General Biochemistry
Introduction to Buffer solutions

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Notes

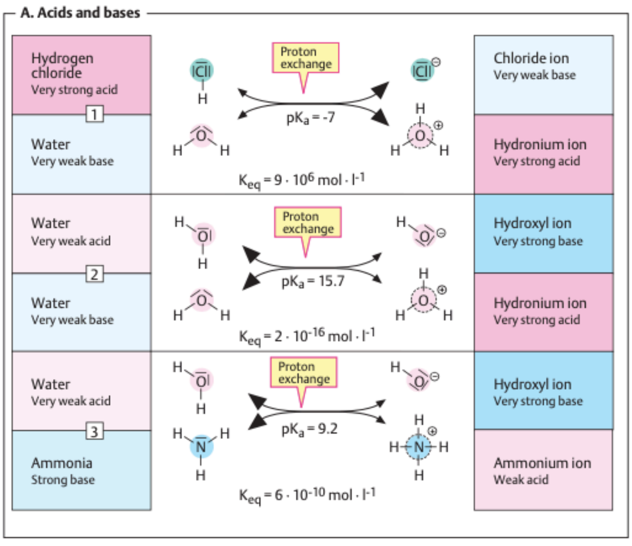
- **Please note that I added here only some questions and figures to guide the students to the main topics.**
- **Please read the following references for the explanation and the main lecture's contents:**

1. **Colour atlas of biochemistry in English language.**
2. **Any other books in Arabic language.**
3. **See websites http://employees.csbsju.edu/hjakubowski/classes/ch331/bcintro/default.html**
4. **https://en.wikipedia.org/wiki/Biochemistry**
5. **https://themedicalbiochemistrypage.org**
6. **www.youtubes.com**

Buffer, Acids and Bases solutions

- Why do we study the solutions in biochemistry?
- What are acids?
- What are bases?
- What are conjucated acids and bases?

Acid and base solutions



What is the equilibrium constant K for the acid— base reaction between H_2O molecule? at 25 ˚C.

The equilibrium constant K for the acid—base reaction between H_2O molecules (**2**) is very small. At 25 °C,

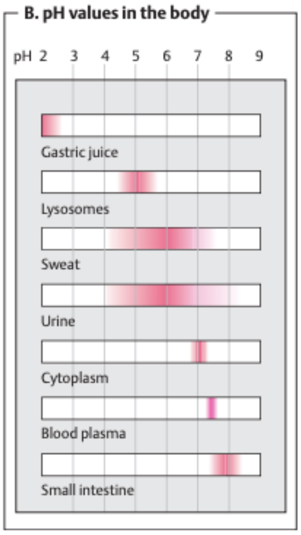
$$K = [H^+] \; [OH^-] / [H_2O] = 2 \quad 10^{-16} \text{ mol} \quad L^{-1}$$

In pure water, the concentration $[H_2O]$ is practically constant at 55 mol L^{-1}. Substituting this value into the equation, it gives:

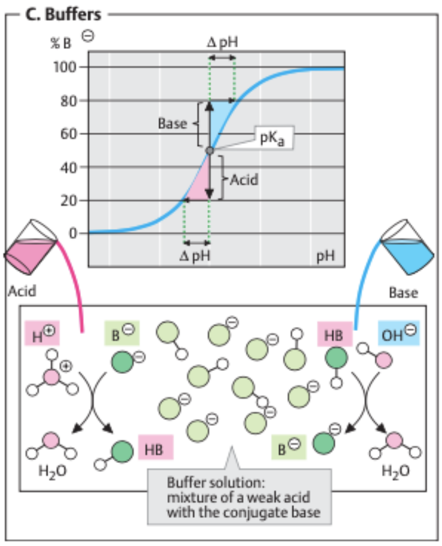
$$K_w = [H^+] \; [OH^-] = 1 \quad 10^{-14} \text{ mol} \quad L^{-1}$$

pH values in the organism

- What are the effect of the pH values on the chemical reactions in each organism?
- Why blood pH is so???



What are buffer solutions?



Prepare Solutions

- Prepare a soultion (xM) from <u>sold chemicals</u> in a spicific volume.
- M=wt (g)/MW * 1000/v (ml). Becarful with the units !
- Prepare a soultion (xM) from <u>stocks of liquid solutions</u> by a dilution in a spicific volume? M1V1=M2V2
- How to change a pH of solution from acidic to a basic and vise versa.
- How to prepare a solution with xM and adjust its pH to x unit?

Why the pH of the blood changes?

- Normal metabolic activity generates acids as the result of the degradation of amino acids, the incomplete oxidation of glucose and fatty acids, and the ingestion of acidic groups in the form of phosphoproteins and phospholipids.
- Acids is initially filtered out of the bloodstream in the kidneys, but the kidneys actively reclaim this bicarbonate before it is lost in the urine.

General Biochemistry
Carbohydrates

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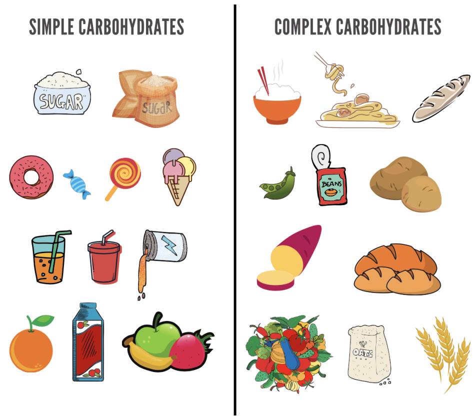
What are carbohydrates ?

- What does our body do with food?
- What is the digestion of the food?
- What are the smallest compound of the food?
- What are the types of the carbohydrates?



Monosaccharide

- The most important natural monosaccharide, **D-glucose**, is an aliphatic aldehyde with six C atoms, five of which carry a hydroxyl group
- Glucose mainly cyclizes to form a six-membered pyranose ring whilst other sugars form five-membered Furanose rings.

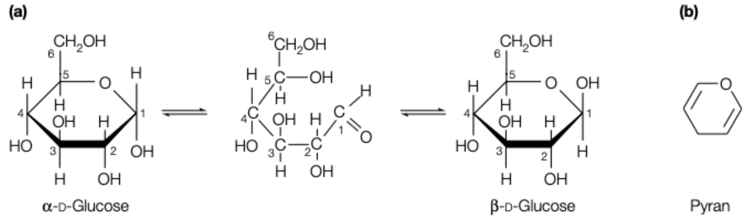
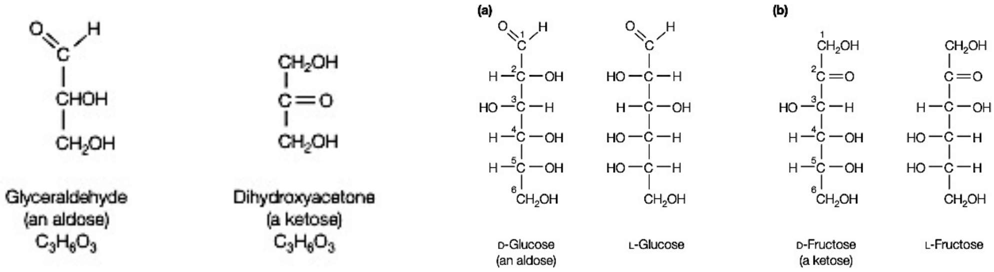


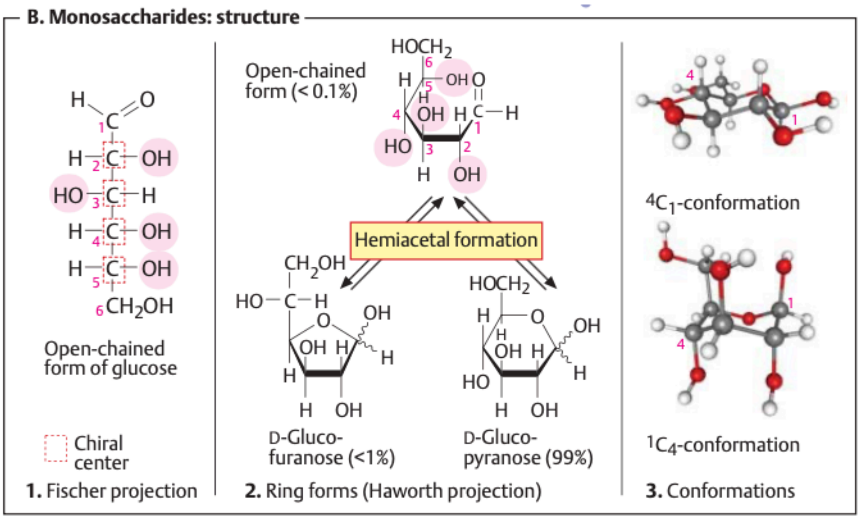
Fig. 5. (a) Cyclization of the open-chain form of D-glucose; (b) the structure of pyran.

Aldoses and ketoses

- A monosaccharide has the general formula (CH2O)*n* and contains either an aldehyde group (an aldose) or a ketone group (a ketose).
- The simplest carbohydrates are the **monosaccharides** that have the general formula (CH2O)*n* where *n* is 3 or more.



Monosaccharides: structure

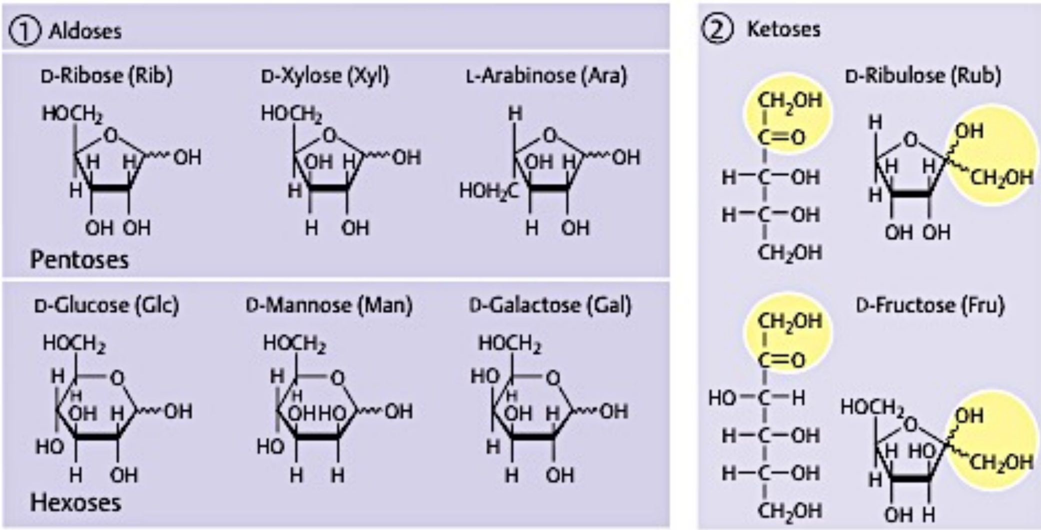


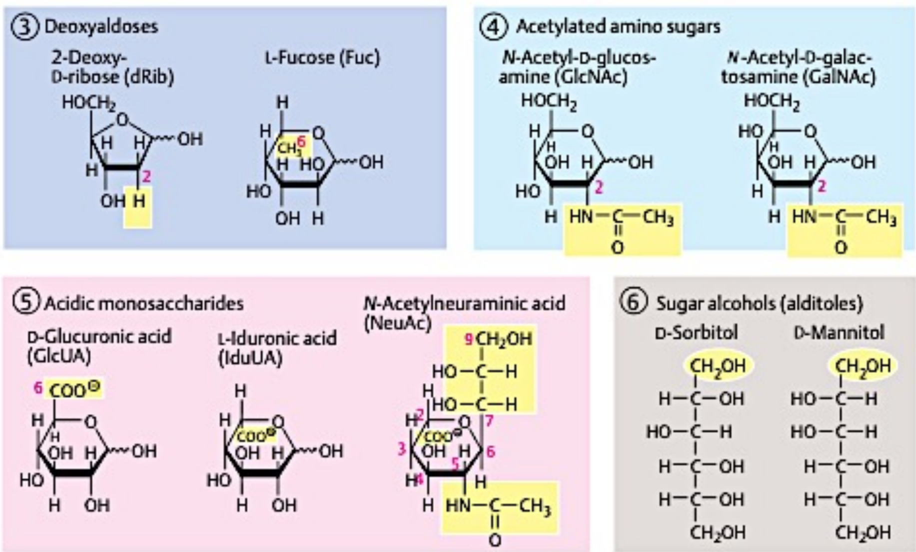
- What is a Fisher structure? What is **Haworth projection?**

Monosaccharides: structure

- The most important natural monosaccharide, **D-glucose**, is an aliphatic aldehyde with six C atoms, five of which carry a hydroxyl group
- What is a hemiacetal ?
- What is a Fisher structure?
- What is **Haworth projection?**

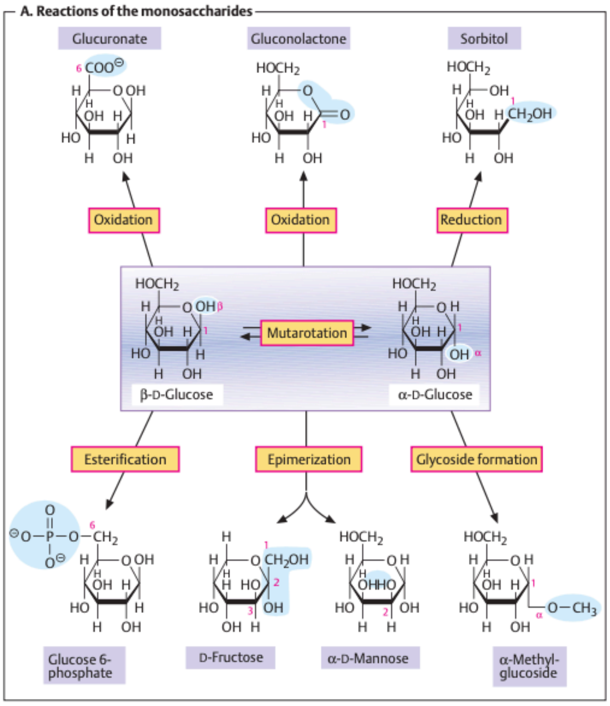
A. Important monosaccharides



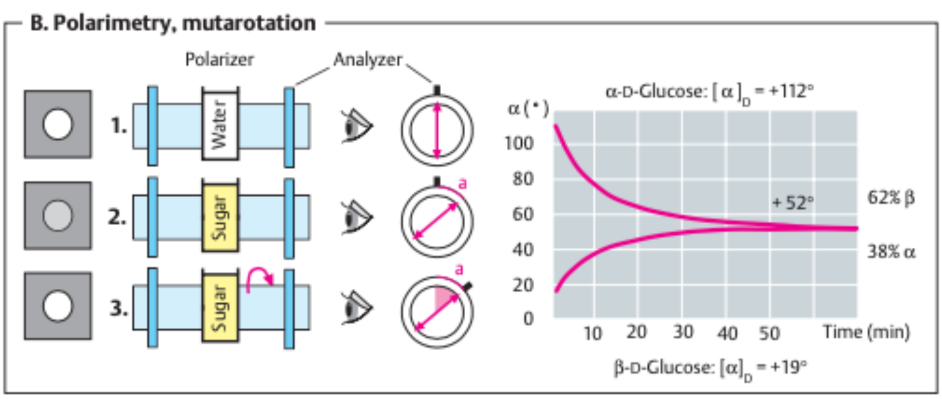


A. Reactions of the monosaccharides

- Oxidation.
- Reduction.
- Esterification
- Epimerization.
- Glycoside formation .



B. Polarimetry, mutarotation



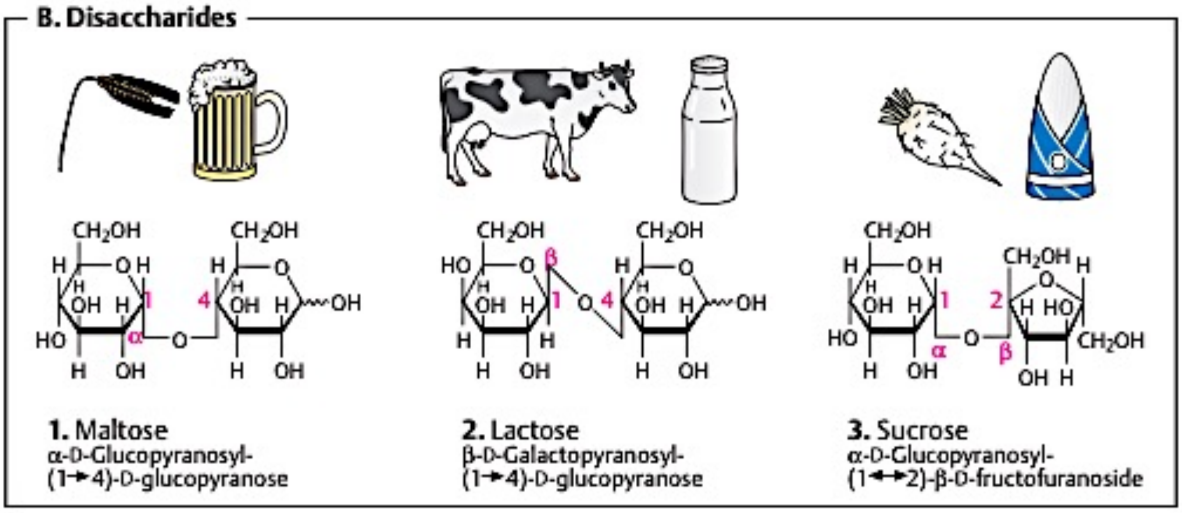
B. Disaccharides

- When the anomeric hydroxyl group of one monosaccharide is bound glycosidically with one of the OH groups of another, a **disaccharide** is formed.
- **Maltose** (**1**) occurs as a breakdown product of the starches contained in malt ("malt sugar"
- **Lactose** ("milk sugar," **2**) is the most important carbohydrate in the milk of mammals.
- **Sucrose** (**3**) serves in plants as the form in which carbohydrates are transported, and as a soluble carbohydrate reserve.

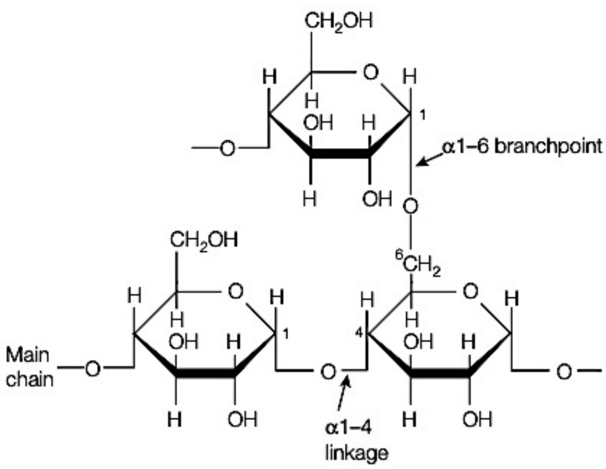
Disaccharide

- A disaccharide is formed when two monosaccharides become joined by a glycosidic bond.
- The bond may be an α- or β-bond depending on the configuration of the anomeric carbon atom involved in the bond.
- Usually the anomeric carbon atom of only one of the two monosaccharides is involved in the bond.
- The covalent bond formed is called a **glycosidic bond**.
- Lactose is a disaccharide formed between the anomeric carbon (C-1) of D- galactose and C-4 of D-glucose. Its bond is called ß **(1→4) bond** which can be abbreviated as1–4.
- Maltose is a disaccharide formed between the C-1 and C-4 positions of two glucose units.
The bond is called alpha a **(1→4) bond** or abbreviated as 1–4.

