الكيمياء الحيوية الغير عضوية

Bio-inorganic chemistry

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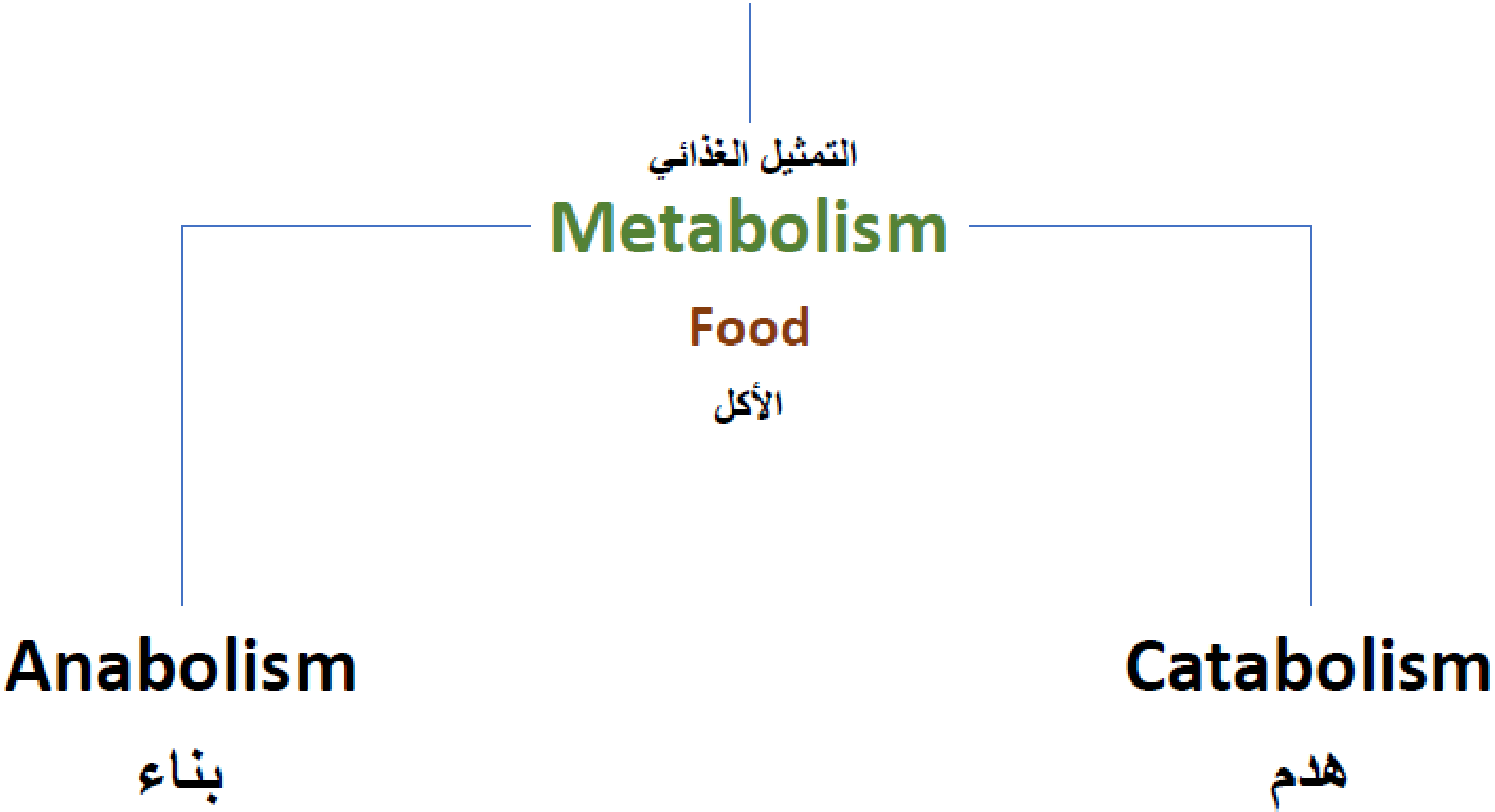
<u>للفرقة الاولى كمستري</u>

Introduction:

Biochemistry is concerned with the chemical composition of cell parts and knowledge how the biochemical reactions occur, as well as the chemical and physical nature of different types of nutrients, the biological function of these substances from cells and their intermediate metabolism.

Our course is focused on studying the chemical compounds that are components of living cells and the materials that can be used in their biosynthesis, including **carbohydrates, lipids,** and **proteins**.

Bio-Chemistry



التمثيل الغذائي

Metabolism

Food

الأكل

Anabolism

بناء

Catabolism

هدم

التمثيل الغذائي هو كل العمليات الحيوية التي تتم داخل الكائن الحي من عمليات هدم وبناء

الأكل

Food

Oxidizable

قابل للأكسدة

- CHO الكربوهيدرات
- Lipids الليبيدات
- Proteins البروتينات

Non-oxidizable

غير قابل للأكسدة

- Vitamins الفيتامينات
- Minerals المعادن
- Water الماء

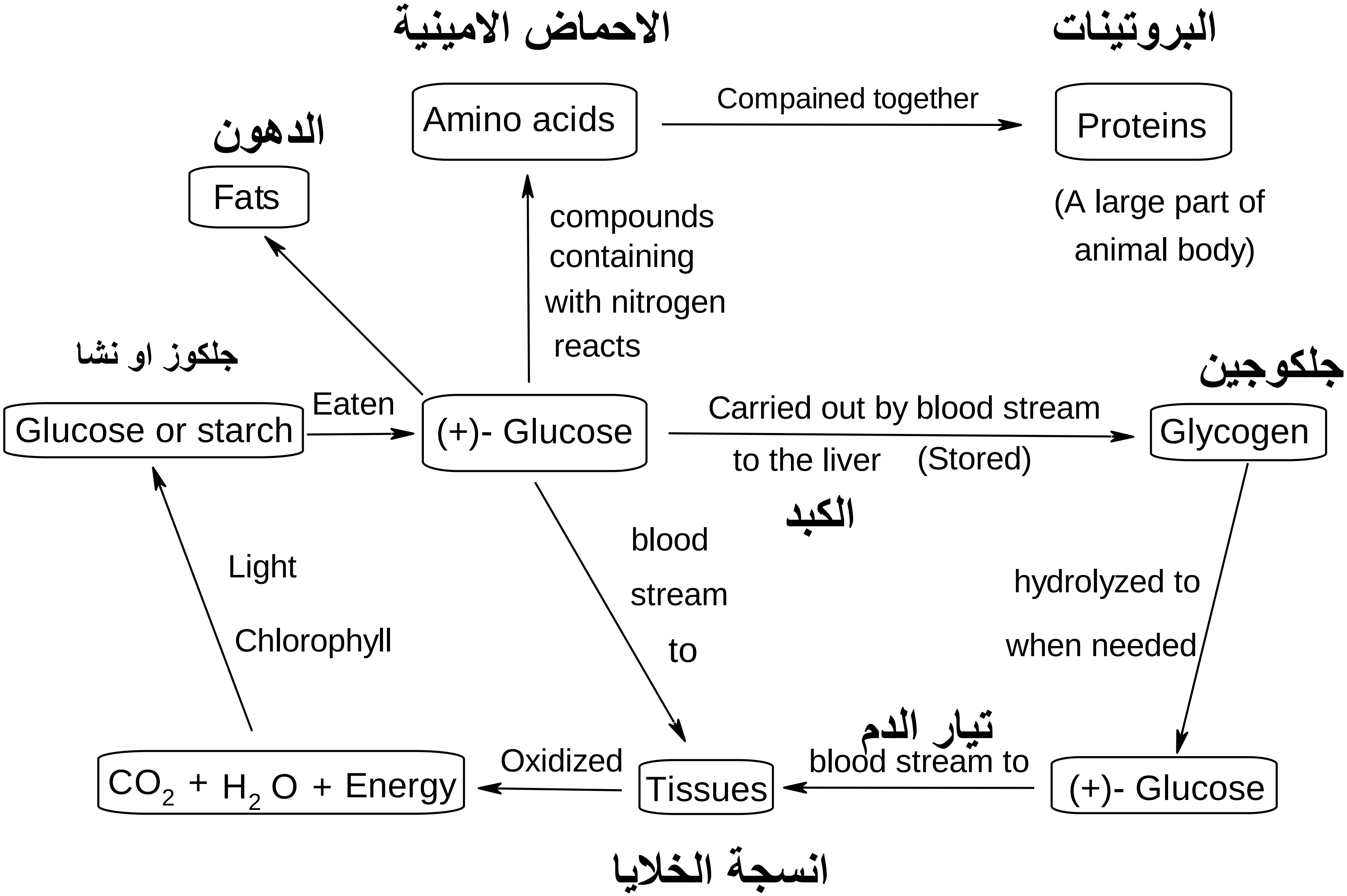
في هذا المقرر سوف نتطرق للدراسة الكيميائية لكلا من الكربوهيدرات والليبيدات والبروتينات

Carbohydrates

Carbohydrates received their name from the fact that the general empirical formula for many members of the class can be written $C_n(H_2O)_n$, hydrated carbon. Sugars, starches, and cellulose-compounds which have important structural and energy functions in the living materials-are all carbohydrates. (Sugars are water soluble carbohydrates).

It would be difficult to overestimate the importance of human beings of carbohydrates.

All carbohydrates are polyhydroxy aldehydes, polyhydroxy ketones, or molecules which yield polyhydroxy aldehydes or ketones on hydrolysis. Monosaccharides are the smallest carbohydrate molecules and include the four-, five-, and six-carbon sugars. Sucrose, table sugar, is one of the disaccharides; disaccharides can hydrolyse to two monosaccharides. Polysaccharides, which include starch and cellulose, yield many monosaccharides molecules upon hydrolysis.



