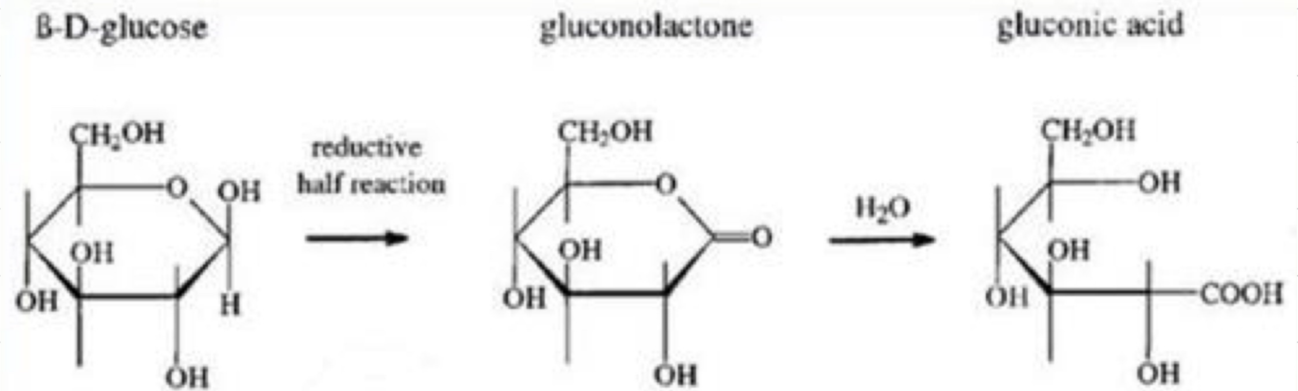
Gluconic Acid

Always Linear

Never cyclic

Oxidation at C1: Cyclic lactone

Cyclic glucose ⟶ gluconolactone (cyclic)



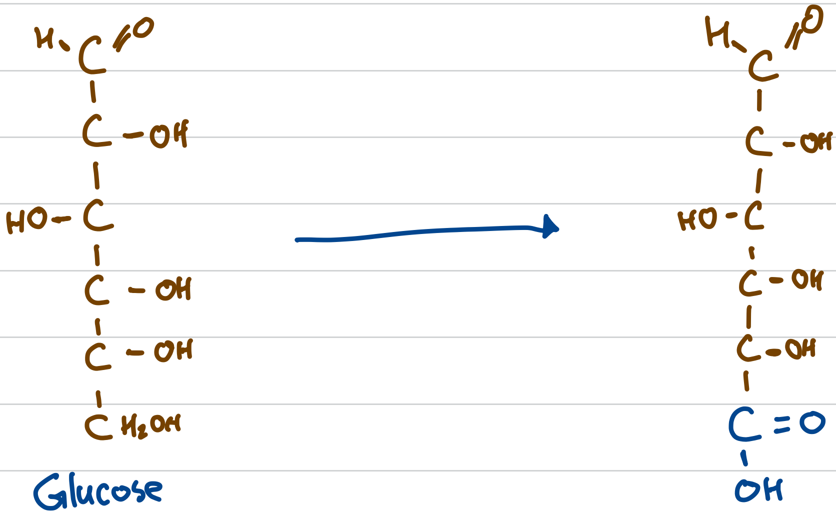
Cyclic Always

Linear always

Oxidation at C6:

Glucose ⟶ Glucuronic Acid / Glucuronate

Conditions: Enzyme



Glucose

Glucuronic Acid

Either cyclic or Linear

* Glucose + weak oxidizing agent: Aldehyde to CO_2H at C1. Gluconate

* Glucose + strong oxidizing agent. Aldehyde to CO_2H at C1. Alcohol to CO_2H at C6.

* Glucose + enzyme: Alcohol to CO_2H at C6. Glucuronate.

* Cyclic glucose + weak oxidizing agent: Alcohol to ketone at C1. Gluconolactone.
↳ then further oxidation into gluconate.

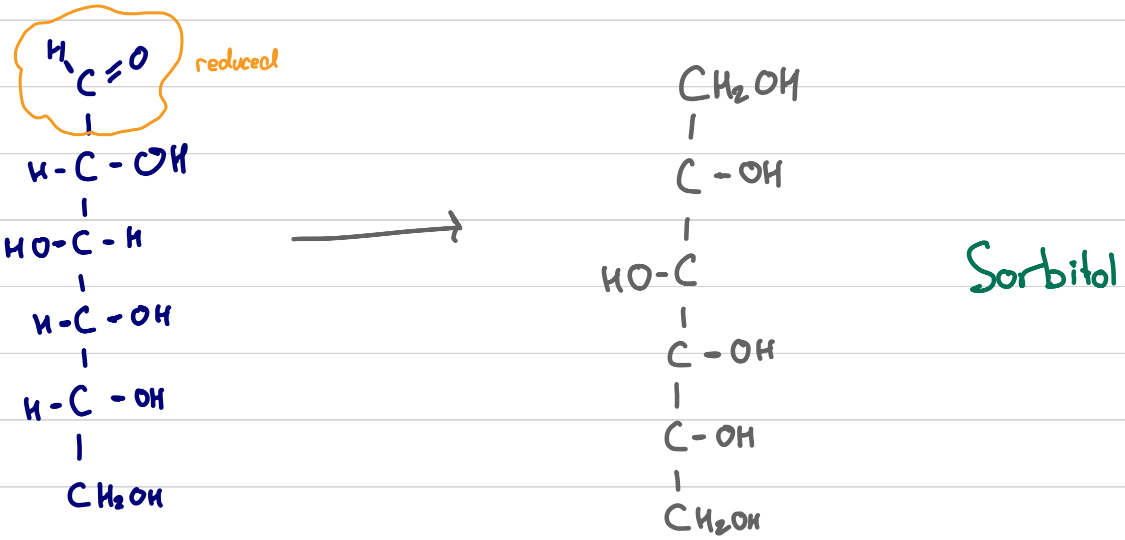
Ketose oxidation... fructose: Transform ketose into its aldehyde isomer, glucose.

Fructose $\rightleftharpoons$ $\boxed{\text{ene-diol}}$ $\rightleftharpoons$ glucose ⟶ gluconate / glucuronate / gluconolacton

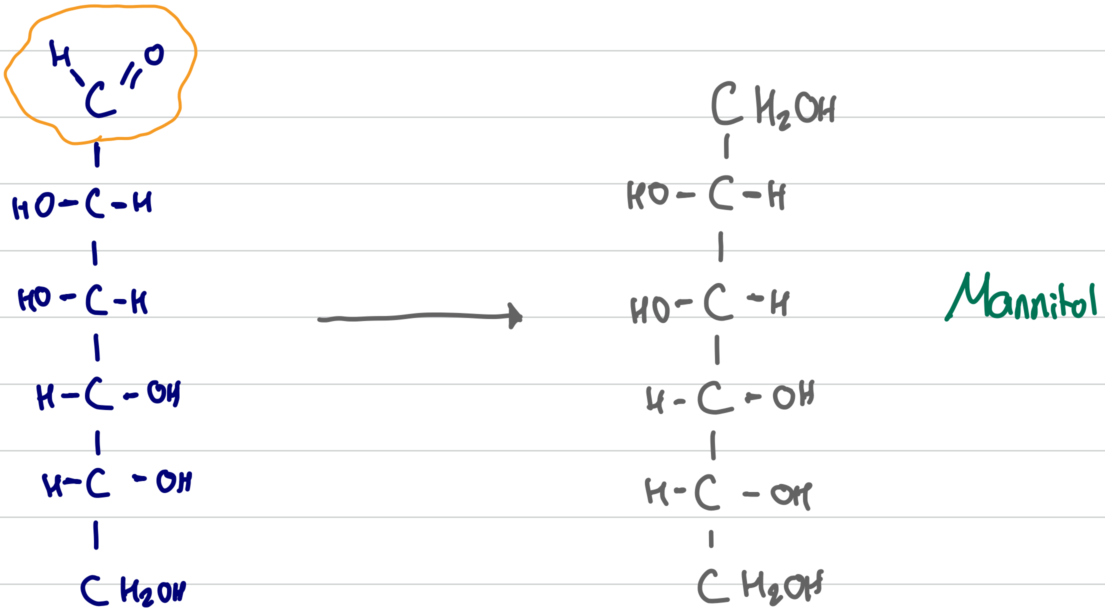
Reduction of sugars:

note: Fructose can be reduced at C2 (ketose) to form either D-sorbitol or D-mannitol

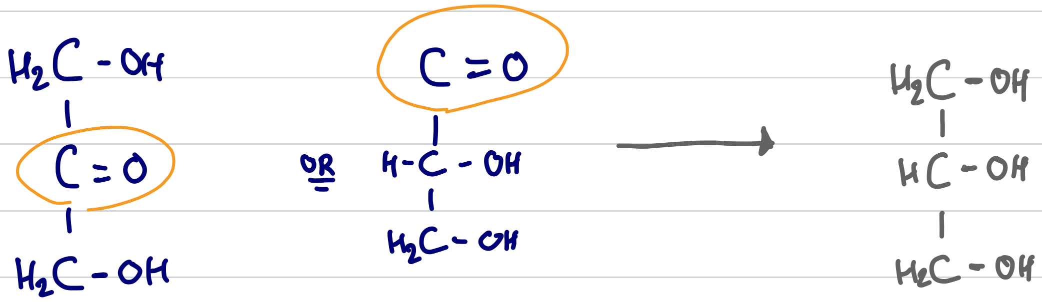
Reduction of D-glucose to form sorbitol.



Reduction of D-mannose to form mannitol:

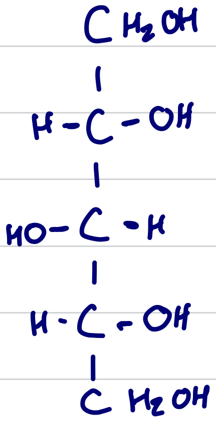


Reduction of trioketose or trioaldose. Dihydroxyacetone / glyceraldehyde

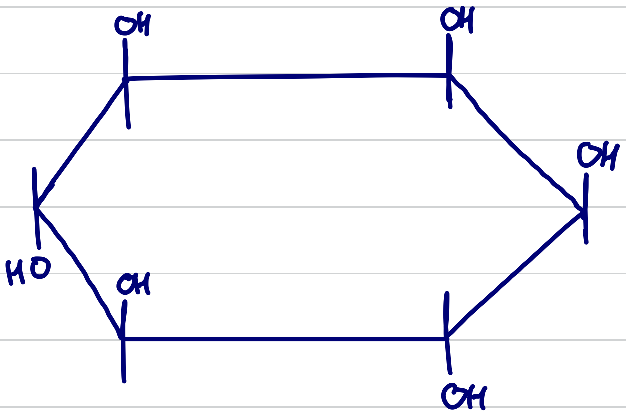


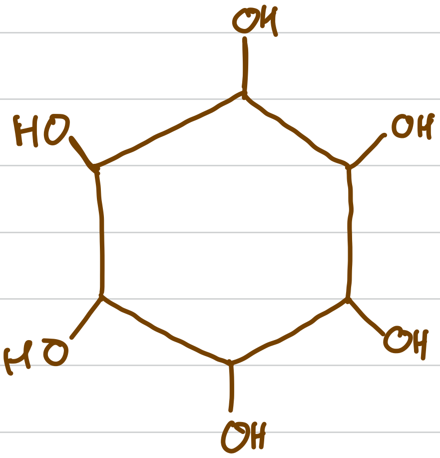
Glycerol

Xylitol: Like sorbitol but remove the last carbon



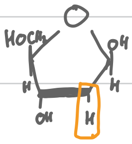
Inositol:





Deoxy Sugars (reduced sugars):

- Deoxyribose



- Deoxygalactoses.. known as Fucose.

Found in carbohydrate of the glycoprotein of RBCs.

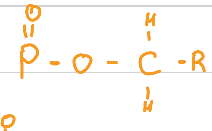
- L-fucose / 6-deoxy-L-galactose

- D-fucose / 6-deoxy-D-galactose

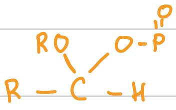
- 6-deoxy-$\overset{\alpha}{\underset{\beta}{\text{or}}}$-D-galacto$\underbrace{\text{furanose}}_{\text{5 ring}}$,

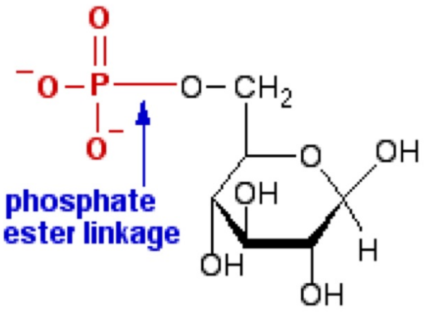
Sugar Esters:

- Phosphate + glucose at C6 => Phosphate ester bond



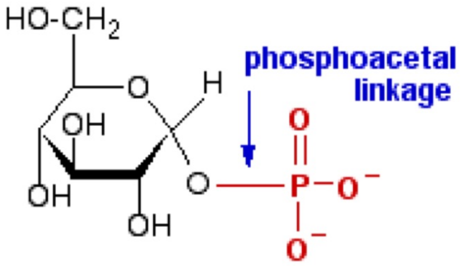
- Phosphate + glucose at C1 => Phosphoacetal bond





phosphate ester linkage

β-D-glucose-6-phosphate
(an ordinary **phosphate ester**)



phosphoacetal linkage

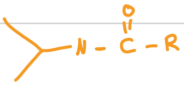
α-D-glucose-1-phosphate
(a **phosphoacetal**)

Amino - Sugars:

Nitrogen bonded to non anomeric carbon.

* Amine group => glucosamine OR GlcN (given its glucose)

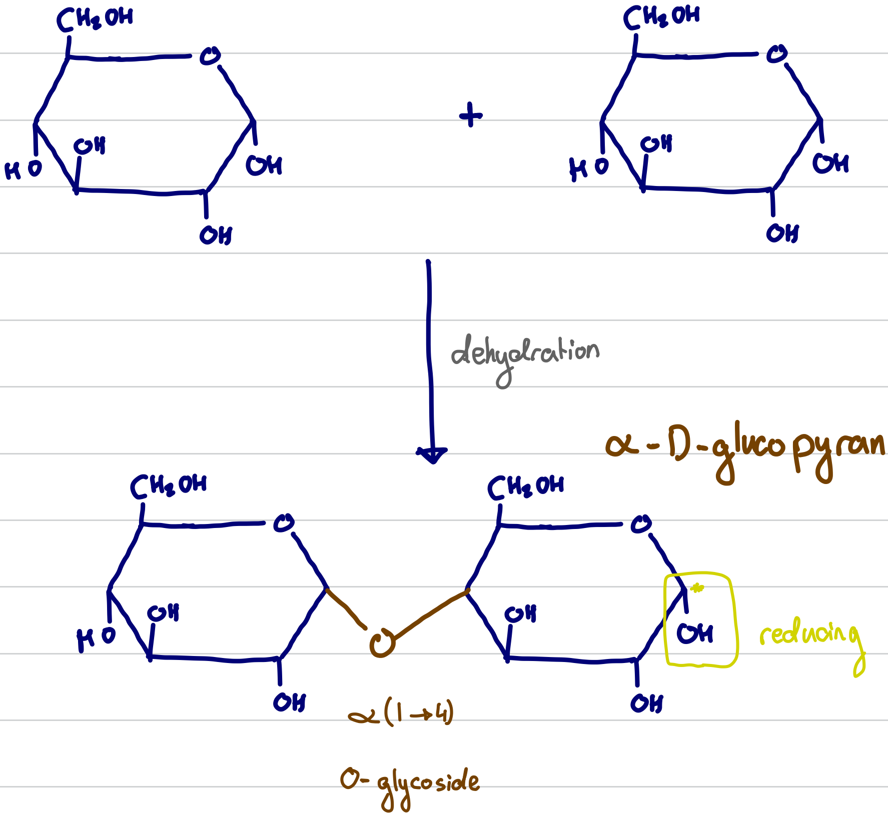
* Amide group => N-acetyl-glucosamine OR GlcNAc



→ N-acetyl

Disaccharides :

