

# VITAMINS



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# INTRODUCTION

- ❖ The word "**vitamin**" comes from the Latin word "**vita**", means "**life**".
- ❖ **Vitamins are organic components in food that are needed in very small amounts for growth and for maintaining good health.**



# FEATURES AND CHARACTERISTICS

- ❖ Vitamins are required in small quantities in the diet because they cannot be synthesized by the body.
- ❖ Water soluble vitamins cannot be stored in human tissues. Their excess is excreted with urine.
- ❖ Significant amounts of fat soluble vitamins can be stored in adipose tissue and the liver.
- ❖ Synthetic vitamins are identical to natural vitamins.
- ❖ Once growth and development are completed, vitamins remain essential nutrients for the healthy maintenance of the cells, tissues, and organs.

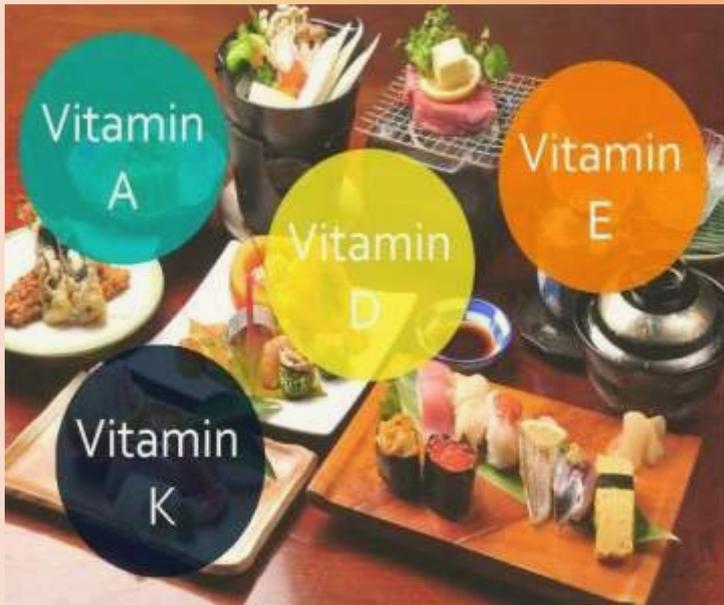
# FUNCTIONS

- ❖ They build up the **immunity** of the body.
- ❖ Prevent and cure various diseases caused by deficiency.
- ❖ Helps in body's metabolism.
- ❖ Stimulate and give strength to digestive and nervous system.
- ❖ Help maintenance of proper health and normal growth.

# CLASSIFICATION

- On the basis of their **solubility** vitamins are mainly 2 types:

## *Fat soluble vitamins*



## *Water soluble vitamins*



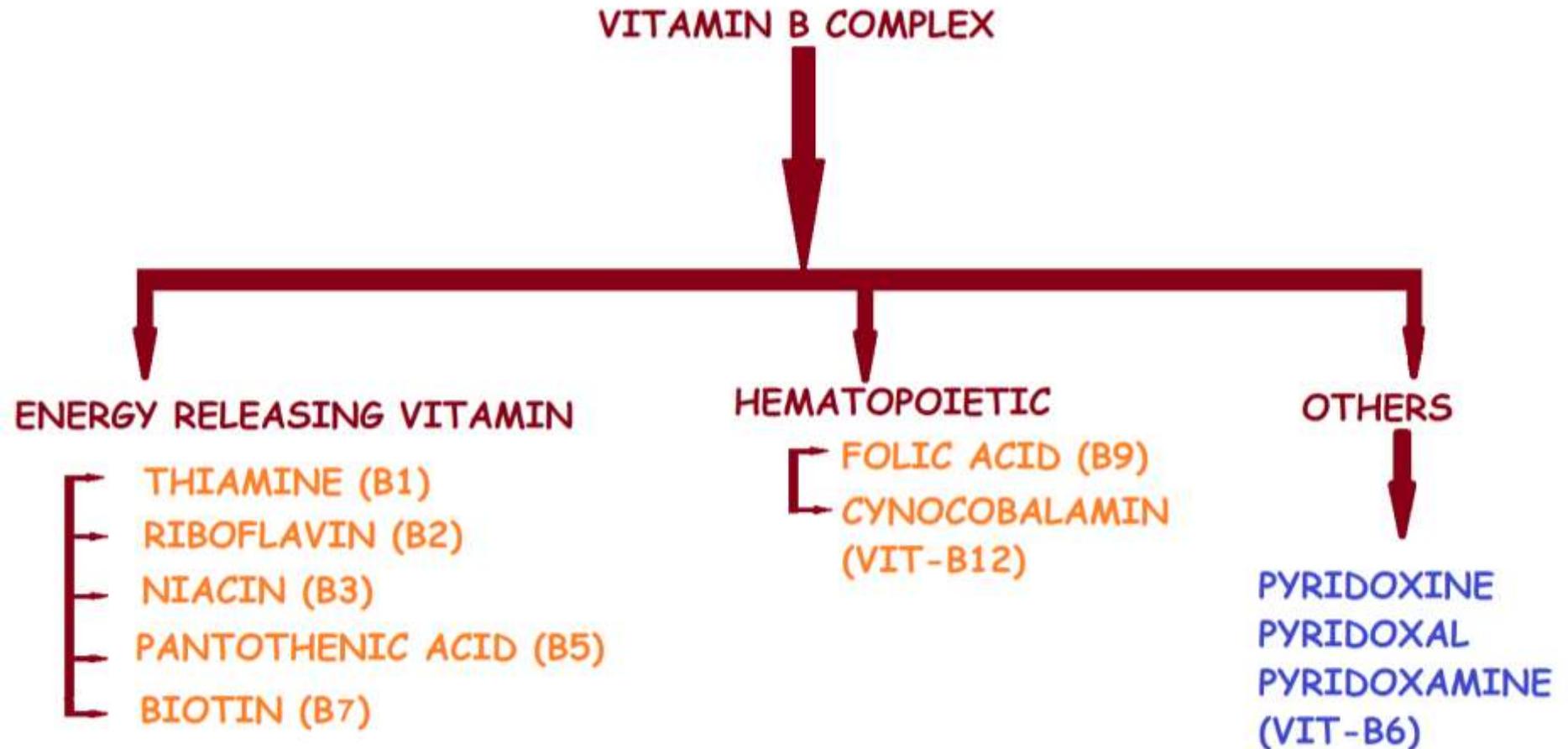


# **WATER SOLUBLE VITAMINS**

# WATER SOLUBLE VITAMINS

- Water soluble vitamins are found in yeast, grain, rice, vegetables, fish, and meat.
- These are essential co-enzymes required in energy releasing mechanisms.
- They also act as co-enzymes for metabolism of proteins, carbohydrates and fats.