الاحماض الامينية

Amino acids

Compained together

البروتينات

Proteins

(A large part of animal body)

الدهون

Fats

compounds containing with nitrogen reacts

جلكوز او نشا

Glucose or starch

Eaten

(+)- Glucose

Carried out by blood stream to the liver (Stored)

الكبد

جلكوجين

Glycogen

Light

Chlorophyll

blood stream to

hydrolyzed to when needed

$CO_2 + H_2O$ + Energy

Oxidized

Tissues

تيار الدم

blood stream to

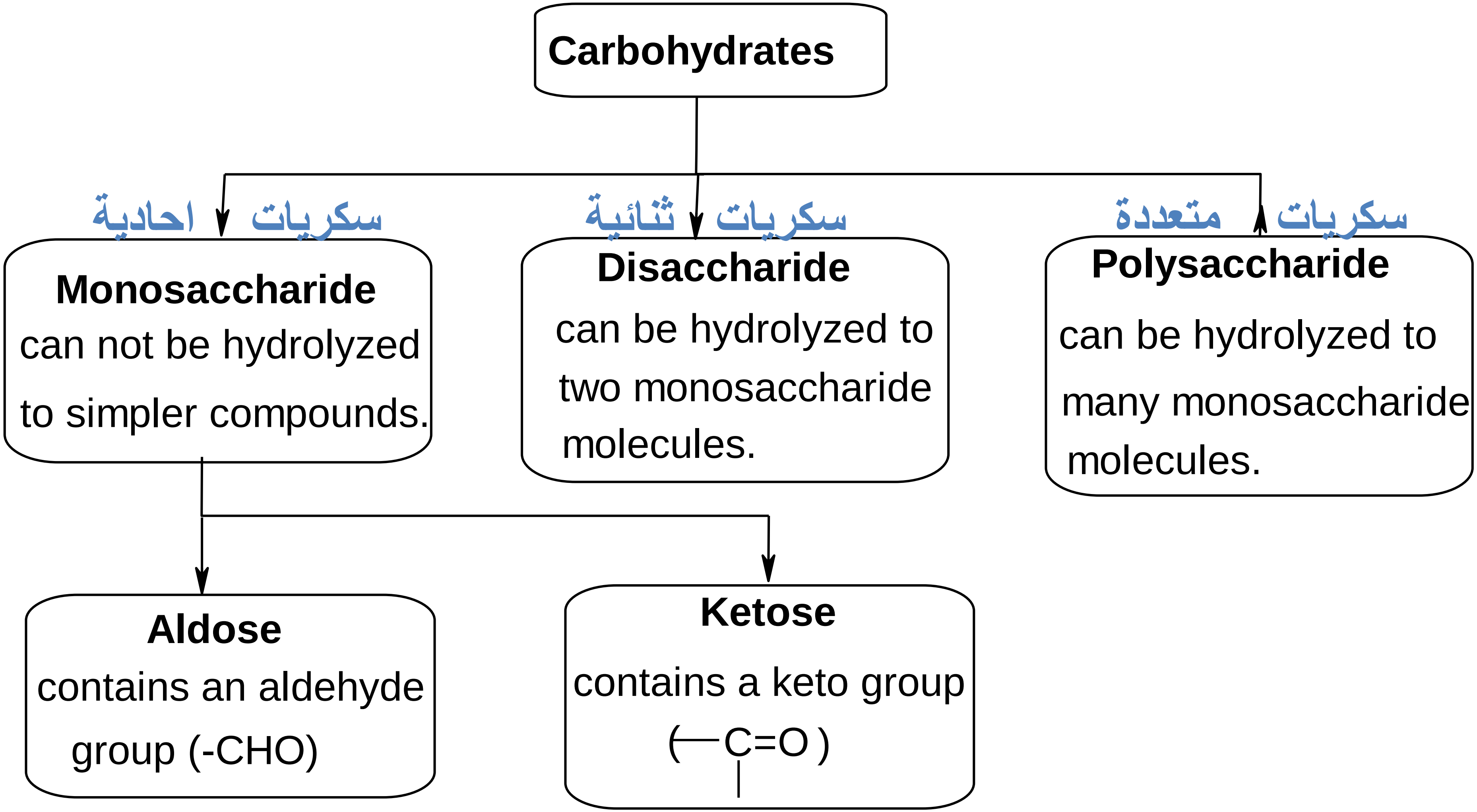
(+)- Glucose

انسجة الخلايا

Definition and Classification

Carbohydrates are polyhydroxy aldehydes, polyhydroxy ketones or compounds that can be hydrolyzed to them. There are three major classes of carbohydrates:

Definition and Classification:



Carbohydrates

سكريات احادية

Monosaccharide

can not be hydrolyzed to simpler compounds.

سكريات ثنائية

Disaccharide

can be hydrolyzed to two monosaccharide molecules.

سكريات متعددة

Polysaccharide

can be hydrolyzed to many monosaccharide molecules.

Aldose

contains an aldehyde group (-CHO)

Ketose

contains a keto group

$(-\underset{|}{C}=O)$

General properties of carbohydrates

- Carbohydrates act as energy reserves, also stores fuels, and metabolic intermediates.

- Ribose and deoxyribose sugars forms the structural frame of the genetic material, RNA and DNA.

- Polysaccharides like cellulose are the structural elements in the cell walls of bacteria and plants.

- Carbohydrates are linked to proteins and lipids that play important roles in cell interactions.

Monosaccharides

($C_6H_{12}O_6$)

Monosaccharides

- The word "Monosaccharides" derived from the Greek word "Mono" means Single and "saccharide" means sugar

- Monosaccharides are polyhydroxy aldehydes or ketones which cannot be further hydrolysed to simple sugar.

- Monosaccharides are simple sugars. They are sweet in taste. They are soluble in water. They are crystalline in nature.

- They contain 3 to 10 carbon atoms, 2 or more hydroxyl (OH) groups and one aldehyde (CHO) or one ketone (CO) group.

Classification of Monosaccharides

Monosaccharides are classified in two ways. **(a)** First of all, based on the number of carbon atoms present in them and **(b)** secondly based on the presence of carbonyl group. The naturally occurring monosaccharides contain three to seven carbon atoms per molecule. Monosaccharides of specific sizes may be indicated by names composed of a stem denoting the number of carbon atoms and the suffix ***-ose***. For example, the terms *triose*, *tetrose*, *pentose*, and *hexose* signify monosaccharides with,

Monosaccharides

$(C\cdot H_2O)_n$

$n = 3,4,5,6$

Polyhydroxy aldehyde or ketone

ose

Aldoses

Ketoses

According to no. of carbon atom

3
Tri

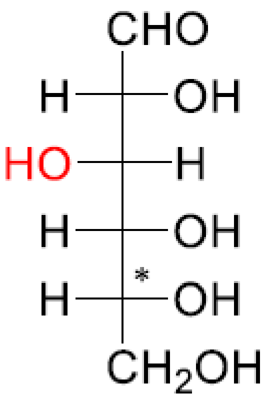
4
Tetra

5
Penta

6
Hexa

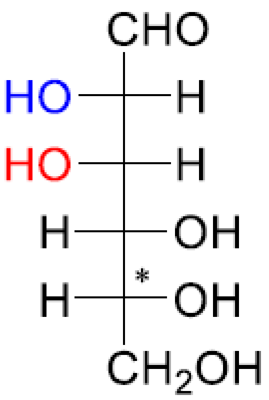
Hexoses

Aldohexose



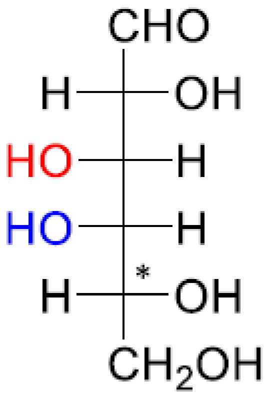
D-Glucose

D-جلوكوز



D-Mannose

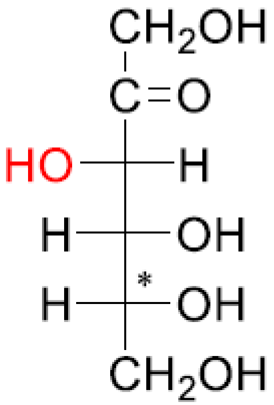
D-مانوز



D-Galactose

D-جلاكتوز

Ketohexose



D-Fructose

D-فركتوز

الفعاليـة البصريـة للسكريات الأحادية

Optical activity of monosaccharides

إذا احتوى المركب على ذرة كربون أو أكثر غير متناظرة **Asymmetric** وتسمى أيضا كيراليه **Chiral** (ذرة كربون تحتوى على أربع استبدالات مختلفة) فالمركب يكون فعالاً بصرياً **Optically active** كما هو الحال فى السكريات الأحادية والأحماض الأمينية.

وعليه فعندما تمر حزمة لضوء مستقطب من جهاز مقياس الأستقطاب **polarimeter** على المحلول فإن شعاع الضوء المستقطب إما يدور يميناً فيكون المركب أيمن الدوران ويرمز له **(+)** أو **(D)** أو يدور يساراً فيكون أيسر الدوران ويرمز له **(-)** أو **(L)**

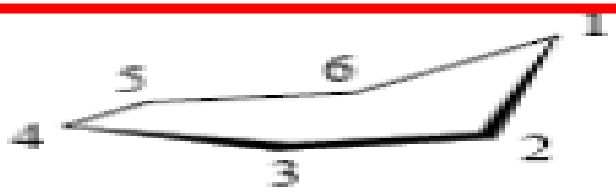
السكر الثلاثي الألدهيدي جليسرالدهيد توجد به ذرة كربون واحدة غير متماثلة أو غير متناظرة هى ذرة الكربون رقم 2 (نجمه) والتى بإستطاعتها تدوير الضوء المستقطب لذلك يوجد هذا المركب بشكل إيزومرين **Stereo isomers** هما **D**، **L**

- All D-sugars have the hydroxyl group at the lowest chiral carbon atom on the right.
- All L-sugars have the hydroxyl group at the lowest chiral carbon atom on the left.