Maltose: α-glucose + α-glucose at α(1→4) glycosidic bond

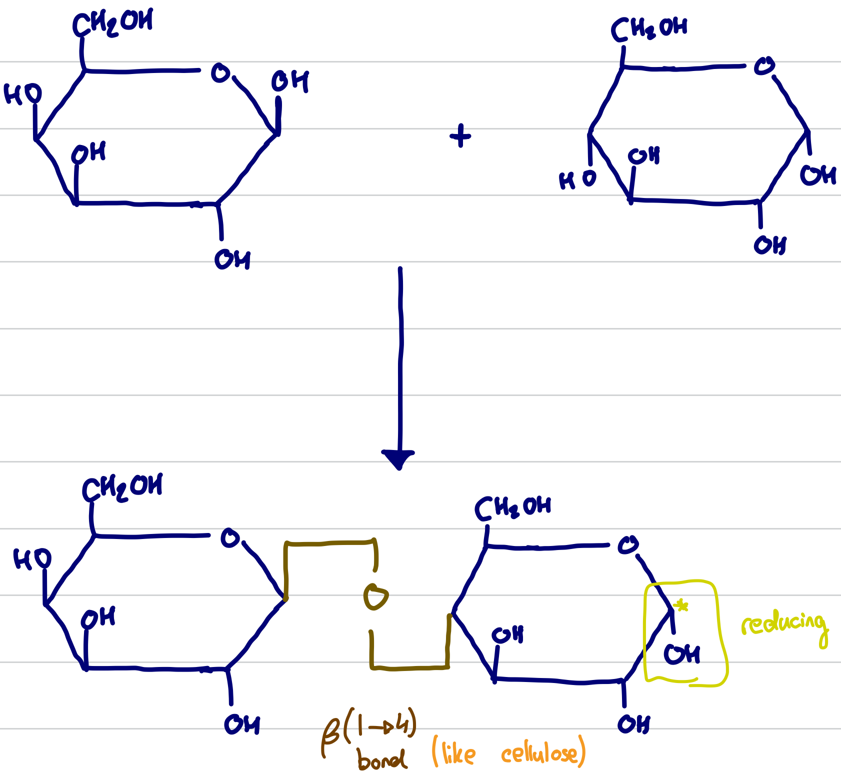


α-D-glucopyranosyl-(1→4)-α-D-glucopyranosyl anomeric carbon

glycosidic

Lactose: β-galactose + $\overset{\alpha}{\underset{\beta}{\text{or}}}$ glucose at β(1→4) glycosidic bond

Always beta



reducing

β(1→4) bond (like cellulose)

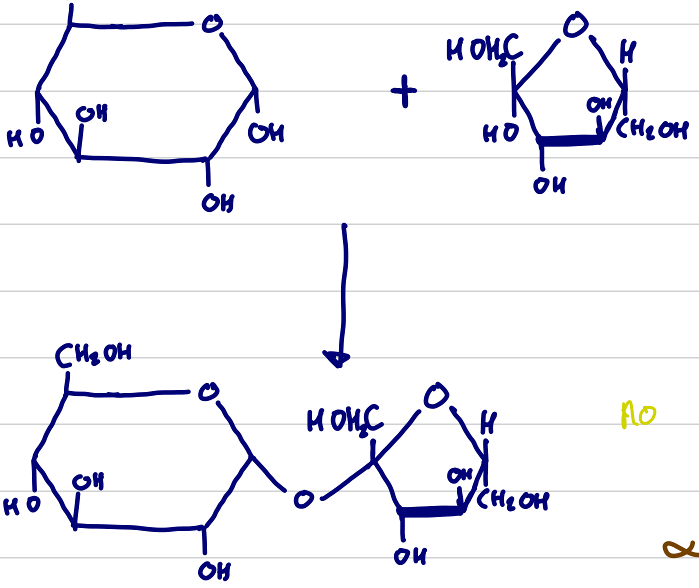
β-D-galactopyranosyl-(1→4)-α-D-glucopyranose

of fructose

Sucrose: α-glucose + β-fructose at α,β(1→2) glycosidic bond

of glucose

both anomeric carbons of residues contribute... so non-reducing sugar.



no need to know these structures or name.

Know: Sucrose = α-glucose + β-fructose at α,β(1→2)

no free anomeric carbons

α,β(1→2)

Lactose problems:

* Lactose intolerance:

→ Lacking Lactase enzyme

→ lactose in intestines. Diarrhea.

→ Bacteria break lactose. Gases produced. Bloating.

* Galactosemia

→ Lacking galactose -metabolizing enzyme. Accumilation of galactose.

→ Galactose converted to sugar alcohol galactitol. Galactitol trapped in cells

→ Water enters cells. Cells swell

→ Severe & irreversable retardation

→ Cataract (cloudy lens in eyes)

Lactulose:

* Formed by isomerising lactose.
* Aids constipation by promoting gut bacteria & regulating immune system

Sucralose:

* Modified sucrose. Replacing -OH with -Cl
* Sucralose is zero-calorie sugar substitute
* Studies show it may cause cancer.

Reducing VS Non-Reducing sugars:

* All monosaccharides - Reducing
* Maltose. α-glucose + α-glucose. $\alpha(1\rightarrow4)$ - Reducing
* Lactose. β-galactose + α-glucose $\beta(1\rightarrow4)$ - Reducing
* Sucrose α-glucose + β-fructose $\alpha,\beta(1\rightarrow2)$ - non-reducing
* All polysaccharides - non-reducing

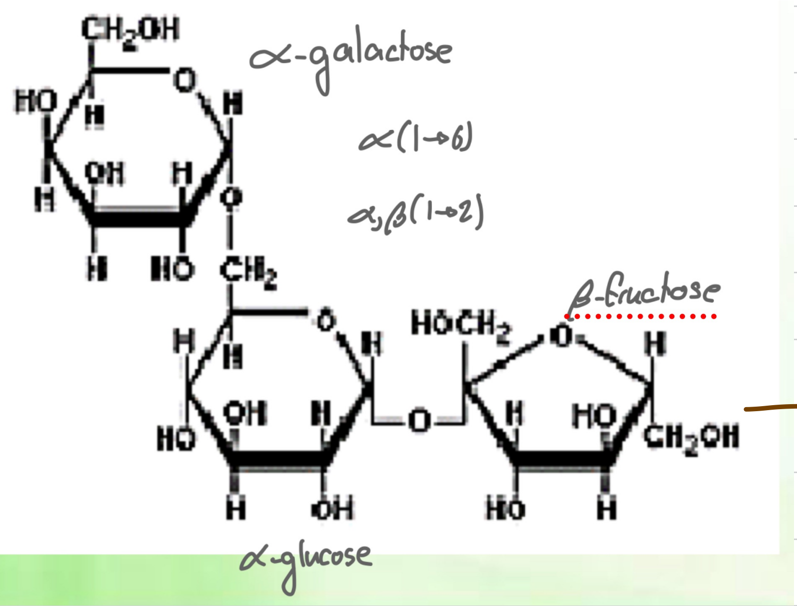
Oligosaccharides: 3 - 10 residues

Raffinose:

Made up of → sucrose → α-glucose, β-fructose
\+ α-galactose

∴ Raffinose ⇒ α-galactose + α-glucose and β-fructose

α(1→6) and α,β(1→2)



→ Raffinose

* Humans can't digest well

* Bacteria aid in digestion. Bloating.

Oligosaccharides as drugs:

- * Streptomycin / Erythromycin → Antibiotics
- * Doxorubicin → chemotherapy for cancer
- * Digoxin → cardiovascular disease

Polysaccharides:

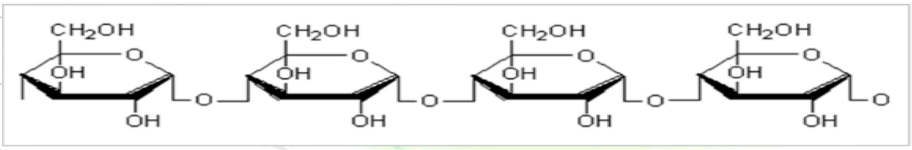
Starch:

↳ 10% - 20% Amylose. α-glucose residues. All $\alpha(1\rightarrow4)$. No branching

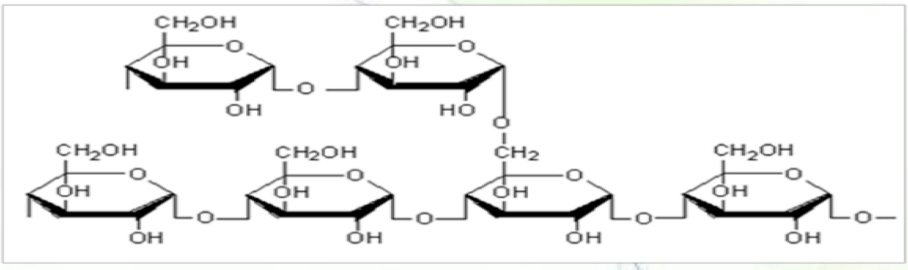
↳ 80 - 90% Amylopectin. α-glucose residues. $\alpha(1\rightarrow4)$ & $\alpha(1\rightarrow6)$. The $\alpha(1\rightarrow6)$ is branches. Branch every 25 glucose residues. Less branching than glycogen

Glycogen:

α-glucose residues. $\alpha(1\rightarrow4)$ with $\alpha(1\rightarrow6)$ branching Branch every 10 glucose residues. More branched than amylopectin



Amylose Structure



Amylopection Structure

Dextran:

* Original chain is $\alpha(1\rightarrow6)$
* Branching at $\alpha(1\rightarrow2)$ / $\alpha(1\rightarrow3)$ / $\alpha(1\rightarrow4)$

Dextran → yeast and bacteria

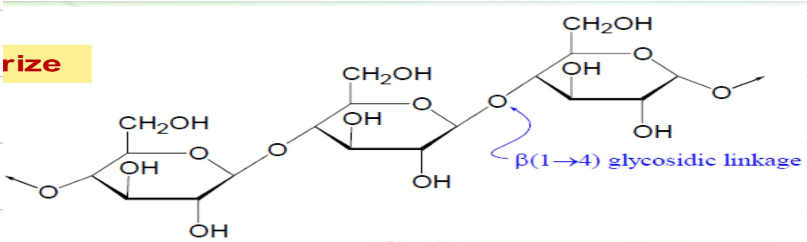
Starch → plants

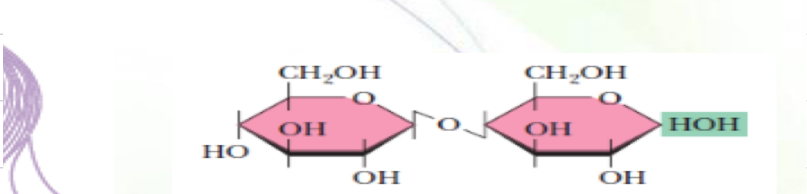
Glycogen → animals

⇒ storage

Cellulose:

- Structural support
- unbranched. Long chain and rigid. Not flexible.
- β-glucose residues. β(1→4) bonds.

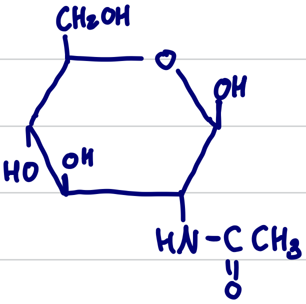




Cellobiose (glucose-β-1,4-glucose)

Chitin:

- Stronger than cellulose. More H-bonding. Rigid and strong.
- Made of beta amino sugars.
- Exoskeleton of animals and insects. Cell wall of Fungi.
- made up of N-acetyl-β-D-glucosamine residues. β(1→4) bonds



β + glucosamine + N-acetyl

β-glucose + amino sugar + amide amino sugar

⇓

N-acetyl-β-D-glucosamine

Don't memorize structure.

Only the name.

note that both cellulose & chitin made of β(1→4). Because β(1→4) is rigid!

Pectin:

- Modified galactose. Galactauronic acid. Oxidized at C6.
- $\alpha(1\to4)$ glycosidic bonds
- Found in plants. Gelatinous. Plant gelatin.

18,438

Glycosaminoglycans (GAGs) and proteoglycans:

- GAGs form proteoglycans. → many sugar with protein.
- GAGs are repeated units of disaccharides. So heteropolysaccharides.
- Made up of modified amino glucose or amino galactose. Sulphurated.
- Glucosamine or galactosamine residues.
- Negative charge. Holds water.

Functions of proteoglycans: → GAGs + protein.

amino-sugars

- Lubrication
- Forms the connective tissue
- Cells - ECM adhesion
- Stimulates cell proliferation

Location + Function of GAGs:

Chondroitin Sulfate:

- Cartilage
- Most abundant

Heparin:

- Anticoagulant

Hyaluronate:

Lubricant and shock absorber in:

- ECM of loose CT
- vitreous humor

Bacterial cell wall and peptidoglycan:

Made of repeat units of NAM and NAG. Heteropolysaccharides. NAMs + NAGs are connected to amino acids

NAM => N- acetylmuramic acid

NAG => N- acetyl glucosamine

(NAM has lactic acid)
↓
then forms amide with N-terminal of amino acids

=> NAMs connected to amino acids.
NAMs + amino acid are bonded to NAGs.

Protein + sugar role:

- Protein Folding
- Protein targetting
- Increasing protein half-life
- Signalling and cell-to-cell communication.

Glycoproteins:

Blood types:

Memorize this: Anything RBC signalling. **Galactose !**

- All contain fucose. A deoxy galactose

A = Amino sugar (acetyl)

- Blood A : N - Acetyl galactosamine
- Blood B : Galactose
- Blood O: Nothing. Only fucose
- Blood AB: Both N-acetylglucosamine and galactose

Same deal with glycolipids → ceramide + Sugar → cerebroside / → globoside / → ganglioside

(sphingosine + F.A)

Glycosidic Linkages in glycoproteins: (alot protein with little sugar attached)

- N- Glycoside : Sugar + amide group of Asparagine (Asn)
- O- Glycoside: Sugar + -OH of Threonine (Thr) or Serine (Ser) or Hydroxylysine (hLys)

Sialic Acid:

* In Glycoproteins & glycolipids. There is a oligosaccharide chain. The **LAST** residue is sialic acid.

(glycolipids → ganglioside)

* Sialic Acid is an amino sugar. Comes from neuraminic acid. It is acidic

* Sialic Acid = N-acetyl neuraminate

* neuraminic acid ⟶ N-acetylneuraminate (sialic acid)

neuraminic acid ↓ amino sugar; N-acetylneuraminate ↓ amino sugar

The glycolipid ganglioside ends with sialic acid. Globoside **does not** end with sialic acid (NANA).

Lipids:

Fatty Acid names:

How to memorize?

* common name * systematic name * Numerical symbol * Omega system
* Structure

Memorize common name and numerical symbol and rest is all findable from the numerical symbol.

Numerical System:

Example: $18:2^{\Delta 9,12}$ ⇒ 18 carbons long. Two double bonds. Location carbon 9 & 12

note: each double bond has $-CH_2$ group in middle. So from one double bond to another it is +3 always. Memorize first location & add 3.

Omega System:

Counting from last carbon until we reach the double bond. Number of this carbon is the omega number.

note: all fatty acids we memorize are cis.

14C: M^0
16C: P^0
18C: S^0 O^1 L^2 L^3
20C: A^4 E^5 D^6
↑ 22C

14 Carbons: $\overset{0}{M}$

1 →

Common name: Myristic Acid

Double bond number: 0

Numerical symbol: 14:0

Systematic name: n-tetradecanoic acid

Omega system: N/A

16 Carbons: $\overset{0}{P}$

2 →

Common name: Palmitic Acid

Double bond number: 0

Numerical symbol: 16:0

Systematic name: n-hexadecanoic acid

Omega system: N/A

Palmitoleic Acid is $16:1^{\Delta 9}$

18 Carbons: $\overset{0}{S}$ $\overset{1}{O}$ $\overset{2}{L}$ $\overset{3}{L}$

3 →

Common name: Stearic Acid

Double bond number: 0

Numerical symbol: 18 : 0

Systematic name: n-octadecanoic

Omega system: N/A

4 →

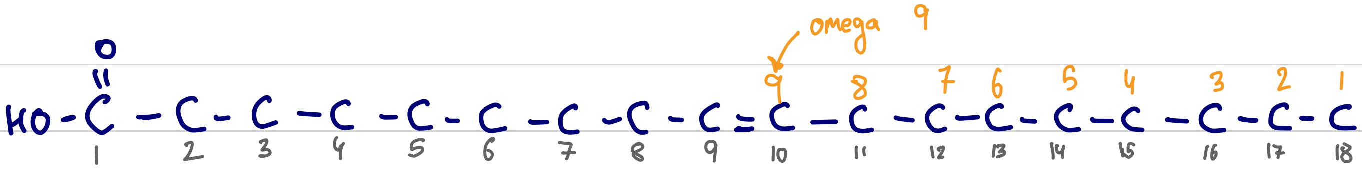
Common name: Oleic Acid

Double bond number: 1

Numerical symbol: $18:1^{\Delta 9}$ → all 18 carbons start double bond at C9.

