

# Vitamins & Cofactors

---

## Vitamins & Cofactors

---

### 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

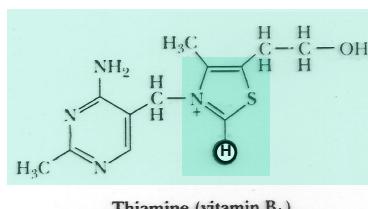
## Vitamins and Coenzymes

Vitamin	Coenzyme Form	Reaction mediated	Human Deficiency Disease
<b>Water-Soluble</b>			
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
<b>Fat-soluble</b>			
① Retinol (vitamin A)	Retinal		Night blindness
② Ergocalciferol (vitamin D <sub>2</sub> ) ③ Cholecalciferol (vitamin D <sub>3</sub> )			Rickets
④ $\alpha$ -Tocopherol (vitamin E)			—
④ Vitamin K			Hemorrhage

# Vitamins & Cofactors

## ① Vitamin B<sub>1</sub>

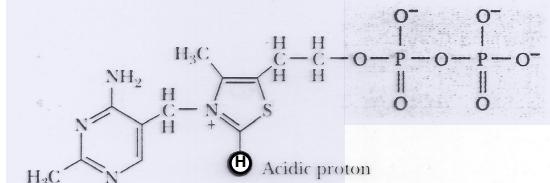
### Vitamin



### 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

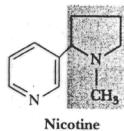


Thiamine pyrophosphate (TPP)

## Vitamins & Cofactors

### ② Vitamin B<sub>3</sub>

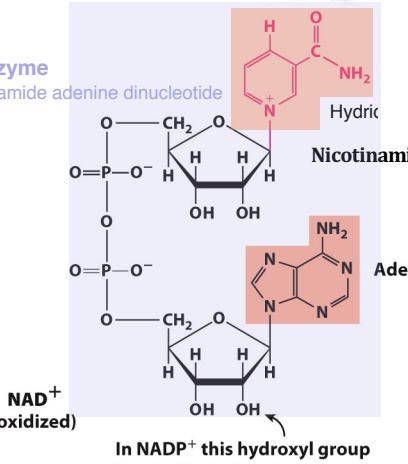
(aka Niacin)



Re-dox

Coenzyme

Nicotinamide adenine dinucleotide



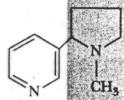
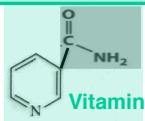
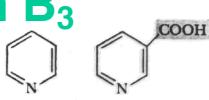
Adenine

- 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

### ② Vitamin B<sub>3</sub>

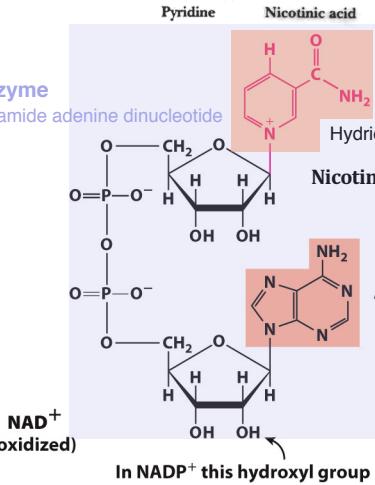
(aka Niacin)