Chair Conformation for Glucose
شكل الكرسي للجلوكوز

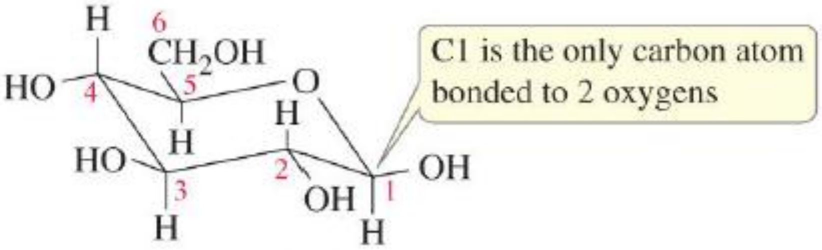
The chair-form of cyclohexane

The boat-form of cyclohexane



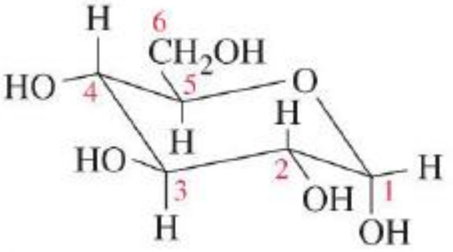
The half-chair form of cyclohexane

The twist-boat form of of cyclohexane

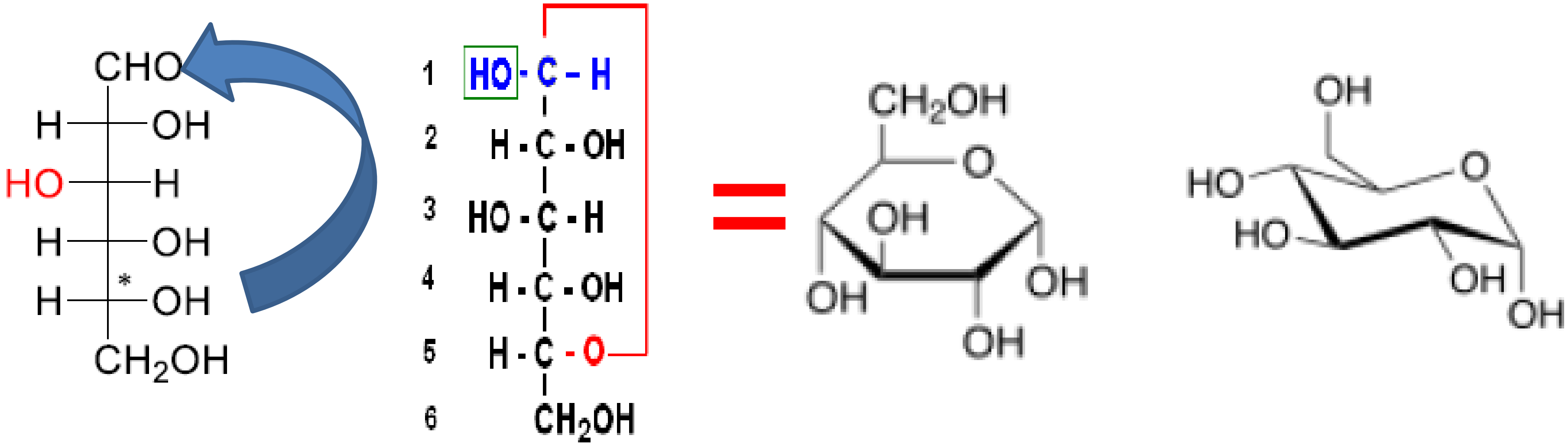


C1 is the only carbon atom bonded to 2 oxygens

chair conformation (all substituents equatorial)

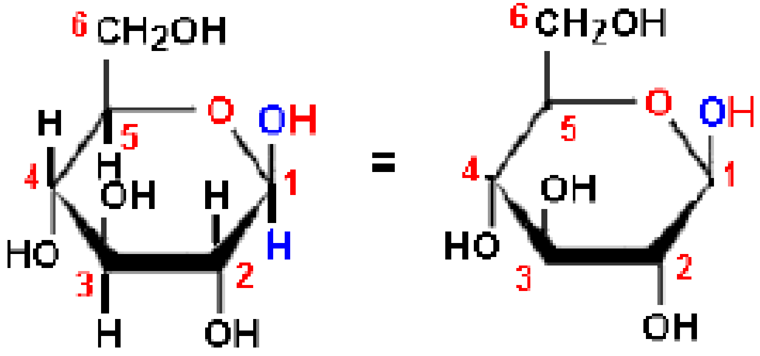


chair conformation (OH on C1 axial)

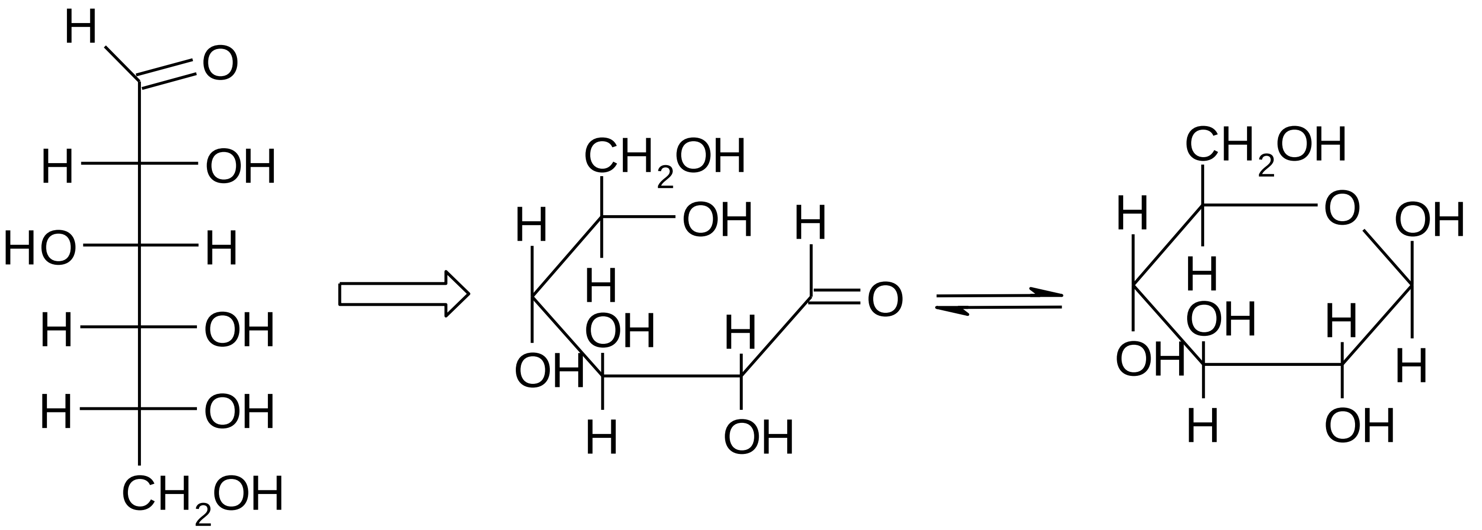


D-Glucose

D-جلوكوز

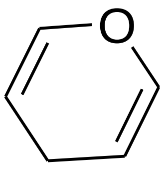


يوجد الجلكوز في الفراغ في شكل الكرسي لانه الاكثر ثبات و اقل طاقة



D-Glucose
(Fischer projection)

Pyranose form
(Haworth projection)



Pyran

تفاعلات السكريات الأحادية

Oxidation → **Sugar acids**

الأكسده → الأحماض السكرية

Reduction → **Sugar alcohols**

الإختزال → السكريات الكحوليه

Or De-oxy sugar

Reaction with NH_3 → **Sugar amine**

التفاعل مع الآمونيا → السكريات الأمينية

Disaccharides

Disaccharides are formed when two monosaccharides are joined together **by an O-glycosidic linkage** and a molecule of water is removed.

Among the most common disaccharides are:

- **Maltose (Malt sugar)**
- **Lactose (Milk sugar)**
- **Sucrose (Cane or beet sugar)**

Polysaccharides

Polysaccharides contain hundreds or thousands of carbohydrate units. Polysaccharides are *not* reducing sugars, since the anomeric carbons are connected through glycosidic linkages.

Nomenclature:

Homopolysaccharide- a polysaccharide is made up of **one type** of monosaccharide unit

Heteropolysaccharide- a polysaccharide is made up of more than **one type** of monosaccharide unit.

UNIT 2: LIPIDS

Introduction, Classification, Properties and Biological importance. Fatty acid nomenclature and structure, Triglycerides formation and its applications.

Introduction

There is a lot of interest these days on healthy diets as well as concerns about heart problems. There is also a strong market for the sales of omega-3 fatty acids, which are said to help lower fat levels in blood. But too many people rely on the supplements to help their hearts and don't understand the chemistry behind it all. Yes, taking omega-3 fatty acids will give you some of the fatty acids your body requires. No, this is not a substitute for eating a healthy diet and exercising. You can't sit in front of the TV set, eating your large pizza, and expect these pills to keep your health. You've got to do things the hard way - eat your vegetables and get some exercise.

Fatty Acids

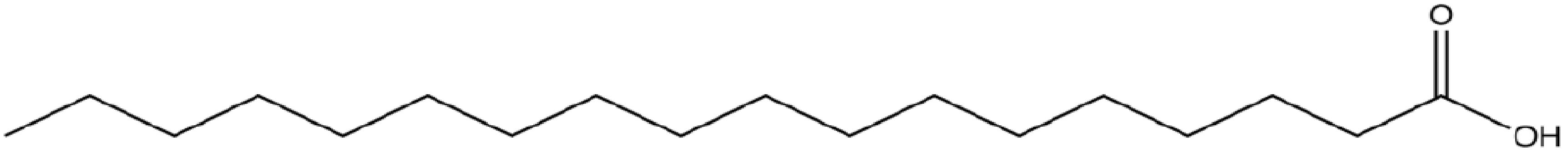
A lipid is an organic compound such as fat or oil. Organisms use lipids to store energy, but lipids have other important roles as well. Lipids consist of repeating units called fatty acids. Fatty acids are organic compounds that have the general formula

$CH_3(CH_2)_nCOOH$, where n usually ranges from 2 to 28 and is always an even number.

