



Water Soluble Vitamins



Water Soluble Vitamins

- ▶ They are heterogeneous group of compounds - differ chemically.
- ▶ Common character – solubility in water.
- ▶ Easily absorbed.
- ▶ Not stored in the body except for Vit B12.
- ▶ Readily excreted in urine.
- ▶ Form coenzymes – biochemical reactions.

Water Soluble Vitamins (B & C)

Water-soluble vitamins are carried to the body's tissues but are not stored in the body. Since they are eliminated in urine, we require a continuous daily supply in our diet.

Water Soluble Vitamins	
Vitamin:	Name:
B1	Thiamine
B2	Riboflavin
B3	Niacin
B5	Pantothenic Acid
B6	Pyridoxine
B7	Biotin
B9	Folate
B12	Cobalamin
C	Ascorbic Acid



Water soluble Vitamins



```
graph TD; A[Water soluble Vitamins] --> B[B Complex]; A --> C[Non B Complex]; B --> D[Energy Releasing]; B --> E[Haematopoietic]; C --> F[Vitamin C]; D --> G["B1, B2, B3, B5, B6, B7"]; E --> H["B9 (Folic Acid) & B12"]
```

The diagram is a hierarchical flowchart. At the top is a blue box labeled 'Water soluble Vitamins'. A red line branches from this box to two red boxes: 'B Complex' on the left and 'Non B Complex' on the right. From the 'B Complex' box, a green line branches to two green boxes: 'Energy Releasing' and 'Haematopoietic'. From the 'Non B Complex' box, a green line leads to a single green box: 'Vitamin C'. From the 'Energy Releasing' box, a purple line leads to a purple box listing 'B1, B2, B3, B5, B6, B7'. From the 'Haematopoietic' box, a purple line leads to a purple box listing 'B9 (Folic Acid) & B12'.

B Complex

Non B Complex

Energy Releasing

Haematopoietic

Vitamin C

B1, B2, B3,
B5, B6, B7

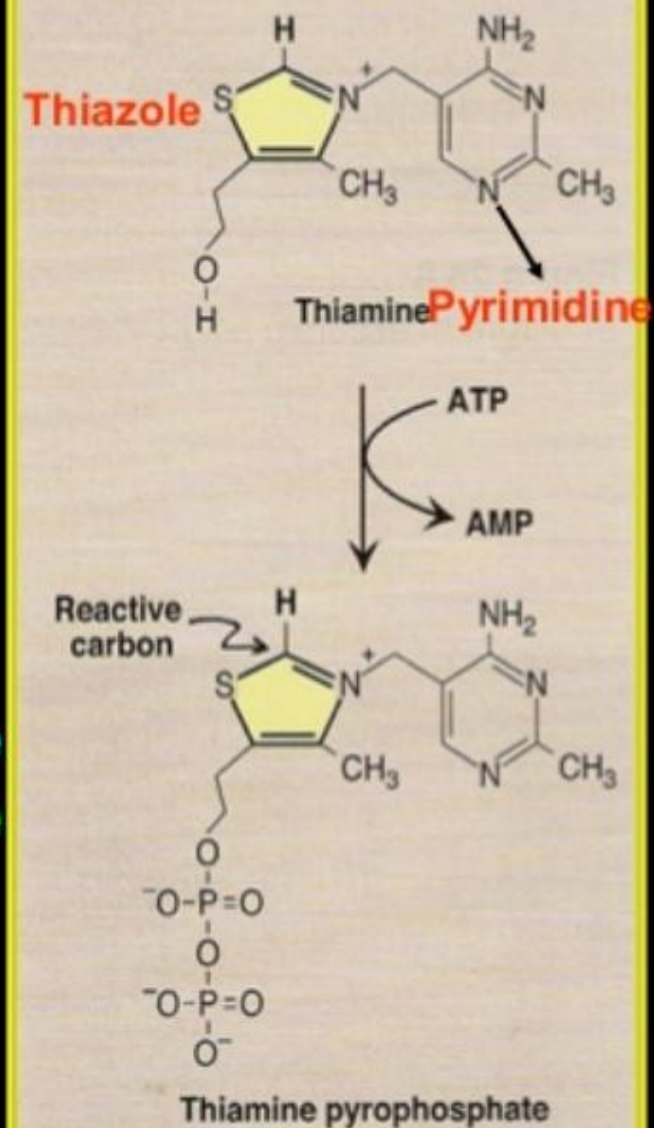
B9 (Folic Acid)
& B12

THIAMINE

- Thiamine is also called as Vitamin B₁.

Structure And Activation

- Thiamine contains a pyrimidine ring and a thiazole ring.
- The active form of thiamine is the coenzyme Thiamine Pyrophosphate (TPP).
- Activation occurs mainly in liver.



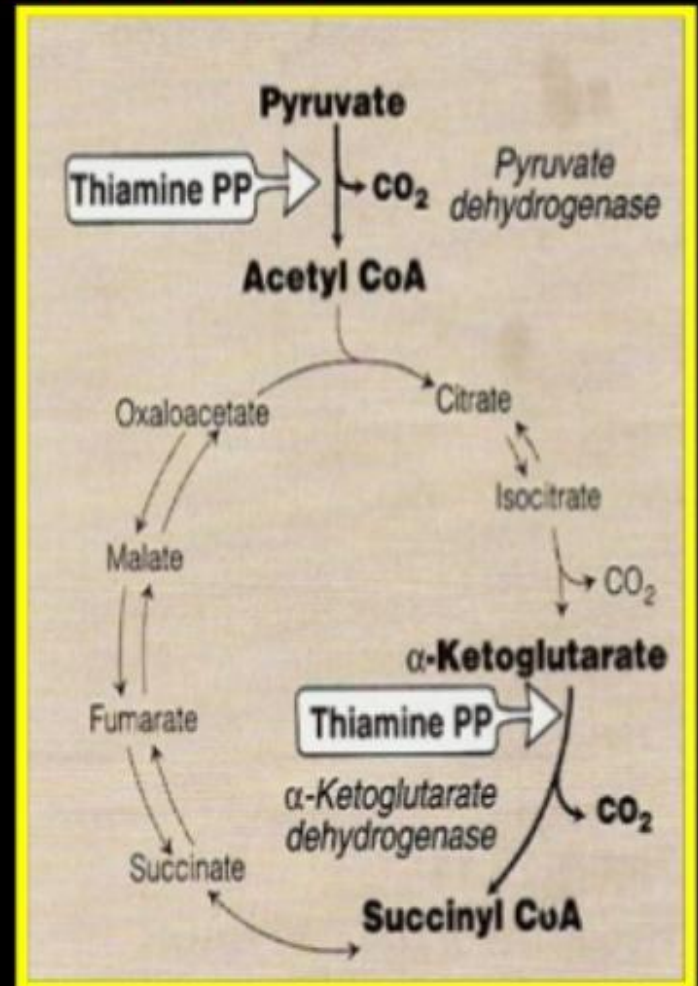
Biochemical Functions

- Thiamine pyrophosphate (TPP) is involved with the energy releasing reactions of carbohydrate metabolism.
- **DECARBOXYLATION REACTIONS**
 1. Pyruvate Dehydrogenase (PDH)
 2. α Ketoglutarate dehydrogenase.



(3C)

(2C)



Causes of Deficiency Manifestation

- Inadequate Diet (**polished rice**): Thiamine is present in the outer layer of rice grains.
- Alcoholism:
- Pregnancy and lactation: Leads to **increase demand**.
- Presence of enzyme *thiaminase* (in raw fish) inactivates thiamine by **breaking the thiazole ring**.

Deficiency Manifestations of Thiamine

- Mainly seen in those consuming **exclusively polished rice**. Deficiency leads to a disease known as **Beri-beri**.
- Beri-beri is of three types.
 - I. Wet Beri-beri:** Edema and weak heart muscles
 - II. Dry Beri-beri:** Degeneration of peripheral nerves and weak muscles.
 - III. Infantile Beri-beri:** Affects infants.