Re-dox

Coenzyme

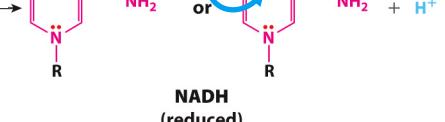
Nicotinamide adenine dinucleotide



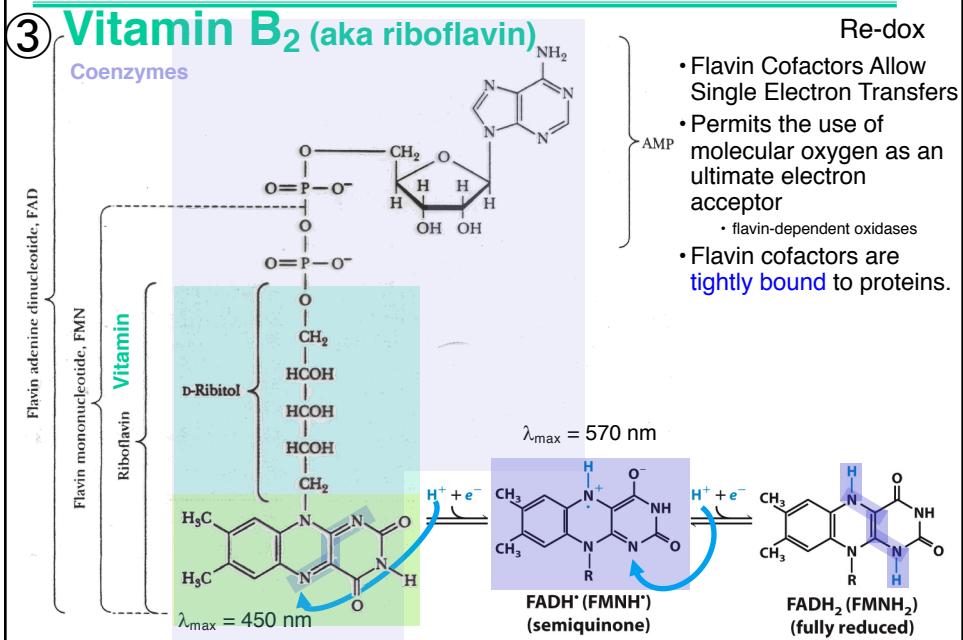
Adenine

- 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**

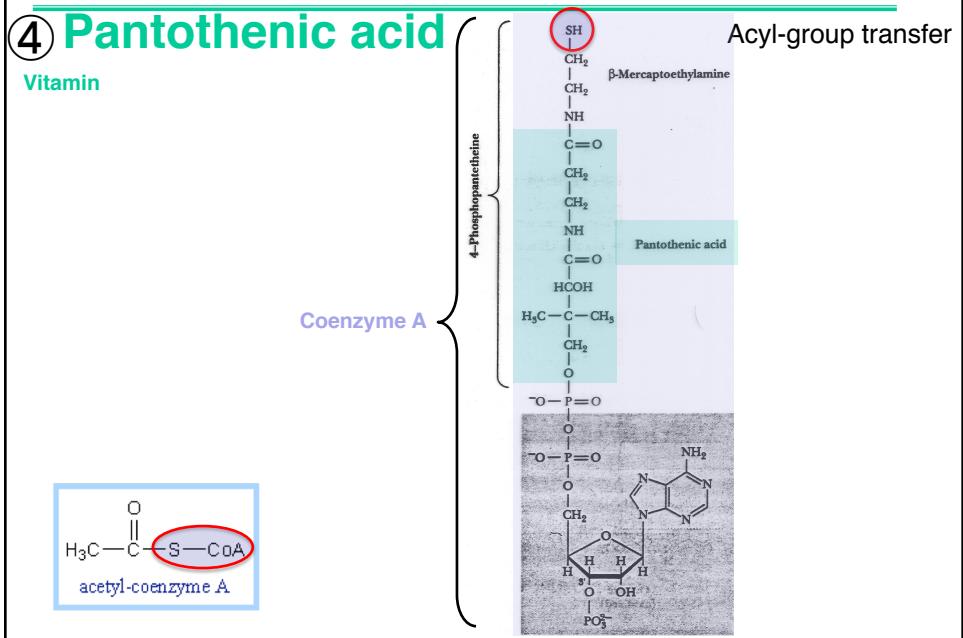
NADH (reduced)



# Vitamins & Cofactors



# Vitamins & Cofactors

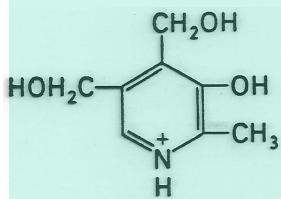


## Vitamins & Cofactors

### ⑤ Vitamin B<sub>6</sub>

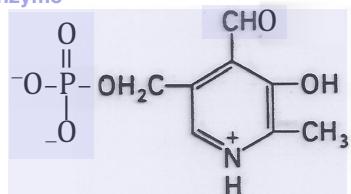
Amino-group transfer

Vitamin



Pyridoxine

Coenzyme



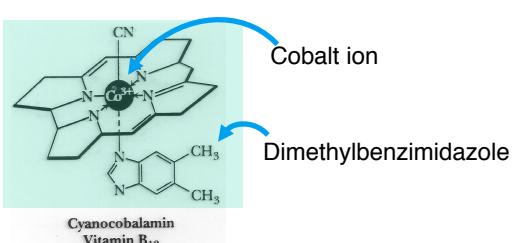
Pyridoxal 5-phosphate  
(PLP)