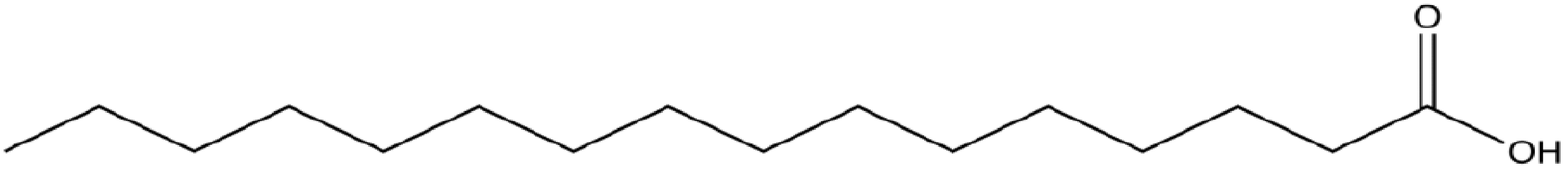
- **There are two types of fatty acids: saturated fatty acids and unsaturated fatty acids.**

Saturated Fatty Acids

In saturated fatty acids, carbon atoms are bonded to as many hydrogen atoms as possible. This causes the molecules to form straight chains, as shown in the figure below. The straight chains can be packed together very tightly, allowing them to store energy in a compact form. This explains why saturated fatty acids are solids at room temperature. Animals use saturated fatty acids to store energy. For example: Stearic and palmitic



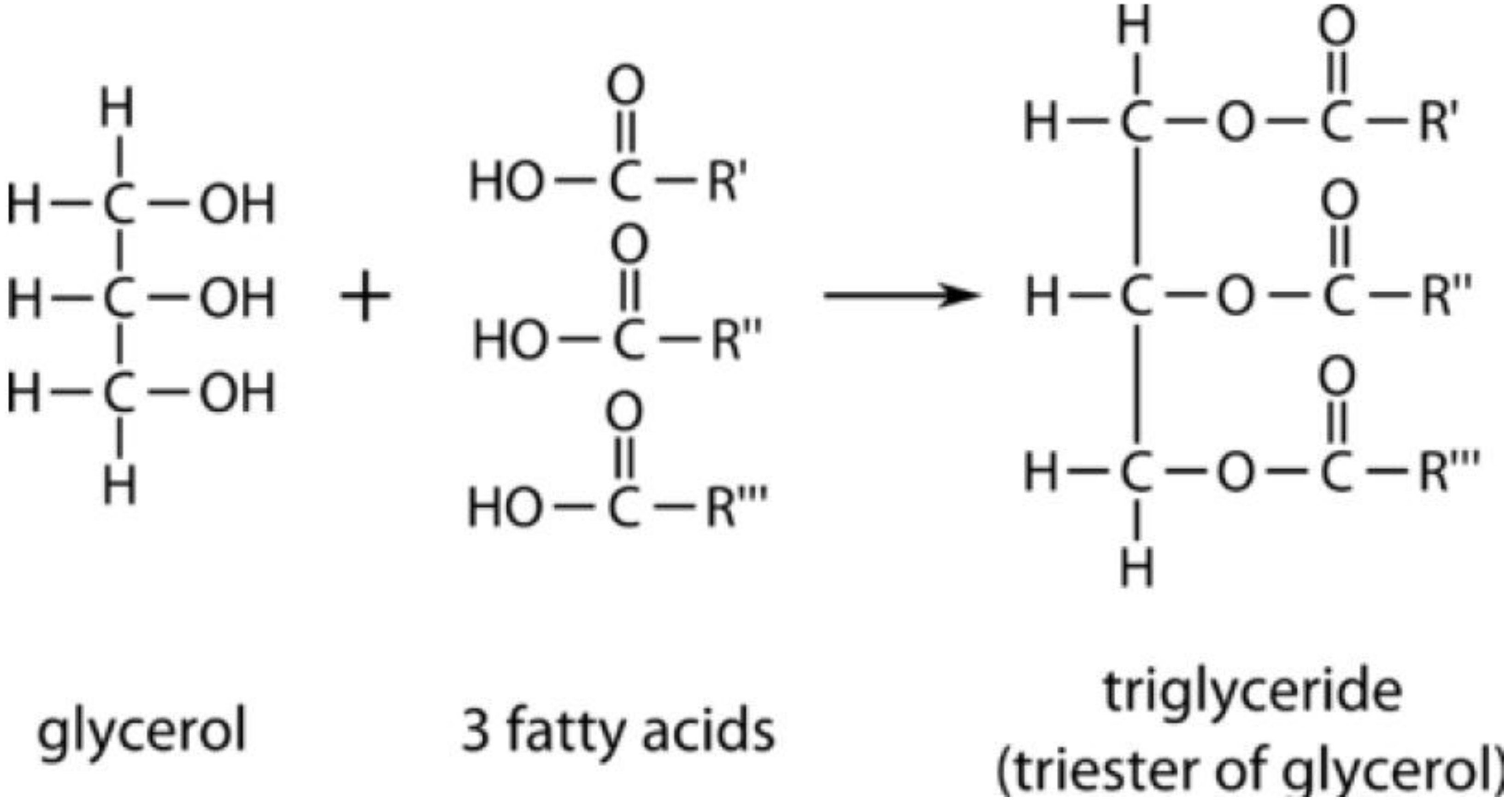
stearic acid



palmitic acid

Unsaturated Fatty Acids

In unsaturated fatty acids, some carbon atoms are not bonded to as many hydrogen atoms as possible due to the presence of one or more double bonds in the carbon chain. Instead, they are bonded to other groups of atoms. Wherever carbon binds with these other groups of atoms, it causes chains to bend (see figure above). The bent chains cannot be packed together very tightly, so unsaturated fatty acids are liquids at room temperature. Plants use unsaturated fatty acids to store energy.


glycerol
3 fatty acids
triglyceride
(triester of glycerol)

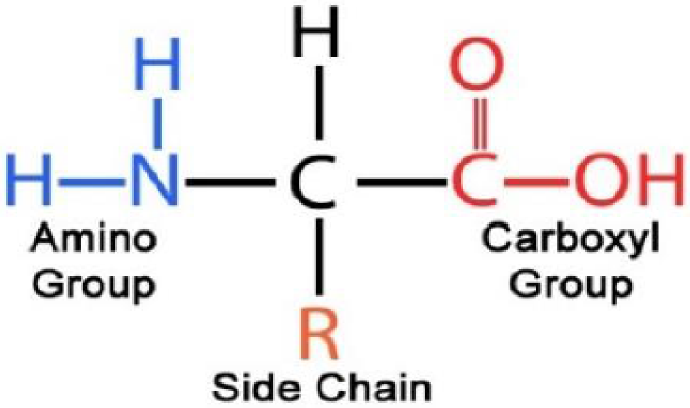
Amino acids and proteines

Amino acids

Amino acids are the building blocks of proteins. It has both an amino group (-NH_2) and an acid group (-COOH). There are more than 300 amino acids that occur in nature and many more yet to be characterized. Only 20 of the amino acids are found in the protein structure. The genetic code exists for only the 20 amino acids.

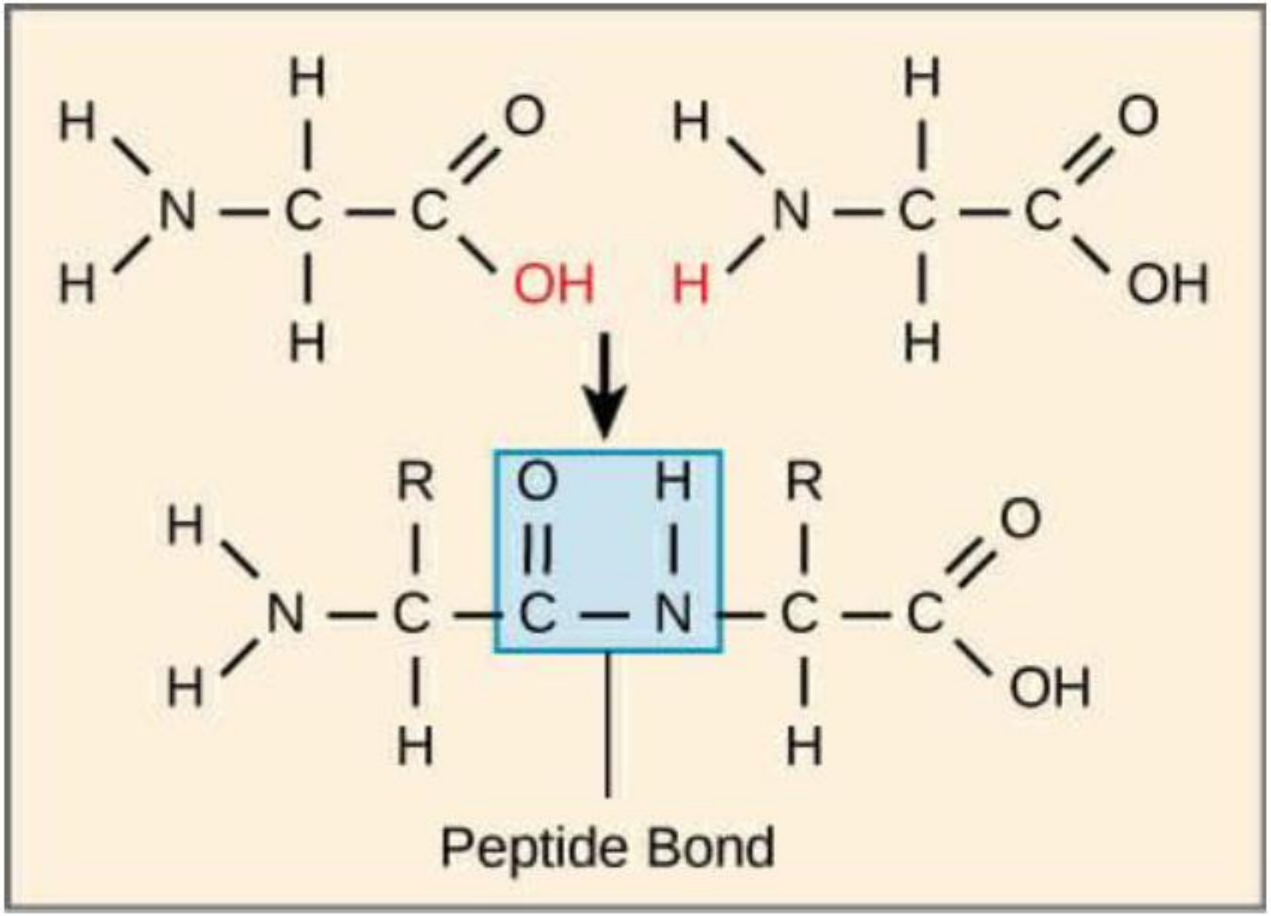
Structure of amino acids

Each amino acid has 4 different groups attached to α-carbon (which is carbon atom next to carboxylic group – COOH).