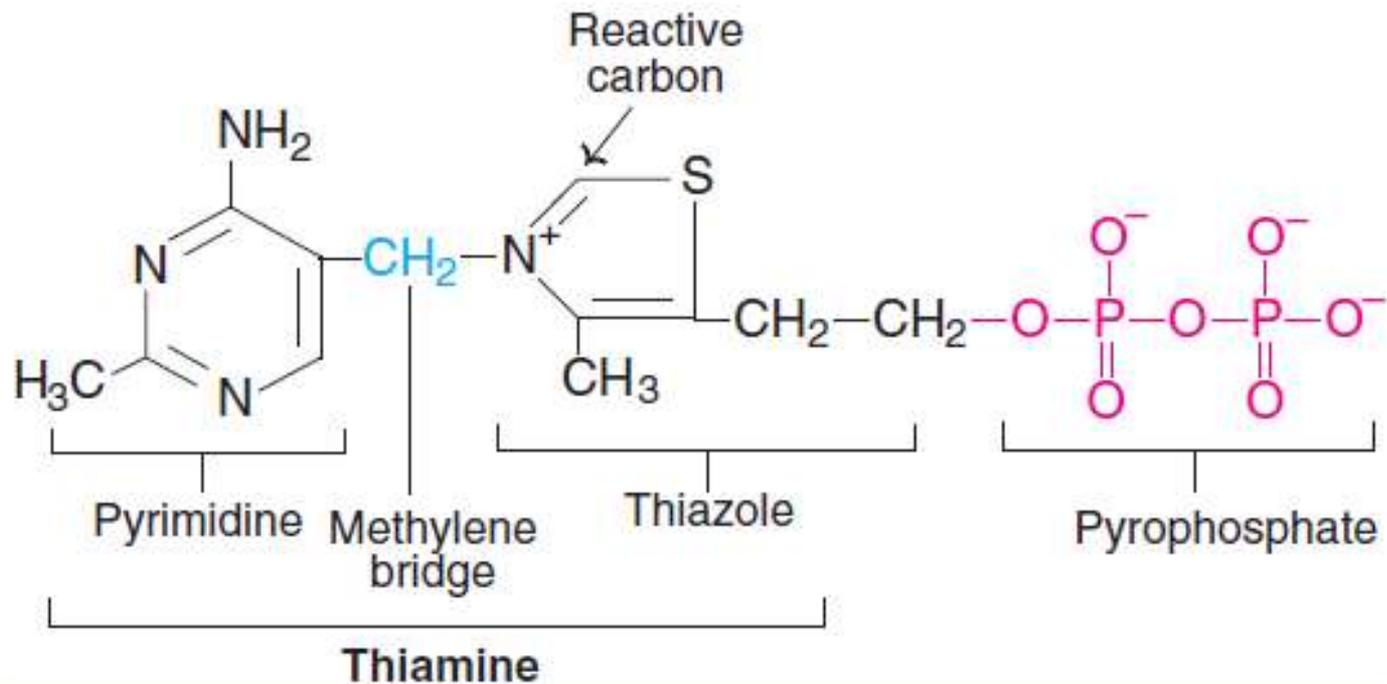
# Vitamin B complex include-



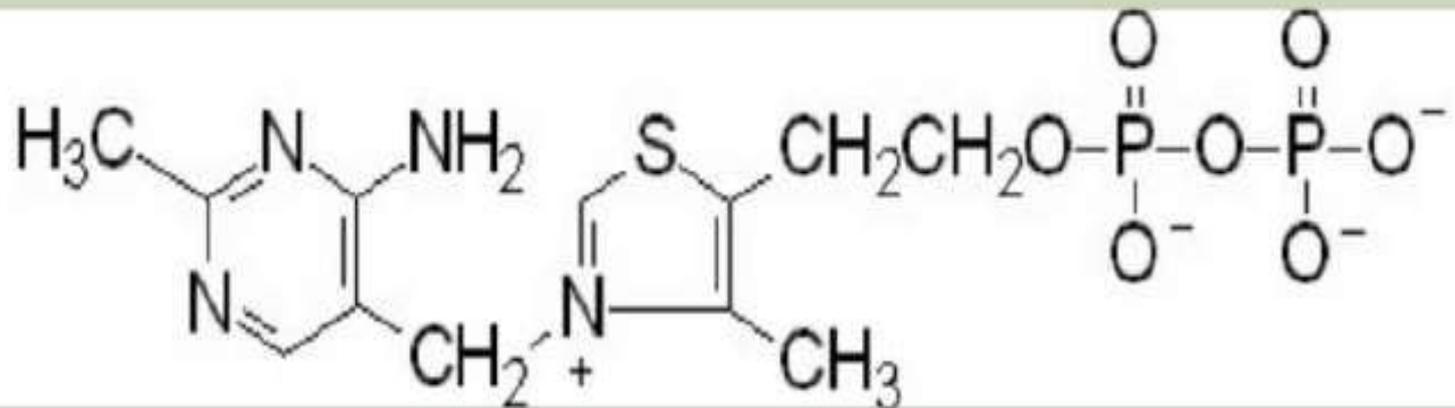
# ***VITAMIN B1 (THIAMINE)***

- It is also called **Anti Beri-Beri factor, Anti Neuritic factor, and** also **Aneurin**.
- It is colorless basic organic compound composed of a sulfated pyramiding ring.
- All living organisms use thiamine, but it is synthesized only in bacteria, fungi, and plants.
- Contains sulfur and nitrogen group
- Destroyed by alkaline and heat
- Coenzyme: Thiamin pyrophosphate (TPP)

# STRUCTURE OF VITAMIN B1 (THIAMINE)



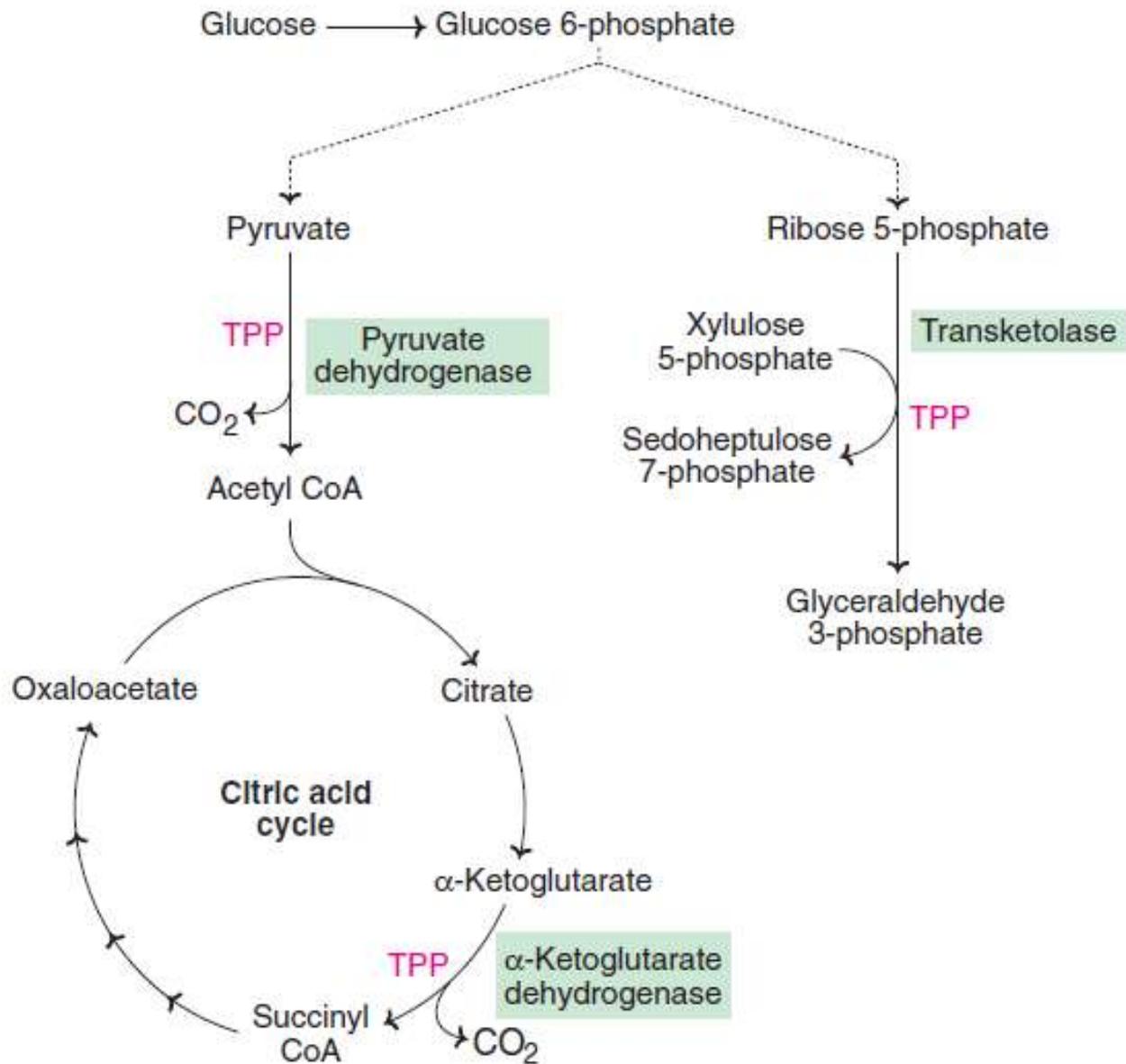
*Fig. 7.17 : Structures of thiamine and thiamine pyrophosphate (TPP).*



Thiamin pyrophosphate (TPP or TDP) is the active form of thiamine.