Vitamin B1/Thiamine

Dietary sources of thiamine

- beans and legumes, seeds
- Meat, fish, egg
- whole grains, nuts
- Dairy, yeast, nuts, legumes
- certain vegetables, such as asparagus, acorn squash, brussels sprouts, spinach, and beet greens

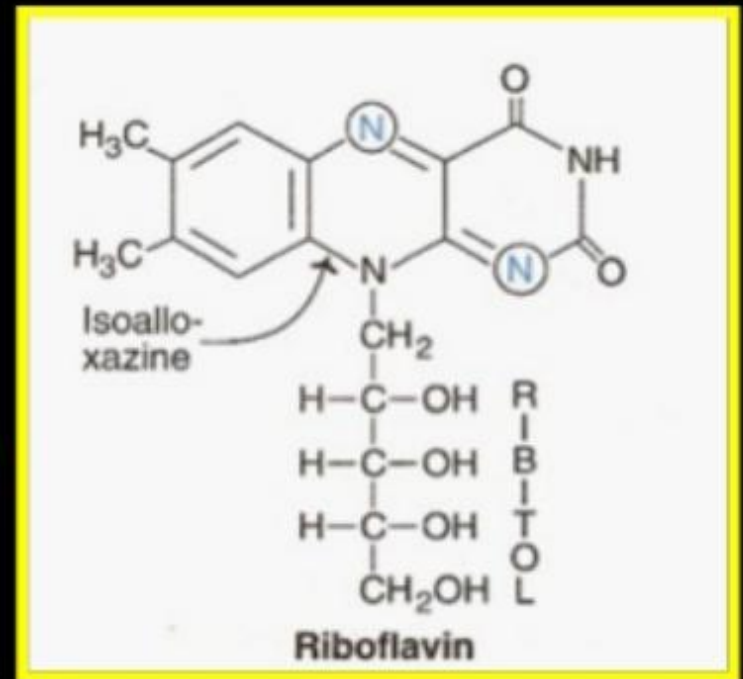


RIBOFLAVIN

- Riboflavin is also known as **Vitamin B₂**

Structure:

- Isoalloxazine ring attached to Ribitol.



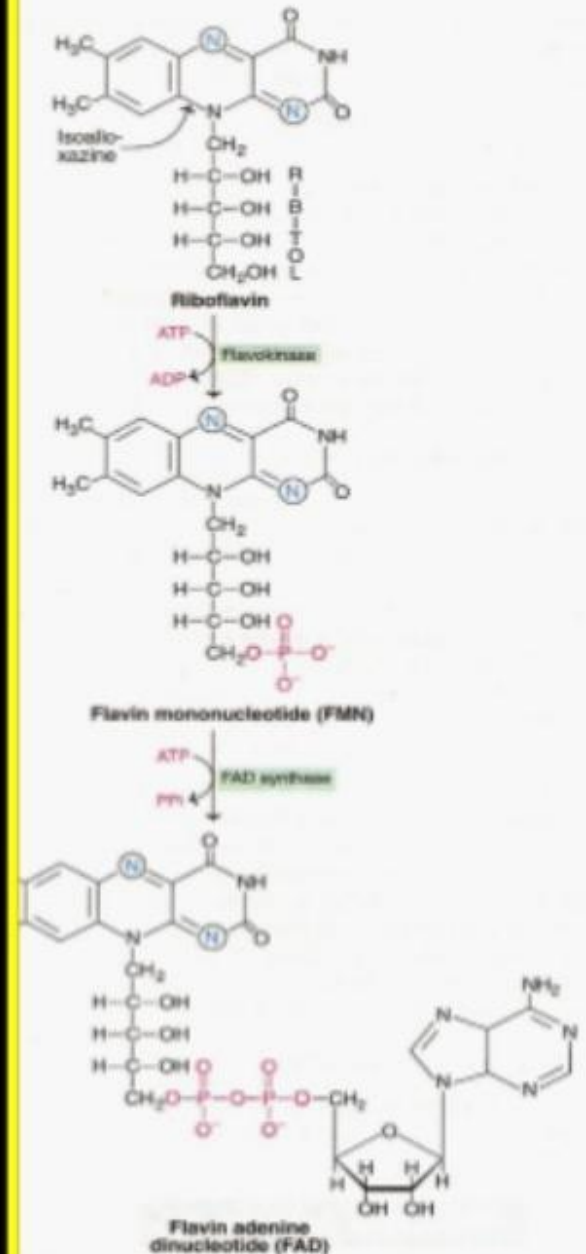
- Stable to heat but **sensitive to light (photosensitive)**.
When exposed to UV rays it gets **destroyed**.

Active Coenzymes of Riboflavin

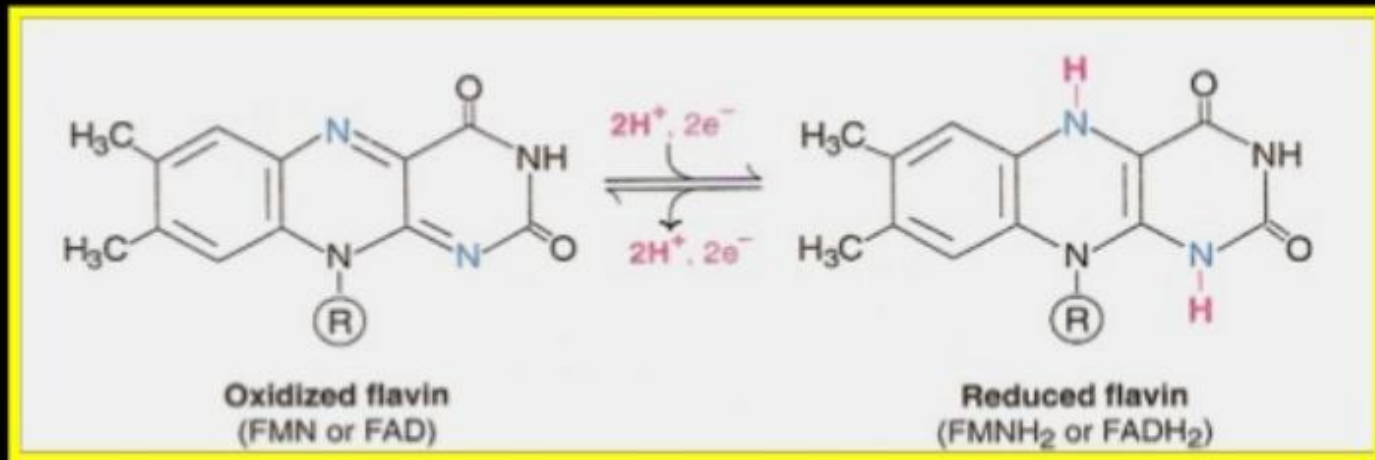
- **FMN:** Flavin mononucleotide
- **FAD:** Flavin adenine dinucleotide



Active forms are formed in the intestine and liver.



Biochemical Functions



- The isoalloxazine ring serves as an acceptor of two hydrogen atoms (with electrons)



- The coenzymes FMN(FMNH₂) and FAD(FADH₂) participate in many oxidation reduction reactions and in the Electron Transport Chain.

Causes of Deficiency

- **Phototherapy:** Riboflavin being light sensitive gets destroyed.
- **Chronic Alcoholics:**
- **Pregnancy and Lactation:** There is increased demand of Riboflavin.

Deficiency Manifestation

- **Glossitis:** Smooth and purplish tongue.
- **Dermatitis:** Inflammation of the facial skin in particular.
- **Cheilosis:** Fissures at the corner of the mouth

Vitamin B2/Riboflavin

Dietary Sources of Riboflavin

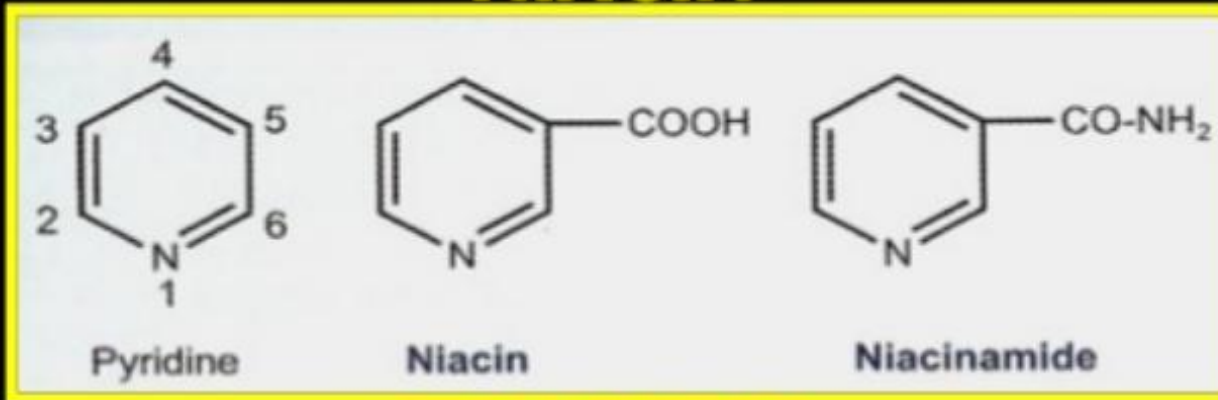
- Rich sources are **liver, dried yeast, egg and whole milk**
- Good sources are **fish, whole cereals, legumes and green leafy vegetables**

Daily Requirement

- Riboflavin is concerned mainly in the metabolism of carbohydrates and requirement is **related to calorie intake**
- Adults on sedentary work require about **1.5 mg per day**.
- During pregnancy, lactation and old age, **additional 0.2 to 0.4 mg /day are required**.