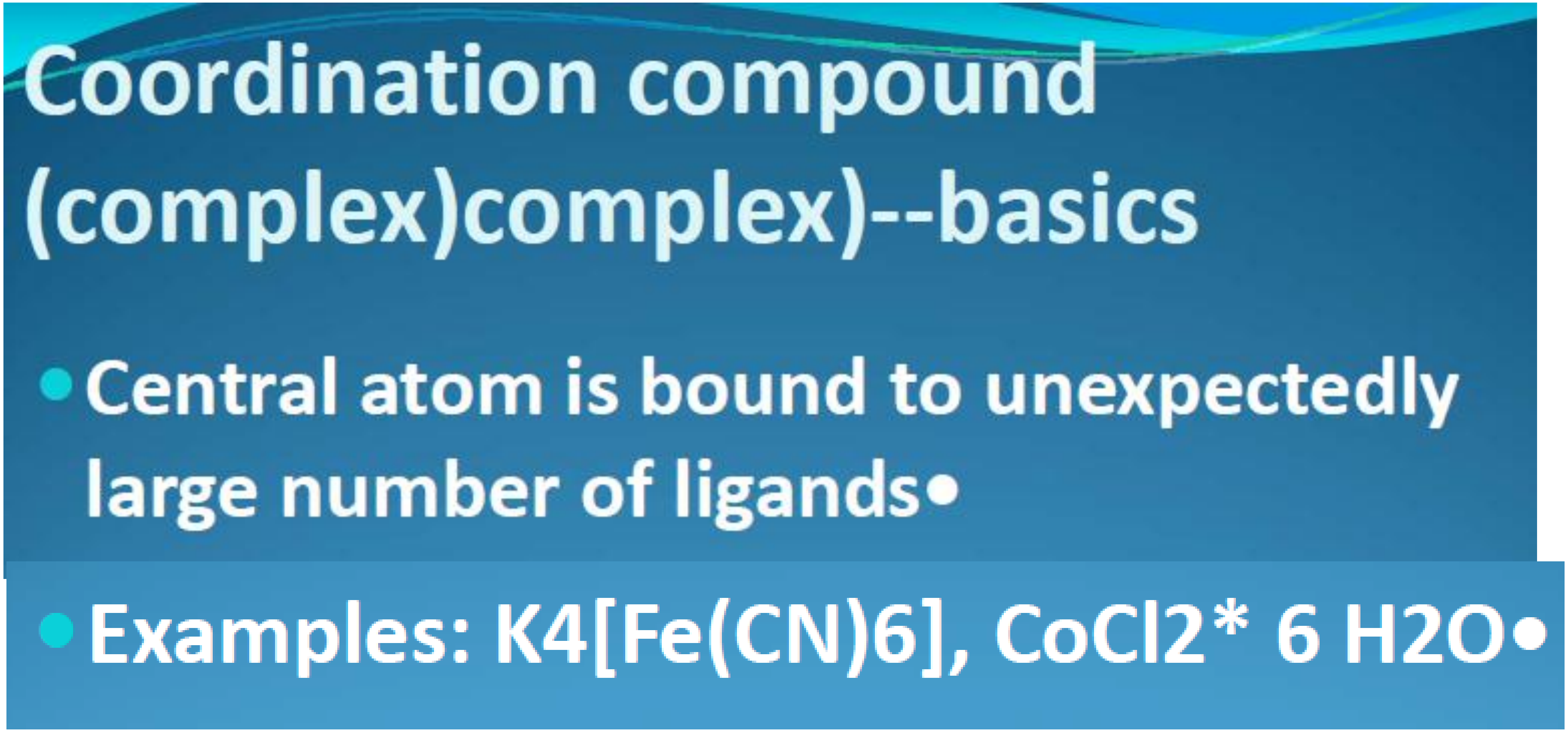


The properties of each amino acid are determined by its specific side chain (R-groups). R-groups vary in structure, size, electric charge, and solubility in water from one amino acid to other.

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


H
H
O
H
H
O
N
C
C
N
C
C
H
OH
H
OH
H
H
R
O
H
R
H
O
N
C
C
N
C
C
H
OH
H
H
Peptide Bond

coordination compound, any of a class of substances with chemical structures in which a central metal atom is surrounded by nonmetal atoms or groups of atoms, called ligands, joined to it by chemical bonds.



Coordination compound (complex)complex)--basics

- Central atom is bound to unexpectedly large number of ligands•
- Examples: K4[Fe(CN)6], CoCl2* 6 H2O•

Properties of central atoms

1- have large charge/radius ratio;
2- hard and have high densities;
3- have high melting and boiling points;
4- form compounds which are often paramagnetic (unpaired electrons)
5- show variable oxidation states;
6- form coloured ions and compounds;
7- form compounds with profound catalytic activity;
8- form stable complexes (Lewise acids).
9- trend to metal –metal bonding (cluster, not important in biology.

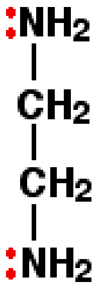
Diamagnetic materials are slightly repelled by a magnetic field and do not retain the magnetic properties when the external field is removed. Paramagnetic materials are slightly attracted by a magnetic field and do not retain the magnetic properties when the external field is removed.

Ligands

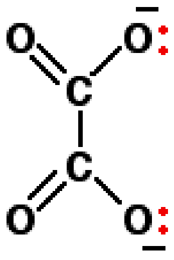
A metal ion in solution does not exist in isolation, but in combination with ligands (such as solvent molecules or simple ions) or chelating groups, giving rise to complex ions or coordination compounds. These complexes contain a central atom or ion, often a transition metal, and a cluster of ions or neutral molecules surrounding it. Ligands are ions or neutral molecules that bond to a central metal atom or ion. Ligands act as Lewis bases (electron pair donors), and the central atom acts as a Lewis acid (electron pair acceptor). Ligands have at least one donor atom with an electron pair used to form covalent bonds with the central atom.

- # Properties of ligands

- Monodentate or
- poly dentate ligand·
- Ambi dentate ligands (nitro-, nitrito)



1,2-diaminoethane



ethanedioate ion

Ligand	Name
I^-	Iodide ion
H_2O	Water
NH_3	Ammonia
OH^-	Hydroxid

Ambidentate ligands are those ligands that can attach themselves to the other central metal atoms through two different atoms. For example the NO2 group can attach itself through nitrogen and oxygen. The SCN also attaches itself through N and S atoms.

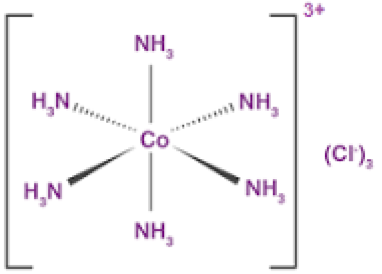
Coordination number,

The number of atoms, ions, or molecules that a central atom or ion holds as its nearest neighbours in a complex or coordination compound or in a crystal.

1- In$[Ag(NH_3)_2]^+$, the central metal atom Ag is bound by two coordinate bonds of NH^3. The coordination number of the compound is 2.

2- An example of a complex compound having coordination number 4 is [Cu(NH3)4]Cl2.

3- The coordination number 1 is only possible when a large metal ion is surrounded by a very bulky ligand that suppresses cluster formation, and there is no coordination of solvent molecules to the metal.



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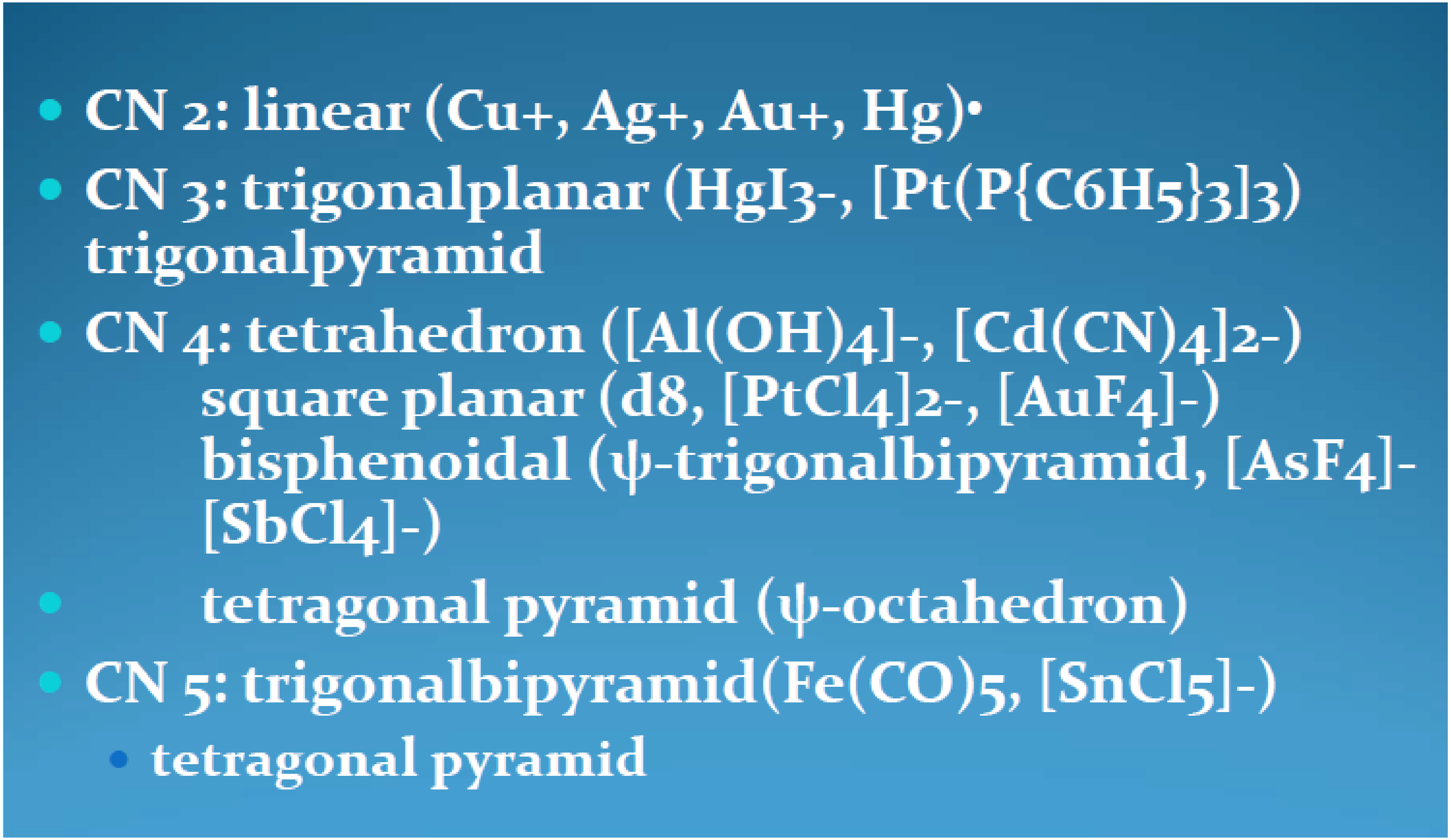
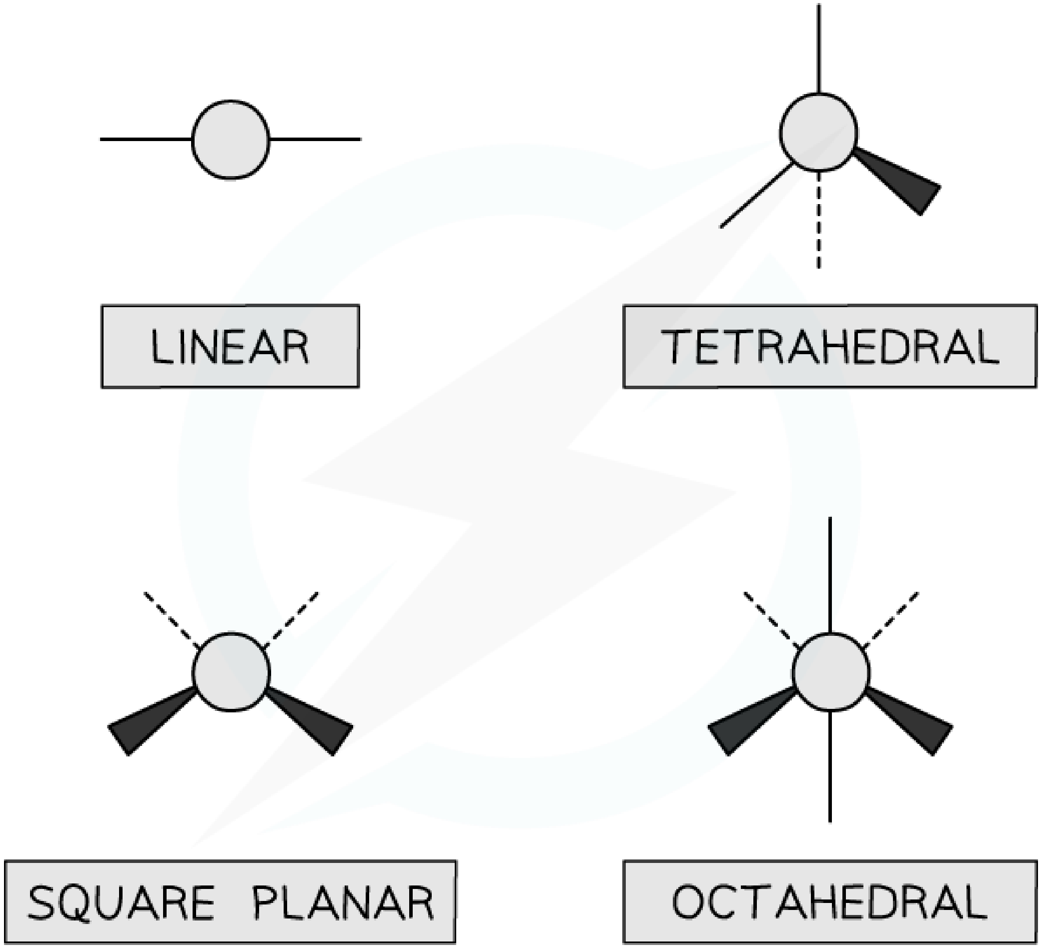
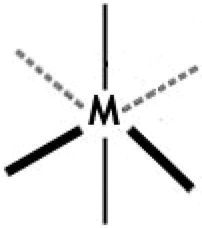
Shapes of complexes