# ***FUNCTIONS OF THIAMINE***

- The coenzyme, thiamine pyrophosphate or cocarboxylase is intimately connected with the energy releasing reactions in the carbohydrate metabolism.
- The most important use of thiamine is in the treatment of beriberi.
- TPP plays an important role in the **transmission of nerve impulse**.
- It helps in the digestion of food.
- It provides strength to muscles.
- It is very useful for the proper functioning of heart.



*Fig. 7.18 : Summary of the reactions dependent on thiamine pyrophosphate (TPP).*

# RECOMMENDED DIETARY ALLOWANCE (RDA)

**The daily requirement of thiamine depends on the intake of carbohydrate.**

A dietary supply of 1-1.5 mg/day is recommended for adults (**about 0.5 mg/1000 K cal of energy**).

For children RDA is 0.7-1.2 mg/day.

The requirement marginally increases in pregnancy and lactation (2 mg/day) old age and alcoholism.

# Normal Range

- **TPP**

173-293mmol/L in erythrocytes

90-140 mmol/L in whole blood

# DIETARY SOURCES OF VITAMIN B1

- 1) Tuna
- 2) Sunflower Seeds
- 3) White Beans
- 4) Black Beans
- 5) Dried and Frozen Peas
- 6) Fresh Peas
- 7) Borlotti (Cranberry) Beans
- 8) Lentil
- 9) Green Beans
- 10) Sesame Seeds



# DEFICIENCY SYMPTOMS

- The deficiency of vitamin B1 results in a condition called **Beri-Beri**.

First described by Takai -

**Beri-Beri** mostly seen in populations consuming exclusively polished rice as staple food.

## The early symptoms of thiamine deficiency

are loss of appetite (anorexia) weakness, constipation, nausea, mental depression, Peripheral neuropathy, irritability etc.

# Types of Beri-Beri

- ❖ Dry
- ❖ Wet
- ❖ Infantile
- ❖ Wernickes-Korsakoff syndrome (cerebral Beri-Beri)
- ❖ polyneuritis

# Dry beri-beri

- This is associated with neurological manifestations resulting in peripheral neuropathy.
- Edema is not commonly seen.
- The muscles become progressively weak and walking becomes difficult.
- The affected individuals depend on support to walk and become bedridden and may even die if not treated.



# Wet Beri – Beri (fluid retention)

**This is characterized** by edema of legs, face, trunk and serious cavities.

- Breathless and palpitation are present.
- The calf muscles are slightly swollen.
- The systolic blood pressure is elevated while diastolic is decreased.
- Fast and bouncing pulse is observed.
- The heart becomes weak and death may occur due to HEART FAILURE



# Infantile Beri-Beri

This is seen in infants born to mothers suffering from thiamine deficiency. The breast milk of these mothers contain low thiamine content.

Infantile beri-beri is characterized by

- ❖ sleeplessness,
- ❖ restlessness,
- ❖ vomiting ,
- ❖ convulsions and
- ❖ bouts of screaming that resemble abdominal colic.
- ❖ Most of these symptoms are due to cardiac dilatation.

# Wernicke – Korsakoff syndrome

This is a disorder mostly seen in chronic alcoholics due to-

- body demands of thiamine increase in alcoholism.
- Insufficient intake or impaired intestinal absorption of thiamine will lead to this syndrome.

It is characterized by

Ophthalmoplegia- rhythmical to and fro motion of the eye balls.

Cerebral ataxia-incoordinated irregular gait

Psychosis & amnesia



# VITAMIN B2 (RIBOFLAVIN)

- The word riboflavin is derived from 2 sources
  - **ribose** – means many ribose sugar found in several vitamins
  - **flavin** – yellow.
- It is widely involved in oxidation- reduction reaction.
- It is also called as beauty vitamin.
- it is yellowish green fluorescent compound soluble in water.

# VITAMIN B2 (RIBOFLAVIN)

- Riboflavin is stable to heat but sensitive to light. When exposed to ultra-violet rays of sunlight, it is converted to **lumiflavin** which exhibits **yellow fluorescence**. So, it is used as food preservative.
- Also called **Warburg Yellow enzyme**.
- The substances **namely**
  - ✓ **lactoflavin** (from milk),
  - ✓ **hepatoflavin** (from liver)
  - ✓ **ovoflavin** (from eggs) are also similar to riboflavin.

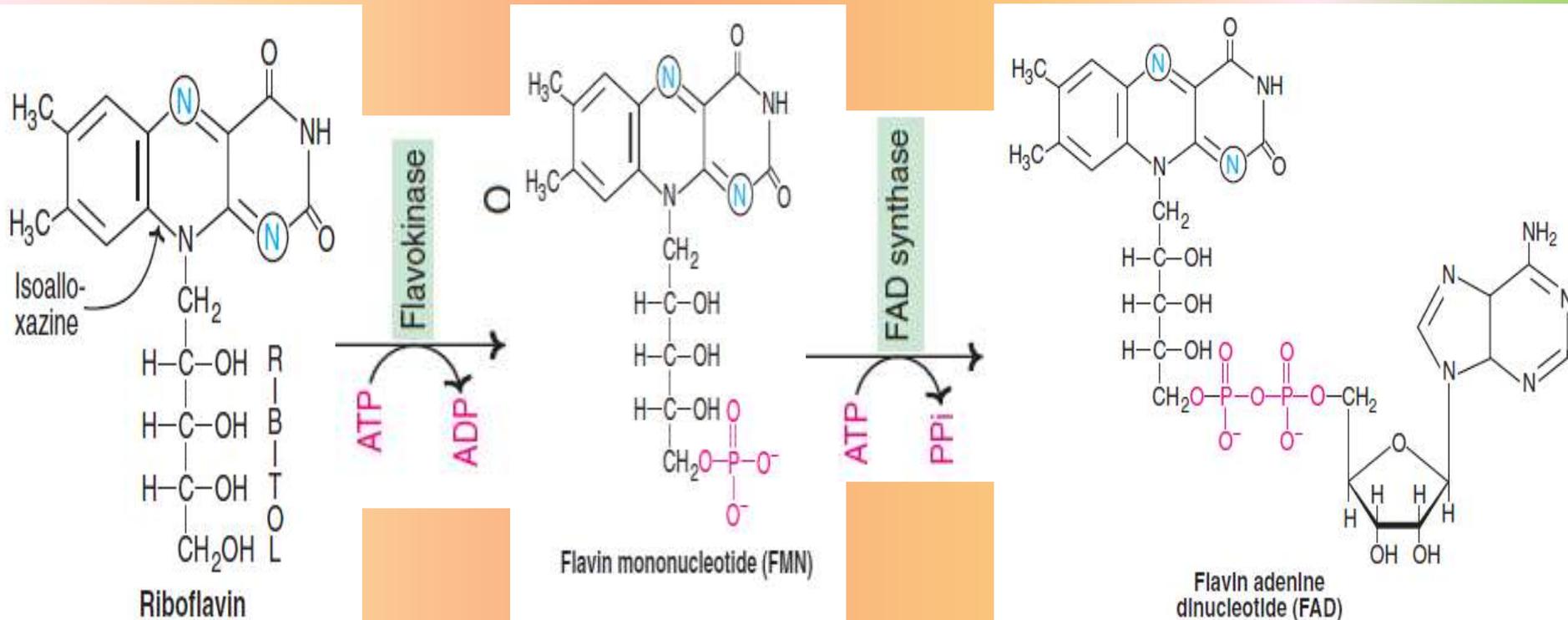
# VITAMIN B2 (RIBOFLAVIN)