Structures of disaccharides



The **α**1–4 linkages in the straight chain and **α** 1–6 branch point linkages in glycogen.



Monosaccharides and disaccharides in biology

- **A. Important monosaccharides**
- The best-known **aldopentose** (**1**), D-*ribose*, is a component of RNA and of nucleotide.
- The most important of the **aldohexoses** (**1**) is D-glucose.
- Phosphoric acid esters of the **ketopentose** D-*ribulose* (**2**) are intermediates in the pentose phosphate pathway
- The most widely distributed of the **ketohexoses** is D-*fructose*.
- In the **deoxyaldoses** (**3**), an OH group is replaced by a hydrogen atom. In addition to 2-*deoxy-D-ribose*, a component of DNA
- Other **acidic monosaccharides** such as D-*glucuronic acid*, D-*galacturonic acid*, and *liduronic acid*, are typical constituents of the glycosaminoglycans found in connective tissue.
- **Sugar alcohols** (**6**) such as *sorbitol* and *mannitol* do not play an important role in animal metabolism.

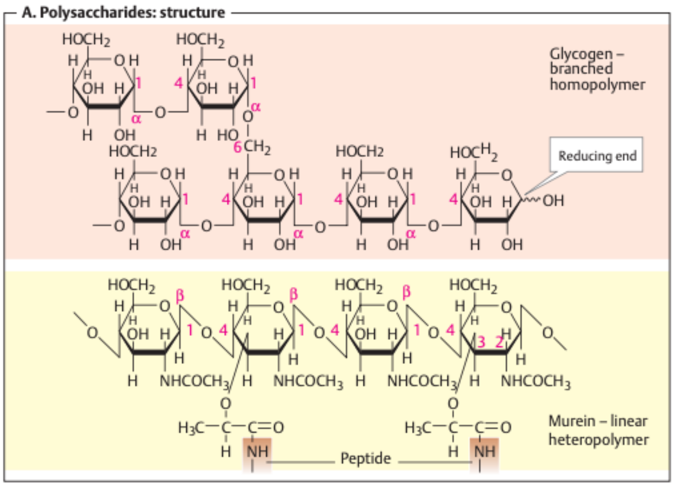
Polysaccharides: overview

- **What are polysaccharides?**
- **Why they are important?**
- **Types of bond?**
- **Structural polysaccharides** provide mechanical stability to cells, organs, and organisms.

Polysaccharides and Oligosaccharides

- ***Polysaccharides:*** Long chains of monosaccharides joined together are collectively called polysaccharides.
- The major storage polysaccharides are glycogen (in animals), starch (in plants) and dextran (in yeast and bacteria). Cellulose is a structural polysaccharide found in plant cell walls.
- Glycogen is a branched-chain polysaccharide containing glucose residues linked by α1–4 bonds with α1–6 branch points.
- ***Oligosaccharides:*** Short chains of monosaccharides linked by glycosidic bonds are called oligosaccharides. Oligosaccharides found in glycoproteins .

A. Polysaccharides: structure



Polysaccharides: structure

- What are **homoglycans** and **heteroglycans?**
- **B. Important polysaccharides?**
- The linear heteroglycan **murein**
- **Dextran.**
- **starches**
- **Chitin**.
- **Glycogen**

B. Important polysaccharides

B. Important polysaccharides

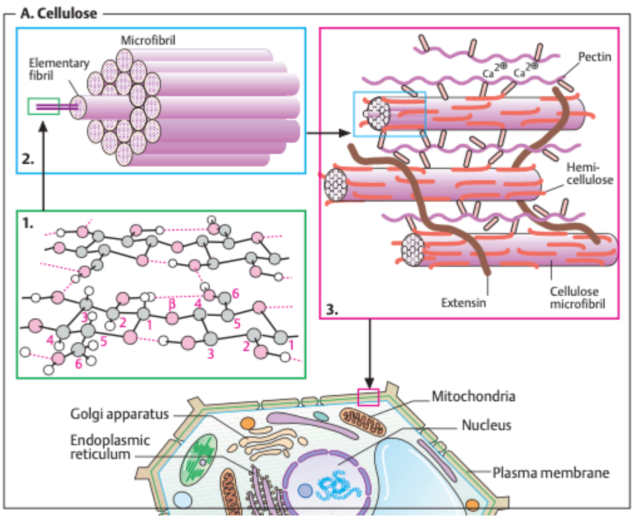
Poly-saccharide	Mono-saccharide 1	Mono-saccharide 2	Linkage	Branch-ing	Occurrence	Function
Bacteria						
Murein	D-GlcNAc	D-MurNAc[1]	β1→4	—	Cell wall	SC
Dextran	D-Glc	—	α1→6	α1→3	Slime	WB
Plants						
Agarose	D-Gal	L-aGal[2]	β1→4	β1→3	Red algae (agar)	WB
Carrageenan	D-Gal	—	β1→3	α1→4	Red algae	WB
Cellulose	D-Glc	—	β1→4	—	Cell wall	SC
Xyloglucan	D-Glc	D-Xyl (D-Gal, L-Fuc)	β1→4	β1→6 (β1→2)	Cell wall (Hemicellulose)	SC
Arabinan	L-Ara	—	α1→5	α1→3	Cell wall (pectin)	SC
Amylose	D-Glc	—	α1→4	—	Amyloplasts	RC
Amylopectin	D-Glc	—	α1→4	α1→6	Amyloplasts	RC
Inulin	D-Fru		β2→1	—	Storage cells	RC
Animals						
Chitin	D-GlcNAc	—	β1→4	—	Insects, crabs	SK
Glycogen	D-Glc	—	α1→4	α1→6	Liver, muscle	RK
Hyaluronic acid	D-GlcUA	D-GlcNAc	β1→4 β1→3	—	Connective tissue	SK,WB

SC= structural carbohydrate, RC= reserve carbohydrate,
WB = water-binding carbohydrate; [1] *N*-acetylmuramic acid, [2] 3,6-anhydrogalactose

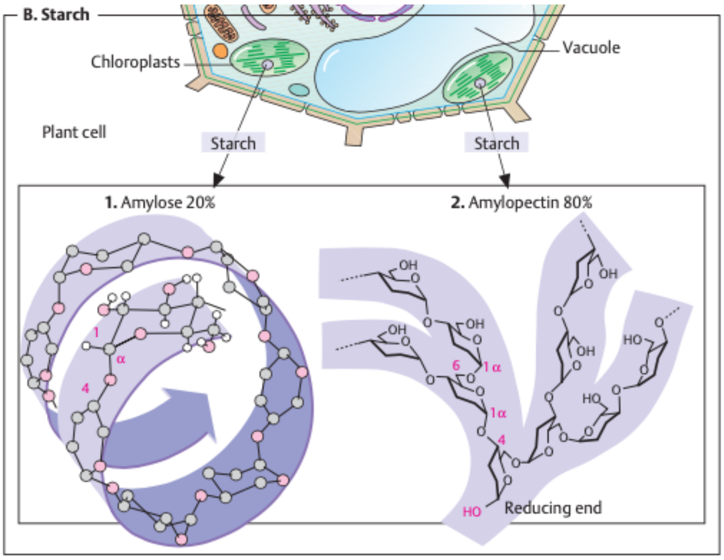
Plant polysaccharides

- Two glucose polymers of plant origin are of special importance among the polysaccharides: β 1-4-linked polymer **cellulose** and **starch**, which is mostly α1- 4-linked.
- **A. Cellulose**
- **B. Starch**

A. Cellulose



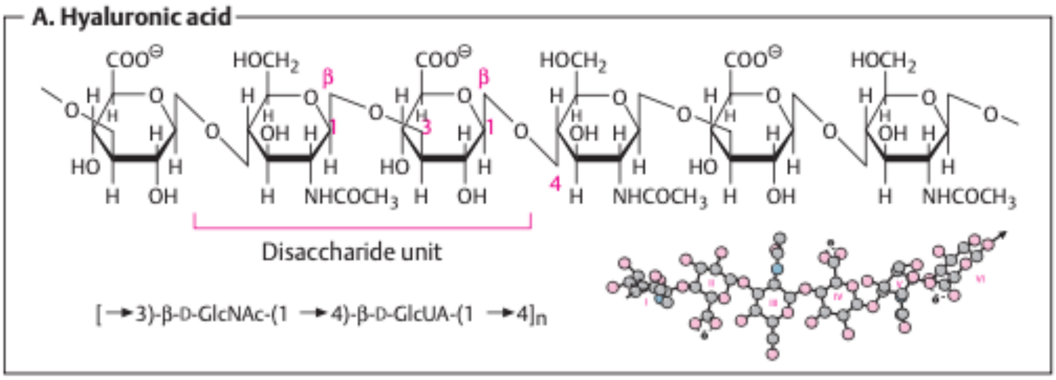
B. Starch



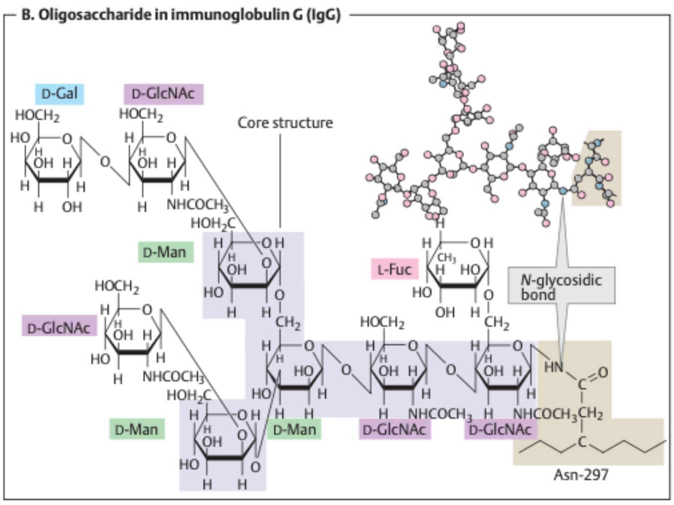
Glycosaminoglycans and glycoproteins

- A. Hyaluronic acid?
- B. Oligosaccharide in immunoglobulin G (IgG)?
- C. Glycoproteins: forms

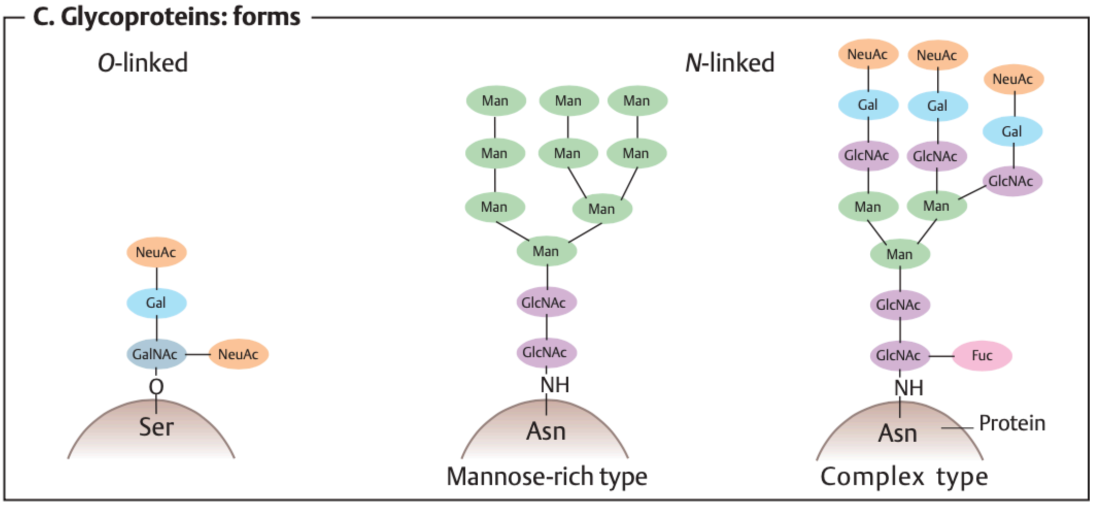
A. Hyaluronic acid



. Oligosaccharide in immunoglobulin G (IgG)



C. Glycoproteins: forms



General Biochemistry

Amino acids: chemistry and properties

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Amino acids: chemistry and properties

A. Amino acids: functions

- Chemical name: (2-aminocarboxylic acids)
- They fulfil various functions in the organism
- They serve as the **components of peptides and proteins**.
- Only the 20 *proteinogenic amino acids* are included in the genetic code and therefore regularly found in proteins.

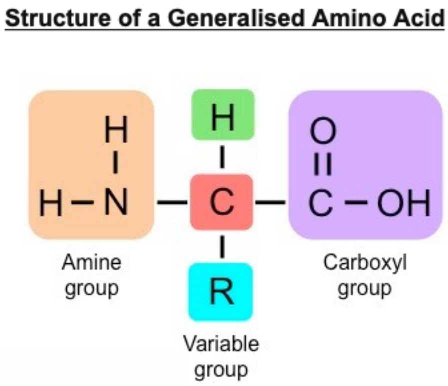
Some functions of amino acids

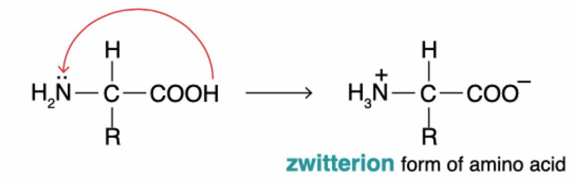
- Some of these amino acids undergo further (post-translational) change following their incorporation into proteins.
- Amino acids or their derivatives are also form components of **lipids**—e. g., serine in phospholipids and glycine in bile salts.
- Several amino acids function as **neurotransmitters** themselves.
- Several non- proteinogenic amino acids function as inter- mediates in the synthesis and breakdown of proteinogenic amino acids.

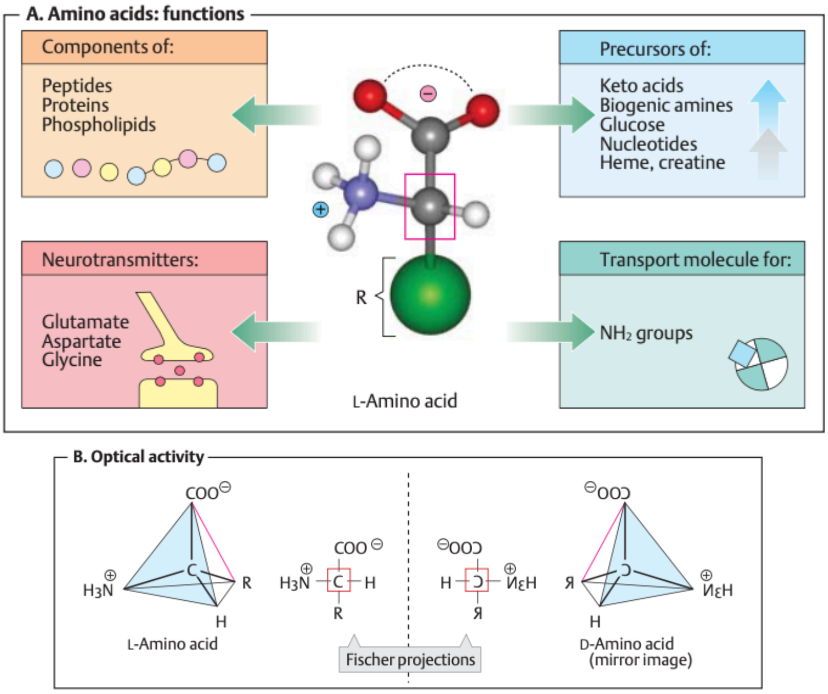
Amino acids: structure

- **B. Optical activity**
- The natural amino acids are mainly α-amino acids, in contrast to β -amino acids alanine and taurine.
- **Zwitterions?**
- The **Fischer projection** (centre) is used to present the formulas for chiral centre molecules.
- Proteins are comprised of long chains of recurring monomers called amino acid
- Amino acids all share a common basic structure, with a central carbon atom bou

1. An amine group (NH_2)
2. A carboxylic acid group (COOH
3. A hydrogen atom (H)
4. A variable side chain (R)

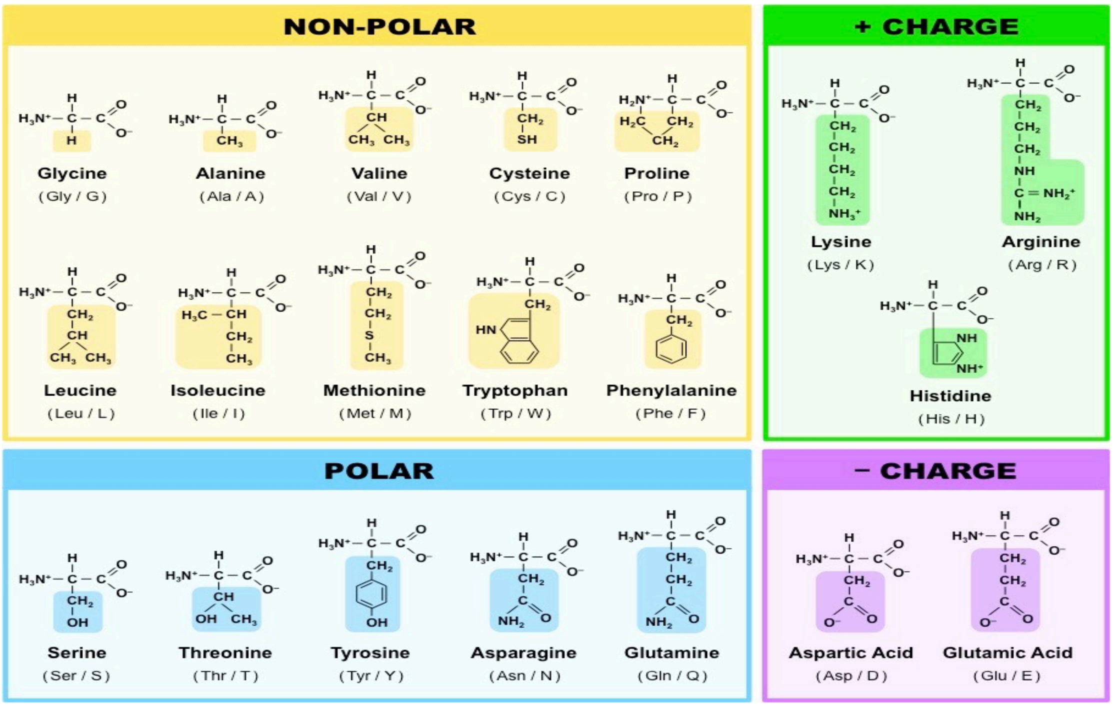






The proteinogenic amino acids

- For each amino acid, the illustration names:
- *Membership of structural classes* I–VII Name and abbreviation, formed from the first three letters of the name (e.g., histidine, His).
- The *one-letter symbol* introduced to save space in the electronic processing of sequence data (H for histidine)

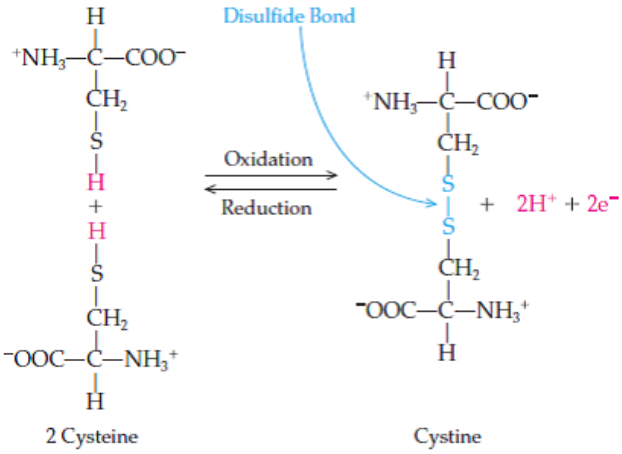


The aliphatic amino acids

- The **aliphatic** amino acids (class I) include *glycine, alanine, valine, leucine*, and *isoleucine*.
- These amino acids do not contain heteroatoms (N, O, or S) in their side chains and do not contain a ring system.
- Their side chains are markedly apolar (non-polar).
- apolar ≠ polar.