NIACIN



STRUCTURE

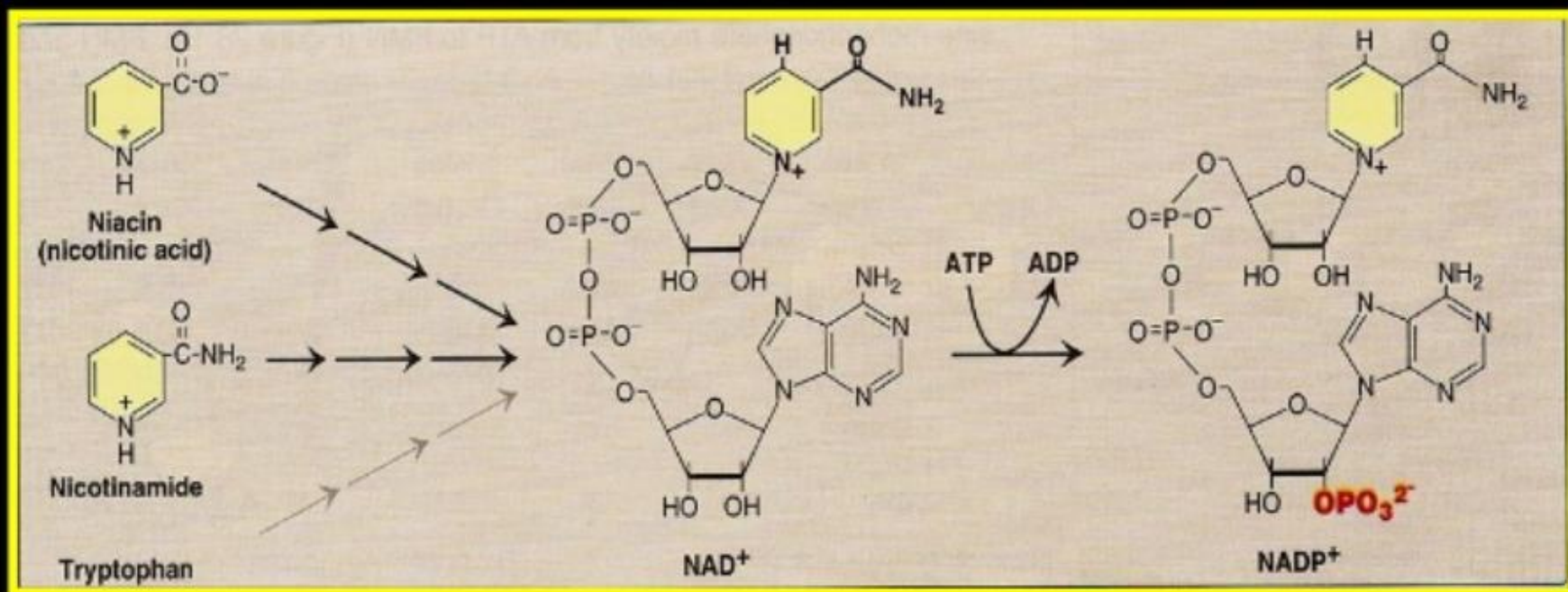
- Niacin is also known as **Vitamin B₃**.
- Niacin (nicotinic acid) is a **Pyridine derivative**.
- The **amide** form of niacin is known as **Niacinamide** or **Nicotinamide**

“Synthesized endogenously from Tryptophan”.



“60 mg of Tryptophan forms 1mg of Niacin”

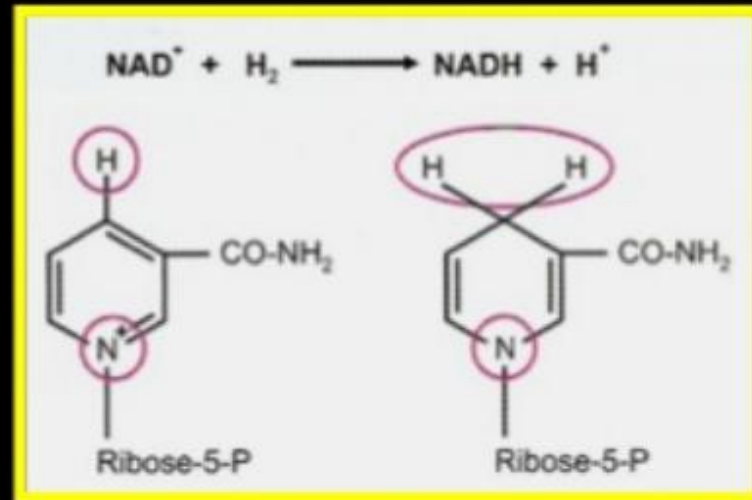
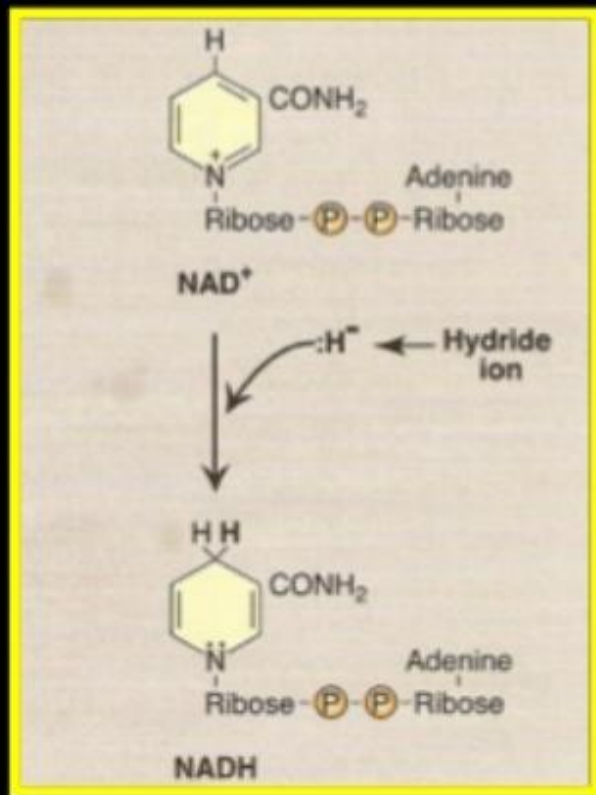
Active Coenzyme forms of Niacin



- Two active coenzymes: Formed in the Liver

NAD⁺ = Nicotinamide adenine dinucleotide.

NADP⁺ = Nicotinamide adenine dinucleotide phosphate



- NAD^+ and NADP^+ are present in oxidized and reduced forms. They undergo reduction of the pyridine ring by accepting Hydride ion (hydrogen atom plus electron)



Biochemical Functions

- The Coenzymes NAD^+ (NADH) and NADP^+ (NADPH) are involved in **oxidation–reduction reactions** in carbohydrate, lipid and protein metabolisms.

Therapeutic doses of Niacin 'lowers blood cholesterol' and causes vasodilatation.

Causes of Niacin Deficiency

- **Inadequate Diet:** Seen in people whose **staple diet is maize**. In maize, niacin is present but in the **bound form** and is unavailable.
- **Pregnancy and Lactation:** Because of increased demand.
- **Chronic Alcoholics:**
- **Vitamin B₆ deficiency:**

Deficiency Manifestation

- Deficiency of Niacin leads to the clinical condition called **pellagra**(=rough skin)

Pellagra is characterized 3 D's:

- **Dermatitis:** Bright red pigmentation occurs which later turns dark resulting in disfiguration of the skin.



- **Diarrhea:** Mild to sever with blood and mucous.
- **Dementia:** Involvement of the nervous system. Irritability, delirium, and poor memory.

