Cofactors:

The first type of enzyme partner is a group called **cofactors**, or molecules that increase the rate of reaction or are required for enzyme function. Cofactors are not proteins but rather help proteins, such as enzymes, although they can also help non-enzyme proteins as well.

Coenzymes:

A specific type of cofactor, **coenzymes**, is organic molecules that bind to enzymes and help them function. Coenzymes are not really enzymes. As the prefix 'co-' suggests, they work with enzymes. Many coenzymes are derived from vitamins.

These molecules often sit at the active site of an enzyme and aid in recognizing, attracting, or repulsing a substrate or product. Remember that a **substrate** is the molecule upon which an enzyme catalyzes a reaction. Coenzymes can also shuttle chemical groups from one enzyme to another enzyme. Coenzymes bind loosely to enzymes, while another group of cofactors do not.

Cofactor is any non-protein component in enzyme. It is an organic molecule or metal ion which the enzymes require in order to catalyze a reaction. Cofactors can be categorized into two groups- organic cofactors and inorganic cofactors. Coenzymes are organic cofactors which are again divided into two groups- co substrates and prosthetic groups. Cofactors which bound loosely to an enzyme are termed as coenzymes and cofactors which bound tightly to an enzyme are termed as prosthetic groups. Coenzymes are heat stable, low molecular weight organic compounds required for the activity of enzymes. Coenzymes act as group transfer reagents. Most coenzymes are linked to enzymes by noncovalent forces. Coenzymes may be separated from the enzyme by dialysis. Essential ions are inorganic cofactors which are again classified as- activator ions (loosely bound) and metalloenzymes (tightly bound).

An enzyme without cofactor is called apoenzyme and the enzyme-cofactor complex is called holoenzyme. Apoenzyme is enzymatically inactive protein.

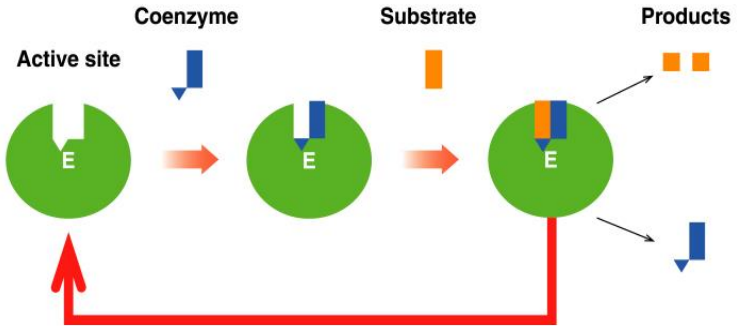
Organic Cofactors = Coenzymes

Inorganic Cofactors = Essential ions

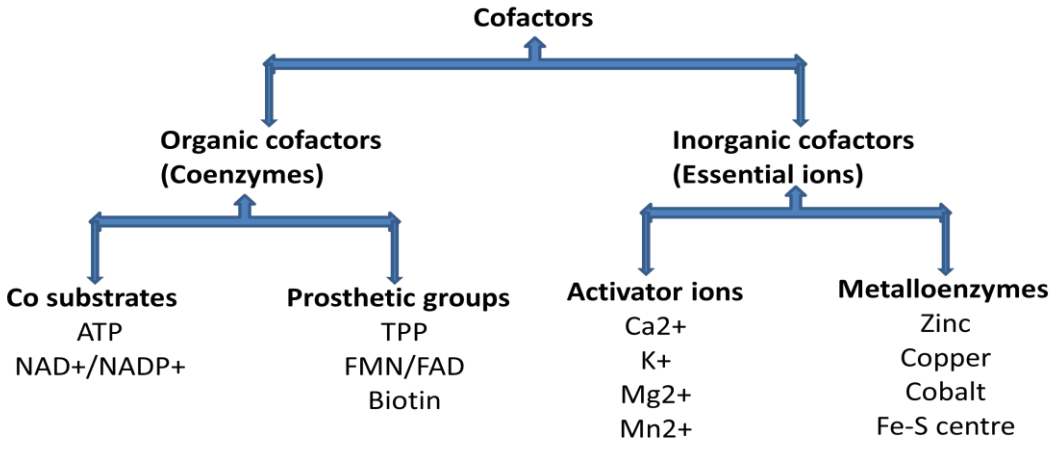
Apoenzyme = Enzyme - Cofactor

Holoenzyme = Enzyme + Cofactor

A coenzyme creates an active site for catalytic activity:



The types of cofactor are given below-



Coenzyme classification:

There are two types of coenzymes-

(1) Metabolite Coenzyme

(2) Vitamin derived Coenzyme

Metabolite coenzymes:

These are generally derived from common metabolites usually from nucleotides. The most commonly used metabolite coenzyme is adenosine triphosphate (ATP).