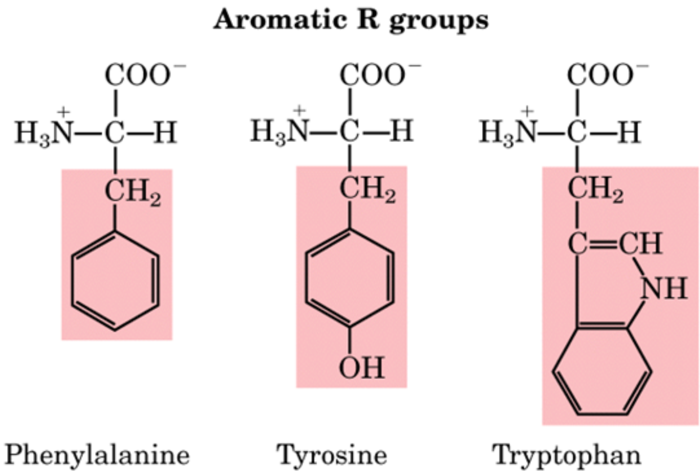
sulfurcontaining amino acids

- The **sulfurcontaining amino acids** *cysteine* and *methionine* (class II), are also apolar (non-polar)..
- However, in the case of cysteine, this only applies to the undissociated state.
- Due to its ability to form disulfide bonds, cysteine plays important role in the stabilization of proteins.
- Two cysteine residues linked by a disulfide bridge are referred to as *cystine*.



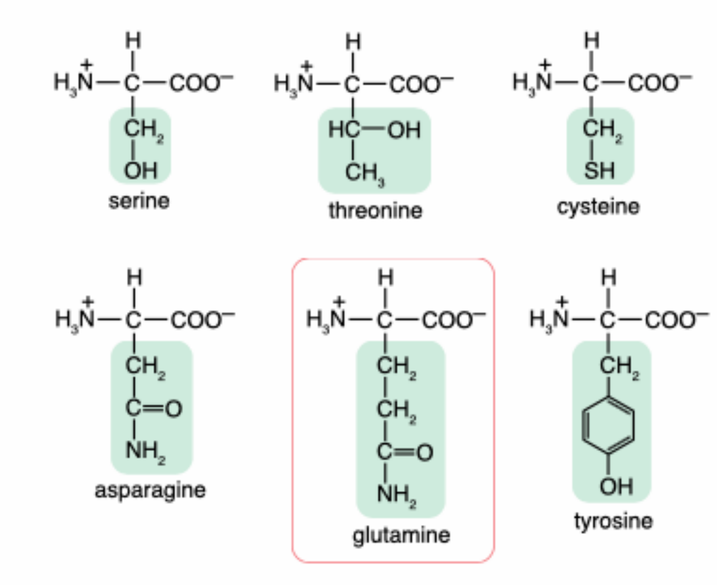
Aromatic amino acids

- The **aromatic amino acids** (class III) contain resonancestabilized rings. In this group, only *phenylalanine* has strongly apolar properties.
- *Tyrosine* and *tryptophan* are moderately polar, and *histidine* is even strongly polar.



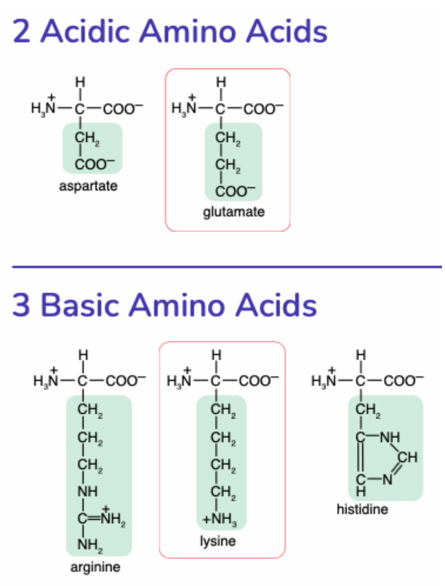
The neutral amino acids

- The **neutral** amino acids (class IV) have hydroxyl groups (*serine*, *threonine*) or amide groups (*asparagine*, *glutamine*).
- Despite their nonionic nature, the amide groups of asparagine and glutamine are markedly polar.

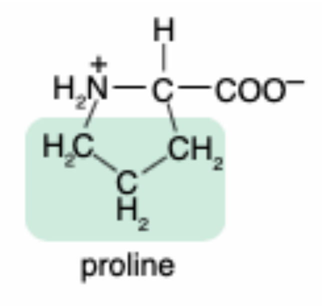


Acidic and and basic amino acid

- The carboxyl groups in the side chains of the **acidic** amino acids *aspartic acid* and *glutamic acid* (class V) are almost completely ionized at physiological pH values.
- The side chains of the **basic** amino acids *lysine* and *arginine* are also fully ionized—i. e., positively charged—at neutral pH.
- Arginine, with its positively charge guanidinium group, is particularly strongly basic, and therefore extremely polar.



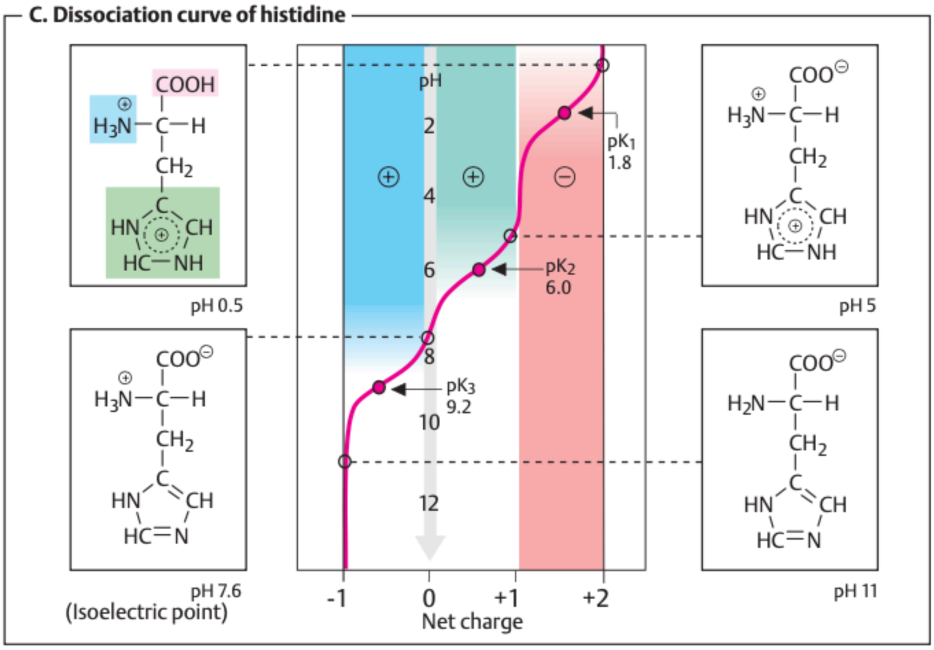
Proline is a special case



- *Proline* is a special case. Together with the α-C atom and the α-NH2 group, its side chain forms a fivemembered ring.
- Its nitrogen atom is only weakly basic and is not protonated at physiological pH.
- Due to its ring structure, proline causes *bending of the peptide chain* in proteins.

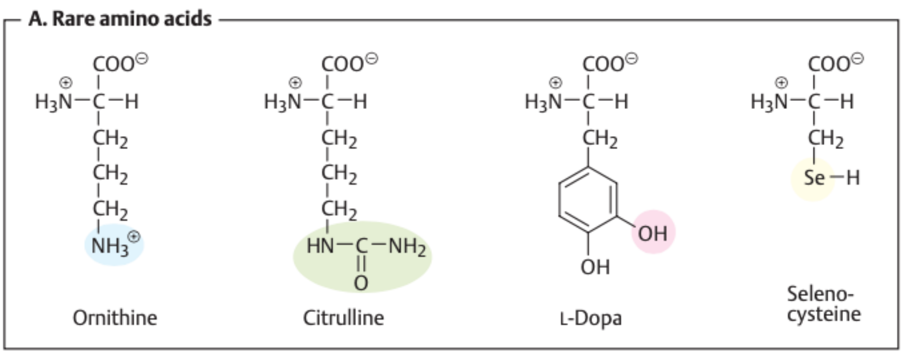
C. Dissociation curve of histidine

- All amino acids have at least two ionizable groups, and their net charge therefore depends on the pH value.
- The COOH groups at the α-C atom have pKa values of between 1.8 and 2.8 and are therefore more acidic than simple monocarboxylic acids.
- The basicity of the α-amino function also varies, with pKa values of between 8.8 and 10.6, depending on the amino acid.
- Acidic and basic amino acids have additional ionizable groups in their side chain.
- **Histidine** can be used here as an example of the pH-dependence of the net charge of an amino acid.



Non-proteinogenic amino acids

- In addition to the 20 proteinogenic amino acids, there are also many more compounds of the same type in nature.
- **Rare amino acids: ornithine, citrulline, Dopa and Selenocysteine**



General Biochemistry

Peptides and proteins: overview

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Functions of Protein

- When amino acids are linked together by acid–amide bonds, linear macromolecules (peptides) are produced.
- Those containing more than 100 amino acid residues are described as **proteins** (polypeptides).
- Every organism contains thousands of different proteins, which have a variety of functions.

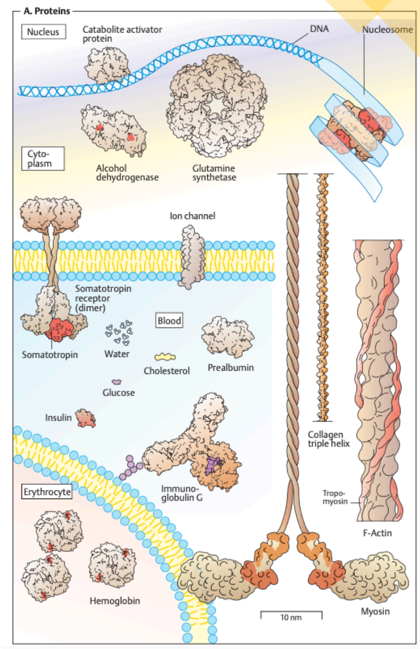
The functions of proteins can be classified as follows:

❑ **Establishment and maintenance of structure: example:**

1. **Collagen** ‘’*shape and stability* of cells and tissues’’.
2. **Histones ‘’**organize the arrangement of DNA in

❑ **Transport:**

1. **Haemoglobin** is well-known transport protein in the erythrocytes.
2. **Prealbumin** (transthyretin; middle.
3. **Ion channels** and other membrane proteins:



Follow….

❑ **Protection and defence. immunoglobulin G.**

❑ **Control and regulation.** The small peptide hormone **insulin regulates the sugar levels in blood.**

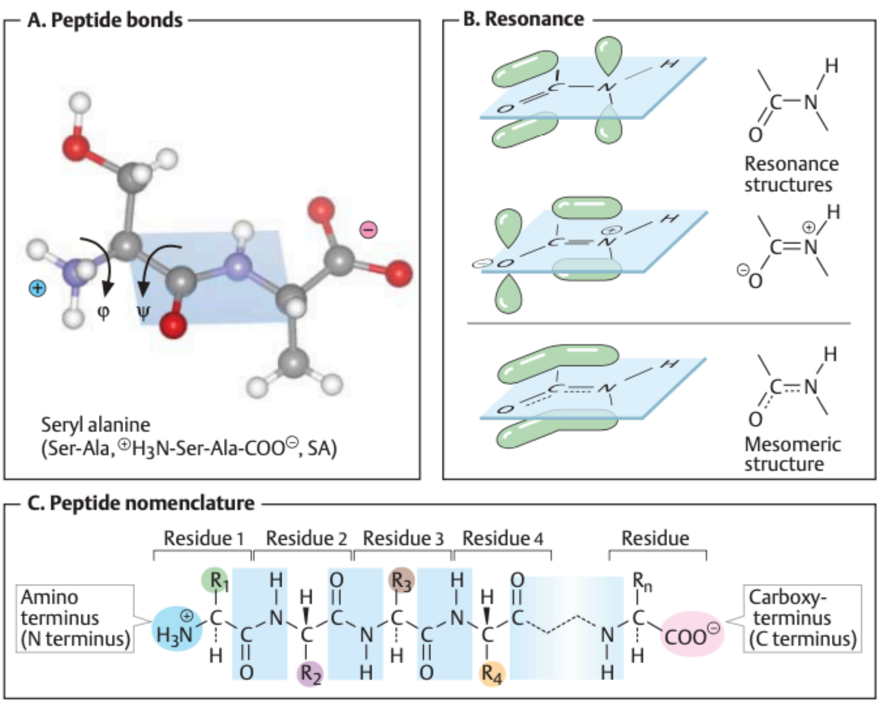
❑**Catalysis: alcohol dehydrogenase** and **glutamine synthetase** etc.

❑**Movement. In** muscle contraction and cell movement. **Myosin and (F-actin)**

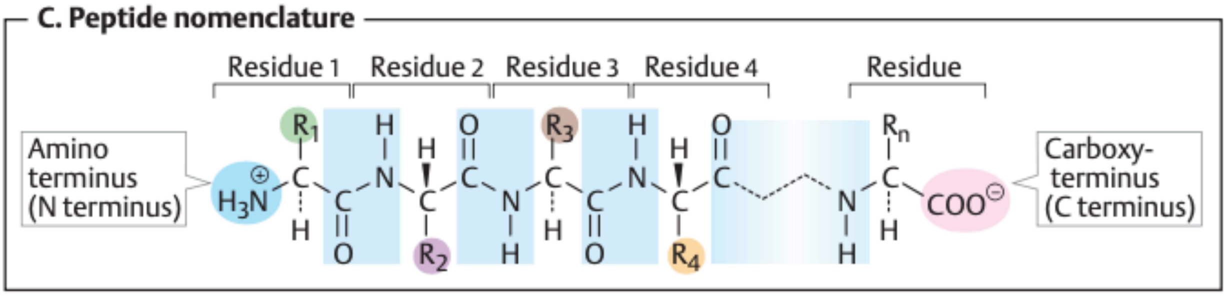
❑ **Storage. storage proteins in** Plants.

Peptide bonds

- **Peptide bond:**
- The amino acid components of peptides and proteins are linked together by *amide* bonds between α-carboxyl and α-amino groups.
- This type of bonding is therefore also known as **peptide bonding**.
- **Resonance**
- There is a combination of a C=O double bond with a C–N single bond.
- Rotations are only possible around the single bonds marked with arrows. The state of these is expressed using the angles ϕ and ψ (see **D**).
- **Conformational space of the peptide chain:**
- C–N bond, rotations are only possible around the N–Cα and Cα–C bonds

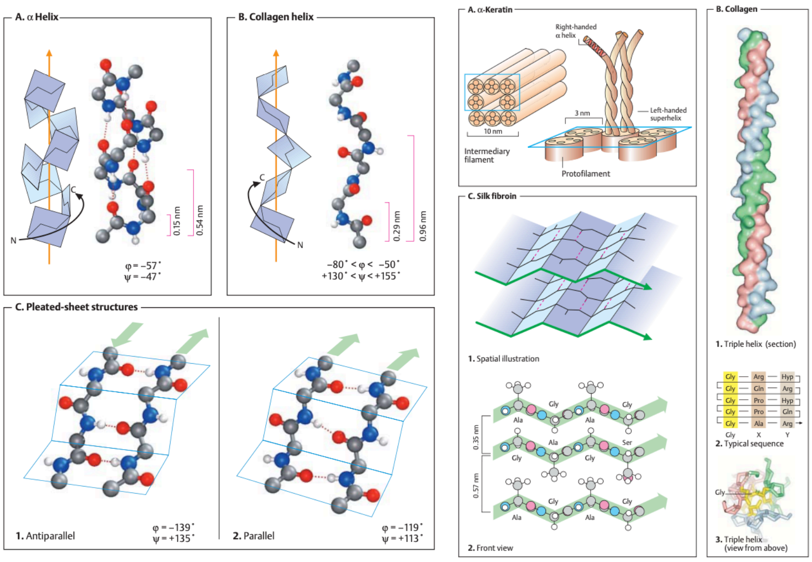


N-terminal and C-terminal

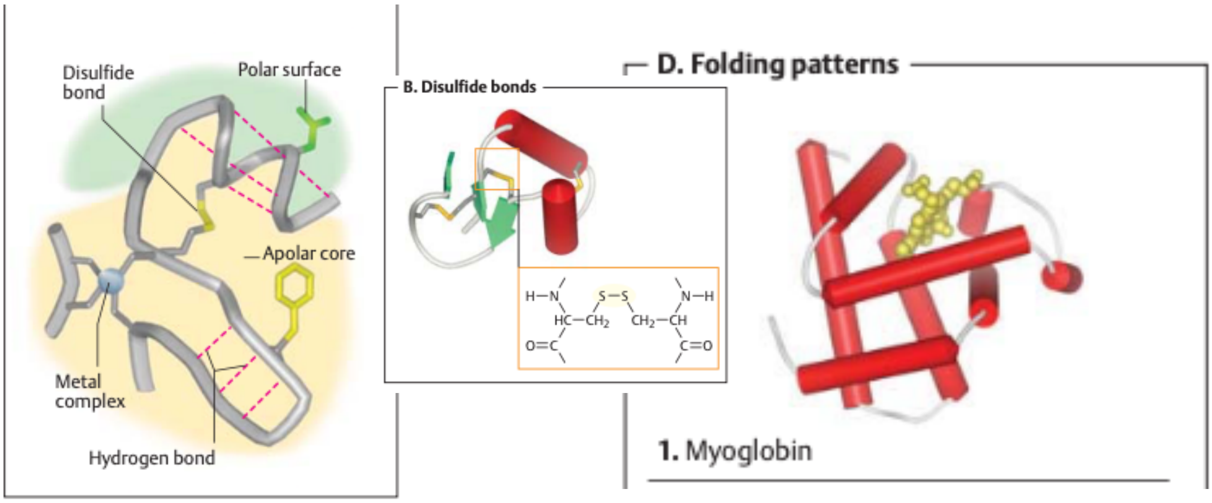


Secondary structures of proteins

- Alpha –Helix: Collagen helix
- Pleated-sheet structures: Beta-Turns
- Structural proteins:
- A. Keratin
- B. Collagen □
- C. Silk fibroin □



Globular proteins: Soluble proteins have a more complex structure than the fibrous, completely insoluble structural proteins.