## Vitamins & Cofactors

### ⑥ Vitamin B<sub>12</sub>

Alkylation

Vitamin

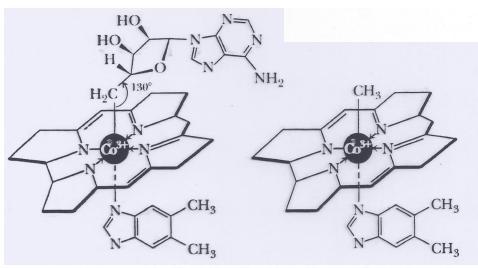


Cobalt ion

Dimethylbenzimidazole

Cyanocobalamin  
Vitamin B<sub>12</sub>

Coenzyme



5'-Deoxyadenosylcobalamin

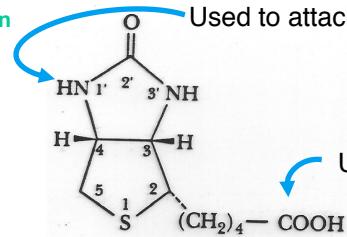
Methylcobalamin

Coenzyme Forms

## Vitamins & Cofactors

### 7 Biotin

Vitamin

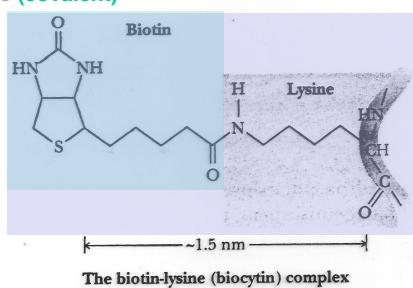


Carboxylations

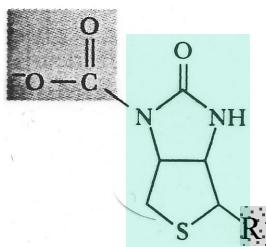
Tightly binds Avidin and streptavidin ( $K_d \approx 10^{-15}$ ); used in biotechnology

Used to attach to enzyme (Lys)

Coenzyme (covalent)



Carboxylbiotin

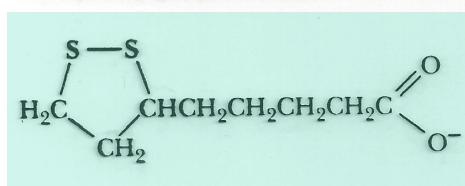


## Vitamins & Cofactors

### 8 Lipoic Acid

Vitamin

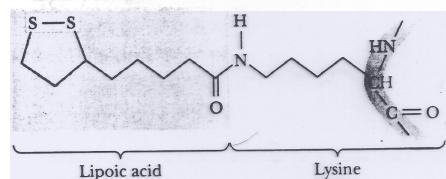
Lipoic acid, oxidized form



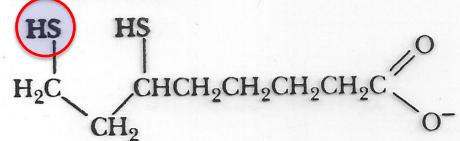
Acyl-group transfer

Coenzyme (covalent)

Lipoamide complex



Reduced form

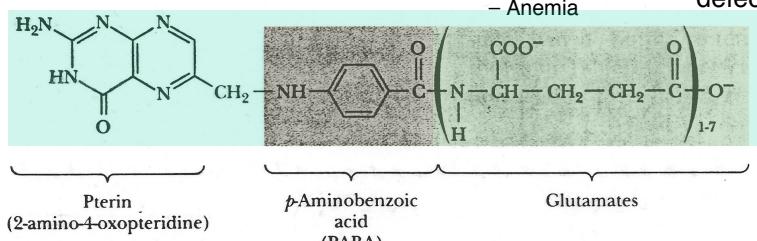


# Vitamins & Cofactors

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

### Vitamin

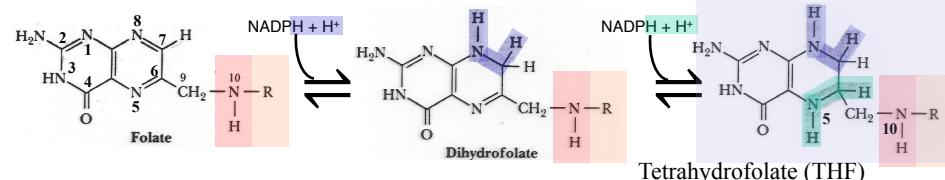
#### Folic acid



One-carbon transfer

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

### Coenzyme

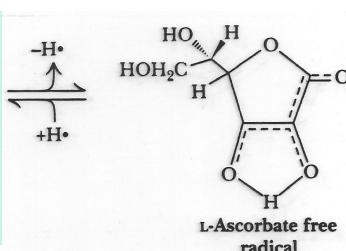
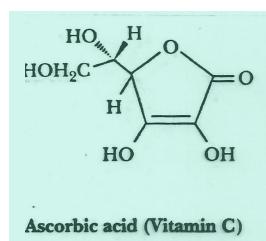


# Vitamins & Cofactors

## ⑩ Ascorbic Acid (aka Vitamin C)

### Vitamin

### Coenzyme



Re-dox