Vitamin B3/Niacin

Dietary Sources of Niacin

- The richest natural sources of niacin are **dried yeast, rice polishing, liver, peanut, whole cereals, legumes, meat and fish**
- About **half** of the requirement is met by the **conversion of tryptophan to niacin**
- About 60 mg of tryptophan will yield 1 mg of niacin

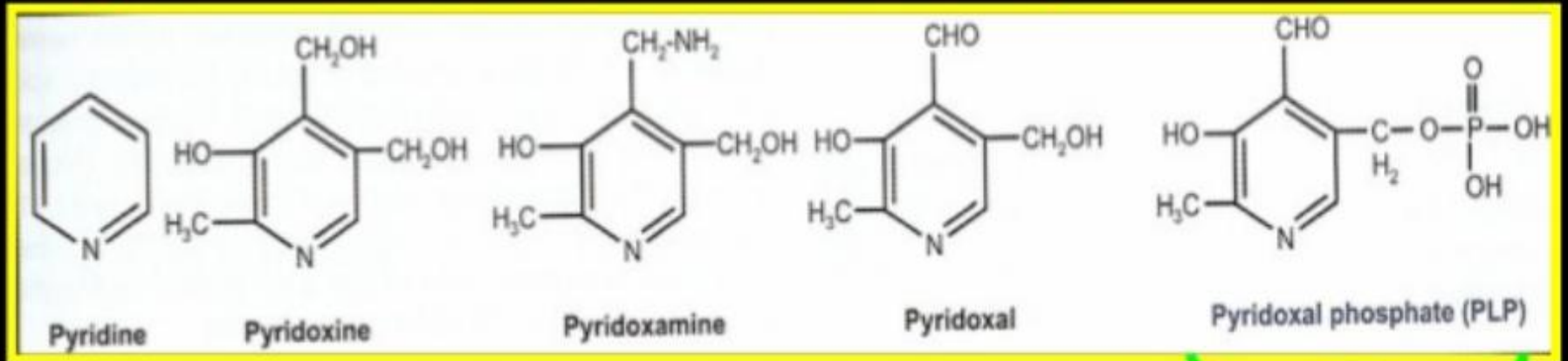


Recommended Daily Allowance (RDA)

Normal requirement is 20 mg/day. During lactation, additional 5 mg are required

PYRIDOXINE

- Pyridoxine is also known as Vitamin B₆.



Active Form

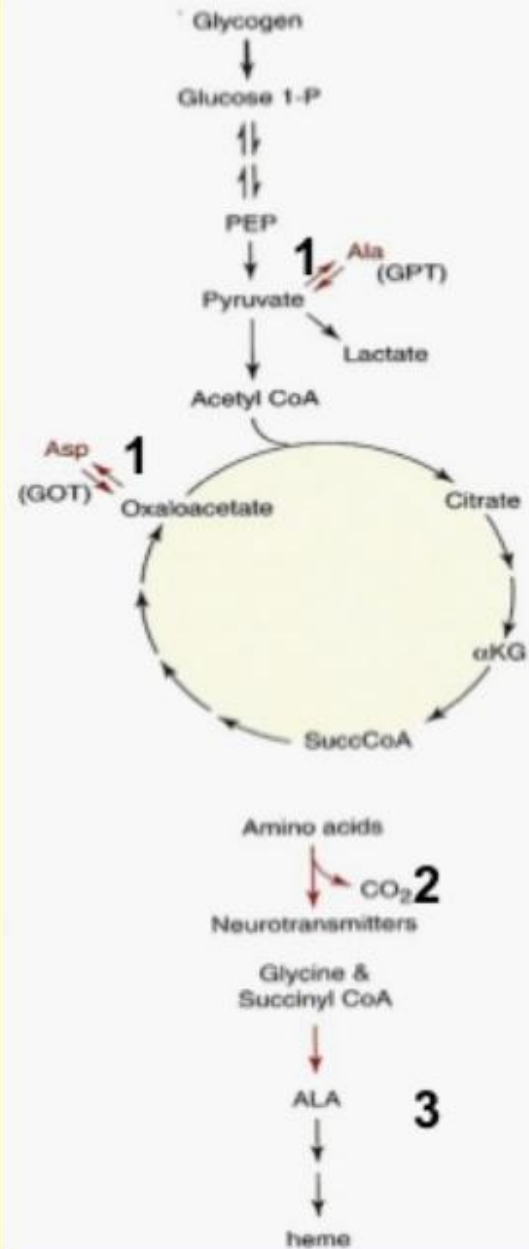
- Vitamin B₆ is used to collectively represent three compounds namely pyridoxine, pyridoxal and pyridoxamine. Structurally they are pyridine derivatives

The active Coenzyme form of B₆ is Pyridoxal Phosphate (PLP) which is synthesized in the intestine from all the three forms.

Biochemical Functions

- Pyridoxal Phosphate (PLP) the active coenzyme form of Vitamin B₆ is closely associated with the metabolism of Amino acids.

1. Transamination.
2. Decarboxylation.
3. Heme synthesis.
4. Deamination.
5. Production of Niacin



Causes of Deficiency

- **Isoniazid:** Antituberculous drug which inhibits pyridoxal phosphate formation.
- **Oral Contraceptive Pills:** Binds to pyridoxal phosphate and inactivate it .

Deficiency Manifestation

- **Neurological Manifestation:**
Convulsions and Demyelination of the nerves
- **Dermatological Manifestation:**
Pellagra because Niacin is not formed from Tryptophan.
- **Hematological Manifestation:**
Hypochromic Microcytic **Anemia** due to inhibition of Heme synthesis.

Vitamin B6/Pyridoxine

Dietary Sources of Vitamin B6

- Rich sources are yeast, rice polishing, wheat germs, cereals, legumes (pulses), oil seeds, egg, milk, meat, fish and green leafy vegetables

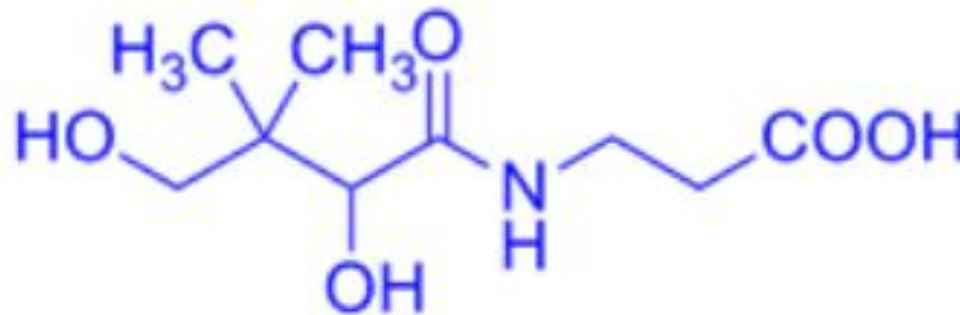
Requirement of B6

- recommended that adults need 1 to 2 mg/day.
During pregnancy and lactation, the requirement is increased to 2.5 mg/day.



Vitamin B5/Pantothenic Acid

- The Greek word “pantos” means everywhere
- As the name suggests, it is widely distributed in nature
- Pantothenic acid contains beta alanine and D-pantoic acid in amide linkage



Pantothenic acid

Vitamin B5/Pantothenic Acid

Co-enzyme Activity of Pantothenic Acid

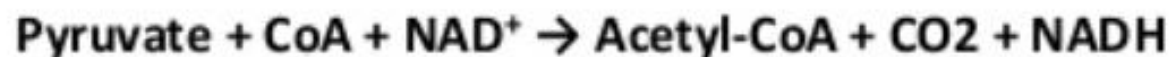
- The beta mercaptoethanol amine ($\text{NH}_2\text{-CH}_2\text{-CH}_2\text{-SH}$) contains one thiol or sulfhydryl ($-\text{SH}$) group
- It is the active site where acyl groups are carried
- Therefore the co-enzyme A is sometimes abbreviated as CoA-SH to denote this active site
- The thio ester bond in acyl-CoA is a high energy bond
- These acyl groups are transferred to other acceptors, for example:

Acetyl CoA + Choline \rightarrow Acetyl choline + CoA (enzyme is acetyl choline synthase)

Vitamin B5/Pantothenic Acid

Co-enzyme Activity of Pantothenic Acid

- Acyl groups are also accepted by the CoA molecule during the metabolism of other substrates, for example:



(Enzyme is pyruvate dehydrogenase)

- The important CoA derivatives are:
 - a) Acetyl CoA
 - b) Succinyl CoA
 - c) HMG CoA
 - d) Acyl CoA.