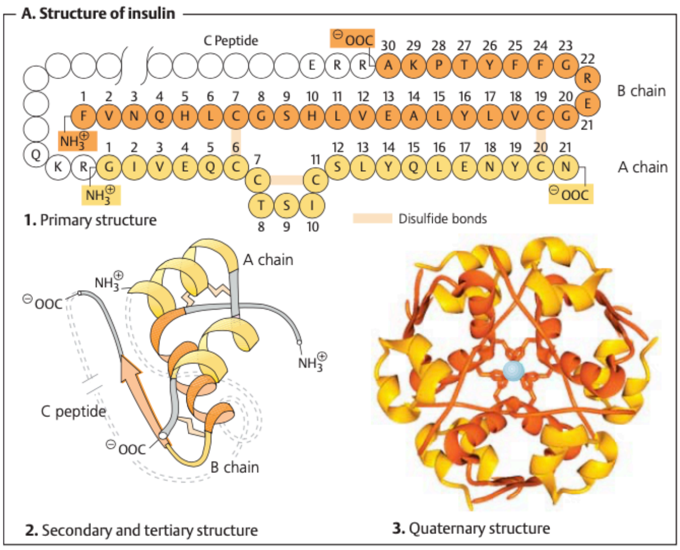
Tertiary and quternary strucutres

- What is a tertiary structure of a protein ?
- Bonds types?
- What is a quaternary structure of a protein ?
- Types?

Molecular models: insulin

- **Function of Insulin:**
- Insulin is a peptide hormone produced by beta cells of the pancreatic islets. It is the main anabolic hormone of the body.
- It regulates the metabolism of carbohydrates, fats and protein by promoting the absorption of glucose from the blood into liver, fat and skeletal muscle cells.
- **Structure of insulin:**
- **Insulin is** a combination of two peptide chains (dimer) named an A-chain and a B-chain, which are linked together by two disulfide bonds.
- The A-chain is composed of 21 amino acids, while the B-chain consists of 30 residues.

Structure of insulin



General Biochemistry
Bases and nucleotides

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1

Bases and nucleotides

- The nucleic acids play a central role in the storage and expression of genetic information.
- They are divided into two major classes: **deoxyribonucleic acid (DNA)** functions solely in information storage, while **ribonucleic acids (RNAs)** are involved in most steps of gene expression and protein biosynthesis.
- All nucleic acids are made up from **nucleotide components**, which in turn consist of a *base*, a *sugar*, and a *phosphate residue*.

2

Nucleic acid bases

- The bases that occur in nucleic acids are *aromatic* heterocyclic compounds derived from either **pyrimidine** or **purine**.
- The purine bases **adenine (A)** and **guanine** (G) and the pyrimidine base **cytosine** (C) are present in both RNA *and* DNA.
- In contrast, **uracil** (U) is only found in RNA.
- In DNA, **uracil** is replaced by thymine (T), the 5-methyl derivative of uracil.

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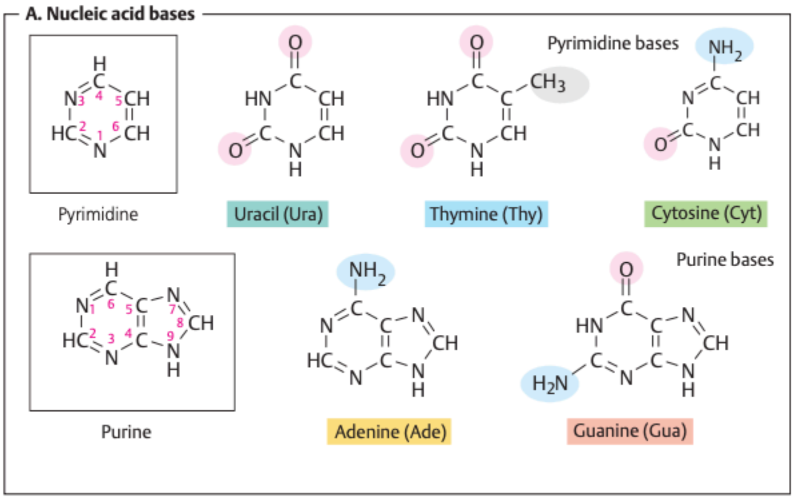
Nucleic acid bases



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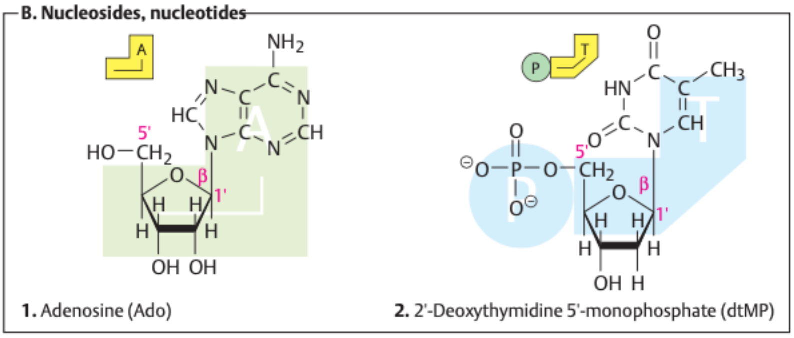
Nucleosides, nucleotides

- Nucleosides (bottom) are **made of a nitrogenous base, usually either a purine or pyrimidine, and a five-carbon carbohydrate ribose**.
- A nucleotide is simply a nucleoside with an additional phosphate group or groups.



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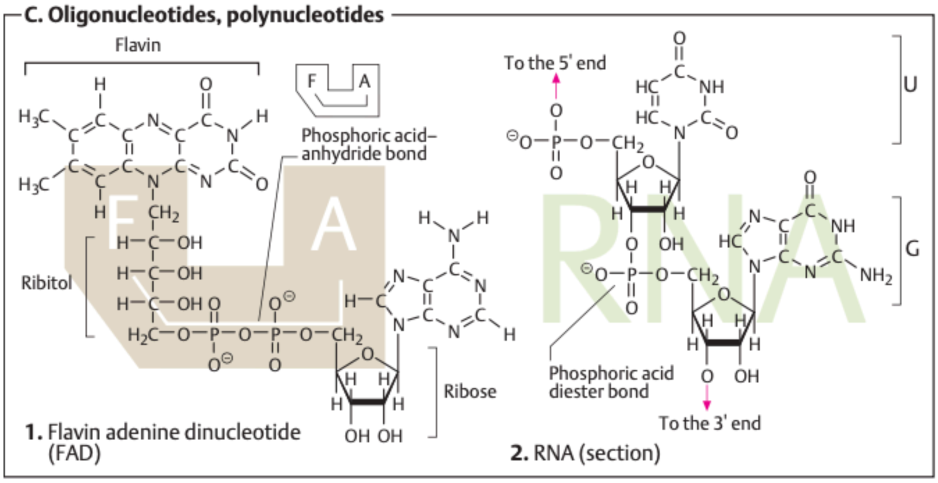
Oligonucleotides, polynucleotides

- **FAD:**
- Phosphoric acid molecules can form acid–anhydride bonds with each other. It is therefore possible for two nucleotides to be linked via the phosphate residues.
- This gives rise to *di- nucleotides with a phosphoric acid–anhydride* structure.
- This group includes the coenzymes NAD(P)+ and CoA, as well as the flavin derivative **FAD.**
- This is the way in which **oligonucleotides**, and ultimately **polynucleotides**, are synthesized.
- **RNA:**
- Polynucleotides consisting of ribonucleotide components are called **ribonucleic acid**
- **(RNA)**, while those consisting of deoxyribonucleotide monomers are called **deoxyribonucleic acid**

6

Oligonucleotides, polynucleotides



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RNA

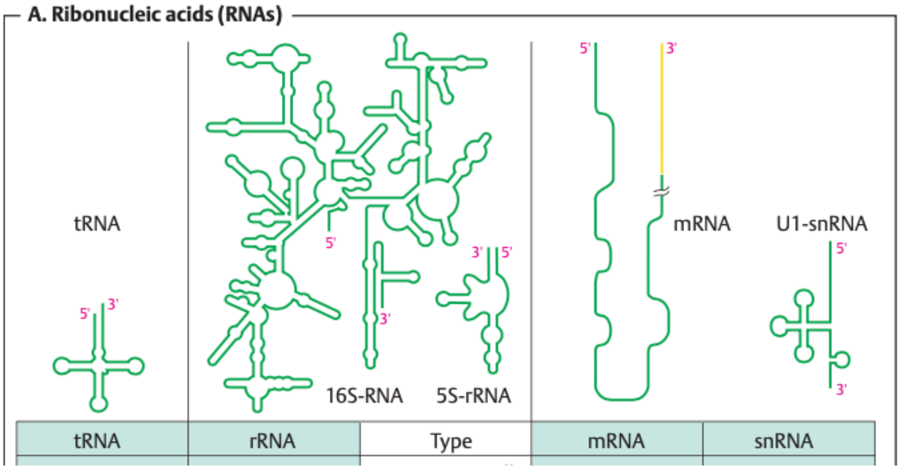
- Ribonucleic acids (RNAs) are polymers consisting of nucleoside phosphate components that are linked by phosphoric acid diester bonds.
- RNAs are involved in all the individual steps of gene expression and protein biosynthesis
- n contrast to DNA, RNAs do not form extended double helices. In RNAs, the base pairs usually only extend over a few residues.
- There are mainly three types of RNA:

1. tRNA: links between the nucleic acids and proteins during translation
2. rRNA: rRNA is a ribozyme which carries out protein synthesis in ribosomes.
3. mRNA: **Messenger RNA** (**mRNA**) is a single-stranded RNA molecule that is complementary to one of the DNA strands of a gene.

- Also, **snRNAs)** are involved in the splicing of mRNA precursors.

8

Types of RNA



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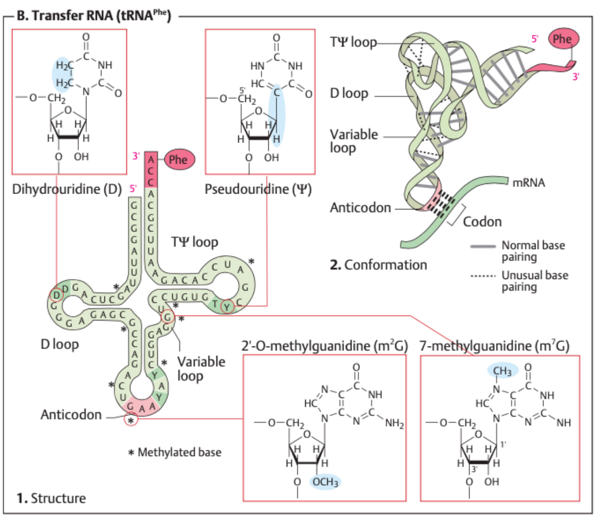
3D structure of tRNA



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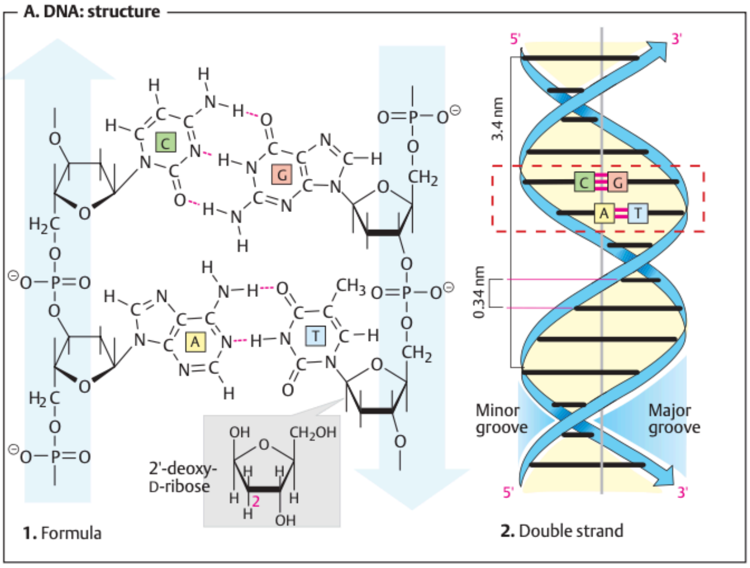
DNA: structure

- **A. DNA: structure**
- deoxyribonucleic acids (DNAs) are polymeric molecules consisting of nucleotide building blocks.
- Instead of ribose, however, DNA contains 2-deoxyribose, and the *uracil* base in RNA is replaced by *thymine*.
- The spatial structure of the two molecules also differs.
- the two strands have to be intertwined to form a **double helix**.
- Due to steric hindrance by the 2-OH groups of the ribose residues, RNA is unable to form a double helix.
- The structure of RNA is therefore less regular than that of DNA .
- **Coding of genetic information**
- In all living cells, DNA serves to **store genetic information**.

11

DNA structure



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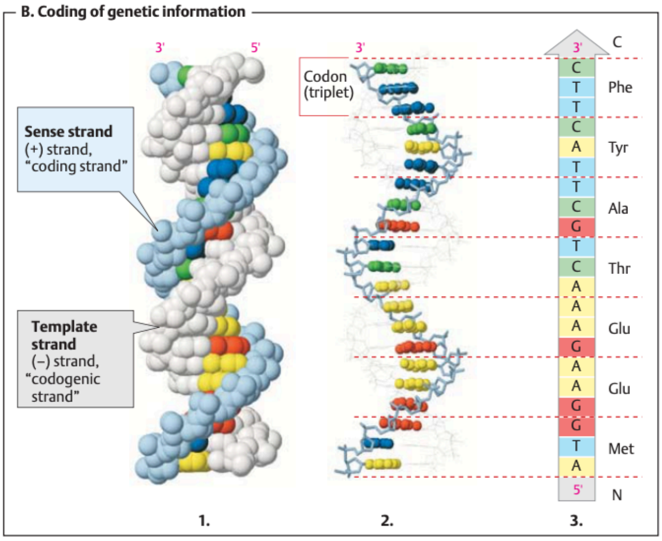
DNA structure



13

General Biochemistry
Lipids and fatty acids

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1

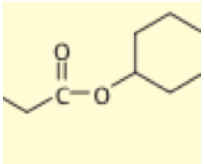
What are lipids? A. Classification

- The **lipids** are a large and heterogeneous group of substances of biological origin that are easily dissolved in organic solvents such as methanol, acetone, chloroform, and benzene.
- By contrast, they are either insoluble or only poorly soluble in water.
- Their low water solubility is due to a lack of polarizing atoms such as O, N, S, and P.
- Lipids can be classified into substances that are either *hydrolyzable*— i. e., able to undergo hydrolytic cleavage—or *nonhydrolyzable*.

2

What are Hydrolysable lipids ?

- The components of the hydrolysable lipids are linked to one another by **ester bonds**.
- They are easily broken down either enzymatically or chemically.
- The simple **esters** include the *fats* (triacylglycerol; one glycerol + three acyl residues).
- **The *waxes*** (one fatty alcohol + one acyl residue).
- **The *sterol esters*** (one sterol + one acyl residue)



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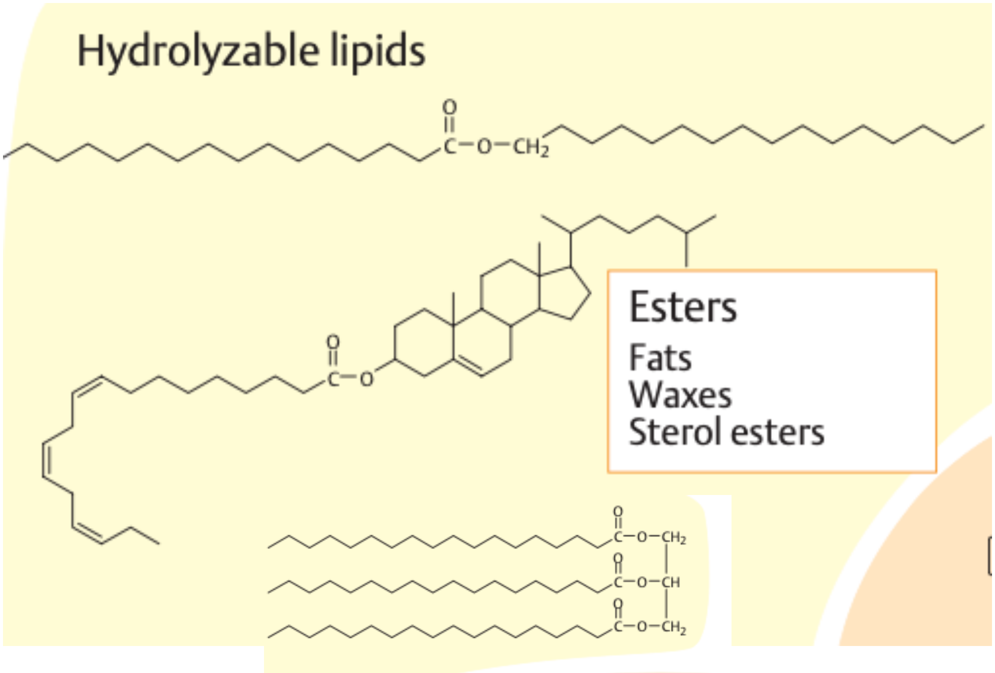

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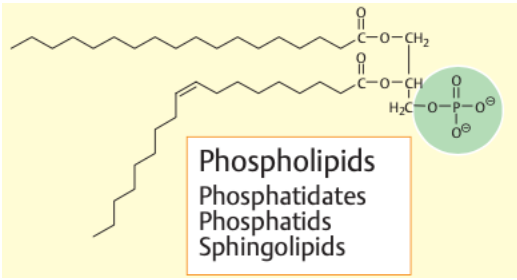
Phospholipids ?

- The **phospholipids** are esters with more complex structures. Their characteristic component is a phosphate residue.
- The **phospholipids** include the *phosphatidic acids* (one glycerol + two acyl residues + one phosphate)
- The ***phosphatides*** (one glycerol + two acyl residues +
- one phosphate + one amino alcohol).
- The **sphingolipids**, glycerol and one acyl residue are replaced by sphingosine.



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B. Biological roles

- **1. Fuel.**

❑ Lipids are an important source of energy in the diet.

❑ Neutral fats in particular are stored in specialized cells.

❑ Fatty acids are released from these again as needed, and these are then oxidized in the mitochondria to form water and carbon dioxide, with oxygen being consumed.

- **2. Nutrients.**

❑ Amphipathic lipids are used by cells to build membranes.

❑ Typical membrane lipids include phospholipids, glycolipids, and cholesterol.

❑ Fats are only weakly amphiphilic and are therefore not suitable as membrane components.

- **Insulation:** Lipids are excellent insulators.