Systematic name: cis-Δ9-octadecenoic acid

Omega system: omega-9 monounsaturated



$$HO-\overset{\overset{O}{\|}}{C}-C-C-C-C-C-C-C-C=C-C-C-C-C-C-C-C-C$$

5 →

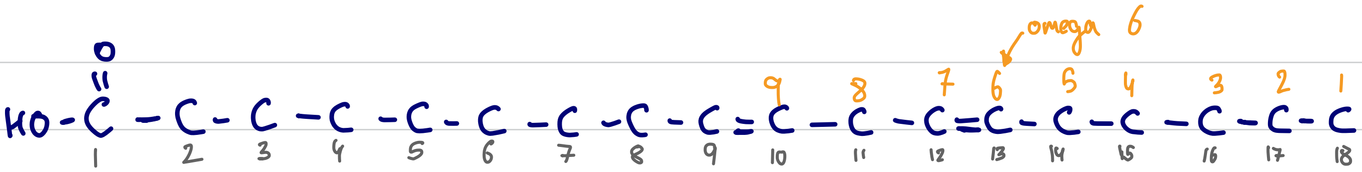
Common name: Linoleic Acid

Double bond number: 2

Numerical symbol: $18:2^{\overset{+3}{\Delta 9,12}}$

Systematic name: cis, cis - Δ^{9}, Δ^{12} - octadecadienoic Acid

Omega system: omega-6 polyunsaturated



$HO-\overset{O}{\overset{\|}{C}}-C-C-C-C-C-C-C-C=C-C-C=C-C-C-C-C-C$

6 →

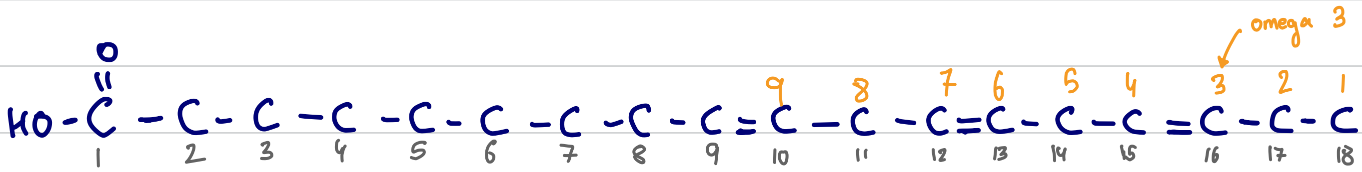
Common name: α-Linolenic Acid

Double bond number: 3

Numerical symbol: $18:3^{\Delta 9,12,15}$

Systematic name: all-cis,cis - Δ9, Δ12, Δ15 - octadecatrienoic acid

Omega system: omega-3 polyunsaturated



$HO-\overset{O}{\overset{\|}{C}}-C-C-C-C-C-C-C-C=C-C-C=C-C-C=C-C-C$

20 carbons: $\overset{4}{A}$ $\overset{5}{E}$ $\overset{6}{D}$ ← 22 carbons

7 →

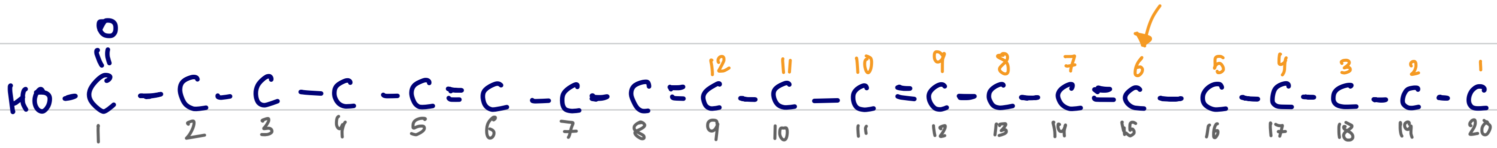
Common name: Arachidonic Acid

Double bond number: 4

Numerical symbol: $20{:}4^{\Delta 5,8,11,14}$

Systematic name: all-cis-Δ5,8,11,14 Eicosatetraenoic Acid

Omega system: Omega-6 polyunsaturated



$$\mathrm{HO-\underset{1}{\overset{\overset{O}{\|}}{C}}-\underset{2}{C}-\underset{3}{C}-\underset{4}{C}-\underset{5}{C}=\underset{6}{C}-\underset{7}{C}-\underset{8}{C}=\underset{9}{\overset{12}{C}}-\underset{10}{\overset{11}{C}}-\underset{11}{\overset{10}{C}}=\underset{12}{\overset{9}{C}}-\underset{13}{\overset{8}{C}}-\underset{14}{\overset{7}{C}}=\underset{15}{\overset{6}{C}}-\underset{16}{\overset{5}{C}}-\underset{17}{\overset{4}{C}}-\underset{18}{\overset{3}{C}}-\underset{19}{\overset{2}{C}}-\underset{20}{\overset{1}{C}}}$$

8 →

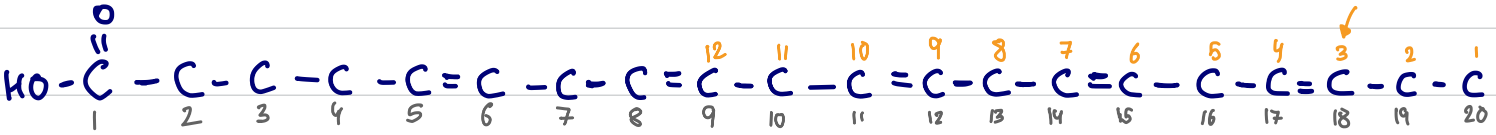
Common name: Eicosapentaenoic Acid (EPA)

Double bond number: 5

Numerical symbol: $20{:}5^{\Delta 5,8,11,14,17}$

Systematic name: not in slides... but $\overset{\text{eico}+}{\text{pentaenoic}}$ acid

Omega system: Omega-3 polyunsaturated



$$\mathrm{HO-\underset{1}{\overset{\overset{O}{\|}}{C}}-\underset{2}{C}-\underset{3}{C}-\underset{4}{C}-\underset{5}{C}=\underset{6}{C}-\underset{7}{C}-\underset{8}{C}=\underset{9}{\overset{12}{C}}-\underset{10}{\overset{11}{C}}-\underset{11}{\overset{10}{C}}=\underset{12}{\overset{9}{C}}-\underset{13}{\overset{8}{C}}-\underset{14}{\overset{7}{C}}=\underset{15}{\overset{6}{C}}-\underset{16}{\overset{5}{C}}-\underset{17}{\overset{4}{C}}=\underset{18}{\overset{3}{C}}-\underset{19}{\overset{2}{C}}-\underset{20}{\overset{1}{C}}}$$

9 →

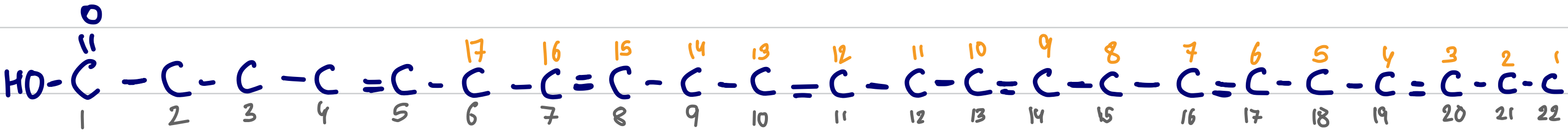
Common name: Docosahexaenoic Acid (DHA)

Double bond number: 6

Numerical symbol: $22:6^{\Delta 4, 7, 10, 13, 16, 19}$

Systematic name: not written... maybe di + eico + hexeinoic

Omega system: Omega 3 polyunsaturated



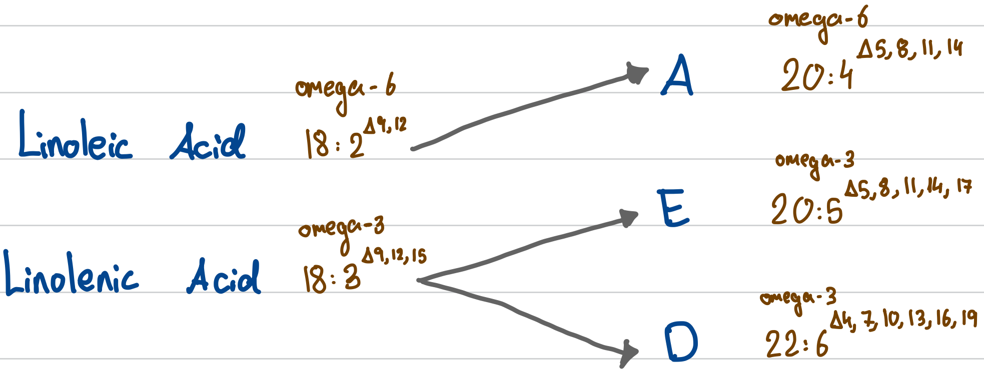
$$HO-\overset{O}{\overset{\|}{C}}-C-C-C=C-C-C=C-C-C=C-C-C=C-C-C=C-C-C=C-C-C$$

Essential Fatty Acids :

- * Linoleic Acid → precurser of Arachidonates
  $18:2^{\Delta 9, 12}$
- * Linolenic Acid → precurser of EPA & DHA
  $18:3^{\Delta 9, 12, 15}$

Memorization tip:

$18: \overset{0}{S}\overset{1}{A}\underbrace{\overset{2}{L}\overset{3}{L}}$ $20: \underbrace{\overset{4}{A}\overset{5}{E}\overset{6}{D}_{22}}$



Linoleic Acid omega-6 $18:2^{\Delta 9,12}$ → A omega-6 $20:4^{\Delta 5, 8, 11, 14}$

Linolenic Acid omega-3 $18:3^{\Delta 9,12,15}$ → E omega-3 $20:5^{\Delta 5, 8, 11, 14, 17}$

Linolenic Acid omega-3 $18:3^{\Delta 9,12,15}$ → D omega-3 $22:6^{\Delta 4, 7, 10, 13, 16, 19}$

Omega 3 makes omega 3

Omega 6 makes omega 6

Fatty Acid melting point:

* Increase number of carbons, higher melting point. Longer chains => more interactions

* Increase unsaturation (c=c), lower melting point. More kinks => Less interactions

* Trans higher melting point than cis.. Cis is kinks but trans looks like saturated so trans more packed & more interactions.

Omega Fatty Acids:

1→ Omega-3 fatty Acids

* Linolenic Acid. $18:3^{\Delta 9, 12, 15}$ → 18-15: 3
* EPA. $20:5^{\Delta 5, 8, 11, 14, 17}$ → 20-17 = 3
* DHA $22:6^{\Delta 4, 7, 10, 13, 16, 19}$ → 22 - 19 = 3

omega 3

Omega 3 are anti-inflamatory

2→ Omega 6 Fatty acids:

* Linoleic Acid. $18:2^{\Delta 9, 12}$ → 18 - 12 = 6
* Arachidonic Acid. $20:4^{\Delta 5, 8, 11, 14}$ → 20 - 14 = 6

omega 6

3→ Omega 9 fatty acids:

* Oleic Acid. $18:1^{\Delta 9}$ → 18 - 9 = 9 omega 9

Omega 9 reduces cholesterol in circulation.

Eicosanoids:

Eicosanoids are derivatives of arachidonic acid $20:4^{\Delta 5,8,11,14}$

Arachidonic Acid → Eicosanoids (cellular function in response to injury)

Types of eicosanoids:

- * Prostaglandins → induces inflammation - COX 2
- * Leukotrienes
- * Thromboxanes → induces platelet aggregation - COX 1
  ↳ cyclooxygenase
- * Prostacyclins

Tip: Eicosanoides:

cox cox cox

P P L T → sounds like platelet

lipo

Aspirin and eicosanoids:

Aspirin → anti-inflamatory affects. Thins the blood. Pain-killer for headaches.

Mechanism:

blood clotting ↑

Aspirin inhibits COX 1 → thromboxane inhibited → inhibits blood clotting

Aspirin inhibits COX 2 → prostaglandins inhibited → inhibits inflammation

↓ inflamation

Side effects:

Excessive bleeding. Especially in elderly. Because thromboxane is inhibited so less blood clotting.

Celebrex as an alternative to aspirin:

Celebrex not inhibits COX 1 → thromboxane not ↓ inhibited → blood clotting normal

Celebrex inhibits COX 2 → prostaglandins inhibited → inhibits inflammation

Aspirin VS Celebrex:

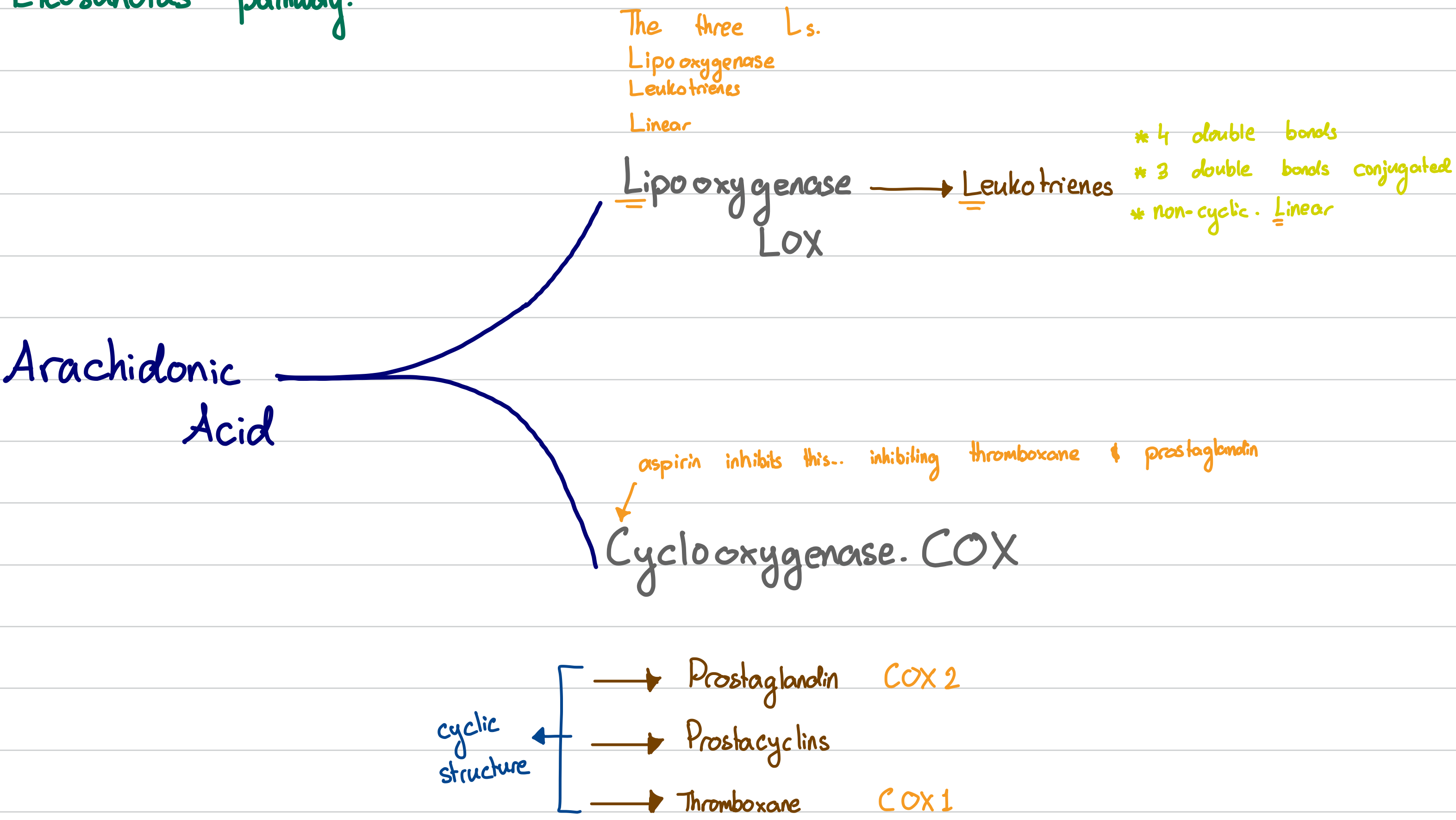
Aspirin:

- * Both COX1 & COX2 inhibited
- * Both prostaglandins & thromboxane inhibited
- * Anti-inflammatory AND anti-blood clotting
- * Excessive bleeding

Celebrex:

- * Only COX2 inhibited
- * Only prostaglandins inhibited
- * Anti-inflammatory but blood clotting normal
- * High risk of stroke & heart problems due to too much blood clotting. Prostaglandin inhibits blood clotting so celebrex increases blood clotting as no inhibition of thromboxane.