Vitamin B5/Pantothenic Acid

Deficiency of Pantothenic Acid

- paresthesia (burning, lightning pain) in lower extremities, staggering gait due to impaired coordination and sleep disturbances
- These deficiency manifestations are rare in human beings
- The syndrome is seen during famine, in prison camps, in chronic alcoholics and in some renal dialysis patients
- In experimental animals, deficiency has resulted in anemia (due to reduced heme synthesis from succinyl CoA), reduced steroidogenesis (due to lack of acetyl CoA), dermatitis, fatty liver and adrenal necrosis.

Vitamin B5/Pantothenic Acid

Sources of Pantothenic Acid

- It is widely distributed in plants and animals
- Moreover, it is synthesized by the normal bacterial flora in intestines
- Therefore, deficiency is very rare
- Yeast, liver and eggs are good sources

Requirement of Pantothenic Acid

- RDA is assumed to be about 10 mg/day



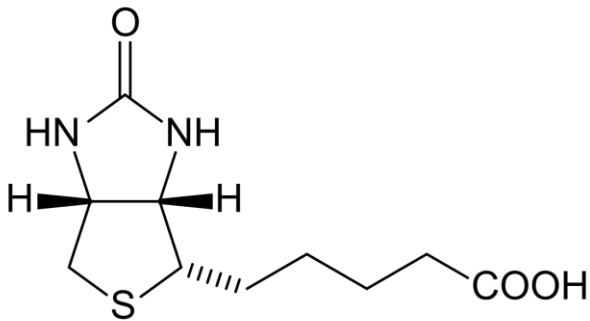
Vitamin B7 / Biotin

Co-enzyme Activity of Biotin

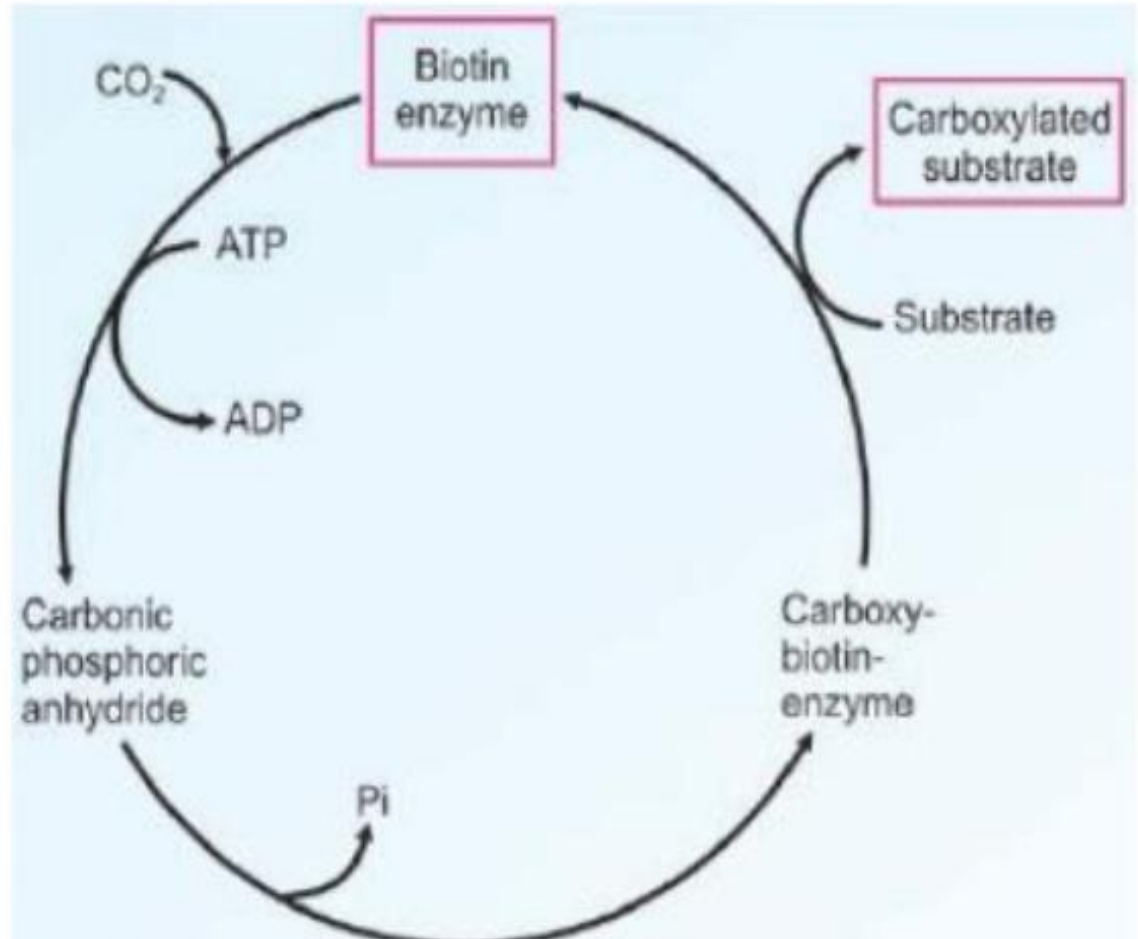
- Biotin acts as co-enzyme for **carboxylation reactions**
- Biotin captures a molecule of CO₂ which is **attached to nitrogen of the biotin molecule**
- The **energy required** for this reaction is provided by ATP
- Then the **activated carboxyl group is transferred** to the substrate.

Vitamin B7/Biotin

Co-enzyme Activity of Biotin



BIOTIN

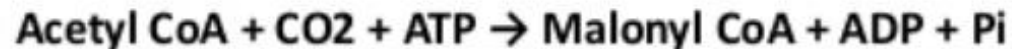


Vitamin B7/Biotin

Biotin Requiring CO₂ Fixation Reactions

Acetyl CoA carboxylase

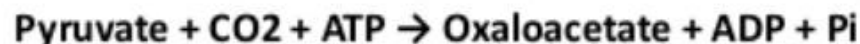
- This enzyme adds CO₂ to acetyl CoA to form malonyl CoA
- This is the rate limiting reaction in biosynthesis of fatty acids



Propionyl CoA carboxylase



Pyruvate carboxylase



- This is important in two aspects. One, it provides the oxaloacetate, which is the catalyst for TCA cycle
- Second, it is an important enzyme in the gluconeogenic pathway

Vitamin B7/Biotin

Deficiency of Biotin

- Prolonged use of antibacterial drugs
- Biotin deficiency symptoms include dermatitis, atrophic glossitis, hyperesthesia, muscle pain, anorexia and hallucinations
- Injection of biotin 100-300 mg will bring about rapid cure of these symptoms.

Vitamin B7/Biotin



Requirement of Biotin

- About 200-300 mg will meet the daily requirements.

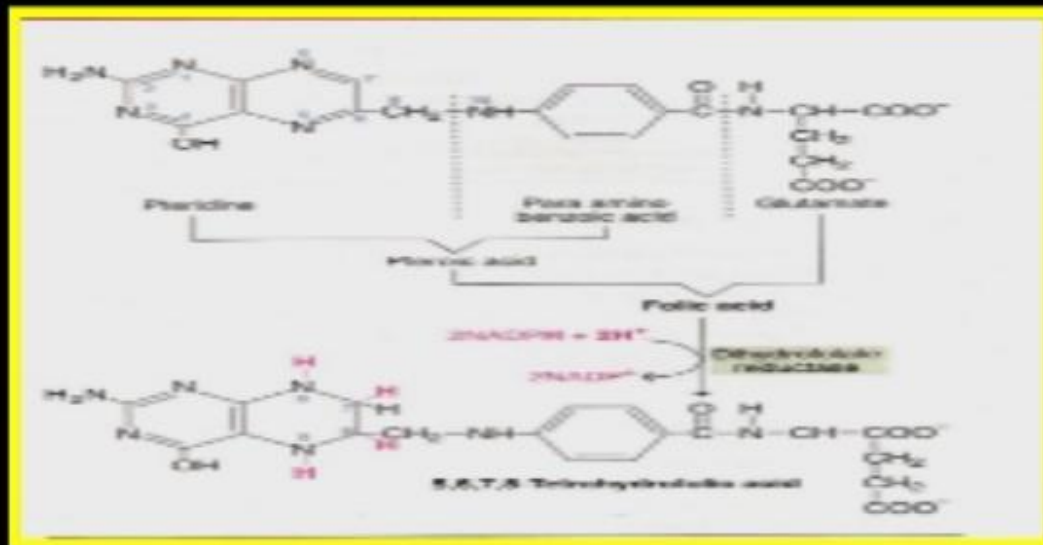
Sources of Biotin

- Normal bacterial flora of the gut will provide adequate quantities of biotin
- Moreover, it is distributed ubiquitously in plant and animal tissues
- Liver, yeast, peanut, soybean,
- milk and egg yolk are rich sources

FOLIC ACID

- Folic Acid Deficiency is the most common vitamin deficiency particularly among pregnant female.