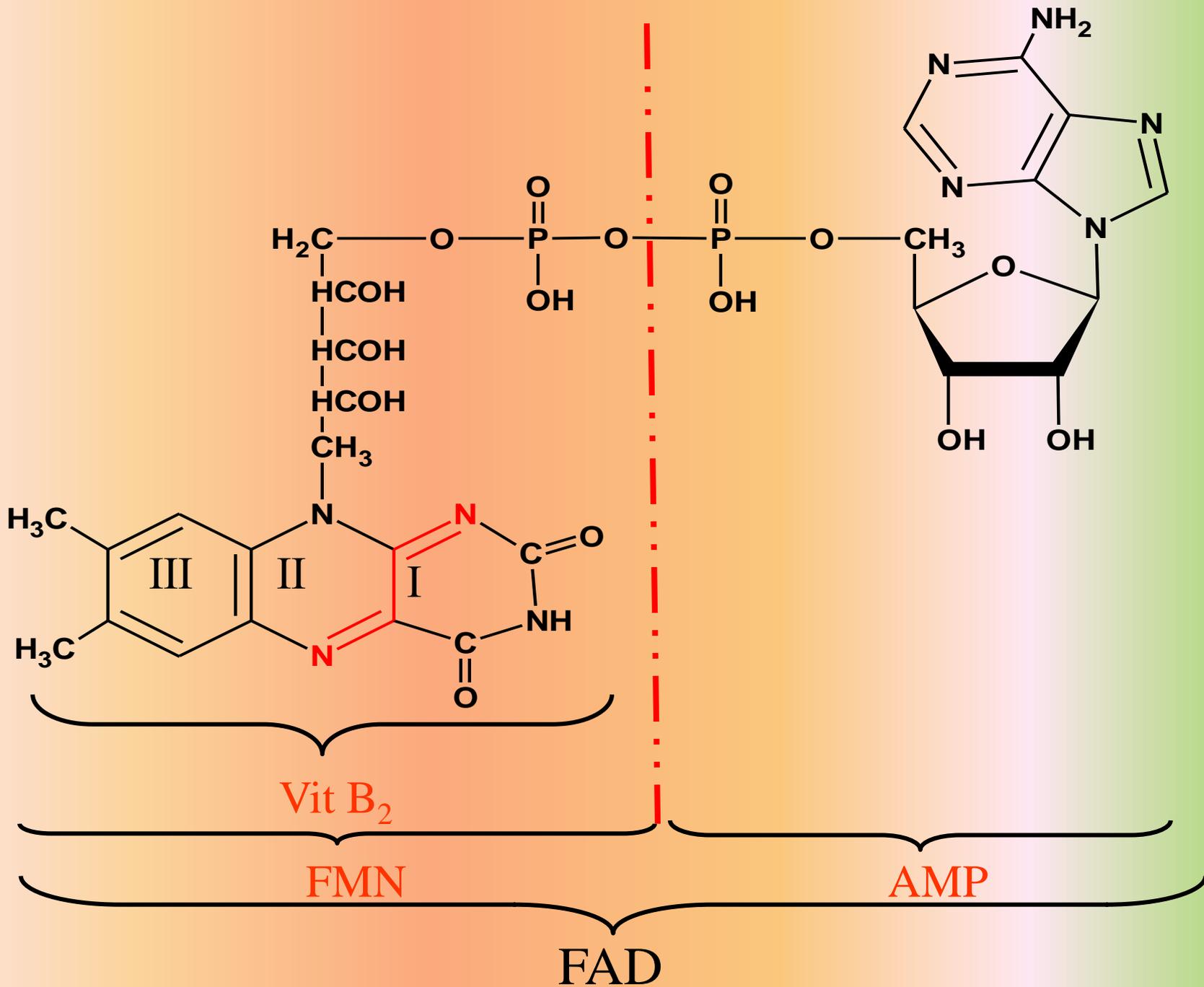
Its active forms:

- ❖ Flavin mononucleotide (FMN)
- ❖ Flavin adenine dinucleotide (FAD)

# RIBOFLAVIN CHEMISTRY

- Riboflavin contains **6,7-dimethyl isoalloxazine** (a heterocyclic 3 ring structure) attached to **D-ribitol** by a **nitrogen atom**. **Ribitol** is an open chain form of sugar ribose with the aldehyde group (CHO) reduced to alcohol (CH<sub>2</sub>OH).

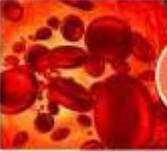




# BIOCHEMICAL FUNCTIONS OF RIBOFLAVIN

- ❑ It is essential for normal growth.
- ❑ Metabolism – It is involved in the metabolism of carbohydrates, fat & proteins.
- ❑ Digestion – it helps in digestion
- ❑ Nervous system – it helps in proper functioning of Nervous system
- ❑ It is very useful for normal tissue respiration.
- ❑ Necessary for healthy mucous membranes
- ❑ Good for skin, nails and eyes
- ❑ It helps in protects the body against cancer.

**6 VITAMIN B2**  
HEALTH BENEFITS

-  **1 PREVENTS MIGRAINES**
-  **2 SUPPORTS EYE HEALTH**
-  **3 PREVENTS & TREATS ANEMIA**
-  **4 HELPS MAINTAIN ENERGY LEVELS**
-  **5 ANTIOXIDANT & CANCER PREVENTION**
-  **6 PROTECTS HAIR & SKIN**

# BIOCHEMICAL FUNCTIONS OF RIBOFLAVIN

The coenzymes FAD and FMN are associated with certain enzymes involved in-

- metabolism of carbohydrate , lipid, protein and purine and
- electron transport chain.