Eicosanoids pathway:



The three Ls.
Lipooxygenase
Leukotrienes
Linear

* 4 double bonds
* 3 double bonds conjugated
* non-cyclic. Linear

aspirin inhibits this.. inhibiting thromboxane & prostaglandin

Simple Lipids.. Triglycerides:

* esterification
* dehydration. 3 H_2O formed

Triglycerides / Triacylglycerols ⇒ Glycerol + 3 fatty acids ⇒ Triglyceride

alcohol carboxylic acid

Simple triacylglycerols ⇒ same fatty acid in all 3
Mixed triacylglycerols ⇒ different fatty acids.

Oil vs Fat:

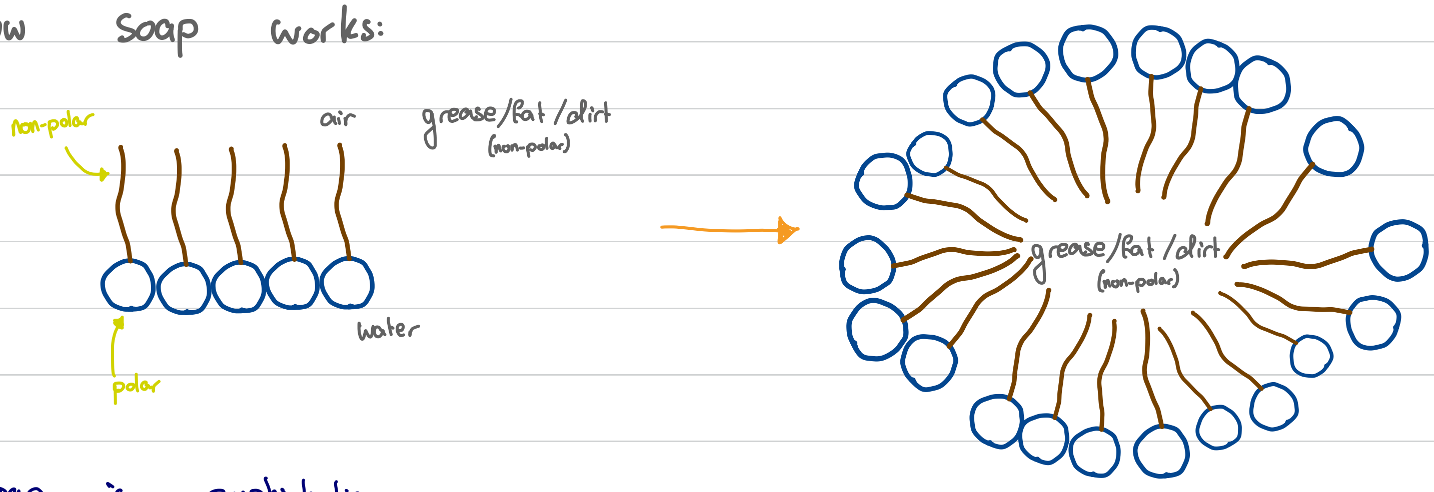
Oil ⇒ liquid at room temp - unsaturated fatty acids in triglyceride.
fat ⇒ solid at room temp - saturated fatty acids in triglyceride.

Triglyceride Reactions:

① Hydrolysis: using water to break the ester bond. Steam / Acid / enzyme (lipase)
Produce glycerol & ionized fatty acids

② Saponification: Alkali hydrolysis to form sodium salt fatty acids which acts as soap. Using NaOH. Produce glycerol & $\underbrace{R-CO_2^- \ Na^+}_{\text{acts as soap}}$

How soap works:

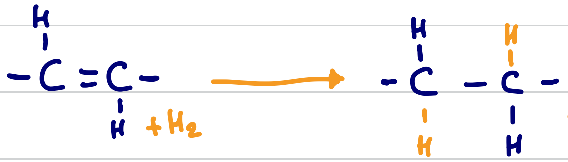


Soap is amphiphatic

Micelle

Hydrogenation:

Adding hydrogen to liquid unsaturated lipids to form solid saturated lipids.



$$-\overset{H}{\underset{}{C}}=\underset{H}{C}- + H_2 \longrightarrow -\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-$$

Saturated

Trans fats produced as side product

Cis Unsaturated → Saturated ~ most → Solid

Cis Unsaturated → Trans unsaturated ~ some → Solid

↳ increase risk of coronary heart disease (CHD) (by atherosclerosis)

Waxes:

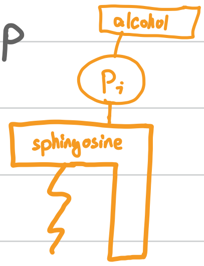
Wax is made of one long alcohol and one long fatty acid.

Properties:

- * indigestable and no nutritional value. Not hydrolysed easily.
- * Very hydrophobic. Coats leaves to prevent water loss
- * Resistant to rancidity. High shelf-life.

Complex Lipids:

① Glycerophospholipids => Glycerol + fatty acid + phosphate ± group

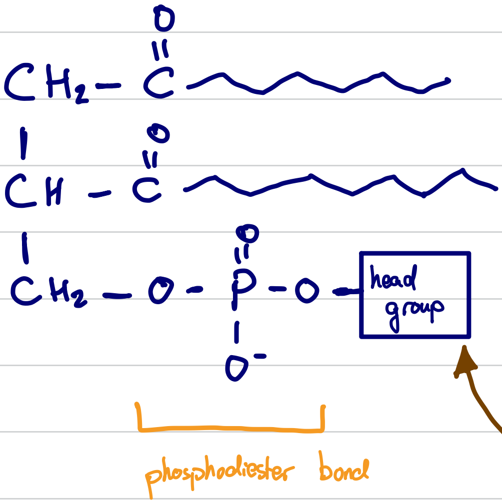


② Shpingo phospholipid => sphingosine + fatty acid + phosphate + group

③ Glycolipids => sphingosine + fatty acid + sugar

Glycerophospholipid:

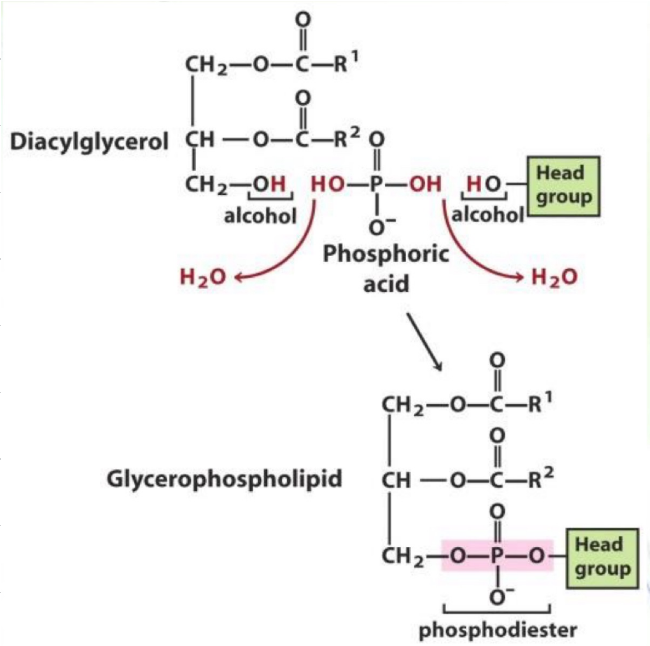
General Structure:



head group is always an alcohol.

naming: phosphatidyl + group name

IE. phosphatidyl choline (Lecithin)



Glycerophospholipids:

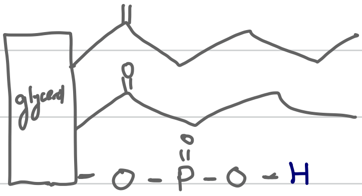
1→

name: Phosphatidic Acid

head group: - H

function: precursor for other glycerophospholipids

Structure:



2→ Lecithin → choline

name: phosphatidylcholine

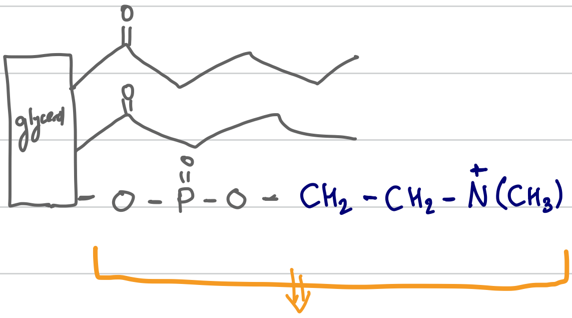
head group: - choline. $- CH_2 - CH_2 - \overset{+}{N}(CH_3)_3$

function:

* most abundant lipid in membrane

* emulsifier. They form micelles easily. Surround non-polar & keep them suspended in water.

Structure:



very polar

Snake venom & lecithin:

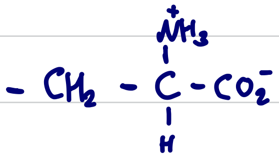
Snake venom has lecithinase enzyme

Lecithin (phosphatidylcholine) $\xrightarrow[\text{hydrolysis of unsaturated fatty acids}]{\text{lecithinase}}$ lyso lecithin → the lysolecithin in red blood cell membrane cause rupture of RBC. Hemolysis.

3→ Cephalins → Serines

name: Phosphatidylserine

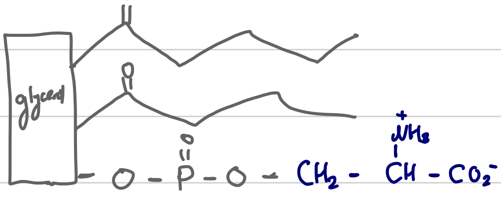
head group: serine.



$- CH_2 - \overset{\overset{+}{N}H_3}{\underset{H}{C}} - CO_2^-$

function: abundant in brain

Structure:



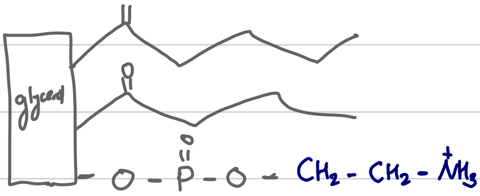
4→ Cephalins → ethanolamine

name: phosphatidyl ethanolamine

head group: - ethandamine. $- CH_2 - CH_2 - \overset{+}{N}H_3$

function: abundant in brain

Structure:



memorization tips:

* cephalins => S + E

→ Serine ~ phosphatidylserine

→ ethanolamine ~ phosphatidyl ethylamine

* cephalic in anatomy means toward head. So cephalins are abundant in cell membranes of nerves of the brain.

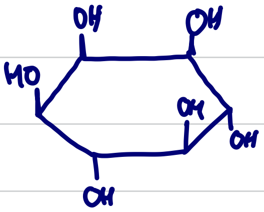
* Lecithin ⟷ Choline

* Lecithins most abundant lipid in membranes

5→ Inositides

name: phosphatidyl inositols ← sourced from brain tissue

head group: - inositol. A cyclic sugar.

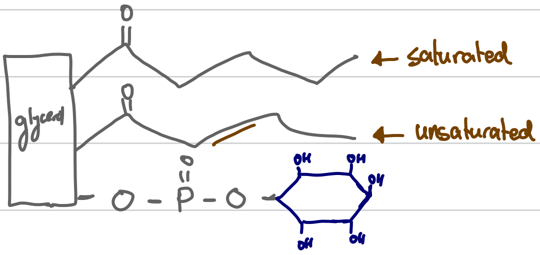


Function:

* cell signalling. Production of second messenger.

In physio.. $Gq \rightarrow PLC \rightarrow \overset{\text{inositol}}{PIP2} \longrightarrow \underset{2^{nd}\ \text{messenger}}{\overset{\text{inositol}}{IP3}} + DAG$

Structure:



6→ Cardiolipins

name: cardiolipins / di phosphatidyl-glycerol

structure: 2 phosphate groups. 3 glycerols. 4 fatty acids

Function:

* cardiolipin. Found in heart
* inner membrane of mitochondria

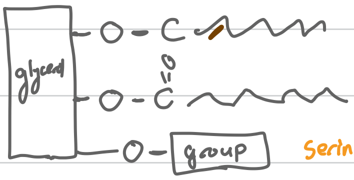
Structure: no need

7→ Plasmologens

name: plasmologens

structure: has ether bond rather than ester. Ether linked with alkene. C-O-CH=CH-C...

Structure:



serine / ethanolamine / choline

Bullet points:

* Plasmologens come from Dihydroxy acetone phosphate (DHAP) ↙ looks so close to glycerol

* ether bond

* with phosphate we can get choline / serine / ethanolamine

* Choline plasmalogen → cardiac tissue
→ platelet activating factors

* Serine plasmalogen

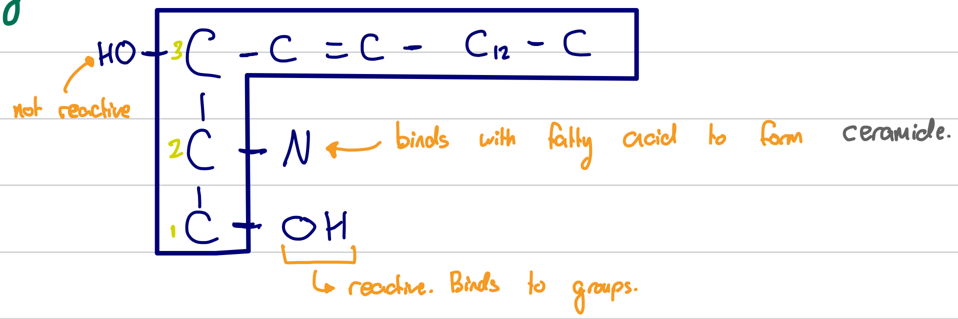
* ethanolamine plasmalogen → myelin sheath

* Found in: brain / muscle / heart / liver / semen (cell membrane)

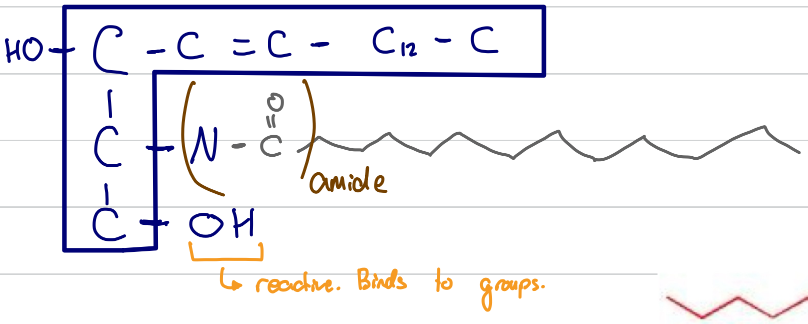
* protects against free radical oxygens (Sacrifices its self)

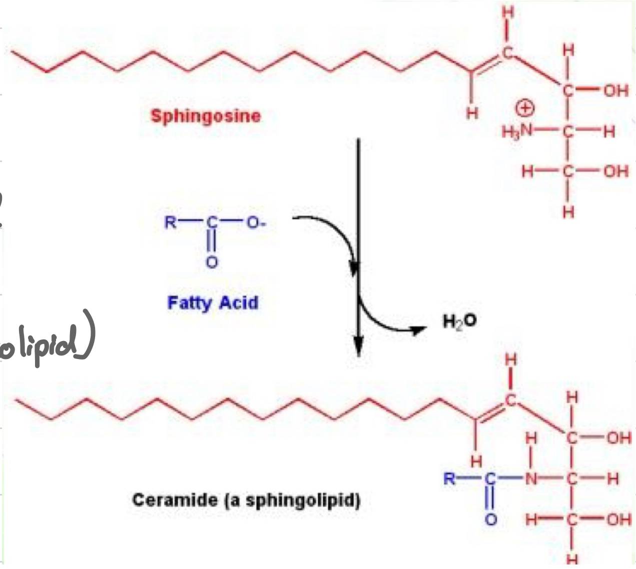
Sphingolipids:

Sphingosine:



Ceramide: Sphingosine + fatty acid at C2. (amide linkage)

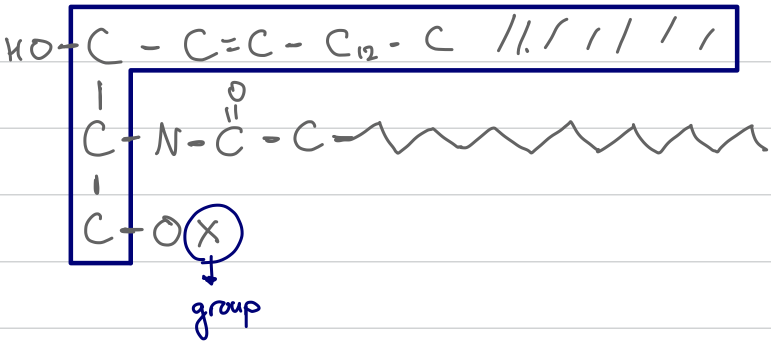




* Ceramide + phosphate C3 ⇒ sphingophospholipid

* ceramide + sugar C3 ⇒ glycolipid (sphingoglycolipid)

Sphingolipid structure:

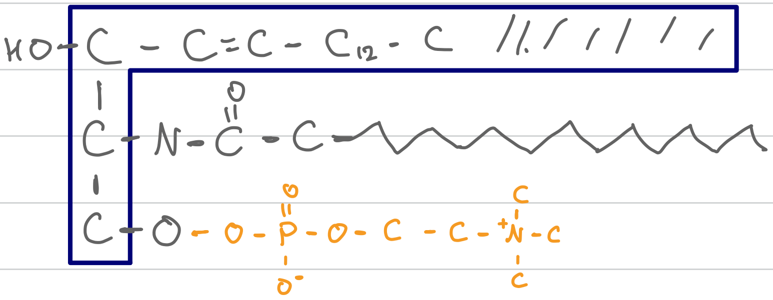


Sphingophospholipid:

Only one. Sphingophospho choline => name: sphingomyelin.