Vitamin derived coenzyme:

These are synthesized by microorganisms and plants, generally obtained from nutrients. Most vitamins must be enzymatically transformed to the coenzyme. Some vitamins directly act as coenzymes but some vitamins help the body to produce coenzymes.

Some vitamins with their coenzymes are listed below:

VITAMINS	COENZYMES
Niacin	NAD(P)+NAD(P)H
Thiamin (B1)	Thiamin-pyrophosphate
Riboflavin (B2)	FMN & FAD
Pantothenate (B5)	Coenzyme A
Pyridoxal (B6)	Pyridoxal phosphate
Cobalamin (B_{12})	Adenosyl and methylcobalamin
Ascorbic acid(C)	Not a coenzyme
Vitamin A	Retinal
Vitamin K	Vitamin K
Biotin/Vitamin	H Biotin
Folate	Tetrahydrofolate

Here we have discussed about some coenzymes in the following:

NAD+ & NADP+:

Both functions as an acceptor of hydrogen atoms and electrons in presence of dehydrogenases and converted into the reduced form.

The oxidized form of coenzymes accepts pairs of electrons whereas the reduced form of coenzymes donate pairs of electrons. They act as co substrates for dehydrogenase and also functions as hydride ion transfer. Niacin is required for the synthesis of these two coenzyme molecules NAD+ & NADP+.

Thiamin-pyrophosphate:

It is a coenzyme which participates in oxidative decarboxylation reactions and transketolase enzyme reaction. It also catalyzes several biological reactions. It is derived from Thiamin (vitamin B1).

FMN & FAD:

Riboflavin (vitamin B2) is required for the synthesis of flavin nucleotides (FMN & FAD). Generally FMN & FAD function as prosthetic groups as they are noncovalently bonded to the enzyme and therefore cannot dissociate. They act as temporary storage of electrons within the proteins and also function in the oxidation/reduction reaction.

Pyridoxal-phosphate:

It is a coenzyme which is derived from vitamin B6. It functions in isomerisation, decarboxylation, racemisation, transamination, side chain elimination reaction involving amino acids.

Biotin:

Biotin is a coenzyme which is derived from vitamin H. It functions in the metabolism of fats and amino acids & also acts as a carrier of activated CO2.

Tetrahydrofolate:

Tetrahydrofolate is derived from vitamin folic acid. It is required in the biosynthesis of purines and pyrimidines.

Cobalamin:

It is a coenzyme which is derived from vitamin B12. It consists of four pyrrole rings with Co2+. Cobalamin participates in the synthesis of acetyl choline. Deficiency of vitamin B12 causes anaemia.

Metal ions can also act as cofactors.

Some enzymes and their cofactors are listed below:

Enzymes	Metal ion cofactors	Function
Cytochrome oxidase	Cu2+	Oxidation-reduction
Catalase	Fe2+/Fe3+	Oxidation-reduction
Alcohol dehydrogenase	Zn2+	Used with NAD+
Carbonic anhydrase	Zn2+	Used with NAD+
Carboxypeptidase A	Zn2+	Used with NAD+
Arginase	Mn2+	removes electrons
Glucose-9-phosphatase	Mg2+	Hydrolyzes phosphate esters

Comparison between Cofactor and Coenzyme

	Cofactor	Coenzyme
Definition	It is a non-protein chemical compounds that are bound tightly or loosely to an enzyme (protein).	It is defined as small, organic, non-protein molecules, which carry chemical groups between enzymes.
Characteristics	These are inorganic substances.	These are organic substances.
Function	It assists in biological transformations.	It aids or helps the function of an enzyme.
Type	They are chemical compounds.	They are chemical molecules.
Bound	It is tightly bound to an enzyme.	It is loosely bound to an enzyme.
Action	They act on catalyst to increase the speed of the reaction.	They act as carries to the enzymes.
Example	Metal Ions like Zn++, K+ and Mg++, etc.	Vitamins, Biotin, Coenzyme A, etc
Definition	It is a non-protein chemical compounds that are bound tightly or loosely to an enzyme (protein).	It is defined as small, organic, non-protein molecules, which carry chemical groups between enzymes.