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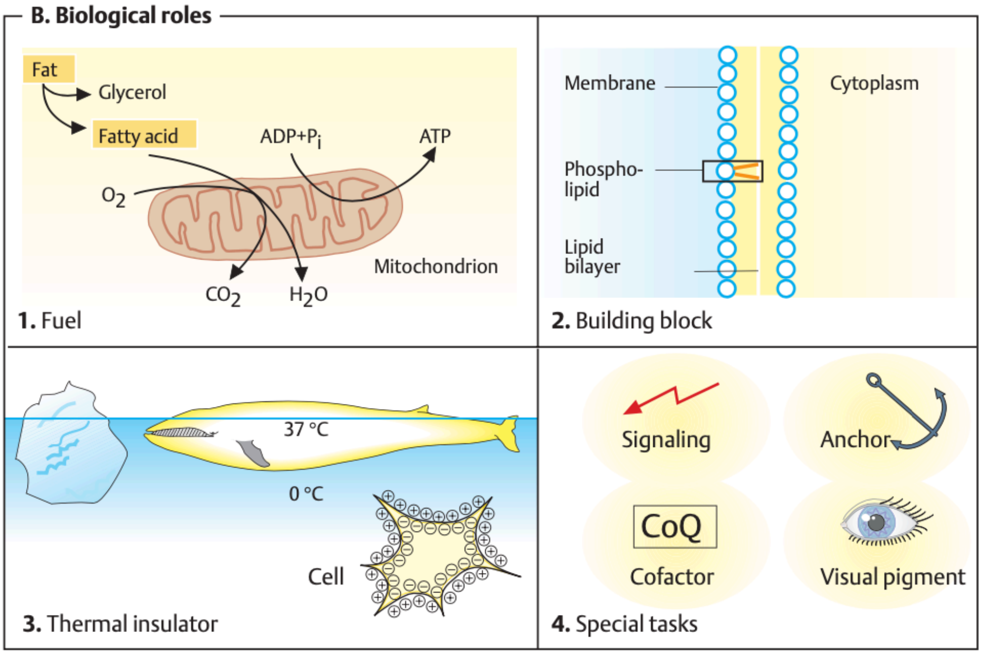

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Furthermore…..

- **4. Special tasks.**

❑Some lipids have adopted special roles in the body:

❑Steroids, eicosanoids, and some metabolites of phospholipids have ***signaling functions***.

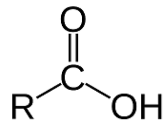
❑They serve as hormones, mediators, and second messengers.

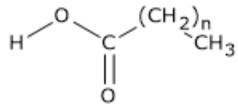
❑Other lipids form *anchors* to attach proteins to membranes

❑The carotenoid retinal, a light-sensitive lipid, is of central importance in the *process of vision*.

8

Fatty acids and fats; A. Carboxylic acids ☐





- The naturally occurring **fatty acids** are carboxylic acids with unbranched hydrocarbon chains of 4–24 carbon atoms.
- They are present in all organisms as components of fats and membrane lipids.
- In these compounds, they are esterified with alcohols (glycerol, sphingosine, or cholesterol).
- **Essential fatty acids** are fatty acids that have to be supplied in the diet.

9

A. Carboxylic acids

Name	Number of carbons : Number of double bonds; Position of double bonds	
Formic acid	1 : 0	Not contained in lipids
Acetic acid	2 : 0	Not contained in lipids
Propionic acid	3 : 0	Not contained in lipids
Butyric acid	4 : 0	
Valerianic acid	5 : 0	
Caproic acid	6 : 0	$HOOC-CH_2-CH_2-CH_2-CH_2-CH_3$ Caproic acid
Caprylic acid	8 : 0	
Capric acid	10 : 0	
Lauric acid	12 : 0	
Myristic acid	14 : 0	
Palmitic acid	16 : 0	
Stearic acid	18 : 0	
Oleic acid	18 : 1; 9	
✱ Linoleic acid	18 : 2; 9,12	

✱ Essential in human nutrition

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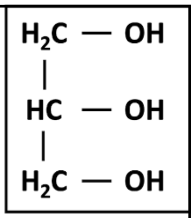
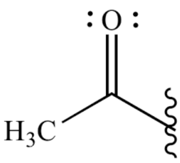
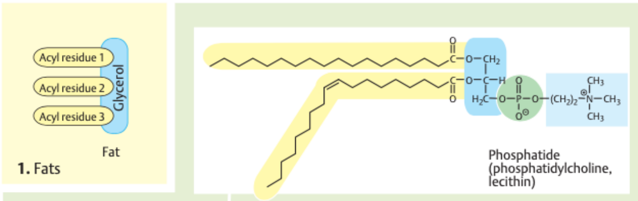
B. Structure of fats



- **Fats** are esters of the trivalent alcohol *glycerol* with three fatty acids.
- When a single fatty acid is esterified with glycerol, the product is referred to as a *monoacylglycerol* (fatty acid residue = acyl residue).
- Formally, esterification with additional fatty acids leads to *diacylglycerol* and ultimately to *triacylglycerol*.
- The carbon atoms of glycerol are not usually equivalent in fats. They are distinguished by their *"sn"* number, where sn stands for "stereospecific numbering."

acyl group





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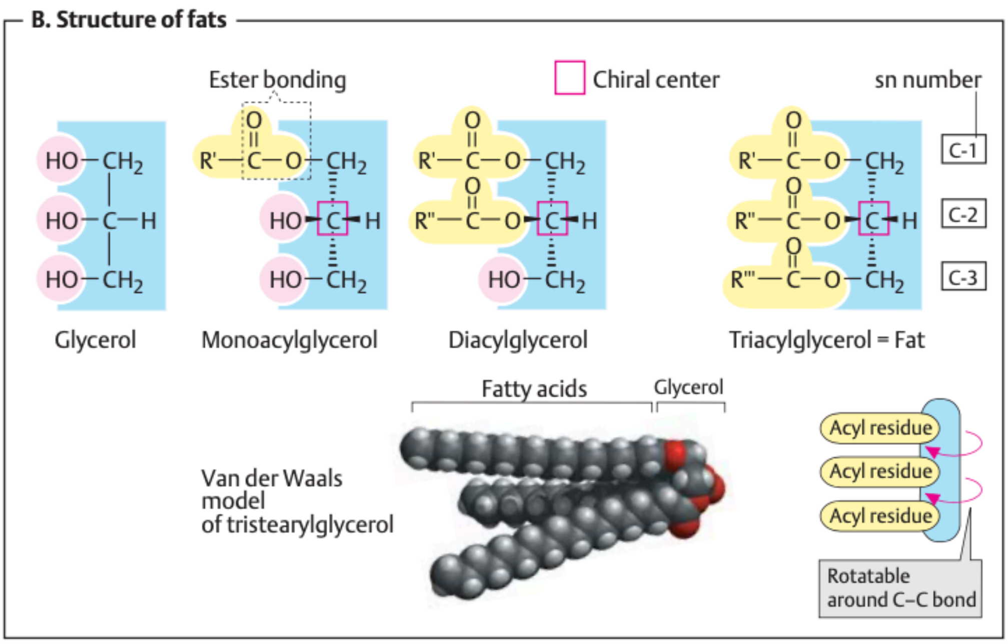

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Phospholipids and glycolipids

- **A. Structure of phospholipids and glycolipids** □

1. **Fats** (triacylglycerol) are esters of glycerol with three fatty acids. Within the cell, they mainly occur as fat droplets. In the blood, they are transported in the hydrophobic interior of lipoproteins.
2. **Phospholipids** are the main constituents of biological membranes.

- Their common feature is a phosphate residue that is esterified with the hydroxyl group at C-3 of glycerol.
- Due to this residue, phospholipids have at least one negative charge at a neutral pH.

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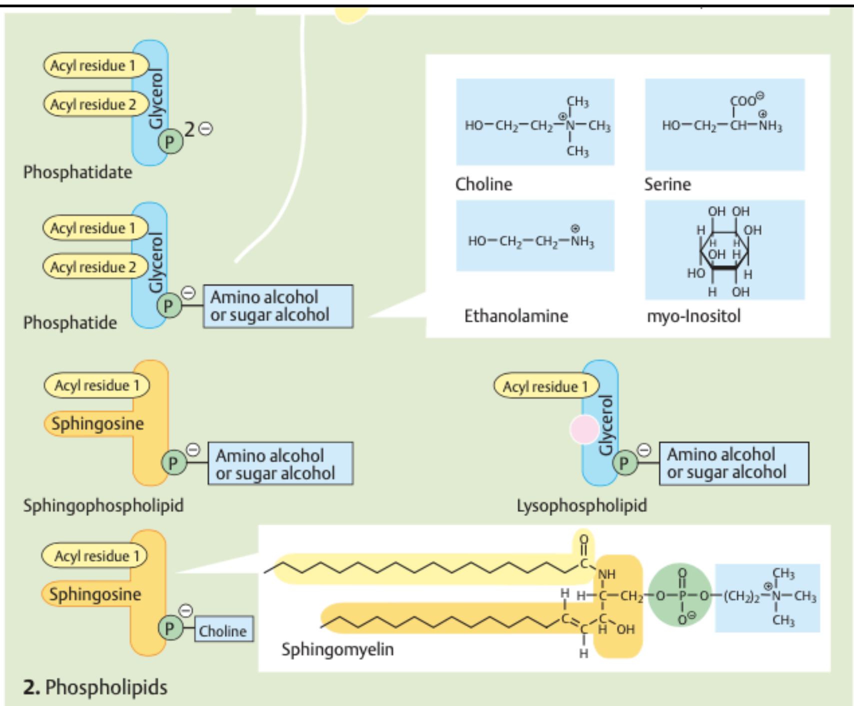

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Derivatives…

- ***Phosphatides*** (anions of the phosphatidic acids), the simplest phospholipids, are phosphate esters of diacylglycerol.
- They are important intermediates in the biosynthesis of fats and phospholipids
- **Phosphatidylcholine** (lecithin) is the most abundant phospholipid in membranes.
- ***Phosphatidylethanolamine*** (cephalin) has an ethanolamine residue instead of choline, and *phosphatidylserine* has a serine residue.

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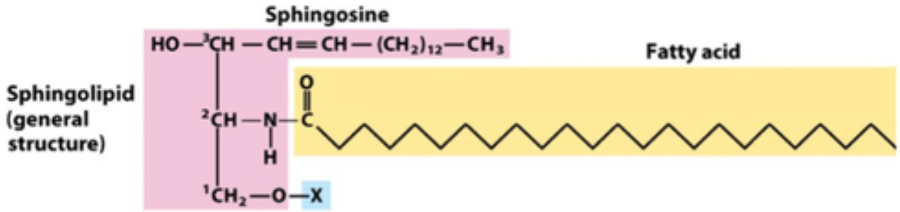
Moreover.. Sphingolipids

- **Sphingolipids** (**3**), which are found in large quantities in the membranes of nerve cells in the brain and in neural tissues.
- In sphingolipids, *sphingosine*, an amino alcohol with an unsaturated alkyl side chain, replaces glycerol and one of the acyl residues.
- When sphingosine forms an amide bond to a fatty acid, the compound is called *ceramide* (**3**).
- ***Sphingomyelin*** (2)—the most important sphingolipid—has an additional phosphate residue with a choline group attached to it on the sphingosine, in addition to the fatty acid.



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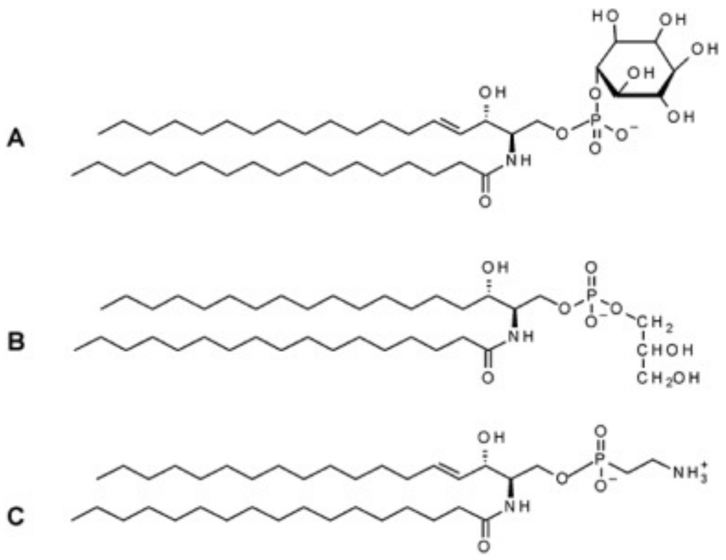
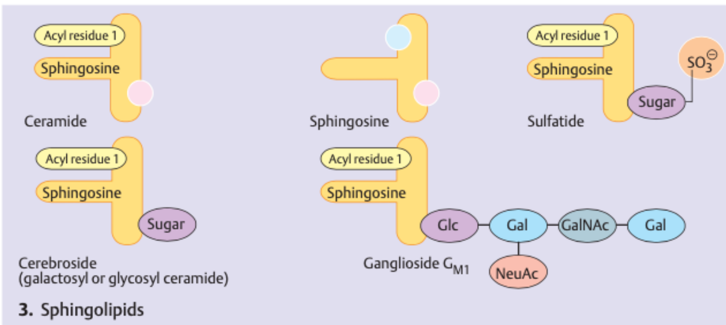
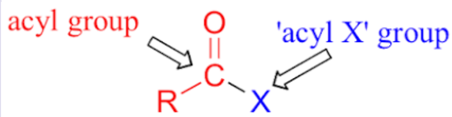
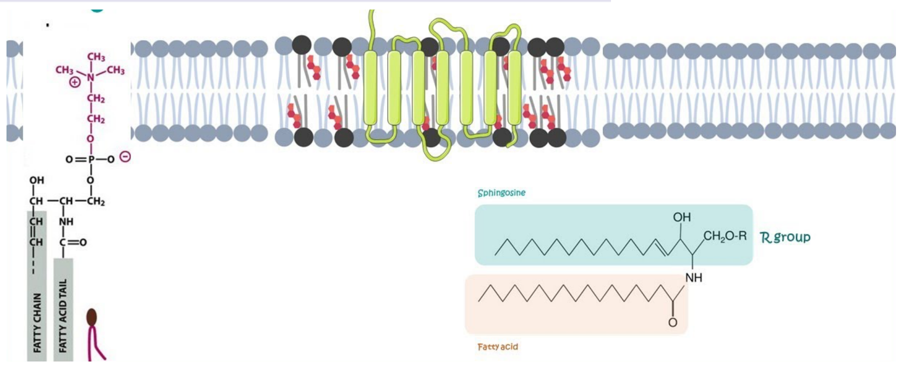


Molecular structures of ceramide phosphoinositol (A), ceramide phosphoglycerol (B) and ceramide aminoethylphosphonate (C).

17







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Also, Glycolipids

- **Glycolipids** (**3**) are present in all tissues on the outer surface of the plasma membrane.
- They consist of sphingosine, a fatty acid, and an oligosaccharide residue, which can some- times be quite large.
- The phosphate residue typical of phospholipids is absent.
- ***Galactosylceramide*** and *glucosylceramide* (known as cerebroside) are simple representatives of this group.
-

19

Isoprenoids

- **A. Activated acetic acid as a component of lipids** □
- Although the lipids found in plant and animal organisms occur in many different forms, they are all closely related biogenetically; they are all derived from **acetyl-CoA**, the "activated acetic acid"
- 1. One major pathway leads from acetyl- CoA to the activated fatty acids (**acyl-CoA**).
- *Fats, phospholipids,* and *glycolipids* are synthesized from these.
- 2. The second pathway leads from acetyl- CoA to isopentenyl diphosphate. (*"active isoprene"*)
- Note:
- All steroids are isoprenoids; that is, they're constructed from isoprene units which then fold into the multi-ring structure of steroids.

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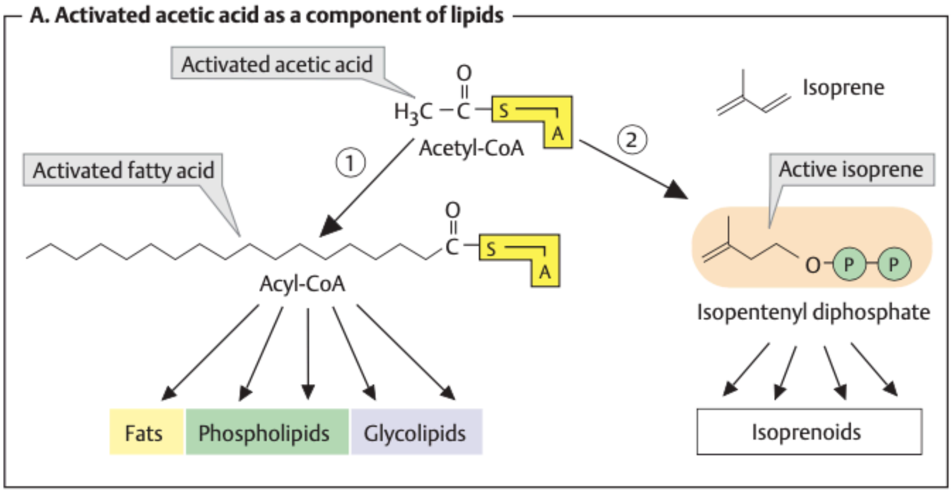
A. Activated acetic acid as a component of lipids



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Steroid structure

- **A. Steroid building blocks.** □
- Steroid is (biochemistry) a class of organic compounds having a structure of 17 carbon atoms arranged in four rings; they are lipids, and occur naturally as sterols, bile acids, adrenal and sex hormones, and some vitamins
- Common to all of the steroids is a molecular core structure consisting of four saturated rings, known as *gonane*. At the end of the steroid core, many steroids also carry a side chain, as seen in *cholestane*.
- The four rings of the steroids are distinguished using the letters A, B, C, and D.

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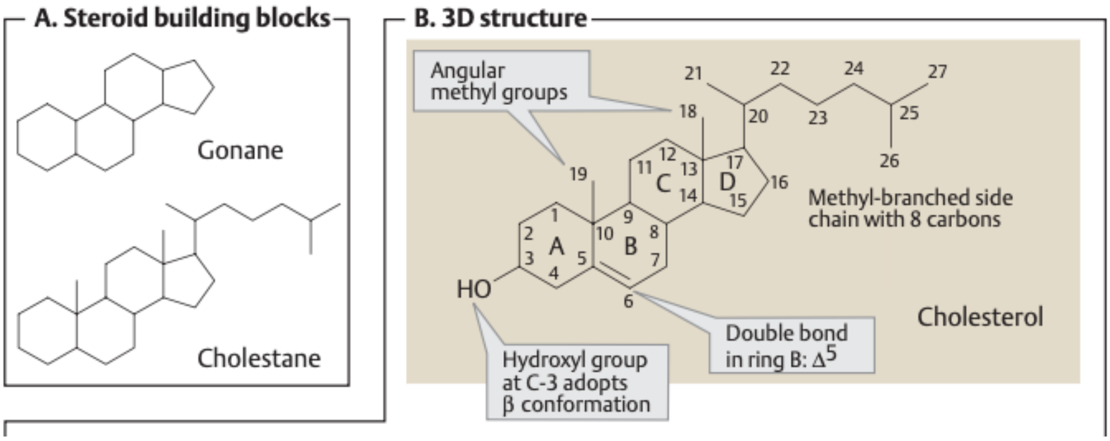
Cholesterol structure



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Steroids: overview

- In animals: The three most important groups of steroids are the *sterols*, *bile acids*, and *steroid hormones*.
- In plants: alkaloids, digitalis glycosides, and saponins.
- **A. Sterols** □
- Sterols are *steroid alcohols*.
- Cholesterol is present in all animal tissues, and particularly in neural tissue. It is a major constituent of cellular membranes.
- The storage and transport forms of cholesterol are its esters with fatty acids.
- In lipoproteins, cholesterol and its fatty acid esters are associated with other lipids.
- Cholesterol is a constituent of the bile and is therefore found in many gallstones.