A few examples are -

# **FAD Dependent enzymes**

## **1.Carbohydrate meta**

- PDH complex
- Alpha KGD Complex
- Succinate dehydrogenase

## **2.Lipid meta.**

- Acyl coA dehydrogenase
- Glycerinaldehyde 3 phosphate

## **3.Protein meta.**

- Glycine oxidase
- D-amino acid oxidase

## **4.Purine meta.**

- Xanthine oxidase

# DIETARY SOURCES OF VITAMIN B2

❖ Dietary sources of vitamin Riboflavin include :

- Liver (Hepatoflavin\*)-rich source
- Eggs (Ovoflavin\*)
- Milk (Lactoflavin\*)
- Yeast
- Green leafy vegetables
- Cereals (fortification beneficial)
- Fruits
- Nuts



# RDA OF RIBOFLAVIN

- 1.1 mg/day for women
- 1.5 mg/day for men
- Toxicity not documented

# TRANSPORT & ABSORPTION

- **Absorption:**
- Riboflavin is present in the food as *FAD, FMN and free riboflavin*
- FMN & FAD are *hydrolysed to free form in upper small intestine*
- *Free form is absorbed by intestinal mucosal cells by sodium dependent transport system*
- **Transport:**
- In the intestinal mucosal cells *riboflavin is converted into FMN* by the action of flavokinase in the presence of ATP

# TRANSPORT & ABSORPTION

- FMN enters the portal circulation
- In the plasma it is transported as Albumin-FMN complex
- FMN complex enters the tissues including liver
- In the *tissues it is converted into FAD*
- **Storage:**
- Riboflavin is mainly *stored in liver*
- It is stored *as FMN & FAD*
- **Excretion:**
- Mainly excreted in urine

# RIBOFLAVIN (VITAMIN B<sub>2</sub>) DEFICIENCIES

## Ariboflavinosis



Cheilosis



Reddening of the cornea

Dermatitis  
Photophobia

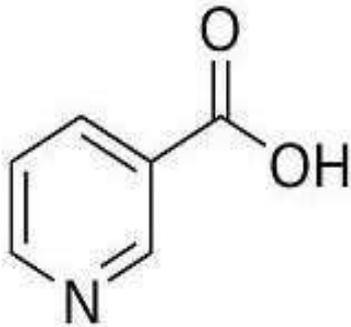
Glossitis



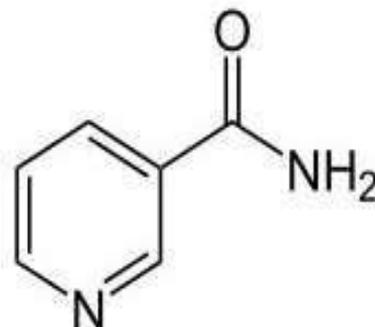


# VITAMIN B3 (NIACIN)

- Vitamin B3 is also known as **niacin** or **nicotinic acid**.
- it is essential for metabolism of carbohydrate, protein & fat.
- It is a colorless, water-soluble solid derivative of pyridine, with a carboxyl group (COOH) at the 3-position.
- It is a pyridine derivative and is a precursor of the coenzyme NAD (**Nicotinamide adenine dinucleotide**).