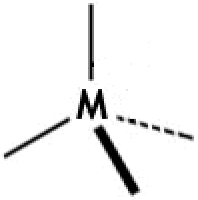


- CN 2: linear (Cu^+, Ag^+, Au^+, Hg)•
- CN 3: trigonalplanar (HgI_3^-, $[Pt(P\{C_6H_5\}_3]_3$) trigonalpyramid
- CN 4: tetrahedron ($[Al(OH)_4]^-$, $[Cd(CN)_4]^{2-}$)
  square planar (d8, $[PtCl_4]^{2-}$, $[AuF_4]^-$)
  bisphenoidal (ψ-trigonalbipyramid, $[AsF_4]^-$ $[SbCl_4]^-$)
- tetragonal pyramid (ψ-octahedron)
- CN 5: trigonalbipyramid($Fe(CO)_5$, $[SnCl_5]^-$)
  - tetragonal pyramid





Octahedral
H_2O and NH_3
ligands



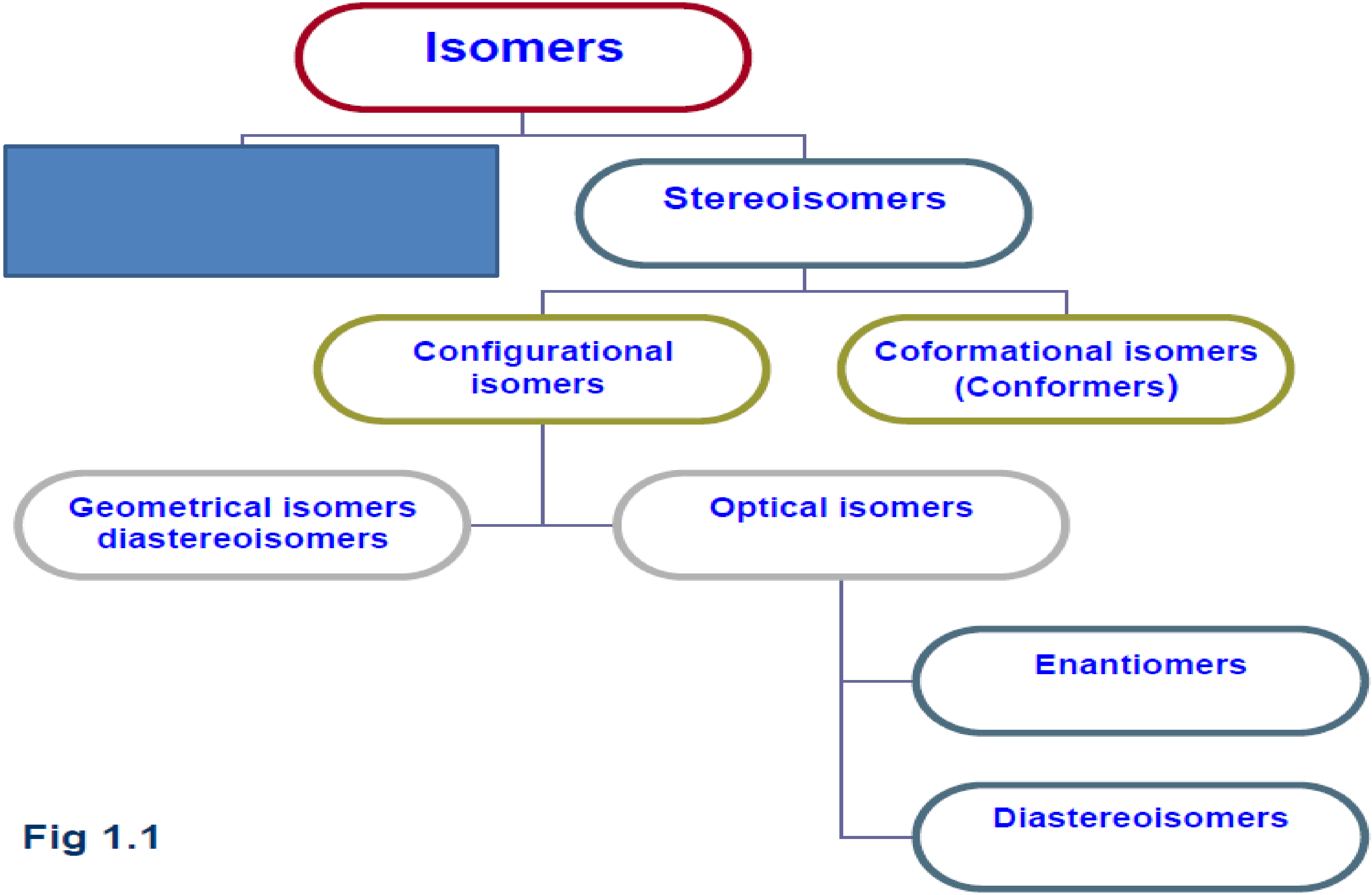
Tetrahedral
Cl- ligands

Linear
When M=Ag+

Isomerism

- Two or more molecules or ions have the same molecular formula but the atoms are arranged differently
- The structures of isomers are not super imposable
- Isomers have different physical (color) and/or chemical properties.

- ***Structural isomerism***
- Ionization isomerism ($[CoCl(NH_3)_5]SO_4$ /$[CoSO_4(NH_3)_5]Cl$)
- Coordination isomerism ($[Co(NH_3)_6][Cr(CN)_6]$ / $[Cr(NH_3)_6][Co(CN)_6]$)
- Linkage isomerism (cyano/ isocyano)



Isomers

Stereoisomers

Configurational isomers

Coformational isomers (Conformers)

Geometrical isomers diastereoisomers

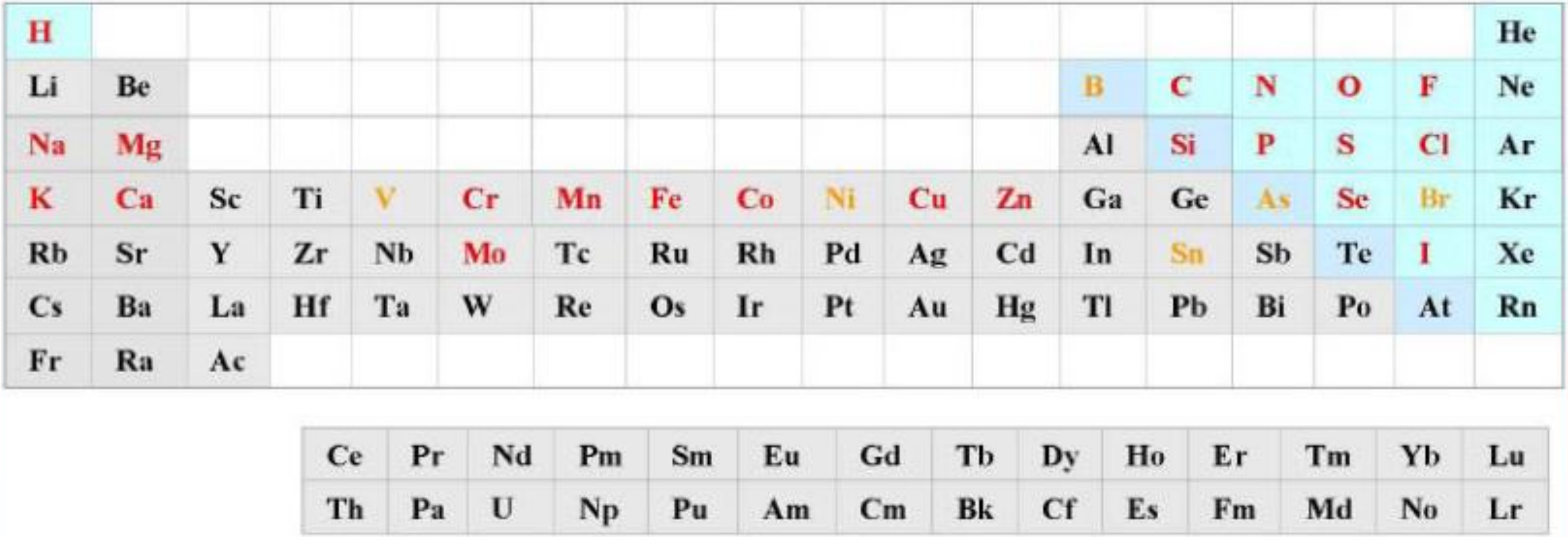
Optical isomers

Enantiomers

Diastereoisomers

Fig 1.1

Periodic table of life



H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Metals

Essential elements for humans (daily requirement: 25 mg)