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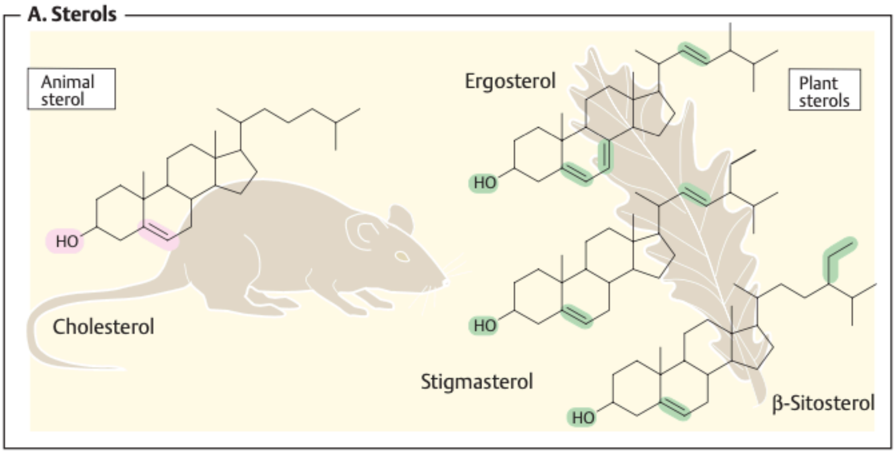
A. Sterols structures



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B. Bile acids □

- ***Bile acids*** are synthesized from cholesterol in the liver.
- Their structures can therefore be derived from that of cholesterol.
- Bile acids keep bile cholesterol in a soluble state as micelles and promote the digestion of lipids in the intestine.
- **Cholic acid** and **chenodeoxycholic acid** are *primary bile acids* that are formed by the liver.
- Note: see dehydroxylation at C-7!

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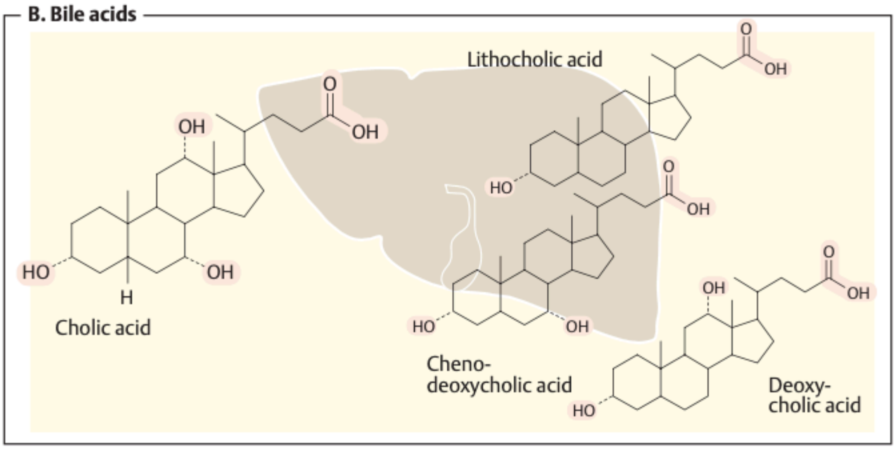
B. Bile acids structures



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C. Steroid hormones ☐

- **C. Steroid hormones ☐**
- The conversion of cholesterol to *steroid hormones* is of minor importance.
- Humans have six steroid hormones: **progesterone**, **cortisol**, **aldosterone**, **testosterone**, **estradiol**, and **calcitriol**.
- With the exception of calcitriol, these steroids have either no side chain or only a short side one consisting of two carbons.
- see the difference of the structures with others.
- **Ecdysone** is the steroid hormone of the arthropods (invertebrate animals, e.g insects etc).

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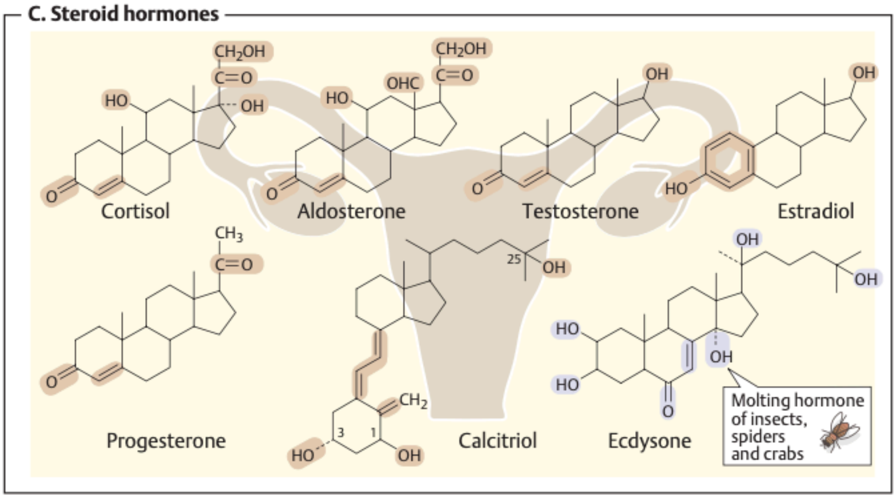
Steroid hormones structures



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General Biochemistry
Hormones

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1

What are hormones?

- **Hormones** are *chemical signaling substances*.
- They are synthesized in specialized cells that are often associated to form *endocrine glands*.
- In the organs, the hormones carry out physiological and biochemical regulatory functions.
- In contrast to endocrine hormones, **tissue hormones** are only active in the immediate vicinity of the cells that secrete them.

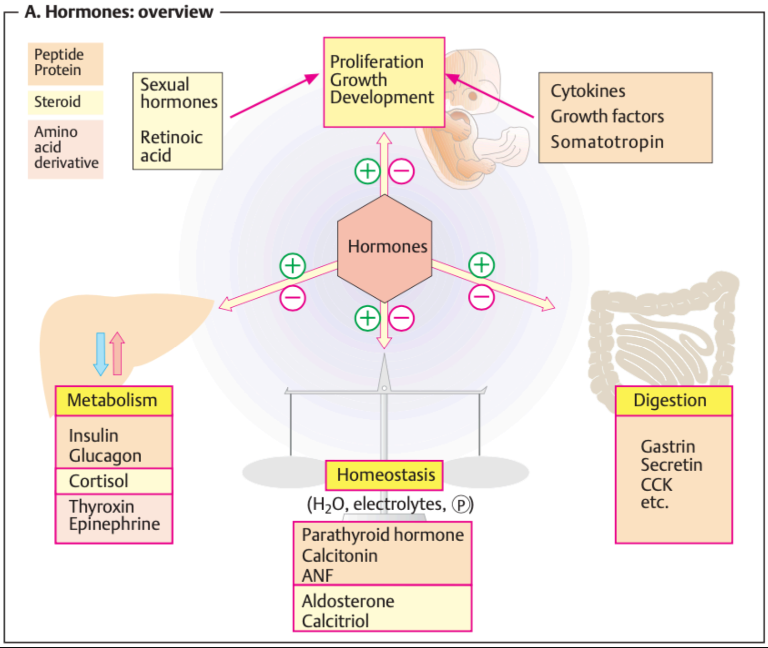
2

Types of hormones?

- The animal organism contains more than 100 hormones and hormone-like substances, which can be classified either according to their structure or according to their function.
- **They are mainly classified into** Lipophilic and Hydrophilic hormones.

3

Most hormones?



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Lipophilic and Hydrophilic hormones ?

- Lipophilic hormone include ***steroid hormones***, ***iodothyronines***, and ***retinoic acid***.
- *They* are relatively small molecules (300–800 Da) that are poorly soluble in aqueous media.
- With the exception of the iodothyronines, they are not stored by hormone-forming cells, but are released immediately after being synthesized.

5

What are the types of Steroid hormones?

- Steroid hormones are all synthesized form cholestrol(p377)
- **Progesterone** is a female sexual steroid.
- It is synthesized in ovaries. The blood level of progesterone varies with the menstrual cycle. The hormone prepares the uterus for a possible pregnancy.
- **Estradiol** is also a female sexual steroid. Like progesterone, it is synthesized by the ovaries and, during pregnancy, by the placenta as well.
- Estradiol controls the menstrual cycle. It is also responsible for the development of the female secondary sexual characteristics (breast, fat distribution, etc.).

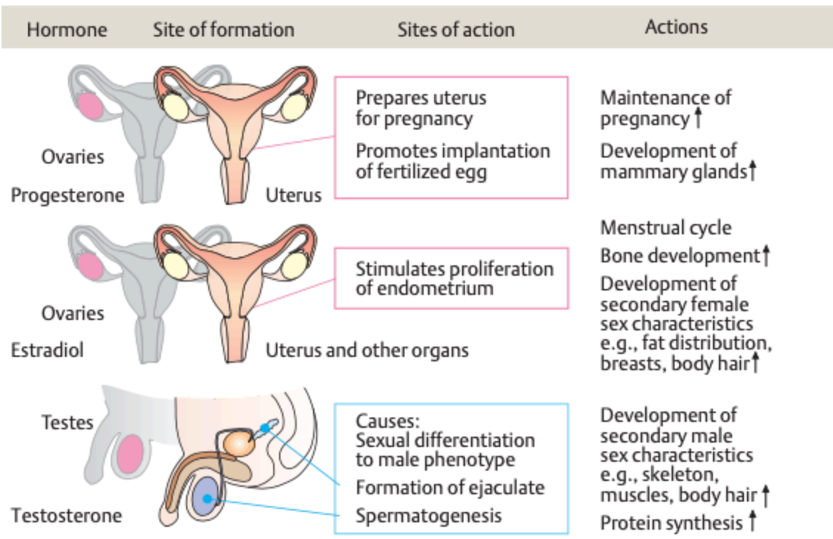
6

What are the types of Steroid hormones?

- **Testosterone** is the most important male sexual steroids.
- It is synthesized in the testes.
- It controls the development and functioning of the male gonads. It also determines secondary sexual characteristics in men (muscles, hair, etc.).

7

Sexual hormones



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What are the types of Steroid hormones?

- **Cortisol**, the most important *glucocorticoid* (**powerful medicines that fight inflammation**).
- *It* is synthesized by the adrenal cortex.
- It is involved in regulating protein and carbohydrate metabolism by promoting protein degradation and the conversion of amino acids into glucose.
- As a result, the blood glucose level rises.
- **Aldosterone**: a *mineralocorticoid,* is also synthesized in the adrenal gland.
- In the kidneys, it promotes Na^+ resorption by inducing Na+/K+ ATPase and Na+ channels. At the same time, it leads to increased K^+ excretion. In this way, aldosterone indirectly increases blood pressure.

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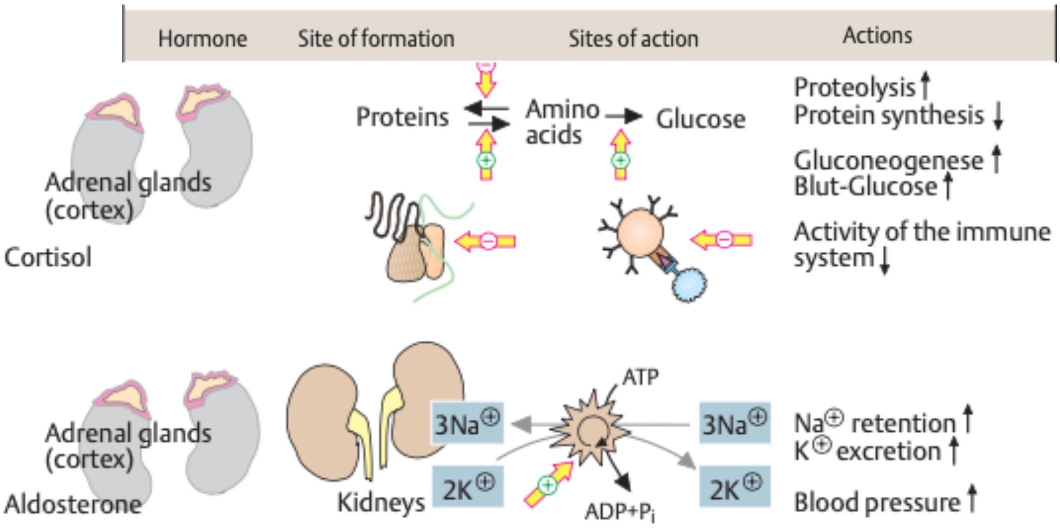
Cortisol



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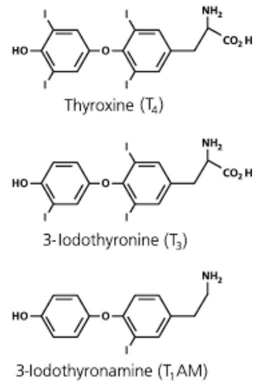
What are the types of Steroid hormones?

- **Iodothyronines**
- The thyroid hormone **thyroxine** (tetra iodothyronine, T4) and its active form **tri iodothyronine** (T3) are derived from the amino acid *tyrosine* synthesized in the thyroid gland
- The iodine atoms at positions 3 and 5 of the two phenol rings are characteristic of them.
- They increase the basal metabolic rate, partly by regulating mitochondrial ATP synthesis. In addition, they promote embryonic development.



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What are the types of Steroid hormones?

- **Calcitriol** is a derivative of vitamin D.
- On exposure to ultraviolet light, a precursor of the hormone can also arise in the skin.
- Calcitriol itself is synthesized in the kidneys.
- Calcitriol promotes the resorption of calcium in the intestine and increases the Ca^{2+} level in the blood.

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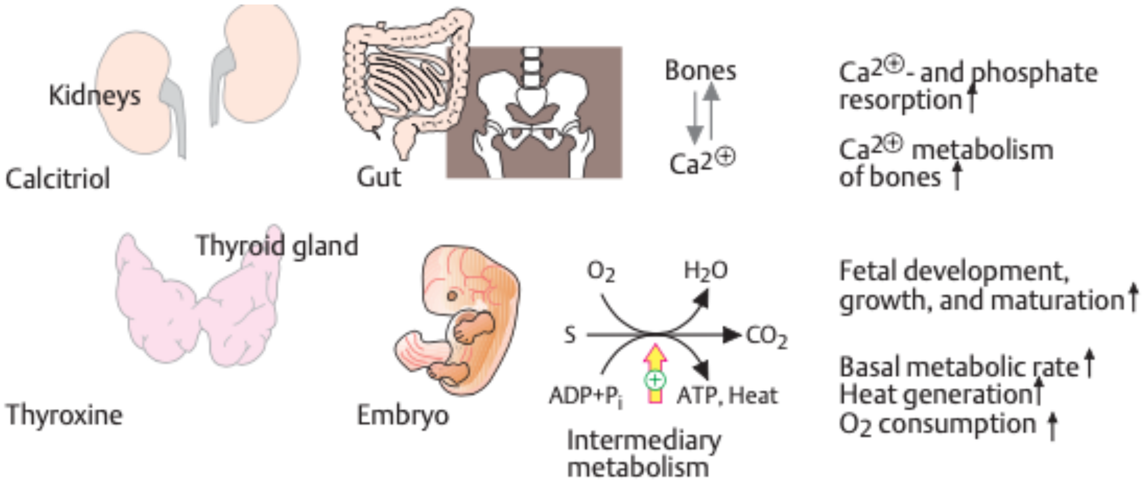
The thyroid hormone thyroxine



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What are the Hydrophilic hormones?

- The hydrophilic hormones are derived from amino acids, or are peptide
- As they are easily soluble, they do not need carrier proteins for transport in the blood.
- They bind on the plasma membrane of the target cells to receptors s and proteins composed of amino acids.

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What are the types of Hydrophilic hormones?

- **Histamine: derived from amino acids □**
- It is an important *mediator* and *neurotransmitter. It* is mainly stored in tissue mast cells in the blood. It is involved in inflammatory and allergic reactions.
- **Epinephrine: derived from amino acids □**
- **It** is a hormone synthesized in the adrenal glands from tyrosine .
- It constricts the blood vessels and thereby increases blood pressure.

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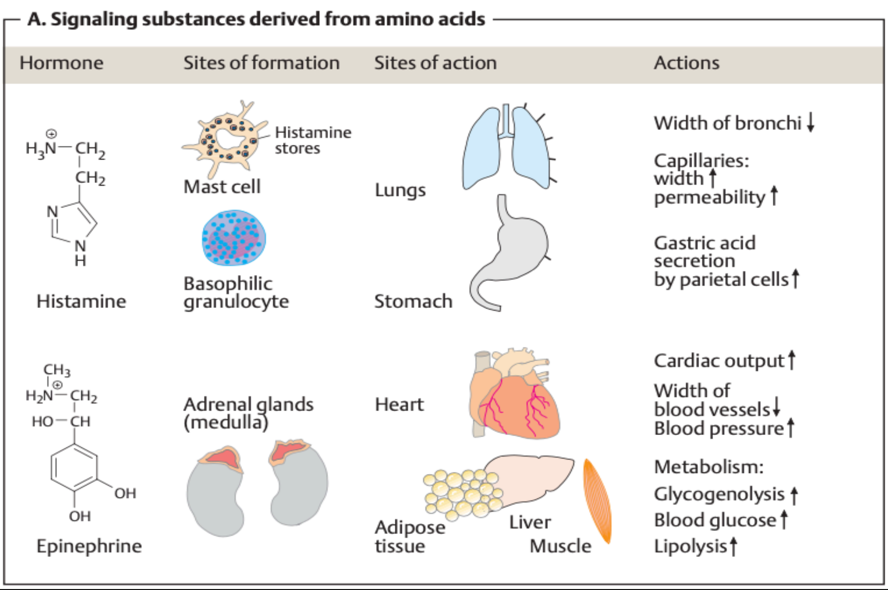
Histamine and Epinephrine



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What are the types of Hydrophilic hormones?
Examples of peptide hormones

- **Thyroliberin** (thyrotropin-releasing hormone, TRH) is one of the necrohormones of the hypothalamus. It stimulates pituitary gland cells to secrete thyrotropin (TSH).
- **Thyrotropin** (thyroid-stimulating hormone, TSH) and the related hormones (luteinizing hormone, LH) and (follicle-stimulating hormone, FSH).
- It stimulates the synthesis and secretion of thyroxin by the thyroid gland.

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What are the types of Hydrophilic hormones?
Examples of peptide hormones

- **Insulin** is produced and released by the B cells of the pancreas and is released when the glucose level rises.
- Insulin reduces the blood sugar level by promoting processes that consume glucose—e. g., glycolysis, glycogen synthesis, and conversion of glucose into fatty acids. By contrast, it inhibits gluconeogenesis and glycogen degradation.
- **Glucagon:** a peptide of 29 amino acids, is a product of the A cells of the pancreas. Its effects are each opposite to those of insulin.