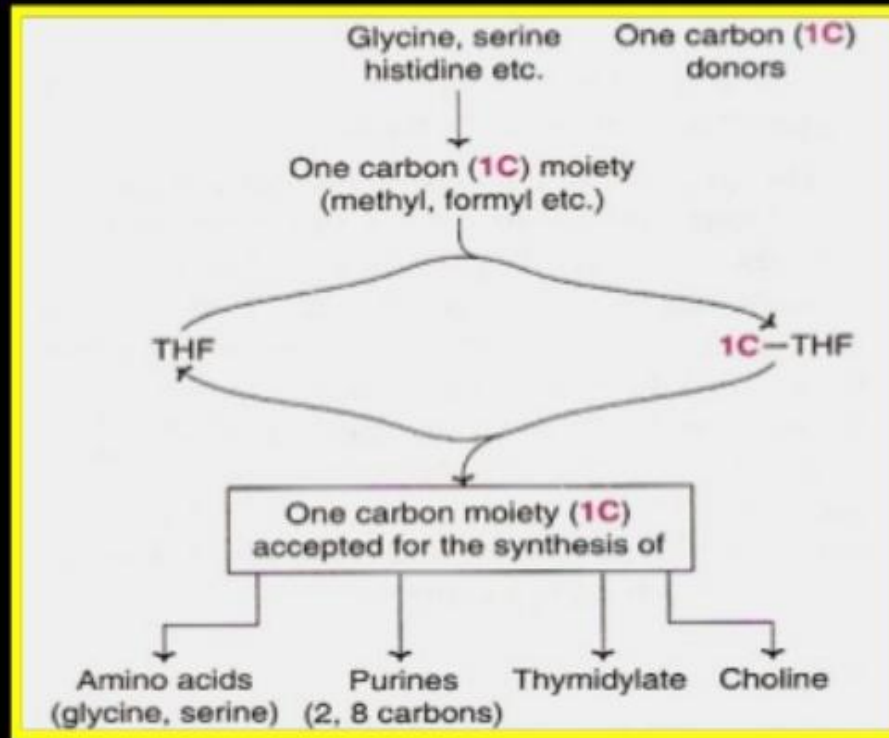
Structure and Active Form



- It is composed of three constituents. Pteridine linked with para-aminobenzoic acid (PABA) is called Ptericoic acid.
- It is then attached to glutamate to form Folic Acid. Active form is Tetrahydrofolic Acid (THF)

Biochemical Functions

- The active coenzyme tetrahydrofolate (THF) is involved in **One Carbon Metabolism**.
- THF serves as **acceptor or donor** of one carbon units (formyl, methyl etc.) in a variety of reactions involving **amino acid and nucleotide metabolism**.



• One carbon compound is an organic molecule that contains **only a single carbon**

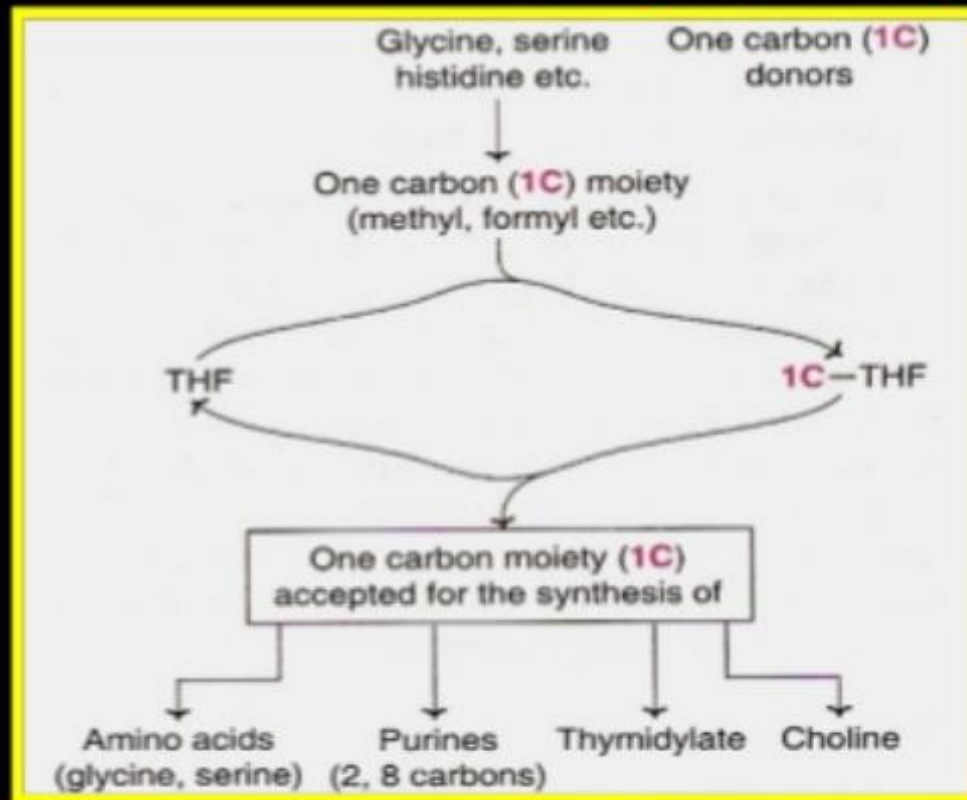
- Methyl (- CH₃)

- Methenyl (- CH=)

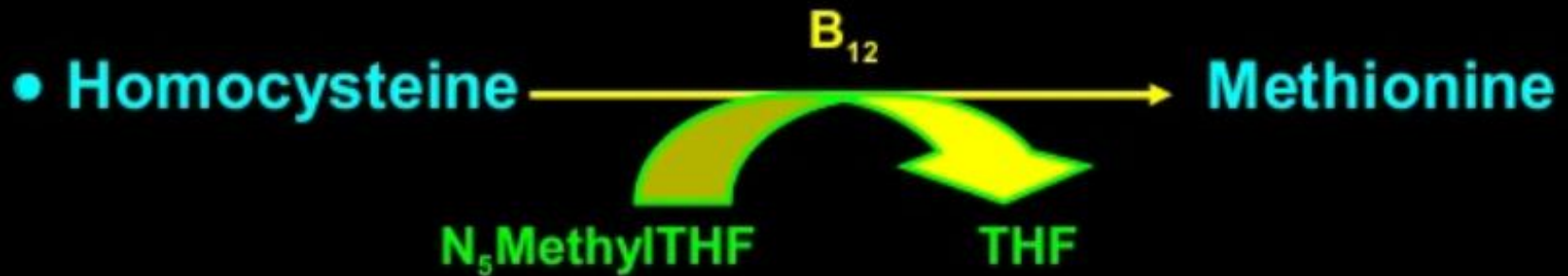
- Methylene (- CH₂-)

- Formyl (- CHO)

Form Different analogs of THF



- **C₂ and C₈ of Purine** \longrightarrow **Incorporated into DNA**
- **Synthesis of choline: For phospholipids and Acetylcholine**



Causes of Deficiency

- **Pregnancy:** Increased requirement because of fast cell division.
- **Diet:** Absence of vegetables in the diet.
- **Drugs:** Methotrexate (anti-cancer drug) inhibits Dihydrofolate reductase so no active THF formed.
- **B₁₂ deficiency**

Deficiency Manifestation

- **Macrocytic Anemia** (large distorted RBC with immature nucleus) with megaloblasts in bone marrow.
- **Neural Tube Defects:** Folic acid deficiency during early pregnancy may lead to neural tube defects (Spina Bifida) in the fetus.