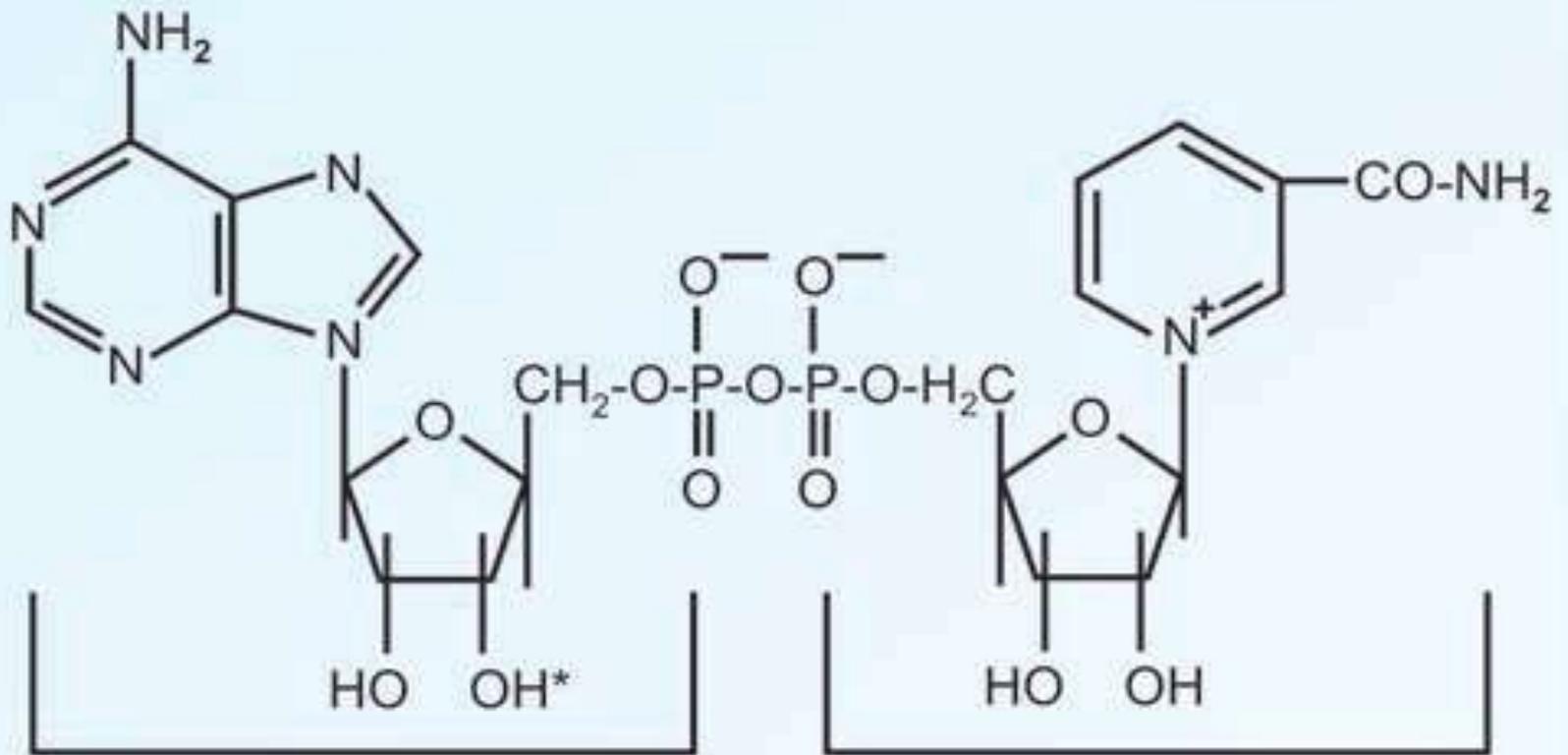
Niacin



Nicotinamide

# CHEMISTRY

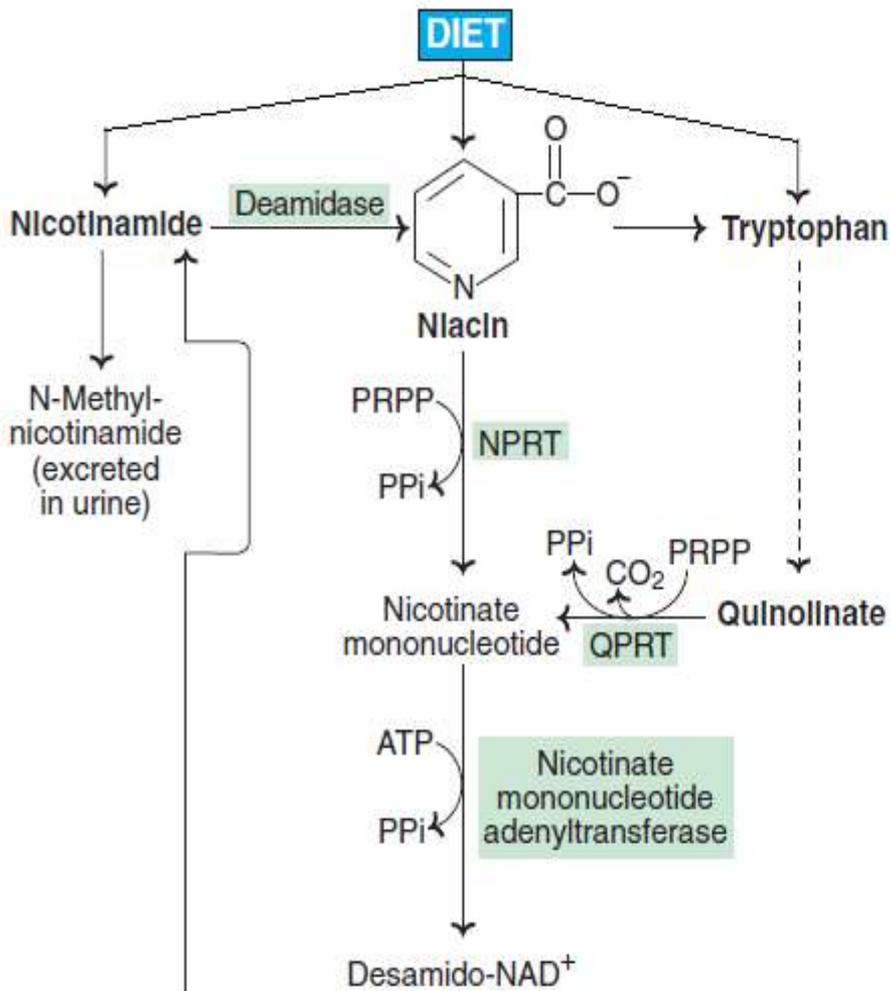
- Niacin is a pyridine derivative, structurally it is **pyridine 3 carboxylic acid**.
- Amide form of niacin is known as **niacinamide** or **nicotinamide**.
- Dietary nicotinamide, niacin & tryptophan contribute to the synthesis of the coenzymes---  
**NAD<sup>+</sup> & NADP<sup>+</sup>**
- The reactive site is the **C atom 4** and the **N** atom of the nicotinamide ring.



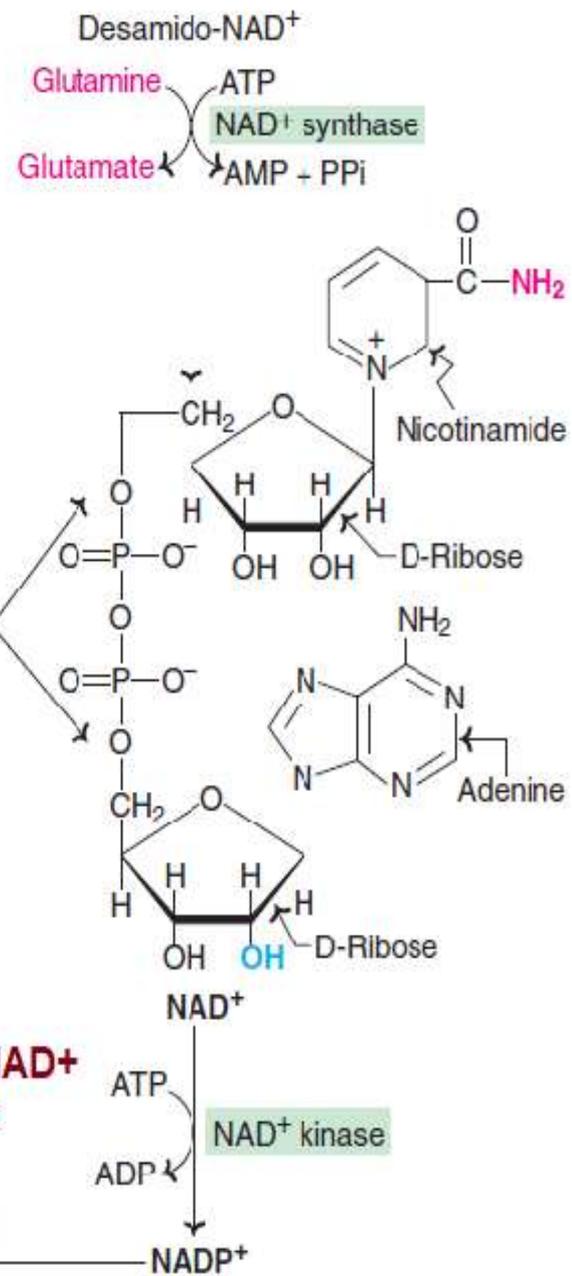
Adenine mononucleotide

Nicotinamide mononucleotide

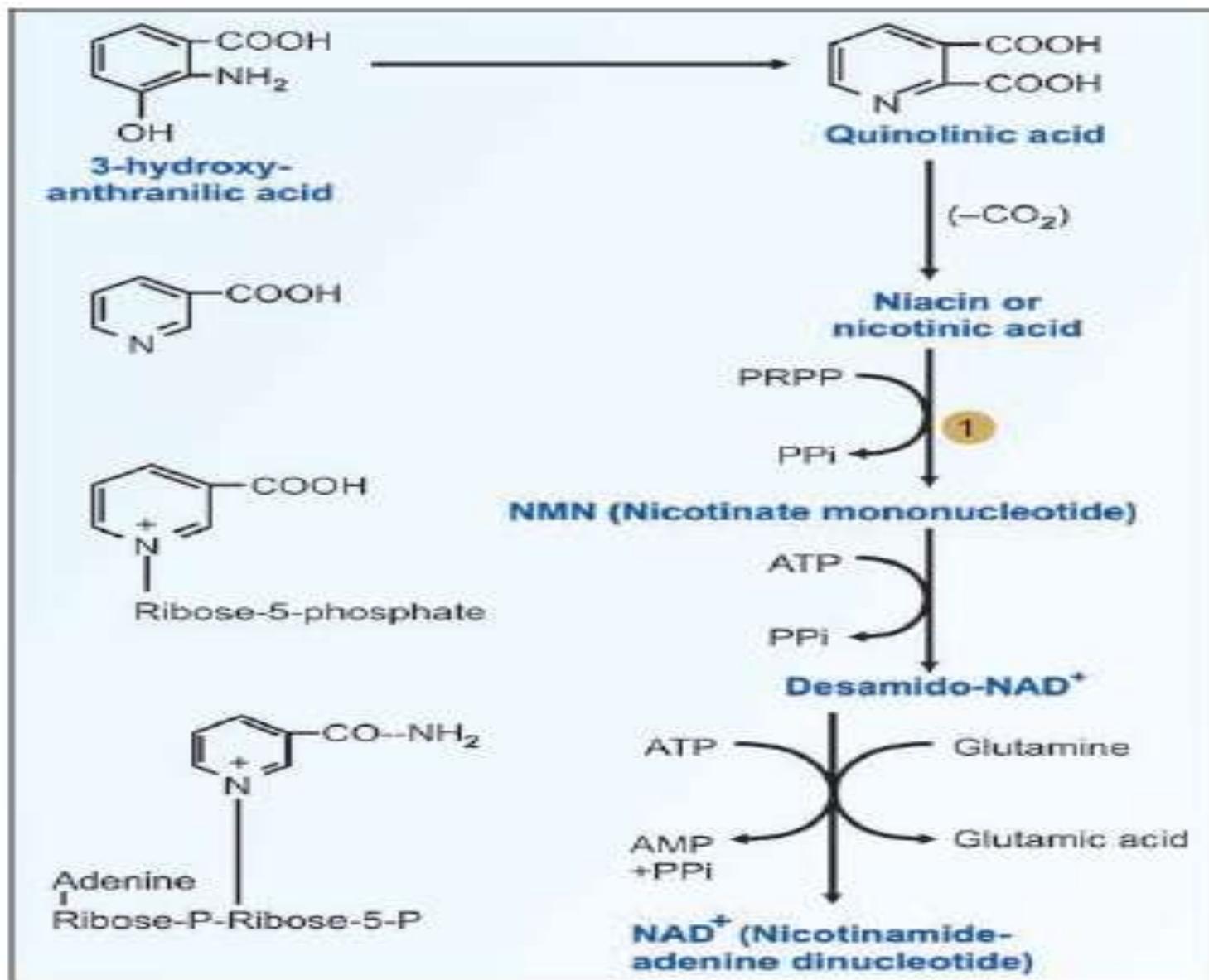
Nicotinamide adenine dinucleotide (NAD<sup>+</sup>)



**Outline of the biosynthesis of nicotinamide nucleotides, NAD<sup>+</sup> and NADP<sup>+</sup> (NPRT-Nicotinate phosphoribosyltransferase; QPRT-Quinolinate phosphoribosyltransferase; PPi-Pyrophosphate; PRPP-Phosphoribosyl pyrophosphate).**



[OH is phosphorylated (-O-PO<sub>3</sub><sup>2-</sup>)]



**Fig. 17.9. Synthesis of niacin from tryptophan;**  
 PRPP= phospho ribosyl pyrophosphate.  
 (1) = quinolinate phosphoribosyl transferase.