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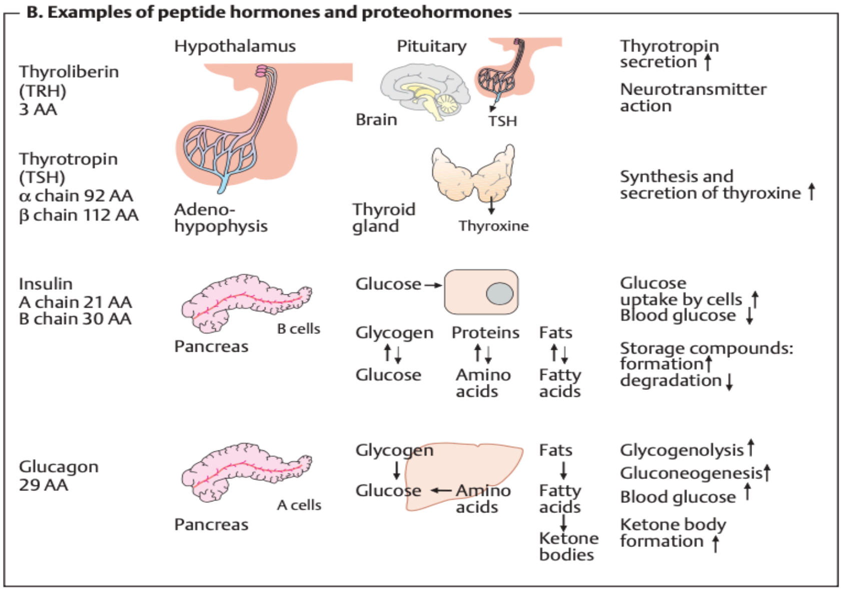
Examples of peptide hormones



General Biochemistry Enzymes

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1

Enzymes: basics

- Enzymes are **biological catalysts**—i. e., substances of biological origin that accelerate chemical reactions.
- The name of enzymes are usually indicated with letters " -ase". For example Polymer<u>ase</u>
- Most all enzymes are **proteins**.
- The catalytic action of an enzyme, its **activity**, is measured by determining the **increase in the reaction rate** under precisely defined conditions ! How

2

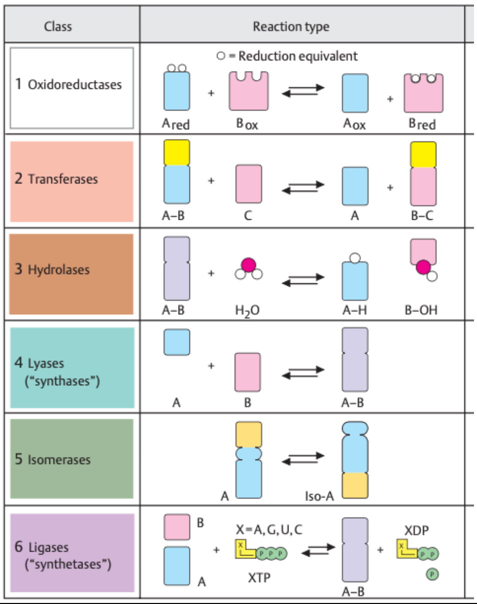
Enzyme classes

- More than 2000 different enzymes are currently known.
- Each enzyme is entered in the *Enzyme Catalogue* with a four-digit Enzyme Commission number (**EC number**).
- For example, lactate dehydrogenase has the EC number *1.1.1.27*
- (class 1, oxidoreductases; subclass 1.1, CH–OH group as electron *donor*; sub-subclass 1.1.1, NAD(P)+ as electron *acceptor*).

3

6 main classes of enzymes

1. The **oxidoreductases**
2. The **transferases**.
3. The **hydrolases ''Lyases''.**
4. The **isomerases**
5. **Ligases.**
6. **Synthetases**



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Enzyme catalysis

- Enzymes are extremely effective **catalysts**.
- They can increase the rate of a catalyzed reaction by a factor of 10^{12} or more.
- **A. Uncatalyzed reaction.**
- **B. Enzyme-catalyzed reaction.**

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A. Uncatalyzed reaction.

- The reaction A+B $\rightarrow$ C+D is used as an example.
- In solution, **reactants A and B** are surrounded by a shell of water molecules (the *hydration shell*), and they move in random directions due to thermal agitation.
- They can only react with each other if they collide in a favorable orientation.

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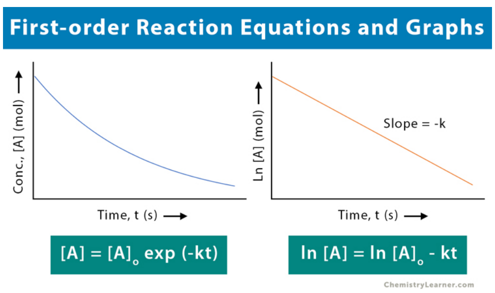
B. Enzyme-catalyzed reaction.

- Shown here is a *sequential mechanism* in which substrates A and B are bound and products C and D are released, in that order.
- Enzymes are able to bind the reactants (their *substrates*) specifically at the **active center**. The *productive* A–B complexes will increase.
- In addition, binding of the substrates results in removal of their hydration shells.
- As a result of the **exclusion of water**, very different conditions apply in the active center of the enzyme during catalysis than in solution

7

Enzyme kinetics I

- The **kinetics** of enzyme-catalyzed reactions (i. e., the dependence of the reaction rate on the reaction conditions) is mainly determined by the *properties of the catalyst*.
- Here we discuss these issues using the example of a simple first-order reaction.
- Dow you remember !



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Enzyme kinetics I : The first-order reaction.

- **E + S ⟷ ES ⟶ E + P**
- For the conversion A → B, the formation of B from EA or ES is a first-order reaction—i. e., v = k [EA] applies.
- The constant k is the *rate constant* of the uncatalyzed reaction.
- *In the absence of an enzyme,* the reaction rate v is proportional to the concentration of substance A.

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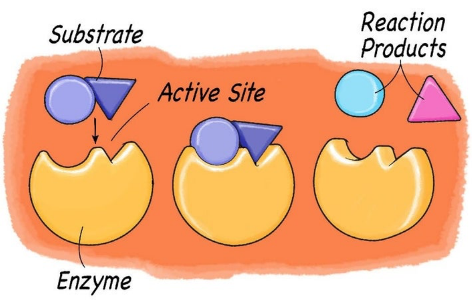
Enzyme kinetics I

- An enzyme attracts substrates to its active site, catalyzes the chemical reaction by which products are formed, and then allows the products to dissociate (separate from the enzyme surface)



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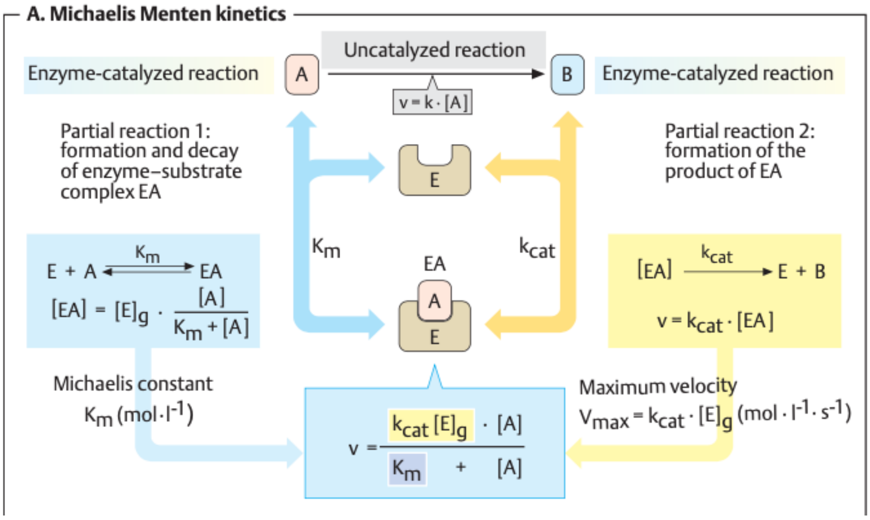
A. Michaelis–Menten kinetics



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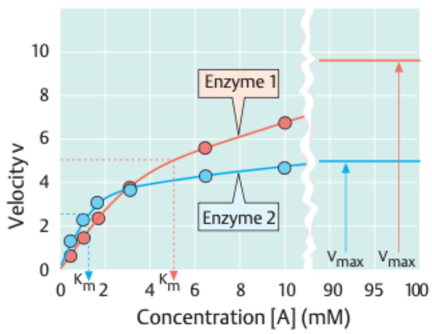
A. Michaelis–Menten kinetics

- The **Michaelis constant** ***K*m** thus describes the state of equilibrium of the reaction.
- The **Michaelis constant** *K*m characterizes the *affinity* of the enzyme for a substrate.
- It corresponds to the substrate concentration at which *v* reaches half of Vmax:
- (if v = Vmax/2, then [A]/(Km + [A]) = 1/2, i.e. [A] is then = Km).
- A *high affinity* of the enzyme for a substrate therefore leads to a *low* *K*m value, and vice versa.



1. Hyperbolic plot

So, enzyme 2 has the higher affinity for A [K_m = 1 mmol l^{-1}); V_{max}, by contrast, is much lower than with enzyme 1.

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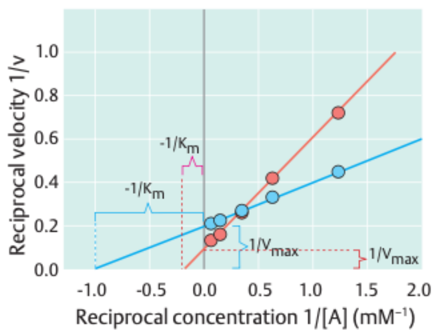
Lineweaver–Burk plot

- Linearity of **Michaelis–Menten kinetics**
- Since v approaches V *approximately* with increasing values of [A], the Michaelis–Menten equation can be arranged in such a way that the measured points lie on a *straight line*.
- 1/v is plotted against 1/[A].
- The intersections of the line of best fit with the axes then produce 1/Vmax and — 1/Km.
- This type of diagram is very clear, but for practical purposes it is less suitable for determining Vmax and Km.



2. Lineweaver–Burk plot

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Isosteric and allosteric enzymes

- Many enzymes can occur in various *conformations*.
- *Depends on the number of Enzyme molecules that are* influenced by substrates and other ligands.
- **For isosteric enzymes** (with only *one* enzyme conformation,: the activity of substrate binding (dashed curve) decreases constantly with increasing [A], because the number of free binding sites is constantly decreasing.
- **In most allosteric enzymes**, the binding activity initially increases with increasing [A], because the free enzyme is present in a low- affinity conformation, which is gradually converted into a higher- affinity form.

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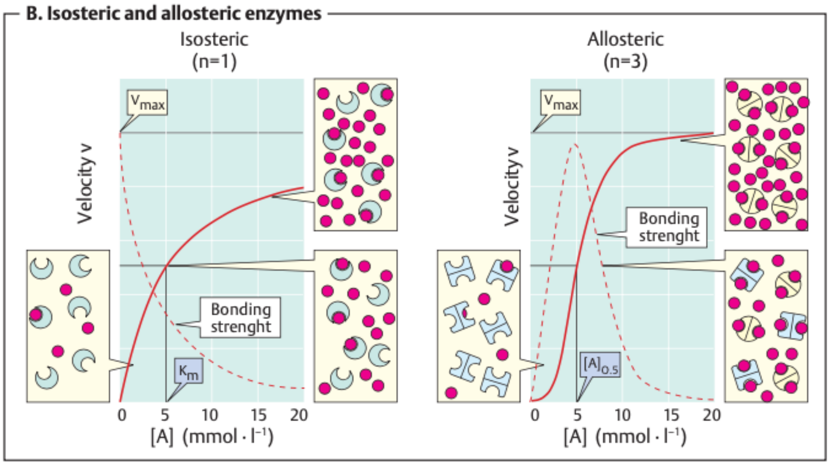
Isosteric and allosteric enzymes



Allosteric enzymes is recognized by their S-shaped (*sigmoidal*) saturation curves, which cannot be described using the Michaelis model.
In other words, the affinity of allosteric enzymes is not constant, but depends on the type and concentration of the ligand.

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Enzyme kinetics II

- The activity of catalytic properties of enzymes, are affected by numerous factors:
- These factors include physical quantities (temperature, pressure).
- The chemical properties of the solution (pH value, ionic strength).
- The concentrations of the relevant substrates, cofactors, and inhibitors.

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Effect of Temperature and pH value on enzyme activity

- The pH value at which enzyme activity is at its maximum is often close to the pH value of the cells (i. e., pH 7).
- However, the proteinase *pepsin*, which is active in the acidic gastric lumen, has a pH optimum of 2.
- The optimal temperatures of the enzymes in higher organisms rarely exceed 50 °C,
- In a high temperature, the enzyme then becomes unstable, and its activity is lost.

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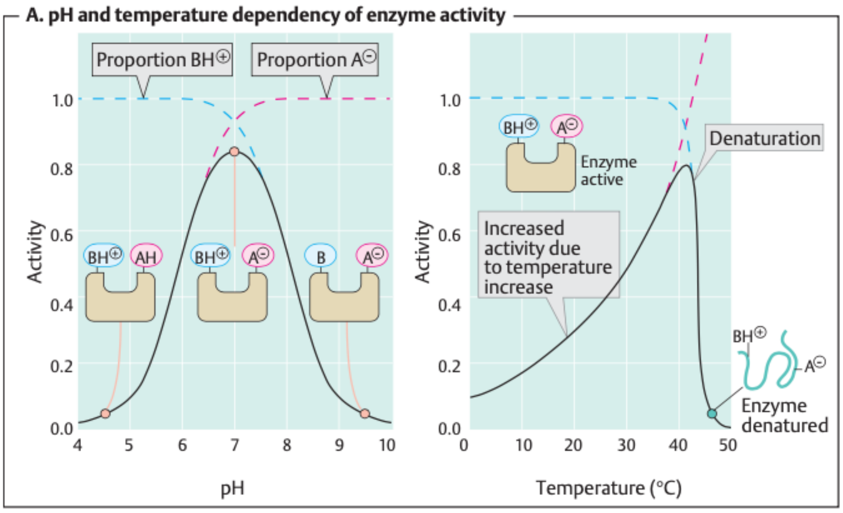
pH and temperature dependency of enzyme activity



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Inhibitors

- **Inhibitors**
- Many substances can inhibit the metabolic processes by influencing the activity of enzymes.
- A large proportion of **medicines** act as enzyme inhibitors.
- **Types of inhibitor:**
- Most enzyme inhibitors act reversibly!
- Competitive inhibitors:
- Non-Competitive inhibitors:

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Competitive and Non-competitive inhibitors:

- **Competitive inhibitors:**
- When the substrate and the inhibitor compete with one another for the *same* binding site on the enzyme, this type of inhibition is referred to as **competitive**.
- The Michaelis constant *K*m increases
- **Non-competitive inhibitors:**
- When an inhibitor interacts with a group that is important for enzyme activity, but does not affect binding of the substrate, the inhibition is **non-competitive.**
- In this case, *K*m remains unchanged, but the concentration of functional enzyme [E]t, and thus Vmax, de- crease.

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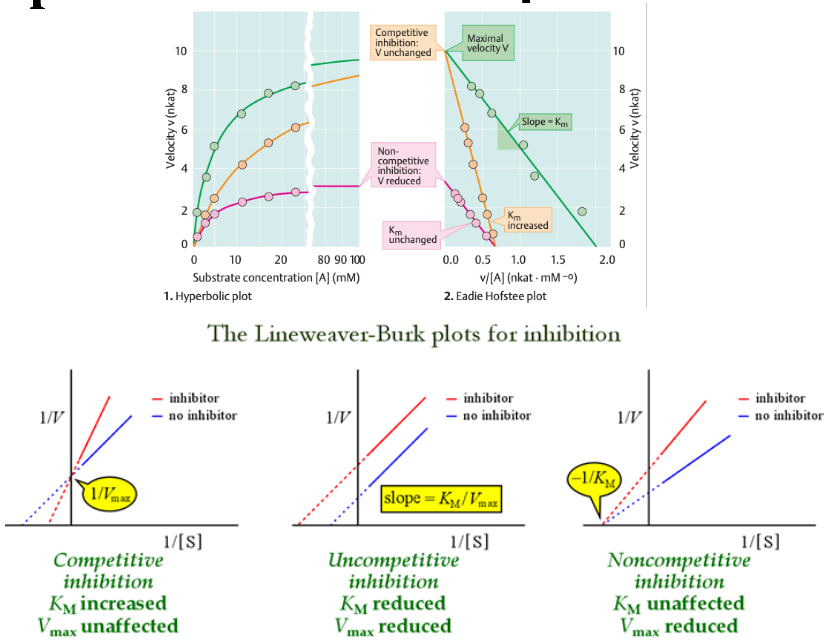
Competitive and Non-competitive inhibitors:



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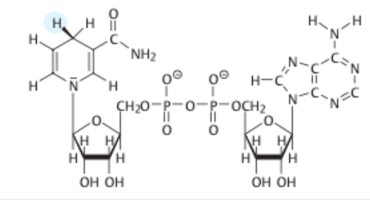
Coenzymes



- Coenzymes are small molecules.
- They cannot by themselves catalyze a reaction, but they can help enzymes to do so.
- In technical terms, coenzymes are **organic no protein molecules that bind with the protein molecule to form the active enzyme.**
- They are often vitamins, or derivatives of vitamins.
- **There are many types of coenzymes.**
- The pyridine nucleotides **NAD+** and **NADP+** (**1**) are widely distributed as coenzymes of dehydrogenases.

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General Biochemistry
Vitamins and minerals

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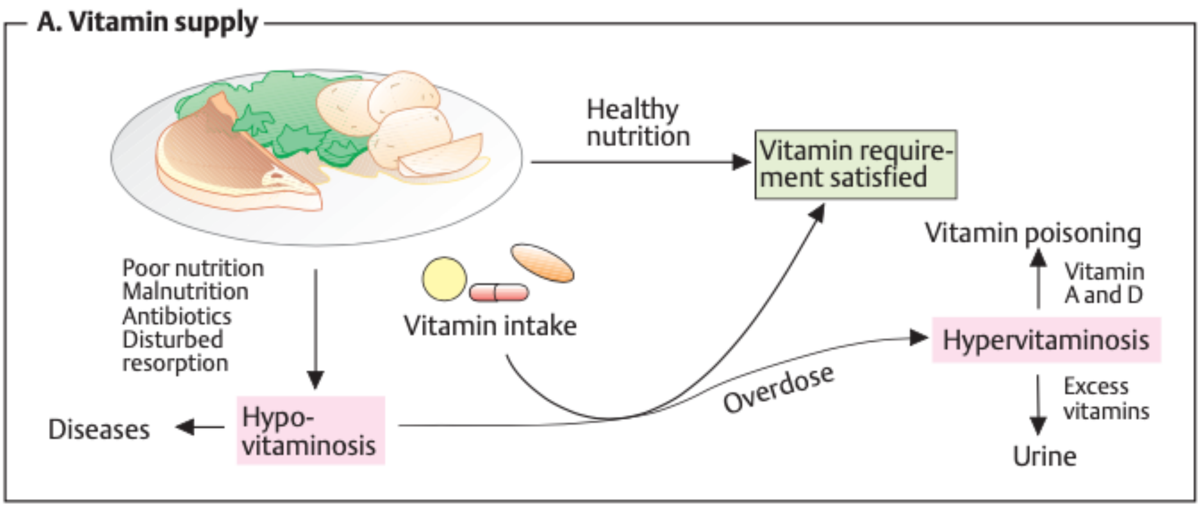
What are Vitamins ?

- **Vitamins** are essential organic compounds that are required in small amounts for metabolism.
- The animal organism is not capable of forming them.
- Most vitamins are **coenzymes**; in some cases, they are also **hormones** or act as **antioxidants**.
- Vitamin requirements differ from species to species and are influenced by age, sex, and physiological conditions such as pregnancy, breast-feeding, physical exercise, and nutrition.

Vitamin supply

- A healthy diet usually covers average daily vitamin requirements.
- By contrast, an unbalanced diet in older people or in starvation cases lead to an enough supply of vitamins from which **hypovitaminosis,** or in extreme cases avitaminosis, can result.
- Anti- biotics can also lead to vitamin deficiencies (K, B12, H) due to the absence of bacterial vitamin synthesis.
- Since only a few vitamins can be stored (A, D, E, B12), a lack of vitamins quickly leads to **deficiency diseases.** These often affect the skin, blood cells, and nervous system.

