

# Vitamins & Cofactors

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## Vitamins & Cofactors

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### Vitamins

- Definition: essential nutrients required in the diet
- Different vitamins for different species
  - e.g., for rats & mice ascorbate is not a vitamin
  - E. coli* do not have any vitamins
- Vitamins are classified as water soluble or fat soluble

### Cofactors/Coenzymes

- Definition: low  $M_r$  molecules that act as carriers or give special functionality to enzymes
- Many coenzymes have vitamin molecules as their basis

Need to know: name, abbreviation, recognize structure, role in chemistry

# Vitamins & Cofactors

## Vitamins and Coenzymes

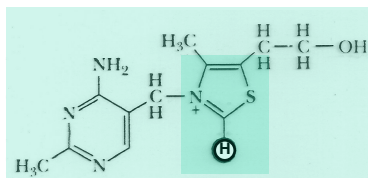
Vitamin	Coenzyme Form	Reaction mediated	Human Deficiency
Water-Soluble			Disease
① Thiamine (vitamin B <sub>1</sub> )	Thiamine pyrophosphate	Acyl-group transfer	Beriberi
② Niacin (nicotinic acid)	Nicotinamide adenine dinucleotide (NAD <sup>+</sup> ) Nicotinamide adenine dinucleotide phosphate (NADP <sup>+</sup> )	Re-dox	Pellagra
③ Riboflavin (vitamin B <sub>2</sub> )	Flavin adenine dinucleotide (FAD) Flavin mononucleotide (FMN)	Re-dox	—
④ Pantothenic acid	Coenzyme A	Acyl-group transfer	—
⑤ Pyridoxal, pyridoxine, pyridoxamine (vitamin B <sub>6</sub> )	Pyridoxal phosphate	Amino-group transfer	dermatitis
⑥ Cobalamin (vitamin B <sub>12</sub> )	5'-Deoxyadenosylcobalamin Methylcobalamin	Alkylation	Pernicious anemia
⑦ Biotin	Biotin-lysine complexes (biocytin)	Carboxylation	—
⑧ Lipoic acid	Lipoyl-lysine complexes (lipoamide)	Acyl-group transfer	—
⑨ Folic acid	Tetrahydrofolate	C1-group transfer	Megaloblastic anemia
⑩ Ascorbic acid (vitamin C)	Ascorbate	Re-dox	Scurvy
Fat-soluble			
① Retinol (vitamin A)	Retinal		Night blindness
② Ergocalciferol (vitamin D <sub>2</sub> )			
③ Cholecalciferol (vitamin D <sub>3</sub> )			Rickets
④ α-Tocopherol (vitamin E)			—
④ Vitamin K			Hemorrhage

# Vitamins & Cofactors

## ① Vitamin B<sub>1</sub>

Acyl-group transfer

Vitamin

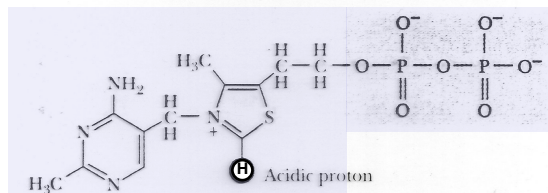


Thiamine (vitamin B<sub>1</sub>)

Thiazole ring

In 1911, Casimir Funk realized that this “amine” was “vital” for life. He coined the term “vital-amine,” which eventually was shortened to the word, “vitamin.”

Coenzyme



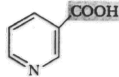
Thiamine pyrophosphate (TPP)

# Vitamins & Cofactors

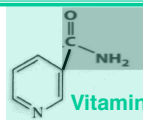
## ② Vitamin B<sub>3</sub> (aka Niacin)



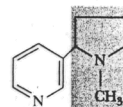
Pyridine



Nicotinic acid



Nicotinamide

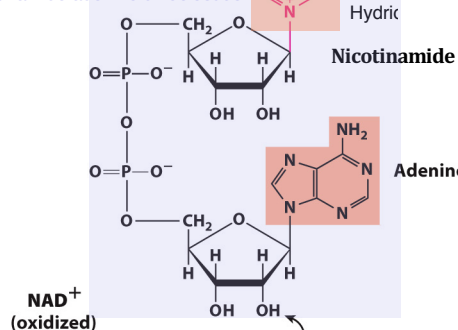


Nicotine

Re-dox

### Coenzyme

Nicotinamide adenine dinucleotide



**NAD<sup>+</sup>**  
(oxidized)

In NAD<sup>+</sup> this hydroxyl group is esterified with phosphate.