Sphingomyelin:

ceramide + phosphate choline. => sphingomyelin.



Component of myelin sheath. Multiple Sclerosis → disease due to the decay of myelin sheath

Glycolipid:

sphingosine + fatty acid
amide

Ceramide + sugar = glycolipid cell receptor & cell recognition.

1 → Cerebrosides

sphingosine + FA

Cerebroside => ceramide + monosaccharide

Cerebroside → ceramide + glucose → glucocerebroside

Cerebroside → ceramide + galactose → galactocerebroside

↓

sulfatides (sulfated galactocerebroside)

↓ in myelin

sulfatides => ceramide (sphingosine + FA) + galactose + sulfur

sulfonated

2 → Globoside

Globoside => 2 or more sugars. NO end sialic Acid (N-acetyl neuraminic Acid) NANA

The sugars are on C1 of ceramide

Sugars include: Glucose / N-acetyl glucosamine / Galactose

3 → Ganglioside:

Ganglioside => 3 or more sugars WITH end sialic Acid (N-acetyl neuraminic acid) NANA

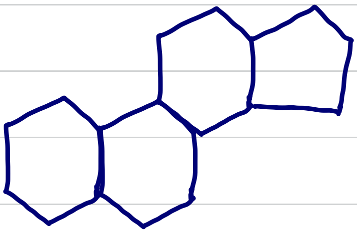
The sugars are on C1 of ceramide

Sugars include: Glucose / N-acetyl glucosamine / Galactose

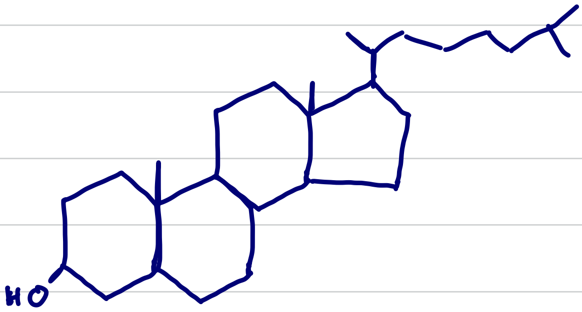
Gangliosides bind cholera toxin. Endocytosis.

Steroids:

Steroid nucleus:



Cholesterol:



Don't memo just understand

Cholesterol is amphipathic

Cholesterol:

isoprene → cholesterol → sex hormones - testosterone / estrogen / progesterone

precursor

→ vitamin D

→ bile salts - amphipathic. Forms micelles. Emulcification of fats

Functions:

- * Regulate membrane fluidity. Not too fluid. Not too rigid.
- * Forms sex hormones
- * Forms vitamin D
- * Forms bile salts

Too much cholesterol causes atherosclerosis

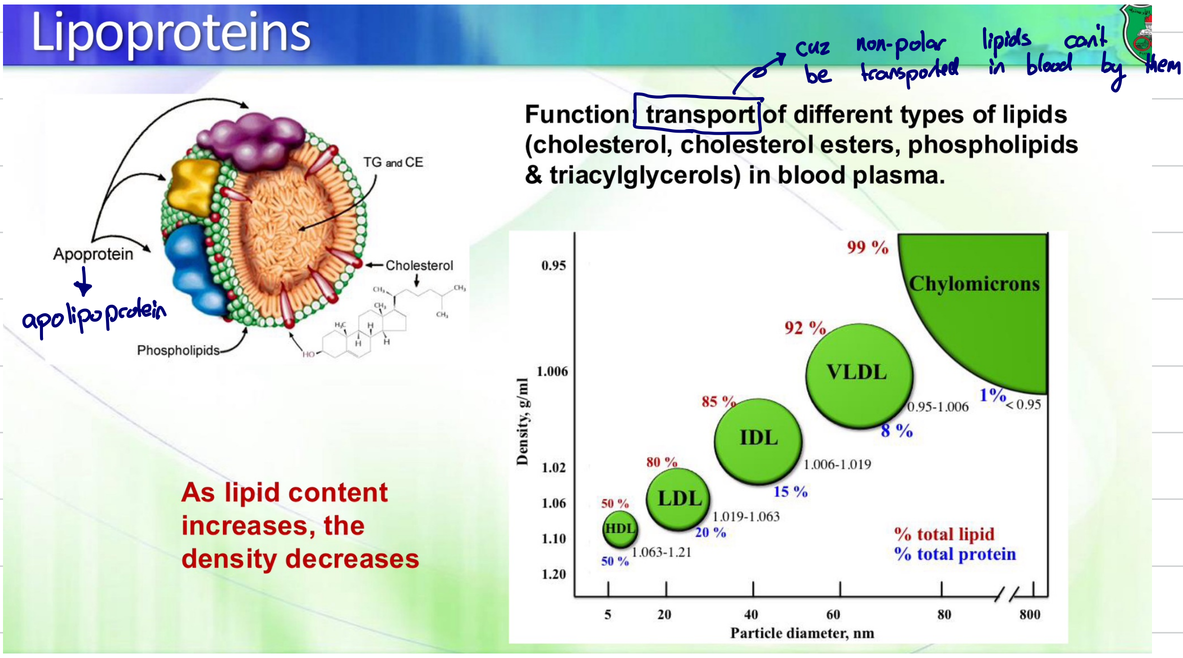
Cholesterol Ester:

Cholesterol-OH + fatty Acid $-CO_2H$ ⇒ cholesterol $\overbrace{- O - \overset{\overset{O}{\|}}{C} -}^{\text{cholesterol ester}}$ fatty acid

⇓ 100% hydrophobic molecule

* Cholesterol esters are used for transport + storage of cholesterol

Lipoproteins:



Lipoproteins

cuz non-polar lipids can't be transported in blood by themselves

Function: transport of different types of lipids (cholesterol, cholesterol esters, phospholipids & triacylglycerols) in blood plasma.

As lipid content increases, the density decreases

Order of less dense (less protein) to more dense (more proteins):

Chylomicrons > VLDL > IDL > LDL > HDL

Apolipoprotein ⇒ PART of a lipoprotein

Smaller = more dense

More protein % = more dense

Cell membrane composition:

- 45 % lipids

lipids = proteins

- 45% proteins
- 10% carbs

Outer Part:

- Lecithin / phosphatidylcholine
- Sphingomyelin (sphingosine + fatty acid + phosphate — choline)
- Glycolipid (cell recognition) (ceramide + sugar) (cerebroside / globoside / ganglioside)
- Cholesterol

Inner Part:

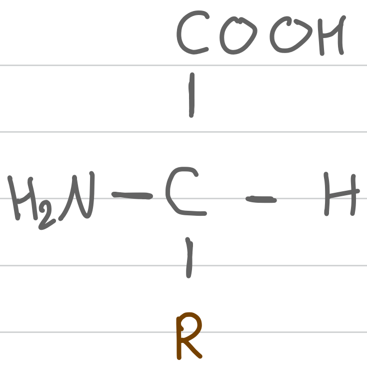
- Cephalins → phosphatidylserine & phosphatidyl ethanolamine
- Phosphatidylinositol → cell signalling (inositol)
- Cholesterol

Membrane Protein:

- pheripheral (outside) (associated with integral + can be removed easily [mild detergent])
- integral (spanning) (hydrophobic interactions + single / $\overset{\text{G-protein}}{\downarrow}$multiple + $\overset{\text{humans}}{\alpha\text{-helix}}$ + $\overset{\text{bacteria}}{\beta\text{-sheat}}$ + form channels)
- Lipid - anchored

Amino Acids:

Name: Amino Acid X



$$\mathrm{H_2N-\underset{\underset{R}{|}}{\overset{\overset{COOH}{|}}{C}}-H}$$

Type: Polar / Non-polar / charged

R group: *

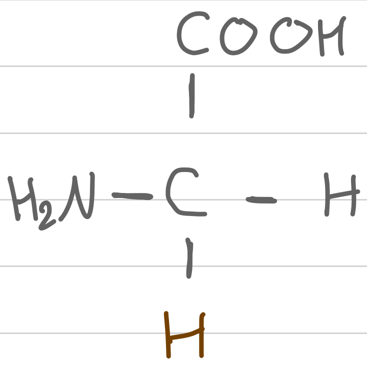
Unique name of functional unit: *

Memorization tip: *

Gooood Luck!

1 →

Name: Glycine (Gly)



$$\mathrm{H_2N-\underset{\underset{H}{|}}{\overset{\overset{COOH}{|}}{C}}-H}$$

Type: non-polar

R group: - H

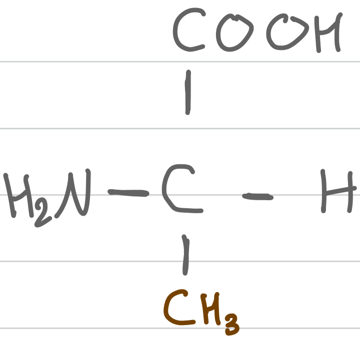
Unique name of functional unit: N/A

Memorization tip: Simplest amino acid.

Extra info: *

2 →

Name: Alanine (Ala)



$$H_2N-\overset{\overset{COOH}{|}}{\underset{\underset{CH_3}{|}}{C}}-H$$

Type: non-polar

R group: - CH_3

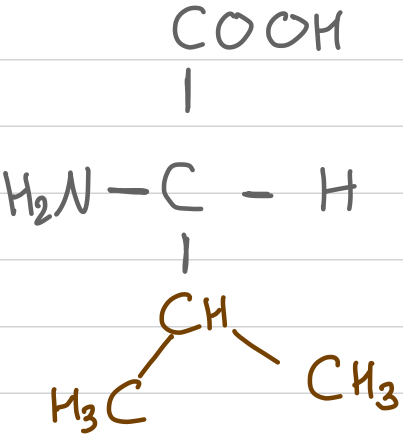
Unique name of functional unit: methyl group

Memorization tip: Alanine => A => first letter => only <u>one</u> methyl group.

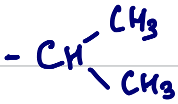
Extra info: *

3 →

Name: Valine (Val)



Type: non-polar

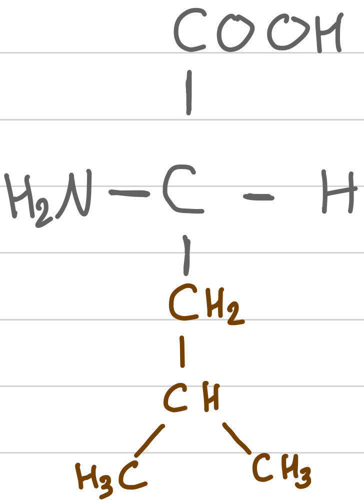
R group: 

Unique name of functional unit: Branch

Memorization tip: Looks like a valley... valine.

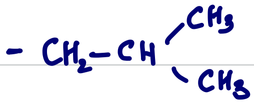
Extra info: One of three essential amino acids

4 →



Name: Leucine (Leu)

Type: non-polar

R group: 
$-CH_2-CH\genfrac{}{}{0pt}{}{CH_3}{CH_3}$

Unique name of functional unit: branch

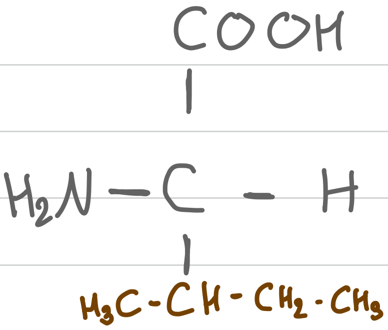
Memorization tip: Lucy => 4 letters => leucine has 4 Methyl groups

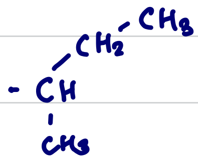
Extra info: One of three essential amino acids

5 →

Name: Isoleucine (Ile)

Type: non-polar



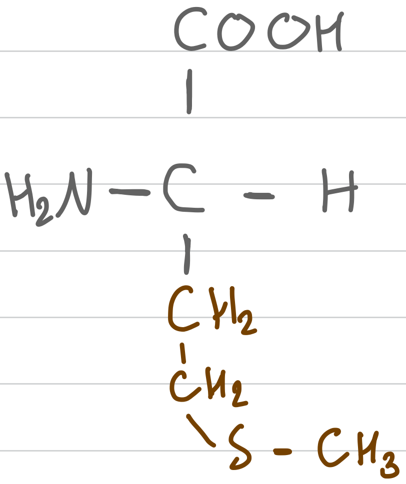
R group: 
$-\overset{CH_2-CH_3}{\underset{CH_3}{CH}}$

Unique name of functional unit: branch

Memorization tip: just different form of Leucine (Leu). 4 methyl groups

Extra info: One of three essential amino acids

6 →



Name: Methionine (Met)

Type: non-polar

R group: $- CH_2 - CH_2 - S - CH_3$

Unique name of functional unit: thioether → $R - S - R'$

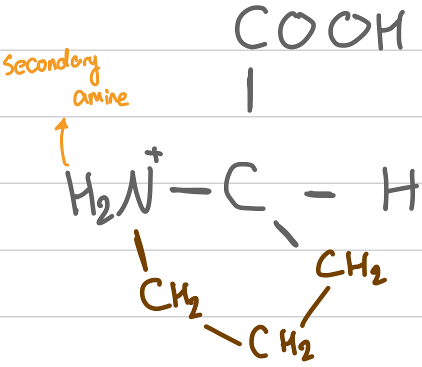
Memorization tip: Thio ⇒ sulfur. Me-thionine ⇒ me having sulfur

Extra info: methionine forms SAM. SAM is a methyl ($-CH_3$) group donor.

⇒ sulfur ?

→ Methionine = SAM = methyl group donor

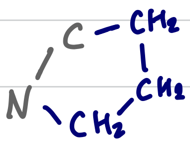
7 →



Name: Proline (Pro)

Type: non-polar

R group:

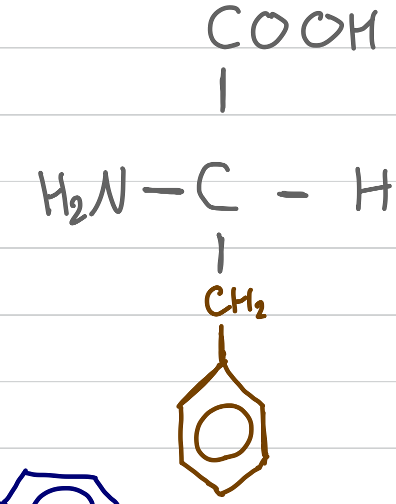


Unique name of functional unit:

Memorization tip: Proline... Pro.. Pro at being only cyclic amino acid

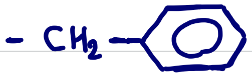
Extra info: The only cyclic amino acid. The ring is small so rigid. Peptide bonds with proline DONT form hydrogen bonding. Peptide bonds with proline are 50/50 cis/trans.

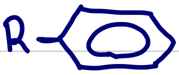
8 →



Name: Phenylalanine (Phe)

Type: non-polar aromatic

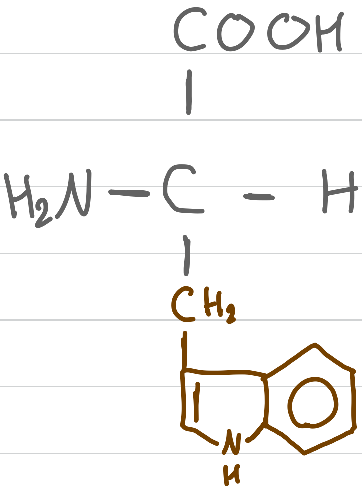
R group: 

Unique name of functional unit: phenyl group. 