Non metals

Presumably essential elements

Symptoms of deficiency:

Mg (muscle cramps), Fe (animea), Mn (infertility)

- Toxic effects in case of high doses (therapeutic width)
- Occurrence of non essential elements (e.g. Rb: 1.1 g / 70 kg) and of contaminations (e.g. Hg)

Functions of "inorganic elements"

- Assembly of structures (DNA, biomineralization), endo-and exoskeletons. Ca, Mg, Zn, Si
- Information carriers (muscle contractions, nerve function). Na, K, Ca, Mg
- Activation of enzymes. Mg, Ca
- Formation, metabolism and degradagationof organic compounds by Lewis acid/base catalysis. Zn, Mg
- ·Transfer of electrons (energy conversion), FeII/FeIII/FeIV, stable due to bioligands
- Uptake, transport, storage and conversion of small molecules
- O_2: Fe, Cu (conversion), Mn (generation)
- N_2: Fe, Mo, V (conversion to ammonia)
- CO_2: Ni, Fe (reduction to methane)

Role of the metallic elements

- The metallic elements playa variety of roles in biochemistry. Several of the most important roles are the following:

- 1. *Regulatory action is exercised by Na+, K+,* $Mg^{2}+$, *and* $Ca^{2}+$. *The flux of these ions through cell membranes and other boundary layers sends signals that turn metabolic reactions on and off.*

- 2. *The structural role of calcium in bones and teeth is well known, but many proteins owe their structural integrity to the presence of metal ions that tie together and make rigid certain portions of these large molecules, portions that would otherwise be only loosely linked. Metal ions particularly known to do this are* $Ca^{2}+$*and* $Zn^{2}+$.

- 3. An enormous amount of *electron-transfer chemistry goes on in biological systems, and nearly all of it critically depends on metal-containing electron-transfer agents. These include cytochromes (Fe), ferredoxins (Fe), and a number of copper-containing "blue proteins," such as azurin, plastocyanin, and stellacyanin.*

Most prominent “bioelements”

- Co: Cobalamine, e.g. Vitamin-B12
- Zn^{2+}: Enzymes, zincfinger(gen. transcription), stabilization of proteins
- SiIV: bones; SiO_2/silicagel
- PV: Hydroxylapatite, ATP, cell membrane, DNA
- Se-II: Selenocysteine
- F-: Fluorapatit($Ca_5(PO_4)_3F$) teeth; Cl-: besides HCO_3-most important free anion, I-: hormones of the thyroid, radiation therapy

Most prominent “bioelements”

- **Na^+,K^+: Electrolytes**
- **Mg^{2+}: Chlorophyll, energy production (ATP →ADP), skeleton**
- **Ca^{2+}: muscle functions, Hydroxylapatite$Ca_5(PO_4)_3(OH)$, $CaCO_3$**
- **VIV/V, MoIV/VI, WIV/VI, MnII/III/IV, FeII/III, NiI/II/III, CuI/II: electron transfer**
- **Fe and Cu: transport and storage of oxygen**
- **FeII, FeIII: Magnetite (Fe_3O_4)**

Terms related to bioinorganic chemistry

- **Active center**: Location in an enzyme where the specific reaction takes place
- **Allosteric enzyme:**
- **Can bind a small** regulatory molecule that influences catalytic activity
- **Apo-enzyme:**
- An enzyme that lacks its metal center or prosthetic groups
- •**ATP:** Adenosine 5'-triphosphate•
- **Biomembrane**: Sheet like assemblies of proteins and lipids (bilayer)
- **Calmodulin:** Ca binding protein involved in metabolic regulation
- **Carbonic anhydrase**: Zn-containing enzyme that catalyzes the reversible decomposition of carbonic acid to carbon dioxide and water
- **Charge-transfer complex**: An aggregate of two or more molecules in which charge is transferred from a donor to an acceptor.
- **Chlorin:** 2,3-Dihydroporphyrin, reduced porphyrin with two non-fused saturated carbon atoms (C-2, C-3) in one of the pyrrolerings.
- **Chlorophyll**: Magnesium complex of a porphyrin in which a double bond in one of the pyrrole rings (17-18) has been reduced. A fused cyclopentanonering is also present

- **Cluster:** Metal centers grouped close together which can have direct metal bonding or through a bridging ligand, e.g. ferredoxin
- ·**Cobalamin**: Vitamin B12, substituted corrin-Co(III) complex·
- **Coenzyme**: A low-molecular-weight, non-protein organic compound (often a nucleotide) participating in enzymatic reactions·
- **Cofactor:** An organic molecule or ion (usually a metal ion) that is required by an enzyme for its activity. It may be attached either loosely (coenzyme) or tightly (prosthetic group).
- ·**Cooperativity:** The phenomenon that binding of an effector molecule to a biological system either enhances or diminishes the binding of successive molecules, e.g. hemoglobin
- **Corrin:** Ring-contracted porphyrinderivative that is missing a carbon
- **Cytochrome:** Hemeprotein that transfers electrons, and exhibits intense absorption bands. The iron undergoes oxidation-reduction between oxidation states Fe(II) and Fe(III).
- **Cytochrome C-oxidase:** The major respiratory protein of animal and plant mitochondria. It catalyzes the oxidation of Fe(II)-cytochromec, and the reduction of dioxygento water. Contains two hemes and three copper atoms, arranged in three centers.

- **CytochromeP-450:** General term for a group of heme-containing monooxygenases The reaction with dioxygenappears to involve higher oxidation states of iron, such as Fe(IV)=O•
- **Desferrioxamine(dfo):** Chelating agent used world-wide in the treatment of iron overload conditions, such as hemochromatosis and thalassemia.
- **Dismutase:** Enzyme that catalyzes a disproportionation reaction•
- **Entaticstate:** A state of an atom or group which has its geometric or electronic condition adapted for function. Derived from entasis(Greek) meaning tension
- **Enzyme:** A macromolecule that functions as a biocatalyst by increasing the reaction rate•FeMo-cofactor: An inorganic cluster found in the FeMo protein of the molybdenum-nitrogenase, essential for the catalytic reduction of N_2 to ammonia
- **Ferredoxin:** A protein containing more than one iron and acid-labile sulfur, that displays electron-transferactivitybut not classical enzyme function
- **Ferritin:** An iron storage protein consisting of a shell of 24 protein subunits, encapsulating up to 4500 iron atoms in the form of a hydrated iron(III) oxide.

- **Heme:** A near-planar coordination complex obtained from iron and dianionicporphyrin•
- **Hemerythrin:** A dioxygen-carrying protein from marine invertebrates, containing an oxo-bridged dinucleariron center•
- **Hemocyanin:** A dioxygen-carrying protein (from invertebrates, e.garthropods and molluscs), containing dinucleartype 3 copper sites•
- **Hemoglobin:** A dioxygen-carrying hemeprotein of red blood cells
- **HiPIP:** High-Potential Iron-sulfur Protein (ferredoxin). Cluster which undergoes oxidation-reduction between the $[4Fe\text{-}4S]^{2+}$and $[4Fe\text{-}4S]^{3+}$states
- **Holoenzyme:** An enzyme containing its characteristic prosthetic group(s) and/or metal(s)•
- **Ion channel:** Enable ions to flow rapidly through membranes in a thermodynamically downhill direction after an electrical or chemical impulse. Their structures usually consist of 4-6 membrane-spanning domains. This number determines the size of the pore and thus the size of the ion to be transported
- **Ionophore:** A compound which can carry specific ions through membranes
- **Ion pumps:** Enable ions to flow through membranes in a thermodynamically uphill direction by the use of an energy source. They open and close upon the binding and subsequent hydrolysis of ATP, usually transporting more than oneion towards the outside or the inside of the membrane

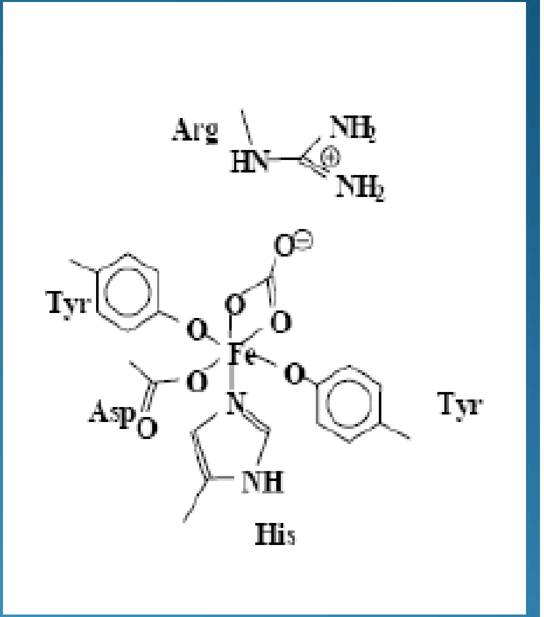
Terms related to bioinorganic chemistry

- **Metalloenzyme:** An enzyme that, in the active state, contains one or more metal ions•Mitochondria: Cytoplasmic organelles, produce ATP by oxidative phosphorylation
- **Myoglobin:** A monomeric dioxygen-binding heme protein of muscle tissue, structurally similar to a subunit of hemoglobin
- **Photosynthesis:** A metabolic process in plants and certain bacteria, using light energy absorbed by chlorophyll and other photosynthetic pigments for the reduction of CO_2, followed by the formation of organic compounds