Adenine

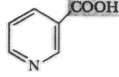
- These are commonly called pyridine nucleotides.
- They **can dissociate** from the enzyme after the reaction.
- In a typical biological oxidation reaction, **hydride** from an alcohol is transferred to NAD<sup>+</sup>, giving NADH.
- Renamed **niacin** for **nicotinic acid** and **vitamin**

# Vitamins & Cofactors

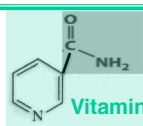
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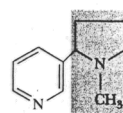
Pyridine



Nicotinic acid



Nicotinamide

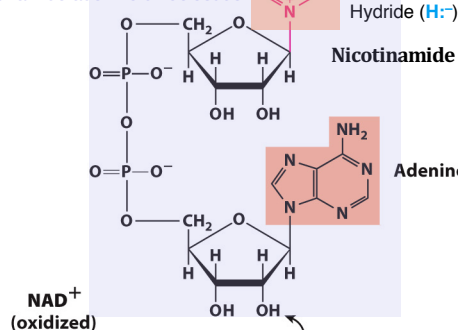


Nicotine

Re-dox

### Coenzyme

Nicotinamide adenine dinucleotide

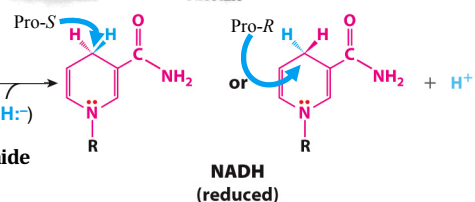


**NAD<sup>+</sup>**  
(oxidized)

In NAD<sup>+</sup> this hydroxyl group is esterified with phosphate.