Memorization tip: Phenylalanine = phenyl group + alanine amino acid

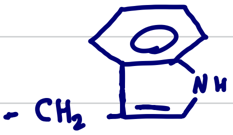
Extra info: *

9 →



Name: Tryptophan (Trp) notice its Trp <u>NOT</u> Try

Type: non-polar aromatic

R group: 

Unique name of functional unit: indole ring.

Memorization tip: Tryptophan ⇒ Tryp ⇒ trip over the R group ⇒ big R-group

Extra info: Tryptophan has amine group. BUT it is not positively charged. Tryptophan is the biggest amino acid.

phenylalanine ⇒ phenyl + alanine

tryptophan ⇒ indole + alanine

note:

histidine

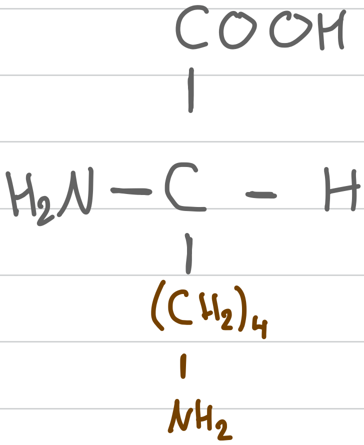
- All positve amino acids have amino group (except tryptophan). H A L

arginine

- All negative amino acids have $-CO_2H$ group. G A

10 →

Name: Lysine (Lys)



Type: positively charged

R group: $-(CH_2)_4-NH_2$

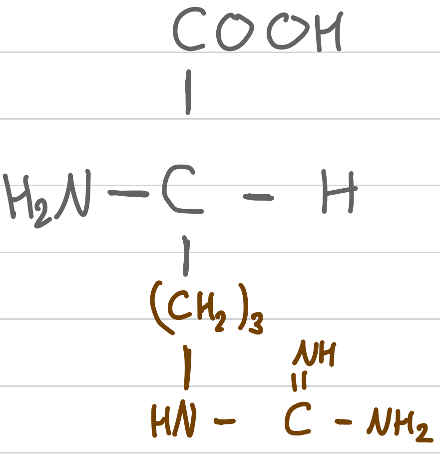
Unique name of functional unit: amino group

Memorization tip: Leucine is Lucy => 4 methyl groups.
Lysine => Lucy + y. y => nytrogen. So lycine is 4 methyl groups with an amino group.

Extra info: HAL the amino acids

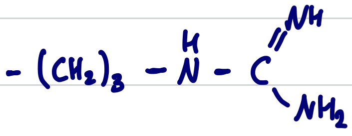
11 →

Name: Arginine.



Type: positively charged

R group:



$-(CH_2)_3-\overset{H}{N}-C\begin{matrix}\nearrow NH \\ \searrow NH_2\end{matrix}$

Unique name of functional unit: guanidinium.

$H_2N-\overset{NH}{\overset{\|}{C}}-NH_2$

g: guanidinium

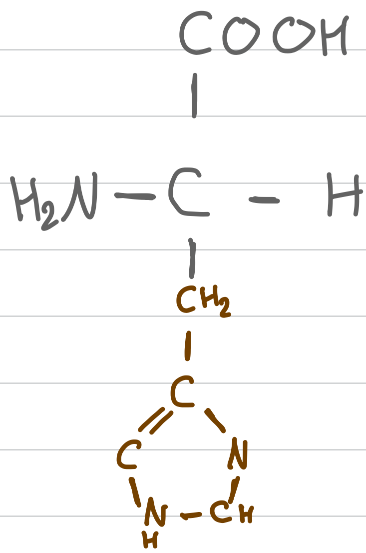
Memorization tip: Arginine has most letters n out of HAL. So it has most Ns.

Extra info: HAL the amino acids

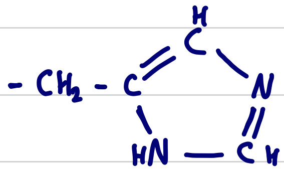
12 →

Name: Histidine (His)

Type: positively charged

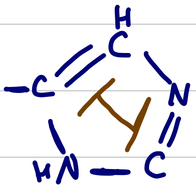


R group:



Unique name of functional unit: imidazole.

Memorization tip: Histidine => Imidazole.



Looks like letter H.

Extra info: the aromatic ring of imidazole can be charged. Ring of tryptophan cant.

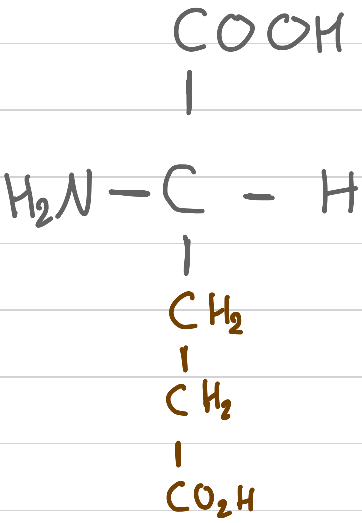
Histidine has one ring. Tryptophan has 2.

Histidine is decarboxylated to form histamine.

13 →

Name: Glutamic Acid (Glu) / Glutamate

Type: negatively charged



R group: $-CH_2-CH_2-CO_2H$

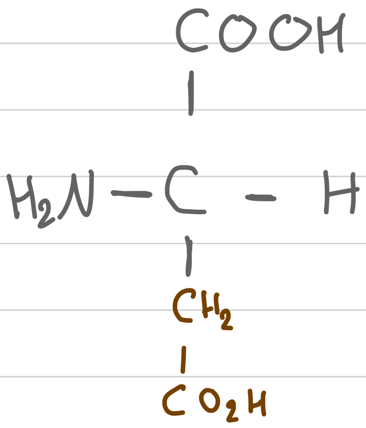
Unique name of functional unit: carboxylic acid

Memorization tip: Glute => means 5. Glutamate has 5 total carbons. So $R = CH_2-CH_2-CO_2H$

Extra info: Glutamine is same with amide group.

14 →

Name: Aspartic Acid (Asp) / Aspartate



Type: negatively charged

R group: $-CH_2-CO_2H$

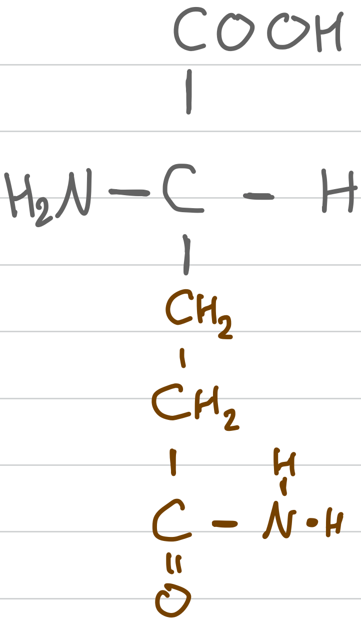
Unique name of functional unit: carboxylic acid

Memorization tip: Aspartic Acid ⇔ alanine. So alanine + CO_2H

Extra info: Asparagine is same with amide group.

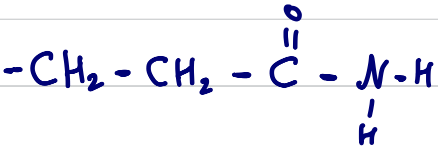
15 →

Name: Glutamine (Gln)



Type: polar

R group:



$-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-H$

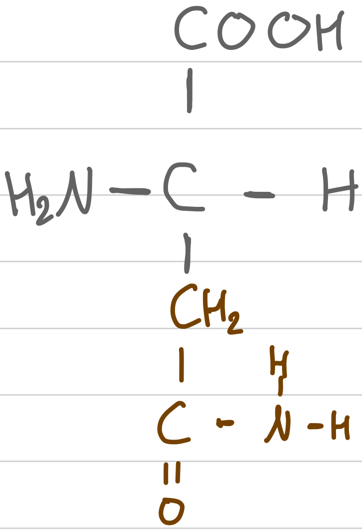
Unique name of functional unit: amide

Memorization tip: Glutamic Acid... but amide

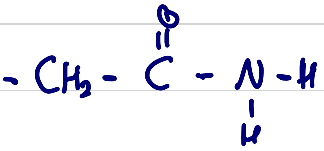
Extra info: *

16→

Name: Asparagine (Asn)



Type: polar

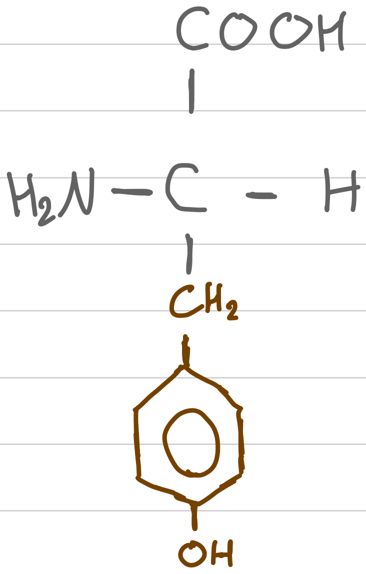
R group: 

$-CH_2-C(=O)-NH-H$

Unique name of functional unit: carboxamide

Memorization tip: Aspartic acid but amide

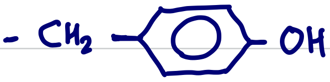
Extra info: *



17→

Name: Tyrosine (Tyr)

Type: polar

R group: 

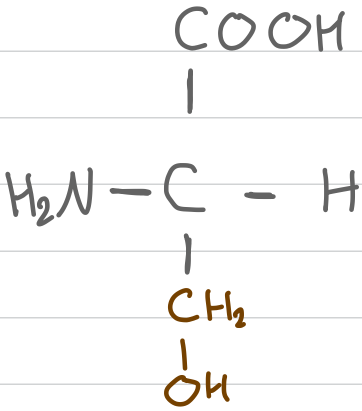
Unique name of functional unit: phenyl + hydroxyl => phenol

Memorization tip: Tyrosine looks like a tire. Also it is phenylalanine + -OH

Extra info: makes catecholamine

18 →

Name: Serine (Ser)



$$H_2N-\overset{\overset{\displaystyle COOH}{|}}{\underset{\underset{\underset{\displaystyle OH}{|}}{\displaystyle CH_2}}{\underset{|}{C}}}-H$$

Type: polar

R group: $-CH_2-OH$

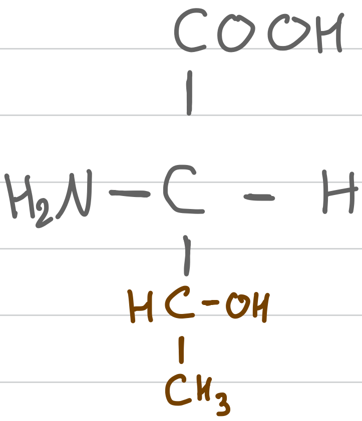
Unique name of functional unit: hydoxy

Memorization tip: O-Glycoside. Have -OH. Thr. Ser. Hyd.Lys

Extra info: *

19 →

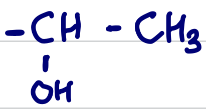
Name: Threonine (Thr)



$$H_2N-\overset{\overset{\displaystyle COOH}{|}}{\underset{\underset{\underset{\displaystyle CH_3}{|}}{\displaystyle HC-OH}}{\underset{|}{C}}}-H$$

Type: polar

R group:



$$-\underset{\underset{\displaystyle OH}{|}}{CH}-CH_3$$

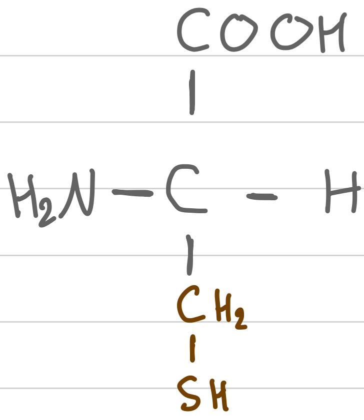
Unique name of functional unit: hydoxy

Memorization tip: Like serine but add an extra $-CH_3$ at end.

Extra info: *

20 →

Name: Cysteine (Cys)



Type: polar

R group: $- CH_2 - SH$

Unique name of functional unit: sulfhydryl / thiol -SH

Memorization tip: like serine but -SH. Cysssssssteine = sulfur.

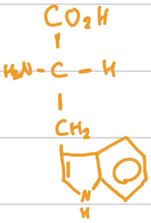
Extra info: Cysteine sulfur is so reactive cuz at end. Forms di-sulfur bridge. Methionine not reactive cuz thioether makes the sulfur hidden.

Functions of Amino Acids:

flight or fight

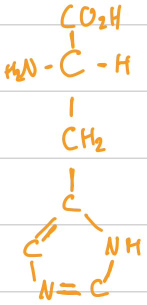
Tyrosine
- → **Catecholamines** ⇒ Tyrosine → Dopa → ① Dopamine → ② Norepinephrine → ③ Epinephrine
- → **thyroxine** ⇒ T_4 thyroid hormone
- → **melanin** ⇒ skin color: Two types. One brown & other red: Eumelanins, Pheomelanins

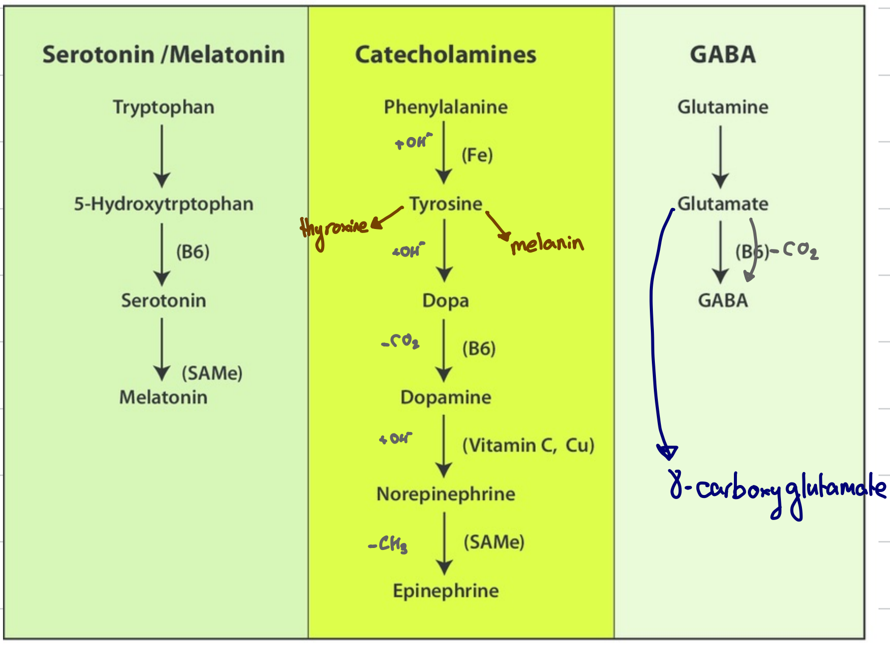
Tryptophan
- → **Serotonin** → A sedative neurotransmitter. Happy hormone
- → **Melatonin** → Day-night cycle. Circadian rhythm. Sleeping hormone.