**Synthesis of the coenzymes – (NAD<sup>+</sup>) & (NADP<sup>+</sup>).**

Sixty milligram of tryptophan is equivalent to 1 mg of niacin for the synthesis of niacin coenzymes).

# DIETARY SOURCES OF NIACIN

## 12 FOODS

containing Niacin (vitamin B3)

Niacin is important for us to include in our daily diet. It has been shown to greatly reduce anxiety and depression. Niacin is also needed to help lower cholesterol levels.



Avocados



Broccoli



Tomatoes



Dates



Mushrooms



Asparagus



Swiss Chard



Pumpkin Seeds



Sweet Potatoes



Carrots



Almonds



Spinach

# RDA OF NIACIN

<b>Men</b>	<b>15-20 mg</b>
<b>Women</b>	<b>13-15 mg</b>
<b>Lactating women</b>	<b>20 mg</b>
<b>Children</b>	<b>8-15 mg</b>
<b>Infants</b>	<b>650 mcg</b>

# BIOCHEMICAL FUNCTIONS

• **As coenzymes -NAD<sup>+</sup> and NADP<sup>+</sup> are involved in a variety of oxidation –reduction reactions by enzymes class-oxidoreductases**

**Source of ADP-ribose for ADP ribosylation of proteins.**

Eg- Poly ADP ribosylation of nucleoproteins involved in DNA repair mechanism

# BIOCHEMICAL FUNCTIONS

- vitamin B3, is very essential for the DNA synthesis.
- it is essential for production of estrogen progesterone & testosterone
- It is also helpful in reducing migraine headaches.
- Vitamin B3, as niacinamide, may improve arthritis symptoms, including increasing joint mobility and reducing the amount of anti-inflammatory medications needed.
- High doses of niacin medications are used to prevent development of atherosclerosis and to reduce recurrent complications such as heart attack and peripheral vascular disease in those with the condition.
- It helps to detoxify the body.
- Vitamin B3, is very essential for the proper digestion of the food.

# Examples of NAD<sup>+</sup> /NADP<sup>+</sup> dependent enzymes

## NAD<sup>+</sup> dependent enzymes-

- Lactate dehydrogenase
- Glyceraldehyde 3-P dehydrogenase
- Pyruvate dehydrogenase
- $\alpha$  -keto glutarate dehydrogenase
- Glutamate dehydrogenase
- $\beta$ -hydroxy acyl co<sub>2</sub>A dehydrogenase
- One NADH +H<sup>+</sup> molecule is oxidised in ETC to give 2.5 ATPs

# DEFICIENCY OF NIACIN

- ❖ A deficiency of niacin results in the disease **pellagra (ITALIAN ROUGH SKIN)**.
- ❖ Deficiency Symptoms
- ❖ 4Ds(diarrohea, dermatitis, dementia & death)
- ❖ Involve GIT, CNS, SKIN

**Dermatitis** (inflammation of skin) is usually found in the areas of the skin exposed to sunlight (neck , dorsal part of feet, ankle and part of face). Increase pigment around neck is known as **Casal's necklace**

**Diarrhea** may be in the form of loose stool, often with blood and mucus. Prolonged diarrhea leads to weight loss.

**Dementia** is associated with degeneration of nervous tissues. The symptoms of dementia , include anxiety , irritability , poor memory, insomnia (sleeplessness) etc.



# Niacin Toxicity

Niacin leads to histamine release which causes vasodilatation

- Prostaglandin mediated cutaneous flushing due to binding of vitamin to a G protein coupled receptor.
- Hepatic toxicity is most serious toxic reaction.

## -Toxicity Symptoms

- Painful flush ,itching , rash
- Dyspepsia, vomiting, diarrhoea
- Excessive sweating
- Blurred vision
- Liver damage-jaundice & increases levels of ALT,AST
- Impaired glucose tolerance

Thank

You

# PANTOTHENIC ACID (VITAMIN B-5)

- It was discovered by Roger J. Williams in 1919.
- Panthothenic acid (Greek : Pantos-everywhere) formerly known as chick anti – dermatitis factor (or filtrate factor), it is widely distributed in nature.

# PANTOTHENIC ACID (VITAMIN B-5)

There are multiple forms of pantothenic acid or compounds that release the active form of the vitamin when digested. In addition to free pantothenic acid, these include:

- **Coenzyme A:** A common source of this vitamin in foods. It releases pantothenic acid in the digestive tract.
- **Acyl carrier protein:** Like coenzyme A, acyl carrier protein is found in foods and releases pantothenic acid during digestion.
- **Calcium pantothenate:** The most common form of pantothenic acid in supplements.
- **Panthenol:** Another form of pantothenic acid often used in supplements.



# CHEMISTRY OF COENZYME A

Coenzyme A – adenine 3 phosphoribose-5- phosphate, phospho-pantothenic acid & ribose.

SH group of ethanolamine moiety is an active group acting as carrier.

So abbreviated as **CO ~ASH**. This is comparable with ATP which is a carrier of activated phosphoryl group

# FUNCTION PANTOTHENIC ACID

- Pantothenic acid plays a key role in a wide range of metabolic
- functions.
- It is required for the formation of coenzyme A, which is necessary for the synthesis of fatty acids, amino acids, steroid hormones, neurotransmitters and various other important compounds.

# DIETARY SOURCES OF VIT B5



**Eggs**



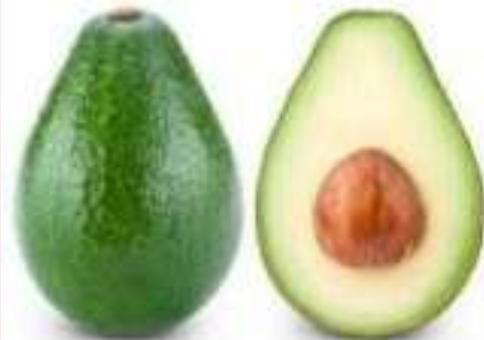
**Cauliflower**



**Mushrooms**



**Corn**



**Avocado**



**Yogurt**



**Sweet Potato**



**Broccoli**

# RDA OF VITAMIN B5

- The requirement of pantothenic acid for humans is not clearly known.
- A daily intake of about **5-10 mg is advised for adults.**

# DEFICIENCY SYMPTOMS

**Burning feet syndrome** first described by **Dr. C. Gopalan** .

Numbness ,tingling & burning in the toes

- Sleeplessness
- fatigue
- Ataxia etc

Pantothenic acid deficiency in experimental animals results in anemia, fatty, liver, decreased steroid synthesis etc.