Terms related to bioinorganic chemistry

- **Type 1,2,3 copper:** Different classes of copper-binding sites in proteins, classified by their spectroscopic properties as Cu(II). Type 1, or blue copper centers the copper is coordinated to at least two imidazole nitrogens from His and one sulfur from Cys. In type 2, or non-blue copper sites, the copper is mainly bound to imidazole nitrogens from His. Type 3 copper centers comprise two spin-coupled copper ions, bound to imidazolenitrogens
- **Zinc finger:** A domain, found in certain DNA-binding proteins, comprising a helix-loop structure in which a zinc ion is coordinated to 2 -4 Cyssulfurs, the remaining ligands being His

Fe in proteins



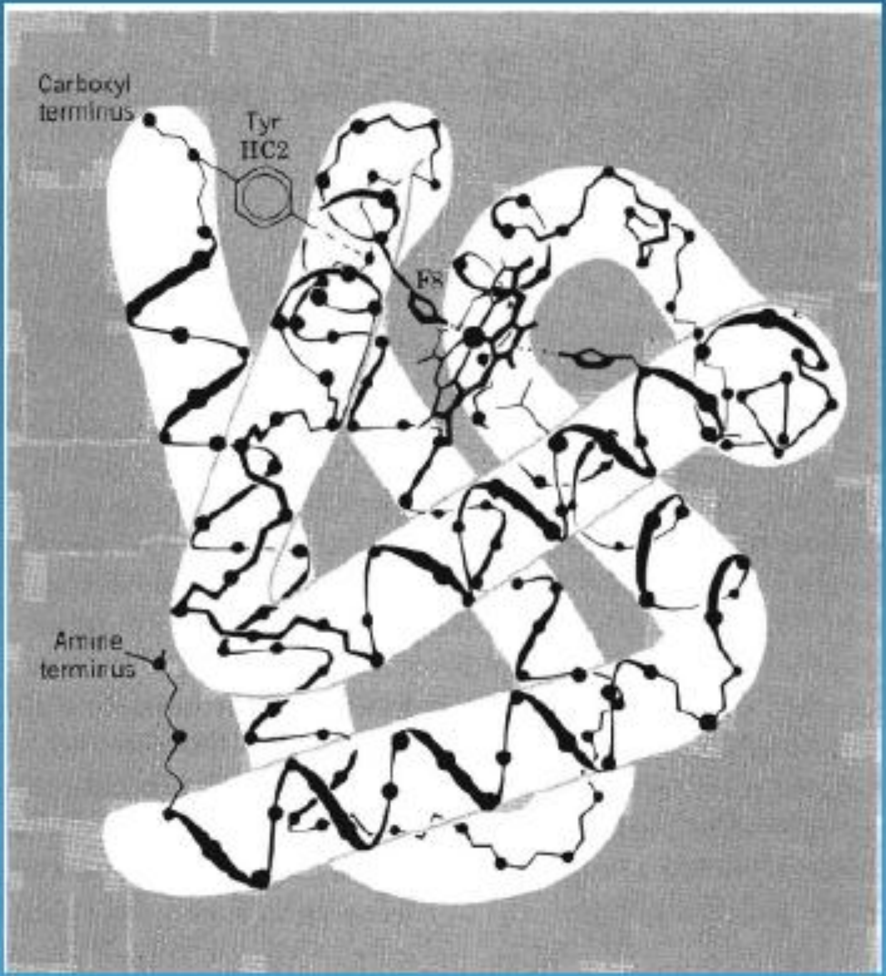
- Transport: Transferrin
- Coordination of Fe by caboxy-and phenolate groups of residues
- Uptake of two Fe(III) and one HCO3-
- Stability of complexes decrease with decreasing pH
- High affinity of Apotransferrin, protection against infections
- Not very specific (Cr3+, Al3+, Cu2+, Mn2+...)
- Release of Fe(III): Reduction to Fe(II) and binding by porphyrine

Fe in proteins

- **Storage: Ferritin**
- **High symmetry of Apoferritin: *F432***
- ***Hollow sphere built from proteins (inner dia.: ~ 7 nm, outer dia. ~ 13 nm)***
- ***Capacity: up to 4500 Fe3+, biomineralization(?)***
- ***Carboxylate groups for Fe(III) binding, core-structure related to Ferrihydrite*** $\mathrm{Fe10O_6(OH)_{18}}$
- ***Exchange via channels (dia. 1nm), tuning of hydrophilic/hydrophobic character via residues***
- ***Release of Fe as Fe(II) via hydrophilic channels***

Fe in proteins

- Hemoglobin



The Bioinorganic chemistry of Cobalt

- The best-known biological function of cobalt is its intimate involvement in the coenzymes related to vitamin B12
- It consists of four principal components:

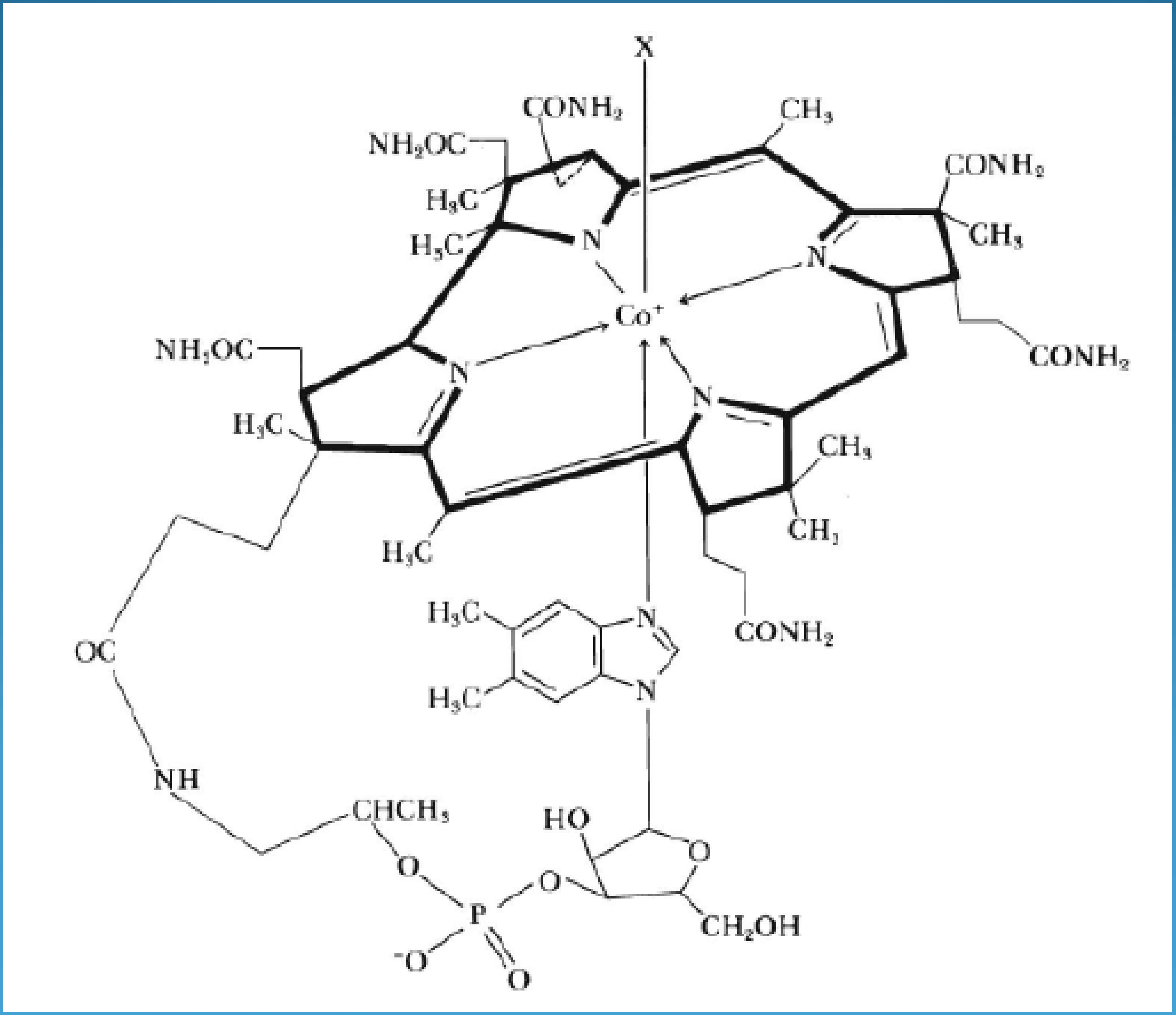
- 1. A cobalt atom.

- 2. A macrocyclic ligand called the *corrin ring, which bears various substituents. The essential corrin ring system is shown in bold lines. It resembles the porphine ring, but differs in various ways, notably in the absence of one methine (=CH-) bridge between a pair of pyrrole rings.*

- 3. A complex organic portion consisting of a phosphate group, a sugar, and an organic base, the latter being coordinated to the cobalt atom.

- 4. A sixth ligand may be coordinated to the cobalt atom. This ligand can be varied, and when the cobalt atom is reduced to the oxidation state +1, it is evidently absent.

Structure of Cobalamin



Cobalamine

- The cobalamins can be reduced in neutral or alkaline solution to give cobalt(Il) and cobalt(I) species, often called BI2r and BI2s respectively.
- powerful reducing agent
- decomposing water to give hydrogen and B12r
- reductions can apparently be carried out *in vivo by reduced ferredoxin.*
- cyano-or hydroxocobalamin is reduced, the ligand (CN-or OH-) is lost, and the resulting five-coordinate cobalt(I) species reacts with ATP in the presence of a suitable enzyme to generate the B12 coenzyme.

Nitrogen fixation

- *Nitrogenases*
- *Consist of 2 proteins*
  - *A Fe protein*
  - *A MoFe protein*
- *Each of them is inactive*
- *Mixing them makes them active*
- The Fe-protein consists of two identical subunits that clasp a ferredoxin unit (Fe_4S_4) between them by forming Fe-S bonds to two cysteine residues in each subunit.

Nitrogen fixation

- The MoFe-protein, so-called because it contains both molybdenum and iron.
- X-ray crystallographic study revealed a metal cluster arrangement
- The structure is still somewhat inaccurate and one of the bridging groups (Y) has not yet been conclusively identified.