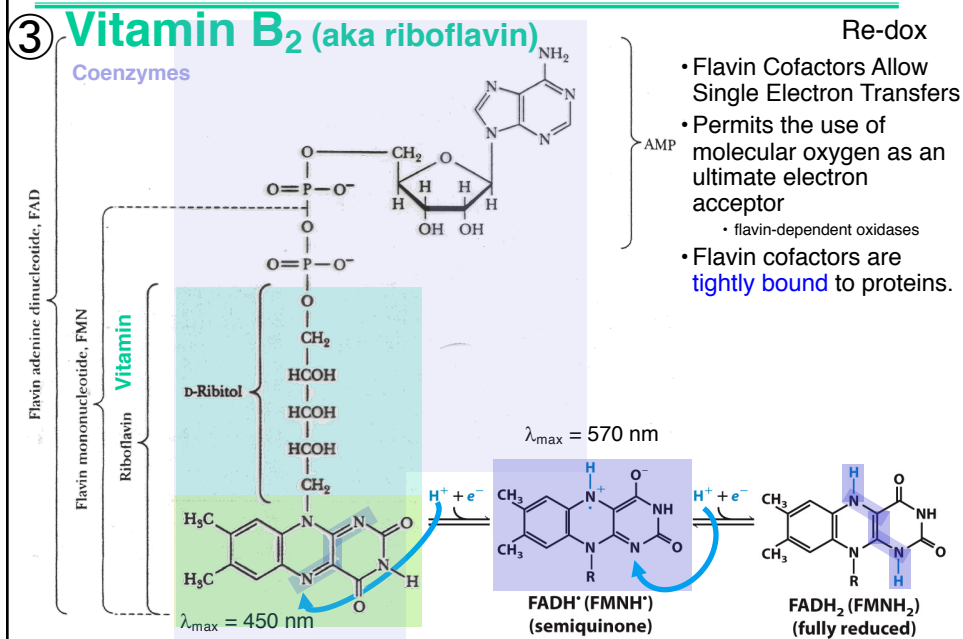
Adenine

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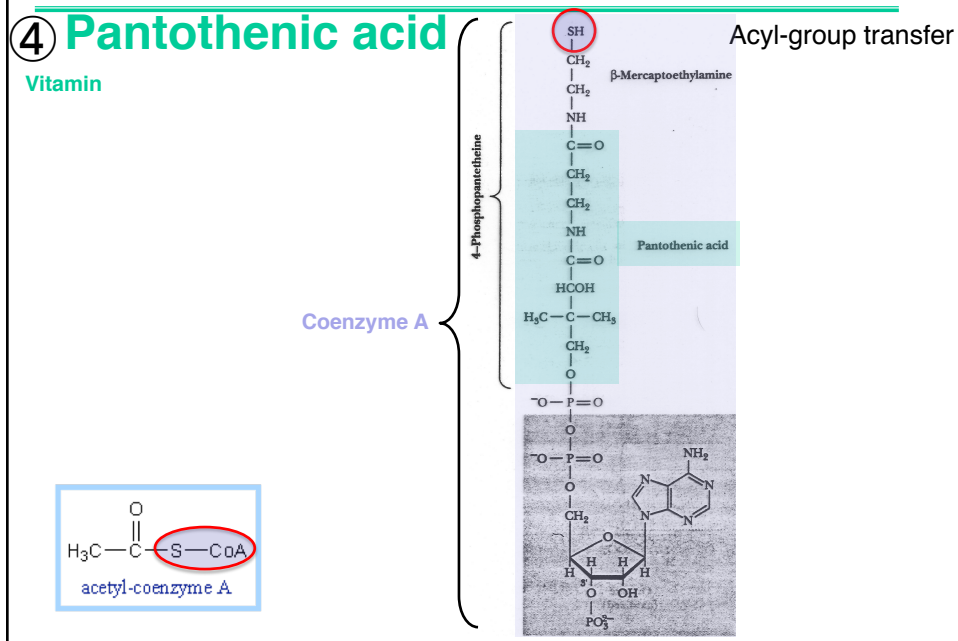


**NADH**  
(reduced)

# Vitamins & Cofactors



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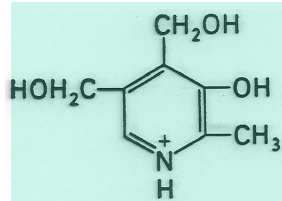


## Vitamins & Cofactors

### ⑤ Vitamin B<sub>6</sub>

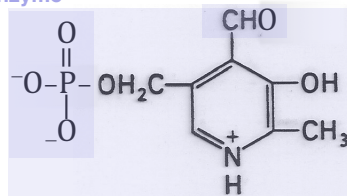
Amino-group transfer

Vitamin



Pyridoxine

Coenzyme



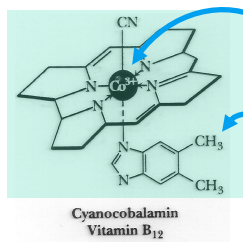
Pyridoxal 5-phosphate  
(PLP)