Histidine $\xrightarrow{\text{decarboxylation}}$ **Histamine** ⇒ Responsible for allergic reactions

Histamine a major cause for asthma





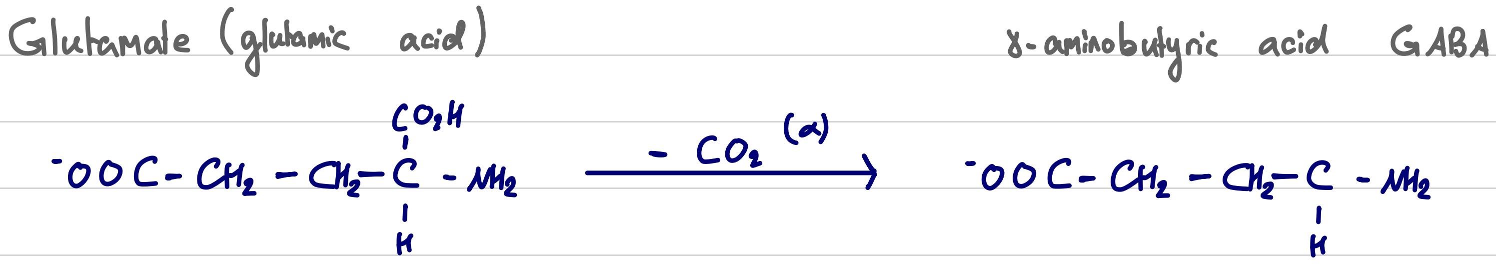
Serotonin /Melatonin	Catecholamines	GABA
Tryptophan ↓ 5-Hydroxytrptophan ↓ (B6) Serotonin ↓ (SAMe) Melatonin	Phenylalanine $+OH^-$ ↓ (Fe) thyroxine ← Tyrosine → melanin $+OH^-$ ↓ Dopa $-CO_2$ ↓ (B6) Dopamine $+OH^-$ ↓ (Vitamin C, Cu) Norepinephrine $-CH_3$ ↓ (SAMe) Epinephrine	Glutamine ↓ Glutamate ↓ (B6) $-CO_2$ GABA Glutamate → γ-carboxyglutamate

Histamine

histidine
↓
histamine

Glutamate & GABA:

Glutamate loses its α-carboxylic group to form GABA (γ-aminobutyric acid)



Glutamate (glutamic acid) γ-aminobutyric acid GABA

$${}^{-}OOC-CH_2-CH_2-\underset{H}{\overset{CO_2H}{C}}-NH_2 \xrightarrow{-\,CO_2\ (\alpha)} {}^{-}OOC-CH_2-CH_2-\underset{H}{C}-NH_2$$

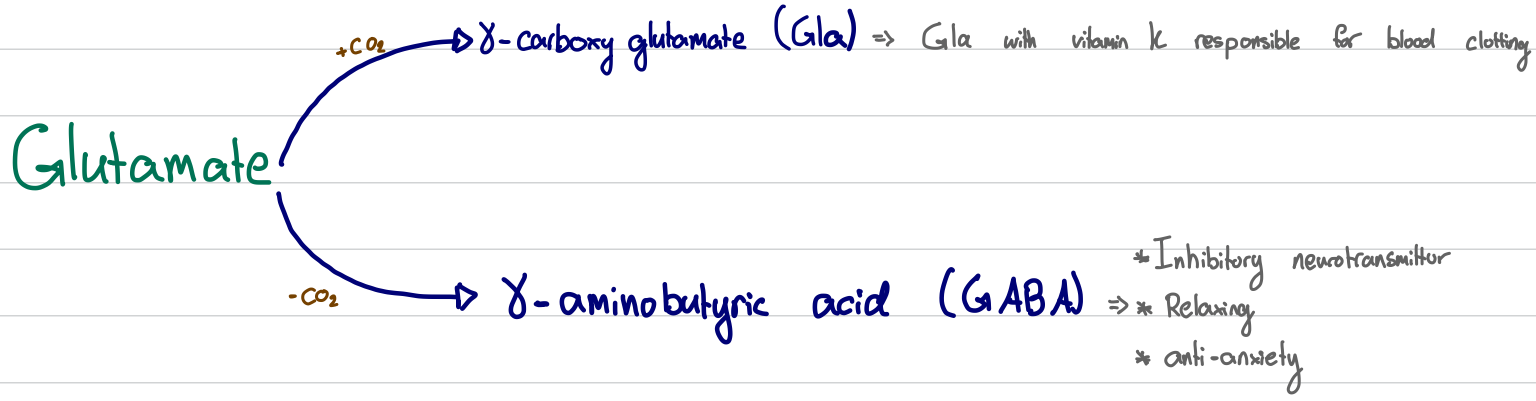
Functions of GABA:

- * Inhibitory neurotransmitter
- * Relaxing affect
- * anti-anxiety

Glutamate and γ-carboxyglutamate (Gla):

Glutamate (Glu) gets carboxylated to form γ-carboxyglutamate (Gla)

* γ-carboxyglutamate and vitamin K play a role in blood clotting.



Glutamate

$+CO_2$ → γ-carboxyglutamate (Gla) ⇒ Gla with vitamin k responsible for blood clotting

$-CO_2$ → γ-aminobutyric acid (GABA) ⇒
- * Inhibitory neurotransmitter
- * Relaxing
- * anti-anxiety

L-Arginine and nitric oxide, NO:

↳ note that in our bodies:
- carbohydrates ⇒ D
- amino acids ⇒ L

Arginine has a nitrogen rich guanidium group... one of those nitrogens are broken off and NO and citrulline are formed.

Arginine → nitric oxide
Arginine → citrulline

Functions of nitric oxide:

- vasodilation
- anti-inflamitory
- inhibit blood coagulation.

Hydroxylated amino acids:

After protein synthesis... we get hydroxylation.

- proline hydroxylated to hydroxyproline
- Lysine hydroxylated to hydroxylysine

⇒ Hydroxyproline and hydroxylysine play a role in collagen strengthening. With the help of vitamin C.

O-glycoside ⇒ Thr (threonine) / Ser (serine) / hyd Lys (hydroxylysine)

Monosodium Glutamate (MSG):

- * sodium ion with glutamate
- * flavour enhancer
- * Has some side affects for some people. Chinese Restaurant syndrome.

Amino Acid ionization:

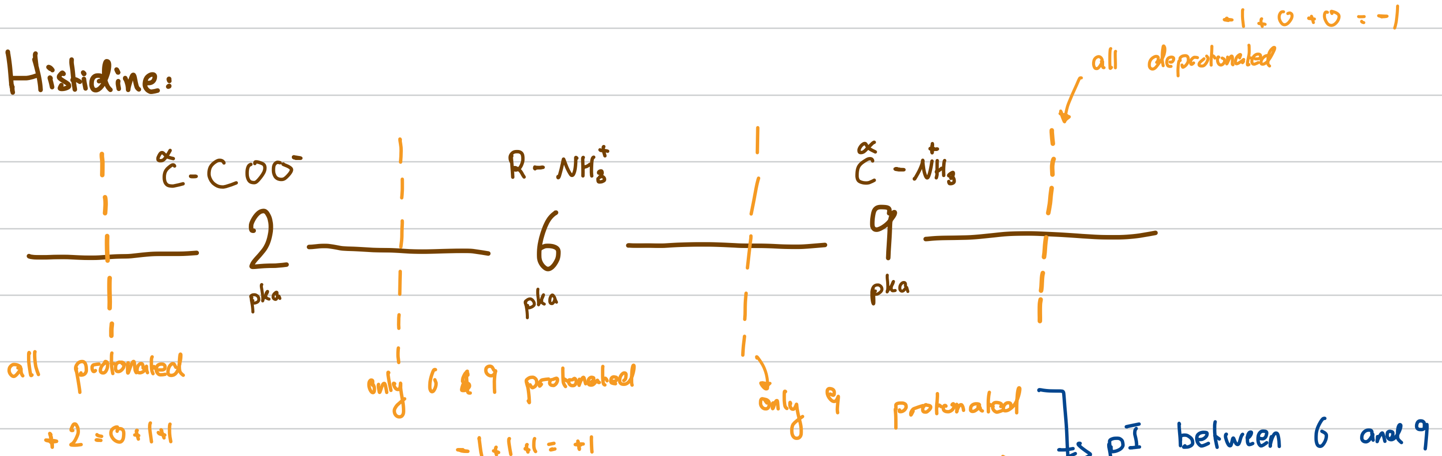
* Zwitterion => Molecule with two opposite charges and net charge is zero
* Isoelectric point => pH at which molecule exists as zwitterion. $pI = \frac{pka_1 + pka_2}{2}$

How to calculate isoelectric point:

① pH < pka => protonated

② pH > pka => deprotonated

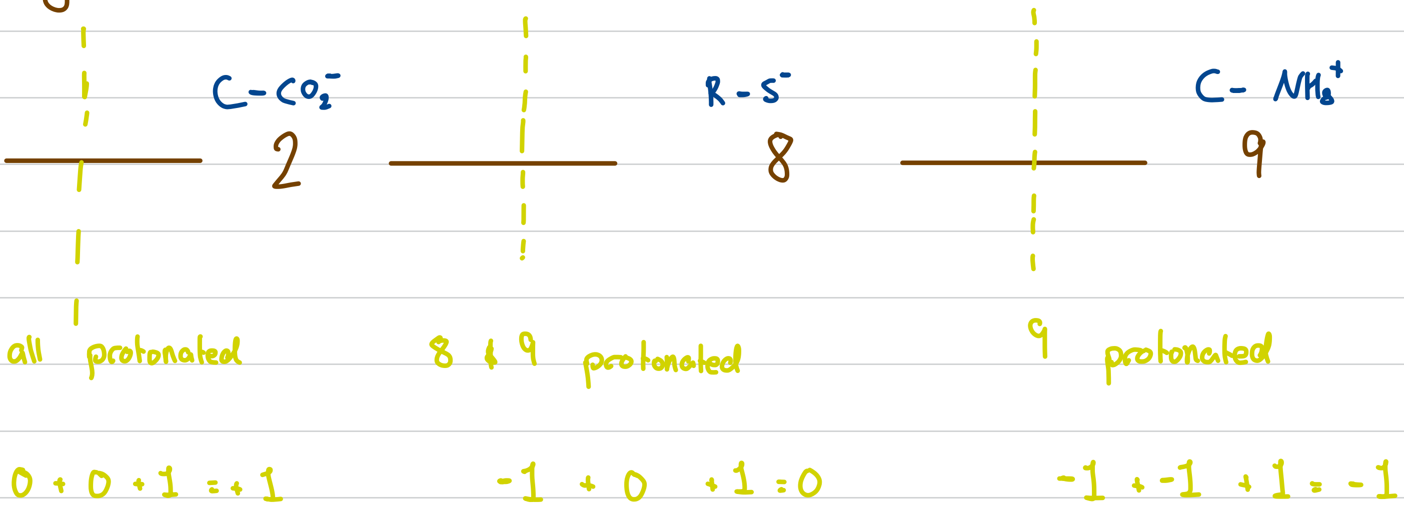
Histidine:



=> pI between 6 and 9

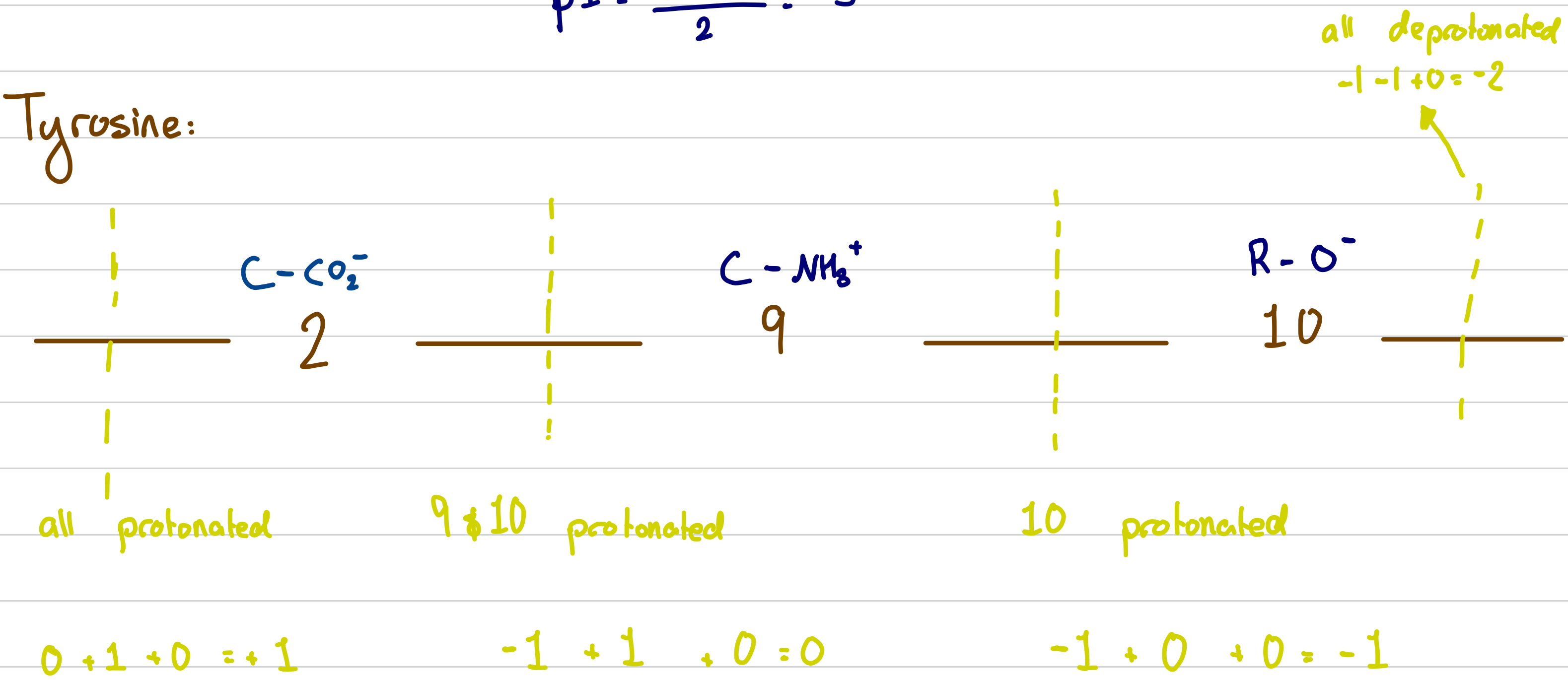
$\frac{6+9}{2} = 7.5$

Cysteine:



$$pI = \frac{2+8}{2} = 5$$

Tyrosine:



$$pI = \frac{2+9}{2} = \boxed{5.5}$$

If you know the value of pka of R-group and type of charge then you can calculate the pI value.

General trend:

- pH below pI => H^+ high => cation forms (positive)
- pH above pI => OH^- high => anion forms (negative)

pka values to memorize:

Acidic groups have low pka & low pI → high H^+ needed to form HA.

Basic groups have high pka & high pI → high OH^- needed to remove H^+

- $\overset{\alpha}{C}-CO_2H$ ⇒ pka = 2
- $\overset{\alpha}{C}-NH_2$ ⇒ pka = 9

Acidic Side Chains ⇒ negatively charged

- Aspartic Acid ⇒ pka = 4

⇒ close to each other

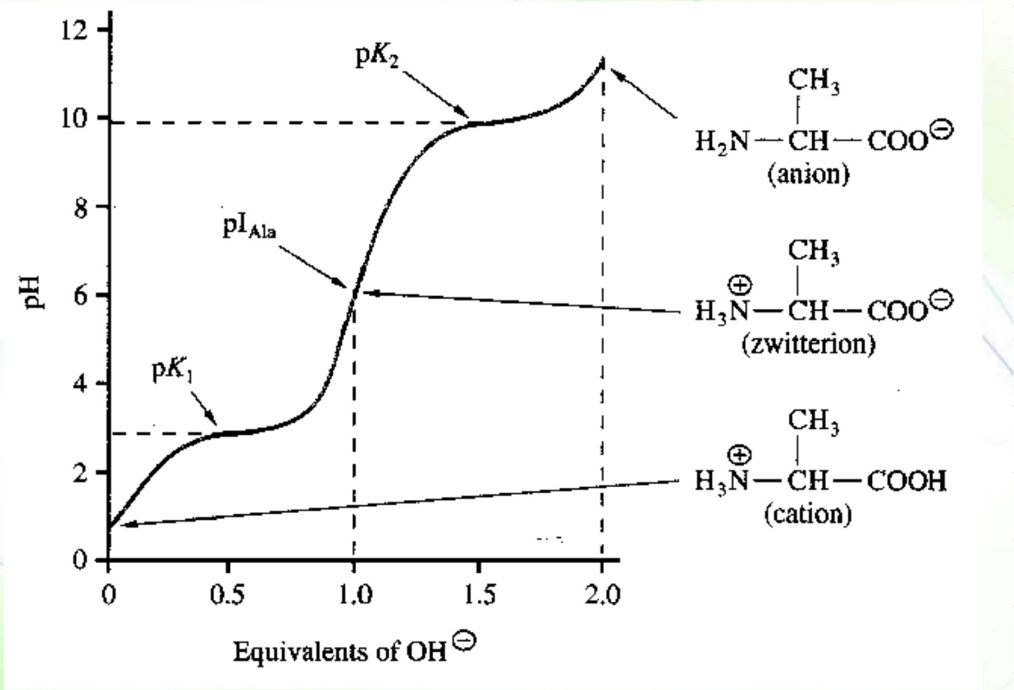
- Glutamic Acid ⇒ pka = 4.1
- Cysteine ⇒ pka = 8 weaker than Glu & Asp so higher number
- Tyrosine ⇒ pka = 10 Special case. Ring