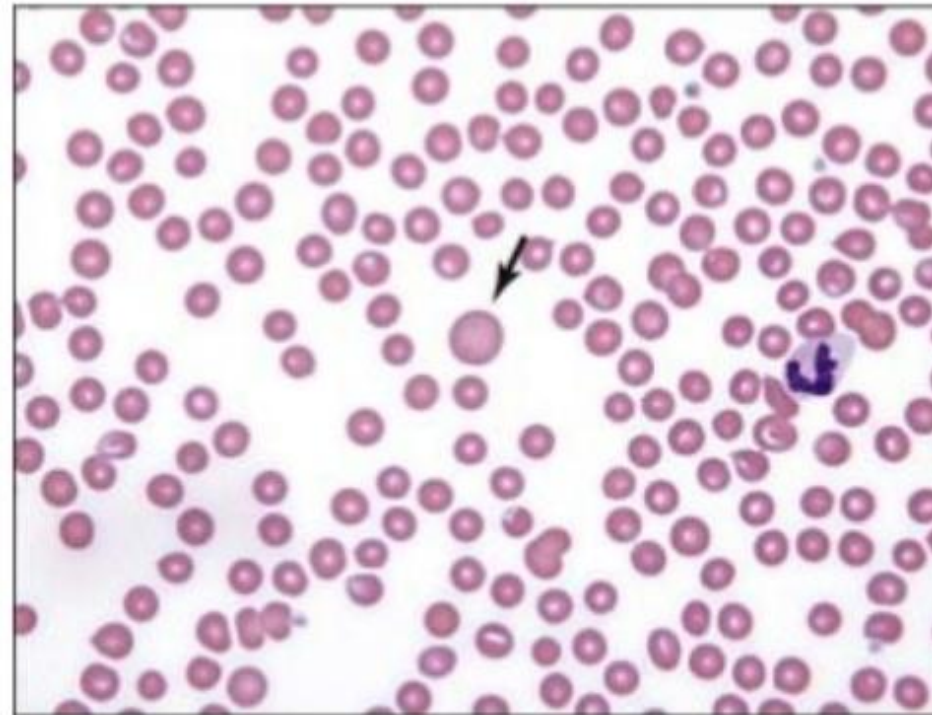
The hematological picture resembles Vitamin B₁₂ deficiency.

Vitamin B9/Folic Acid

Deficiency Manifestations

Macrocytic Anemia

- **Reticulocytosis** is a condition where there is an increase in reticulocytes, immature red blood cells
- These abnormal RBCs are **rapidly destroyed in spleen**
- This hemolysis leads to the **reduction of lifespan of RBC**
- **Reduced generation and increased destruction of RBCs result in anemia.**



Vitamin B9/Folic Acid

Sources of Folic Acid

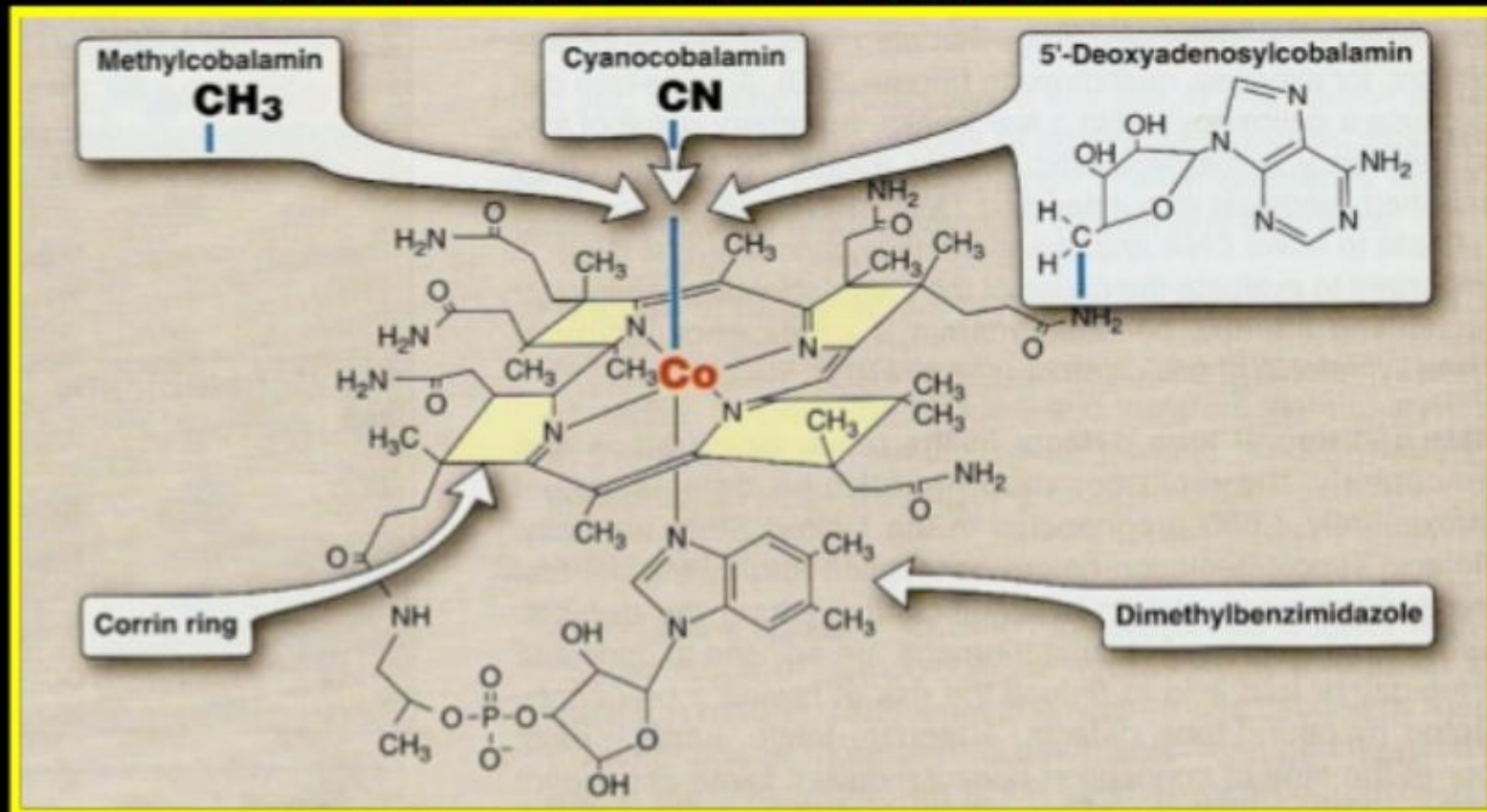
- Rich sources of folate are yeast, green leafy vegetables
- Moderate sources are cereals, pulses, oil seeds and egg
- Milk is a poor source for folic acid.



Vitamin B₁₂

- Vitamin B₁₂ is also known as Cobalamin

Structure and Active form

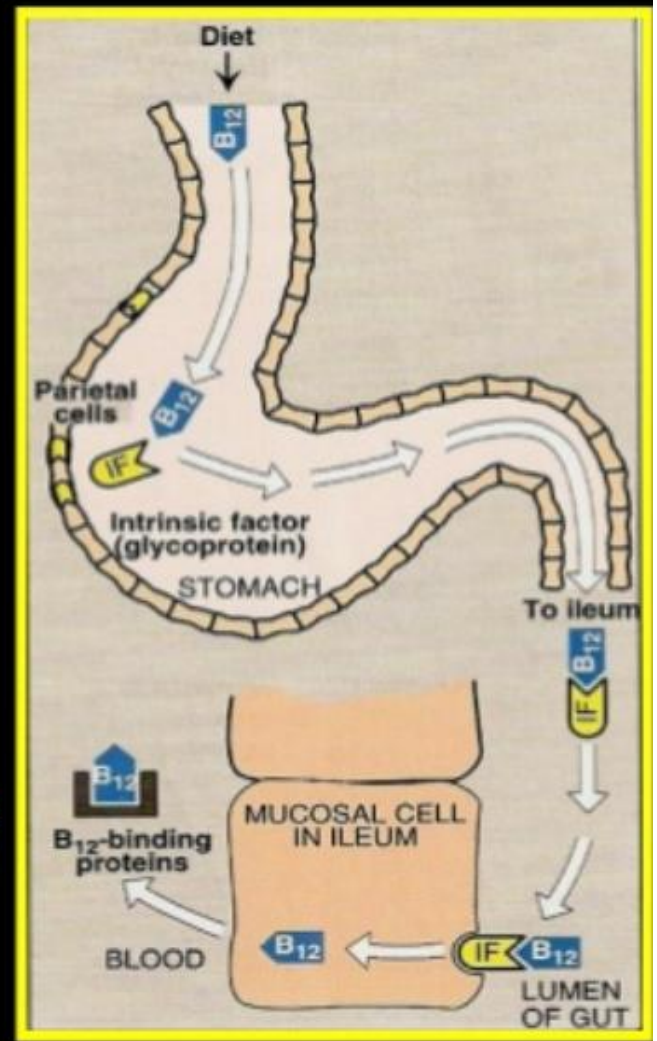


- Cobalamin contains a **corrin ring** with four pyrrole rings and **COBALT** at the centre.