## Vitamins & Cofactors

### ⑥ Vitamin B<sub>12</sub>

Alkylation

Vitamin

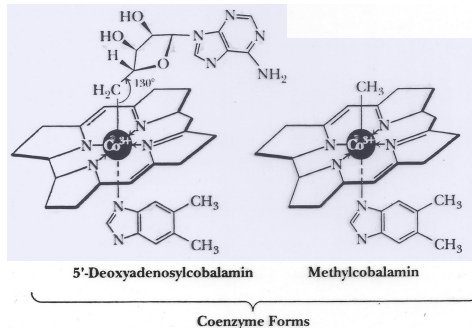


Cyanocobalamin  
Vitamin B<sub>12</sub>

Cobalt ion

Dimethylbenzimidazole

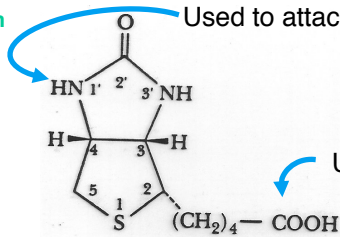
Coenzyme



## Vitamins & Cofactors

### 7 Biotin

Vitamin

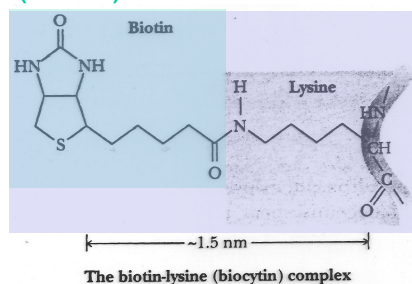


Used to attach carboxyl group ( $-CO_2^-$ )

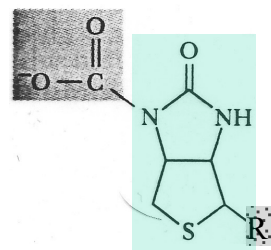
Tightly binds Avidin and streptavidin ( $K_d \sim 10^{-15}$ ); used in biotechnology

Used to attach to enzyme (Lys)

Coenzyme (covalent)



Carboxylbiotin

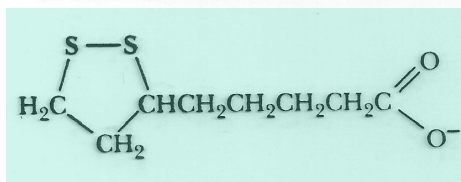


## Vitamins & Cofactors

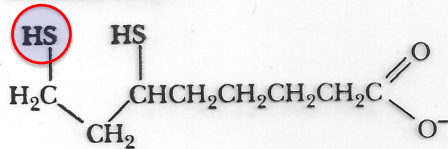
### 8 Lipoic Acid

Vitamin

Lipoic acid, oxidized form



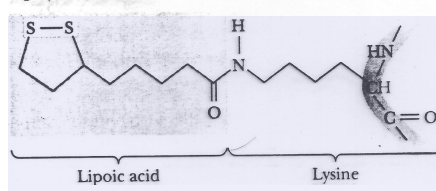
Reduced form



Acyl-group transfer

Coenzyme (covalent)

Lipoamide complex



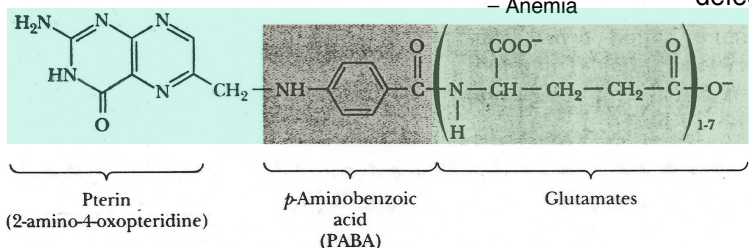
# Vitamins & Cofactors

## ⑨ Folic Acid (aka Vitamin B<sub>9</sub>)

One-carbon transfer

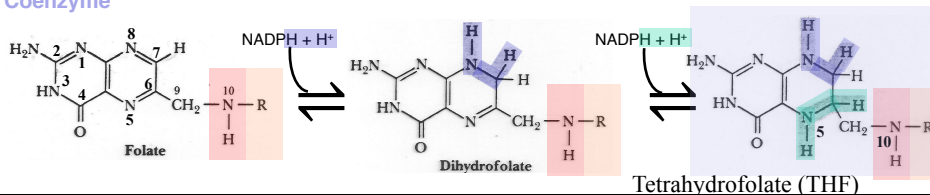
Vitamin

Folic acid



- Folate deficiency:
  - Diarrhea
  - Depression
  - Confusion
  - Anemia
- During pregnancy: fetal neural tube defects

Coenzyme



# Vitamins & Cofactors

## ⑩ Ascorbic Acid (aka Vitamin C)

Re-dox

Vitamin

Coenzyme