Basic Side Chains ⇒ positively charged

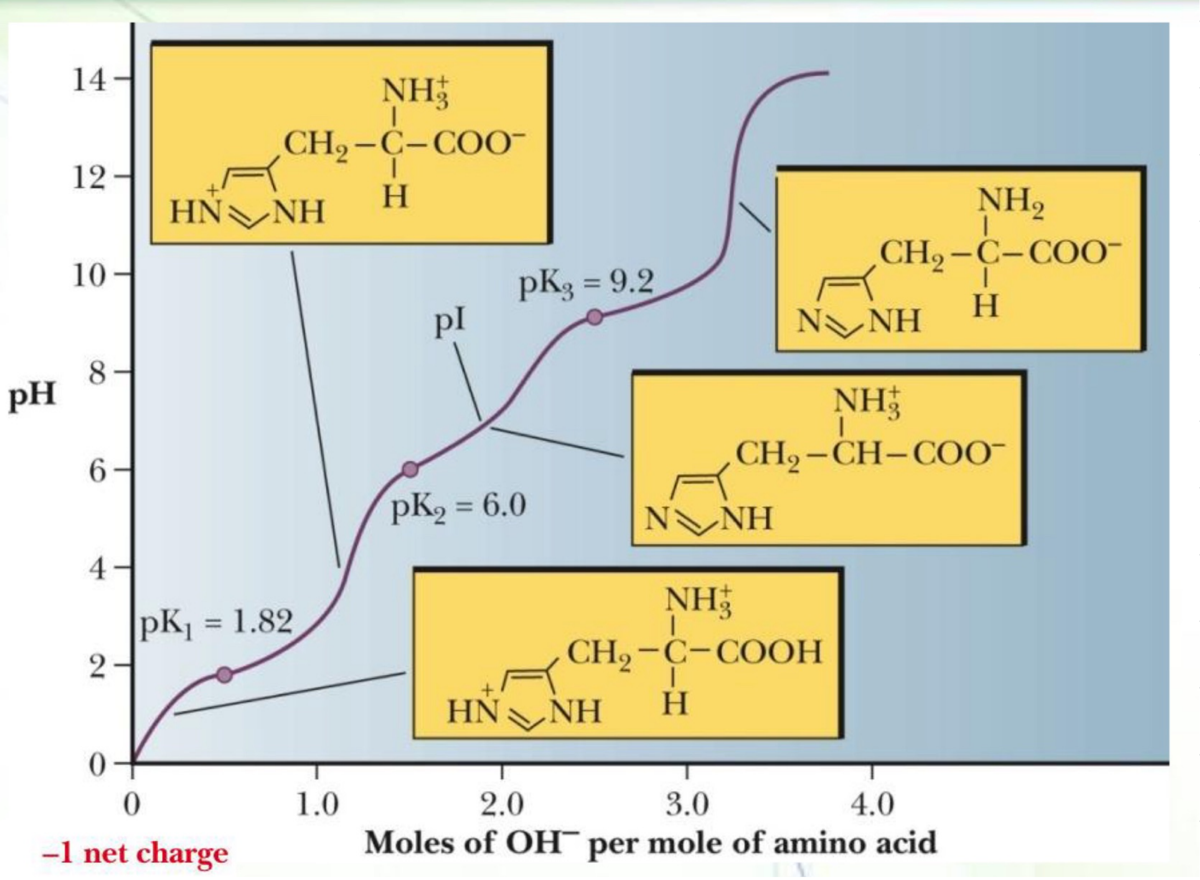
- Arginine ⇒ pka = 12.5

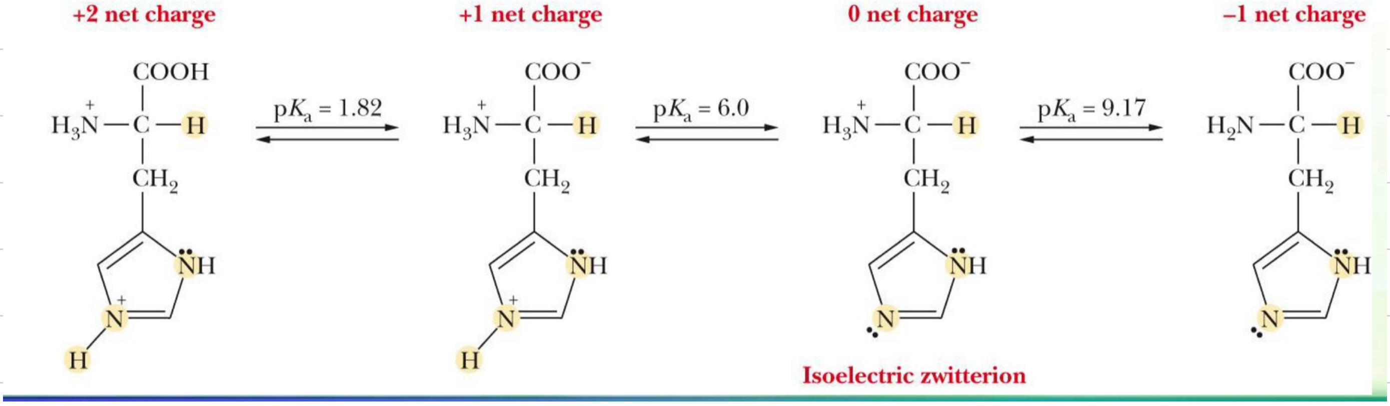
⇒ close to each other

- Lysine ⇒ pka = 11
- Histidine ⇒ pka = 6 Special case. Ring



[conjugate base]





Ile - His - Ser - Glu - Arg - Ala - His pH= 6

H_2N	no	NH_2	no	CO_2H	NH_2	no	NH_2	CO_2H	
9		6		4	12.5		6	2	
prot.		50/50		deprot.	prot.		50/50	deprot.	
+1		+ 0.5		-1	+1		+0.5	-1	⇒ +1

Nucleic Acids:

. (1)

. (2)

. (3)

key terms:

DNA / RNA made of monomers called nucleotides.

Gene = A strand of DNA that codes for a protein

Chromatin = DNA + proteins (histones) (in eukaryotic cell only)

Nucleosome core: Two DNA loops + octamer

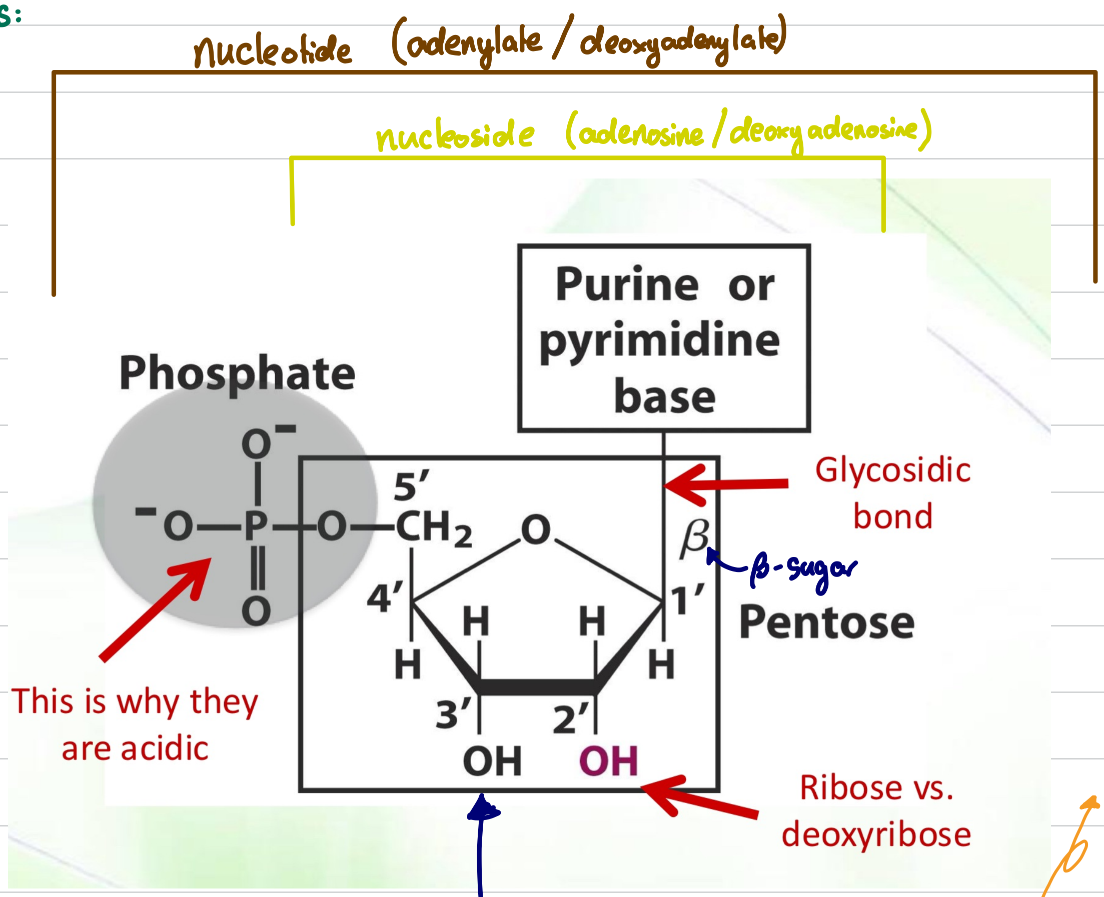
8 histone core
- 2 H2A
- 2 H2B
- 2 H3
- 2 H4

Chromatosome: H1 + nucleosome core.

Linker DNA = DNA between one chromatosome & another chromatosome

Nucleosome = Chromatosome + linker DNA. structural unit of chromatin.

Nucleotides:



Phosphate added here to 3' carbon. (adding nucleotide. ester bond formation)

peptide we add a.a to CO_2^- terminal.

DNA we add nucleotides to 3' end always.

phosphodiester bond formed

CANT add a nucleotide to 5' carbon.

nucleotide + nucleotide:

5' C added to 3' C.
Via phosphate group.

Naming nucleotides / nucleosides:

Im taking adenine as a base. Note that riboses with uracil. Deoxyriboses with thymine.

1 → no phosphate + ribose. Ribose nucleoside: adenosine

2 → Phosphate + ribose. Ribose nucleotide: Adenylate / adenosine 5'-monophosphate

3 → no phosphate + deoxyribose. deoxyribose nucleoside: deoxyadenosine

4 → Phosphate + deoxy ribose. deoxyribose nucleotide: Deoxyadenylate / deoxyadenosine 5'-monophosphate

d = deoxygenated

Bases:

* Purines = two rings. G A ⇒ guanine & adenine

* Pyrimidines = one ring. C U T ⇒ cytosine & uracil (RNA) & thymine (DNA)

5' T G C A 3' → First letter is 5'. Nucleotides are added to 3' carbon.

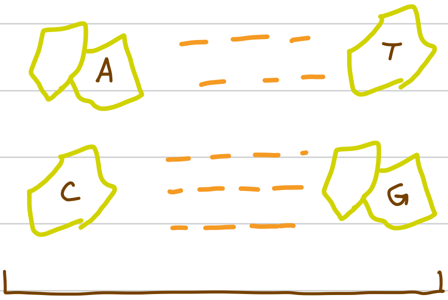
Chargaff rule

A ⋮⋮ T

G ⋮⋮⋮ C

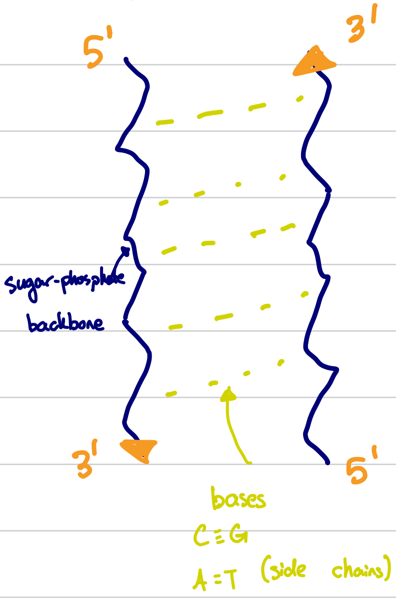
H-bonding

A = T
C = G
A + G = C + T
purine = pyrimidines

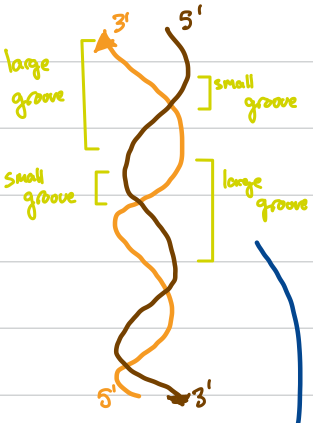


Same length always
CG length = AT length

DNA structure:



* complementary base pairing
* anti-parallel strands
* double helix
* sugar-phosphate backbone
* stable and flexible
* alternating major & minor grooves



proteins interact with DNA in its major/large grooves

(interactions are between amino acids and bases in certain regions of DNA)

note that
RNA is a single strand.
RNA has ribose
RNA has uracil & not thymine

DNA packing:

$H1\ \overbrace{H2A\ \ H2B\ \ H3\ \ H4}^{Core}$

(5 types)

Chromatin has nucleosomes that are units of DNA + 8 histone core proteins.

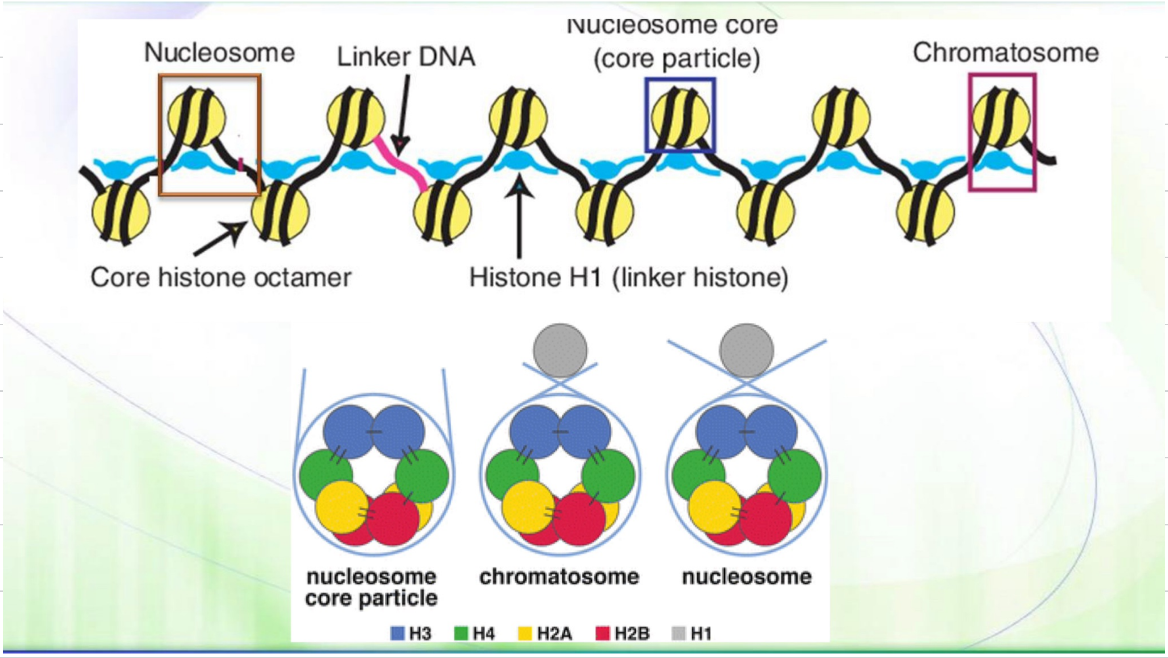
Histones

☐☐ H2A + ☐☐ H2B + ☐☐ H3 + ☐☐ H4] Histone core protein made of 8 histones. Forming octamers. DNA wraps around the core. Nucleosome core formed.

H1] closes the nucleosome. Forming chromatosome

$\begin{pmatrix} 2 & H2A \\ 2 & H2B \\ 2 & H3 \\ 2 & H4 \end{pmatrix}$

Organization: DNA wrapped around octamer histone core <u>twice</u>. H1 comes outside the double loop and closes it. One chromatosome to another joined by linker DNA. Histones are positive so they can interact with negative DNA.



Euchromatin vs Heterochromatin:

- * Euchromatin is not condensed
- * Euchromatin lacks H1 histone

- * Heterochromatin is condensed
- * Heteochromatin has H1

DNA stabalizing factors:

- * Histones
- * Cations (Na^+ / Mg^{2+})

- * Hydrophobic Stacking → Helical twists / → Propeller twists } ⇒ these are responsible for DNA's helical shape.

(hydrophic interactions b/w bases)

RNA:

* Ribozymes → RNA acting as enzymes

1 → miRNA:

micro RNA

→ post-transcription transpason repression

2 → pi RNA:

piwi interacting RNA

→ transpason repression by DNA methylation

3 → si RNA

short RNA

→ RNA interference

4 → sno RNA

small RNA

→ RNA modification

→ rRNA processing

5 → t RNA

transfer RNA

→ mRNA translation

6 → rRNA

ribosomal RNA

→ mRNA translation