- There are two active coenzyme form:
 - Deoxyadenosyl Cobalamin:
 - Methylcobalamin

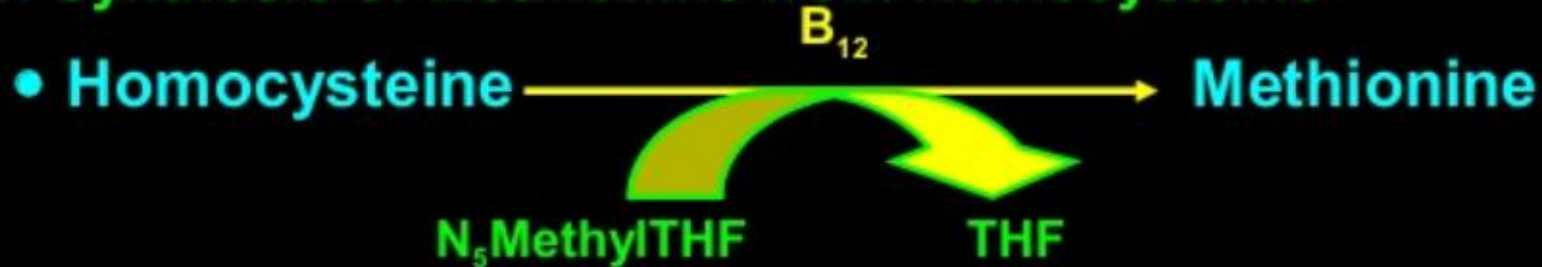
Absorption and Storage

- Absorption of Vitamin B₁₂ requires a glycoprotein known as **intrinsic factor** produced in the **stomach** in presence of **HCL**.
- Stored in the **liver** in the form of **Deoxyadenosyl Cobalamin**.



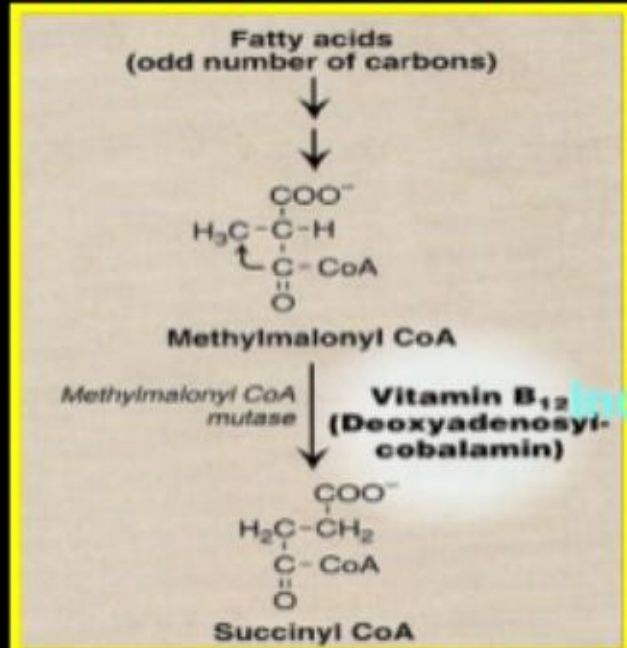
Biochemical Functions

1. Synthesis of Methionine from Homocysteine



- Thus B_{12} deficiency results in decreased THF that leads to reduced nucleotide and DNA synthesis.

2. Isomerization of Methyl malonyl CoA:



Causes of Deficiency

- **Vegetarians:** Vitamin B₁₂ is mainly present in animal diet.
- **Decreased Absorption:** Due to Gastrectomy and malabsorption diseases.
- **Pernicious Anemia:** Antibodies are formed against Intrinsic Factor leading to decreased absorption of Vitamin B₁₂.
- **Pregnancy, lactation and alcoholics:**

Deficiency Manifestation

- **Megaloblastic Anemia:** The peripheral blood shows Megaloblasts with large immature nucleated RBC.
- **Nervous Manifestation:** Degeneration of nervous system due to demyelination.

Vitamin C

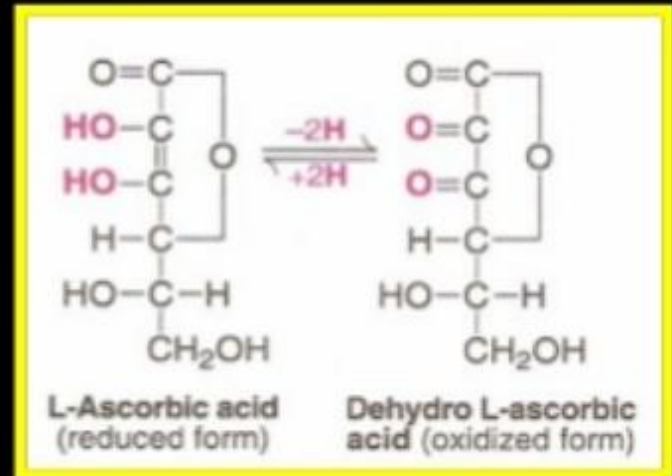
- **Ascorbic acid (Toxic to viruses, bacteria, and some malignant tumor cells)**
- **Antioxidant**
- **water-soluble**



Vitamin C

- Vitamin C is also known as **Ascorbic Acid**
- Structurally vitamin C resembles a **carbohydrate (hexose)**.

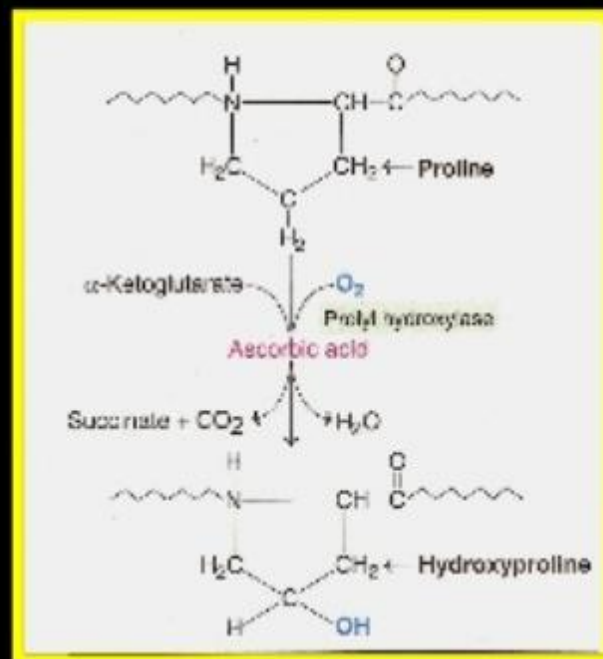
- **Heat sensitive** and gets destroyed by cooking. In the process of cooking 70% of vitamin C is lost.



- Does not have any active coenzyme form but acts as a **strong reducing agent**.

Biochemical Functions

- Collagen formation:



- Vitamin C is required for hydroxylation of proline and lysine. The hydroxyproline and hydroxylysine formed are essential for the collagen cross-linking and the strength of the fibre.

- **Antioxidant Role:** Vitamin C acts as an **antioxidant** preventing tissue injury due to oxidative damage by free radicals:

- Fights infection.
- Reduces the risk of cancer and coronary artery disease.

- **Immunological Function:** Vitamin C enhances the synthesis of **Immunoglobulins** (antibodies) and increases the **phagocytic functions** of leukocytes.

Deficiency Manifestations

Clip slide

Deficiency is manifested as **Scurvy** which is characterized by:

- Hemorrhages under the skin, bone fragility, joint pain.
- Poor wound healing, frequent infections.
- Spongy and bleeding gums, loosened teeth.



Dietary Source Of Vitamin C/Ascorbic Acid

- Rich sources are **amla** (Indian gooseberry) (700 mg/100 g), **guava** (300 mg/100 g), lime, **lemon** and **green leafy vegetables**

Requirement of Vitamin C

- Recommended daily allowance is **75 mg/day** (equal to 50 ml orange juice)
- During pregnancy, lactation, and in aged people requirement may be **100 mg/ day**.