Vitamin supply



Vitamin deficiencies and hypervitaminoses

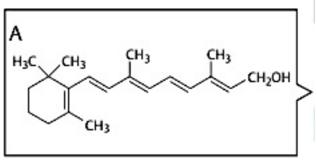
- The causes of vitamin deficiencies can be treated by improving nutrition and by taking vitamins in tablet form.
- An overdose of vitamins only leads to **hypervitaminoses**, with toxic symptoms, in the case of vitamins A and D.
- Normally, excess vitamins are rapidly excreted with the urine.
- Symptoms of hypervitaminosis A include vision problems, changes in the skin, and bone pain.
- The symptoms of Hypervitaminosis D include **Confusion, apathy, recurrent vomiting, abdominal pain, polyuria, polydipsia, and dehydration.**

Lipid-soluble and water-soluble vitamins

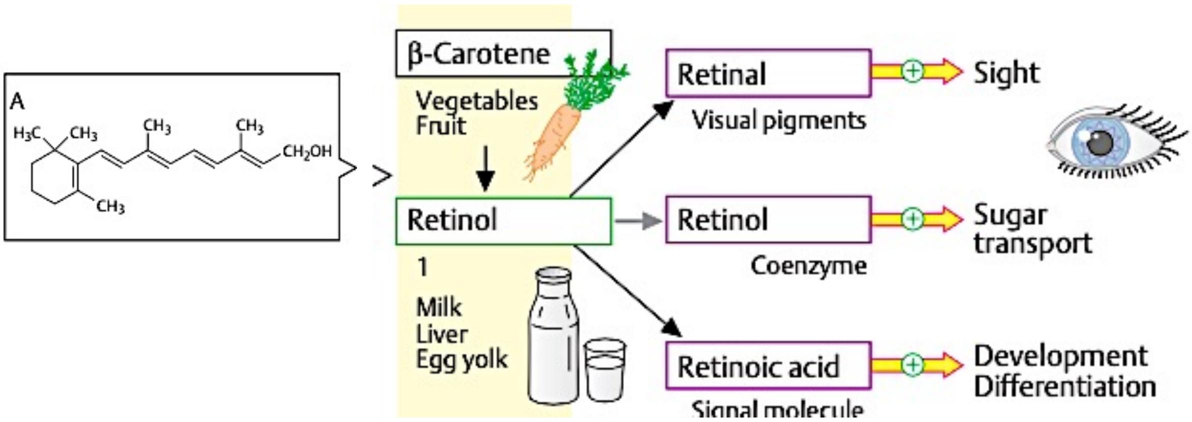
- **The lipid-soluble vitamins** include vitamins A, D, E, and K, all of which belong to the isoprenoids as either lipid-soluble or water-soluble.
- **Vitamin A (retinol)** is the parent substance of the *retinoids,* which include *retinal* and *retinoic acid*.
- β-carotene occurs in fruits and vegetables (particularly carrots).
- **Retinal** is involved in visual processes as the pigment of

Vitamin A (retinol)

- **Vitamin A (retinol)** is the parent substance of the *retinoids,* which include *retinal* and *retinoic acid*.
- The retinoids also can be synthesized by cleavage from the provitamin; β-carotene.
- β-carotene occurs in fruits and vegetables (particularly carrots).
- **Retinal** is involved in visual processes as the pigment of
- Vitamin A deficiency can result in *night blindness, visual impairment,* and *growth disturbances*.

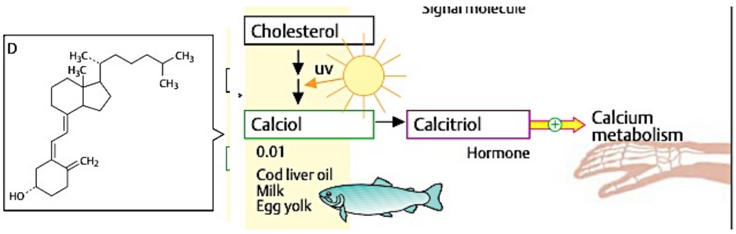


Vitamin A



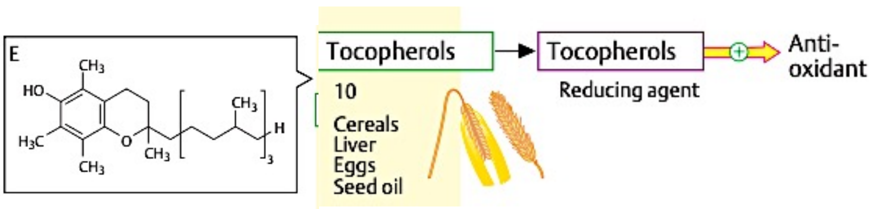
Vitamin D (calciol, cholecalciferol)

- **Vitamin D (calciol, cholecalciferol)** is the precursor of the hormone *calcitriol*.
- Together with two other hormones (parathyrin and calcitonin), calcitriol regulates the calcium metabolism.
- Calciol can be synthesized in the skin from 7-dehydrocholesterol by a photochemical reaction.
- Vitamin D deficiencies only occur when the skin receives insufficient exposure to ultraviolet light and vitamin D is lacking in the diet.
- Deficiency is observed in the form of *rickets* in children and *osteomalacia* in adults.



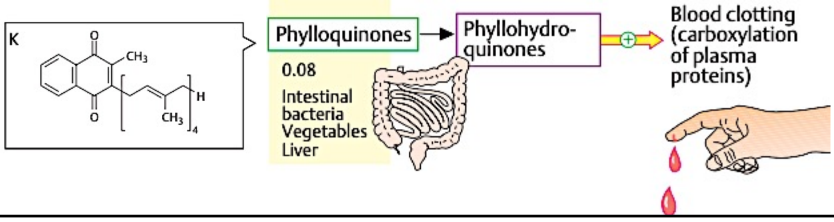
Vitamin E (tocopherol)

- **Vitamin E (tocopherol)** occur in plants (e.g., wheat germ).
- They contain what is known as a *chroman ring*.
- In the lipid phase, vitamin E is mainly located in biological membranes, where as an *antioxidant* it protects unsaturated lipids against free radicals and other radicals.



Vitamin K (phylloquinone)

- **Vitamin K (phylloquinone)** are involved in carboxylating glutamate residues of coagulation factors in the liver.
- Vitamin K antagonists inhibit this reduction and consequently carboxylation as well.
- This fact is used to inhibit blood coagulation in *prophylactic treatment against thrombosis*.
- Vitamin K deficiency occurs only rarely, as the vitamin is formed by bacteria of the intestinal flora.



Water-soluble vitamins I

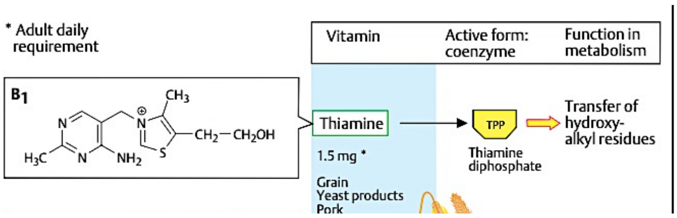
1. Vitamin B1 (thiamine)
2. Vitamin B2
3. Riboflavin
4. Folate
5. Nicotinate
6. Pantothenic acid

Water-soluble vitamins II

1. Vitamin B6
2. Vitamin B12
3. Vitamin C
4. Biotin vitamin H

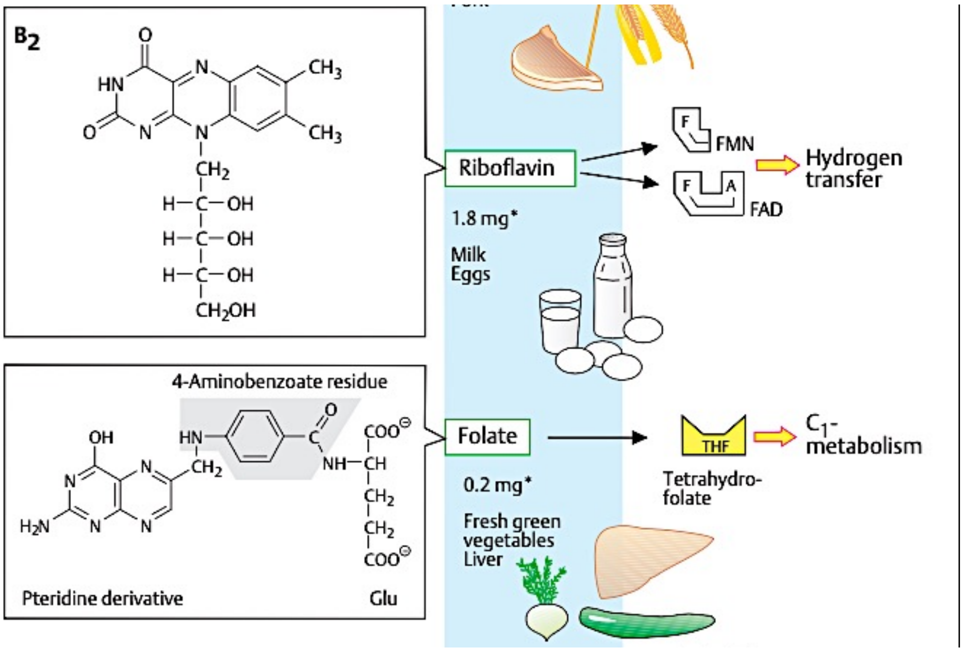
Water-soluble vitamins I, such as

- **Vitamin B1 (thiamine)** contains two heterocyclic rings—a *pyrimidine ring* (a six-membered aromatic ring with two Ns) and a *thiazole ring* (a five-membered aromatic ring with N and S), which are joined by a methylene group.
- The active form of vitamin B1 is **thiamine diphosphate** (TPP).
- Thiamine was the first vitamin to be discovered, around 100 years ago.
- Vitamin B1 deficiency leads to *beriberi,* a disease with symptoms that include neurological disturbances, cardiac in- sufficiency, and muscular atrophy.



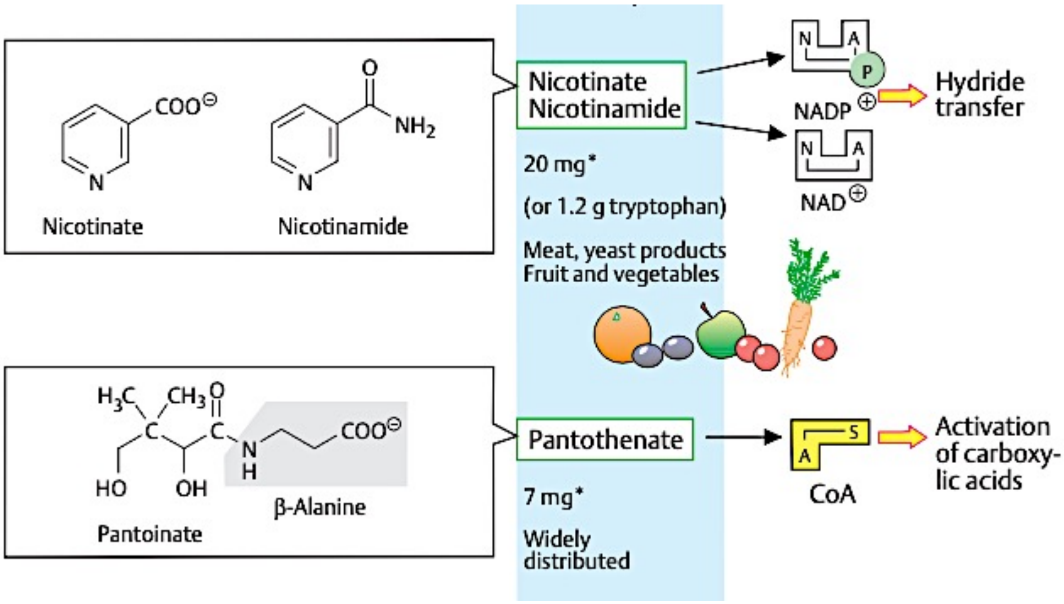
Vitamin B2: Riboflavin, Folic acid, B3 and B5

- **Vitamin B2** is a complex of several vitamins: riboflavin, folate, nicotinate, and pantothenic acid.
- **Riboflavin also known as Vitamin B2** (from the Latin *flavus,* yellow) serves in the metabolism as a component of the redox coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD;).
- As prosthetic groups, **FMN** and **FAD** are cofactors for various oxidoreductases.
- No specific disease due to a deficiency of this vitamin is known.
- **Folate,** the anion of **folic acid**. It serves as a coenzyme in the C1 metabolism.
- Folate deficiency is relatively common, and leads to disturbances in nucleotide biosynthesis and thus cell proliferation.



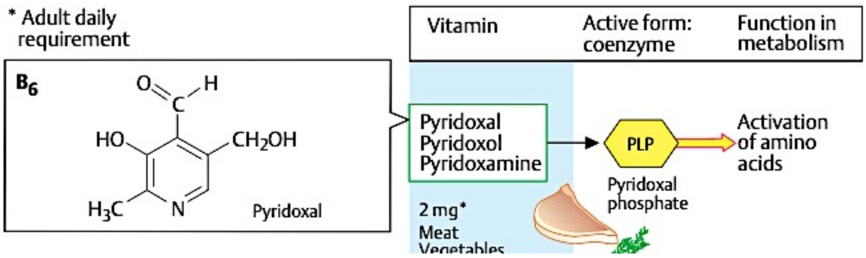
Nicotinamide B3 and Pantothenic acid B5

- **Nicotinate** and **nicotinamide also known as vitamin B3 or niacin,** together referred to as "niacin," are required for biosynthesis of the coenzymes nicotinamide adenine dinucleotide (**NAD+**) and nicotinamide adenine dinucleotide phosphate (**NADP+**).
- These both serve in energy and nutrient metabolism as carriers of *hydride ions*.
- It appears in the form of skin damage (*pellagra*), digestive disturbances, and depression.
- **Pantothenic acid** also **known as vitamin B5** is an acid amide consisting of β -alanine and 2,4-dihydroxy-3,3-di- methylbutyrate (pantoic acid).
- It is a precursor of *coenzyme A,* which is required for activation of acyl residues in the lipid metabolism. deficiency diseases are rare.



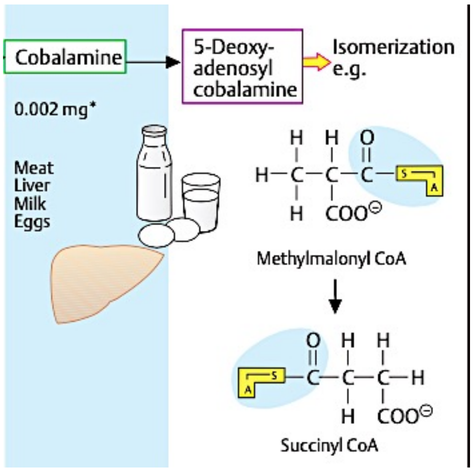
Water-soluble vitamins II, such as

- **Vitamin B6** consists of three substituted pyridines—**pyridoxal**, **pyridoxol**, and **pyridoxamine.** The illustration shows the structure of pyridoxal, which carries an aldehyde group (–CHO) at C-4.
- The active form of vitamin B6, **pyridoxal phosphate,** is the most important coenzyme in the amino acid metabolism.
- Vitamin B6 deficiency is rare.



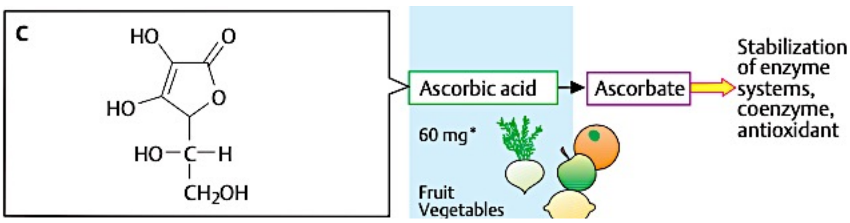
Vitamin B12 (cobalamine)

- **Vitamin B12 (cobalamine)** is one of the most complex low-molecular-weight substances occurring in nature.
- The vitamin is exclusively synthesized by microorganisms.
- Vitamin B12 deficiency is usually due to an absence of intrinsic factor " is a protein that helps your intestines absorb vitamin B12" . This leads to a disturbance in blood formation known as *pernicious anemia*.



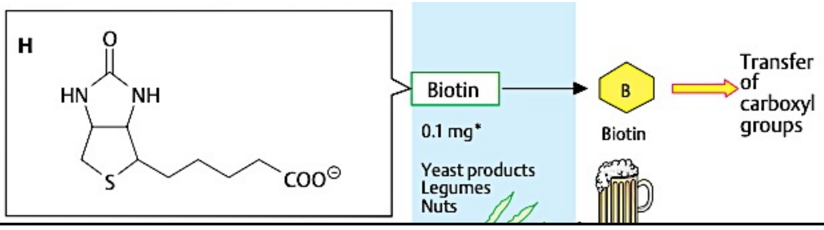
Vitamin C: Ascorbic acid

- **Vitamin C** is L-**ascorbic acid.** The two hydroxyl groups have acidic properties.
- Humans, apes, and guinea pigs require vitamin C because they lack the enzyme L-*gulonolactone oxidase*, which catalyzes the final step in the conversion of glucose into ascorbate.
- Vitamin C is particularly abundant in fresh fruit and vegetables.
- Ascorbic acid serves as a reducing agent in variations reactions (usually hydroxylations).
- Among the processes involved are *collagen synthesis etc*.
- The daily requirement for ascorbic acid is about 60 mg.
- Vitamin C deficiency only occurs rarely nowadays in the form of *scurvy*, with connective-tissue damage, bleeding, and tooth loss.



Vitamin H (biotin)

- **Vitamin H** (**biotin**) is present in liver, egg yolk, and other foods; it is also synthesized by the intestinal flora.
- The human body needs biotin to **metabolize carbohydrates, fats, and amino acids, the building blocks of protein**. Biotin is often recommended for strengthening hair and nails, and it's found in many cosmetic products for hair and skin
- In the body, biotin is covalently attached via a lysine side chain to enzymes that catalyze carboxylation reactions.
- Biotin binds to *avidin*, a protein found in egg white.
- Biotin deficiency only occurs when egg whites are eaten raw.



Minerals and trace elements

- **Minerals**:
- **Water** is the most important essential inorganic nutrient in the diet. In adults, the body has a daily requirement of 2–3 L of water, which is supplied from drinks, water contained in solid foods, and from the *oxidation water* produced in the respiratory chain.
- **The elements**
- The elements essential for life can be divided into **macro elements** (daily requirement > 100 mg) and **microelements** (daily requirement < 100 mg).
- The macro elements include the **electrolytes** sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg), and the nonmetals chlorine (Cl), phosphorus (P), sulfur (S), and iodine (I).
- **The essential microelements are only required in trace amounts.**
- This group includes iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cobalt (Co), chromium (Cr), selenium (Se), and molybdenum (Mo). Fluorine (F) is not essential for life, but does promote healthy bones and teeth.
- The storage site for many trace elements is the liver.
- In many cases, the metabolism of minerals is regulated by *hormones*.

Some of Mineral deficiencies:

- *Calcium deficiency* can lead to rickets, osteoporosis, and other disturbances.
- *Chloride deficiency* is observed as a result of severe Cl– losses due to vomiting.
- *Iodine deficiency* is widespread there and can lead to goiter ‘’**irregular growth of the thyroid gland”** .
- *Magnesium deficiency* can be caused by digestive disorders or an unbalanced.