Dermatitis



Stomatitis



Glossitis



Abnormal brain-wave patterns



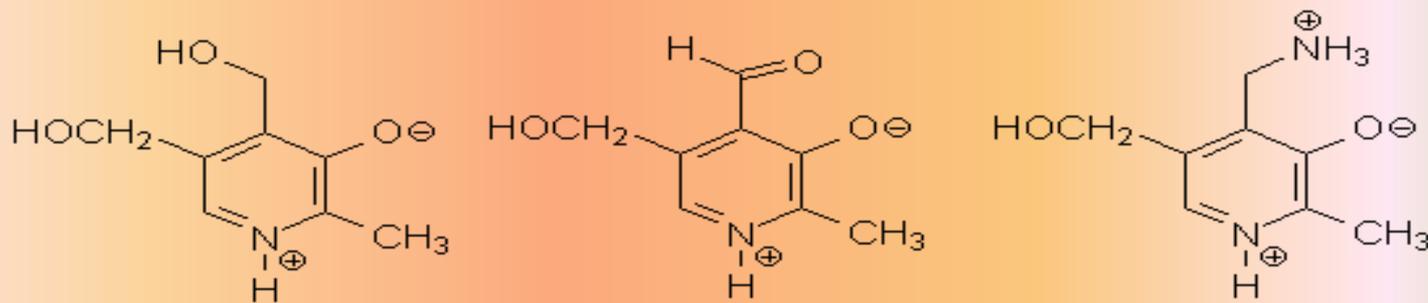
convulsion

Thank

You

# PYRIDOXINE (VITAMIN B6)

- Vitamin B<sub>6</sub> refers to a group of chemically very similar compounds which can be interconverted in biological systems.
- Vitamin B<sub>6</sub> is part of the vitamin B complex group, and its active form, Pyridoxal 5'-phosphate (PLP) serves as a cofactor in many enzyme reactions in amino acid, glucose, and lipid metabolism.
- It is white crystalline substance soluble in water and alcohol.



Pyridoxine

Pyridoxal

Pyridoxamine

Vitamin B<sub>6</sub>

# PYRIDOXINE (VITAMIN B6)

- Pyridoxine, pyridoxal and pyridoxamine are phosphorylated by a common enzyme.
- The enzyme is pyridoxal kinase.
- The phosphate group is provided by ATP.
- The three coenzymes are interconvertible.



Pyridoxine



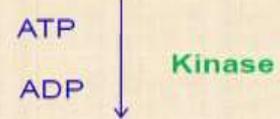
Pyridoxal



Pyridoxal Phosphate



Pyridoxamine



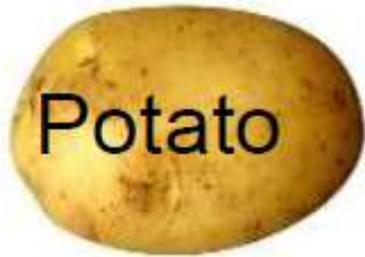
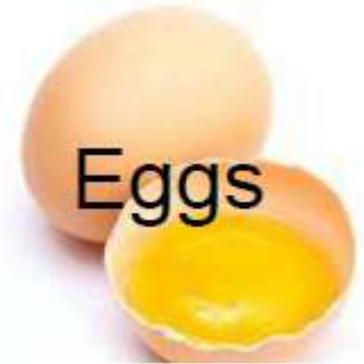
Pyridoxamine Phosphate



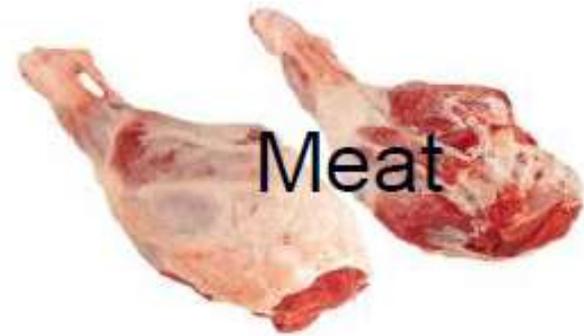
4-Pyridoxic acid

# PYRIDOXINE (VITAMIN B6)

- Pyridoxine, pyridoxal and pyridoxamine are converted into coenzymes.
- The coenzymes are;
  - Pyridoxine phosphate
  - Pyridoxal phosphate
  - pyridoxamine phosphate



**Dietary sources of pyridoxine**



# RECOMMENDED DIETARY ALLOWANCE

- The requirement of pyridoxine for an adult is 2- 2.2mg/day.
- During lactation, pregnancy and old age, an intake of 2.5mg/dl is recommended.
- High protein diet increases B-6 requirement.

# FUNCTIONS OF PYRIDOXINE (VITAMIN B6)

- PLP is the coenzyme of Vit-B6 is found attached to  $\epsilon$ -amino group of lysine in the enzyme.
- PLP is associated with amino acid metabolism.
- PLP is involved in;
  - Transamination
  - Decarboxylation
  - Transulfuration
  - Condensation

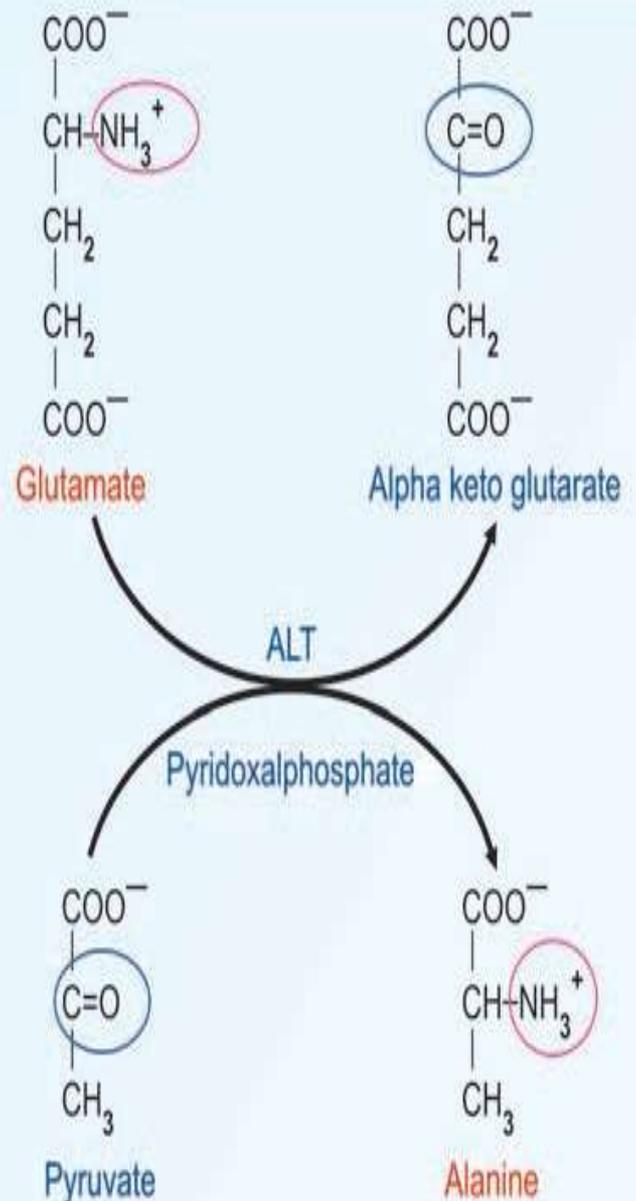
# Transamination

These reactions are catalysed by specific transaminases

The amino group of an amino acid is transferred to an  $\alpha$ -keto acid

This results in the formation of a new amino acid and a new  $\alpha$ -keto acid

PLP acts as a carrier of the amino group



Summary

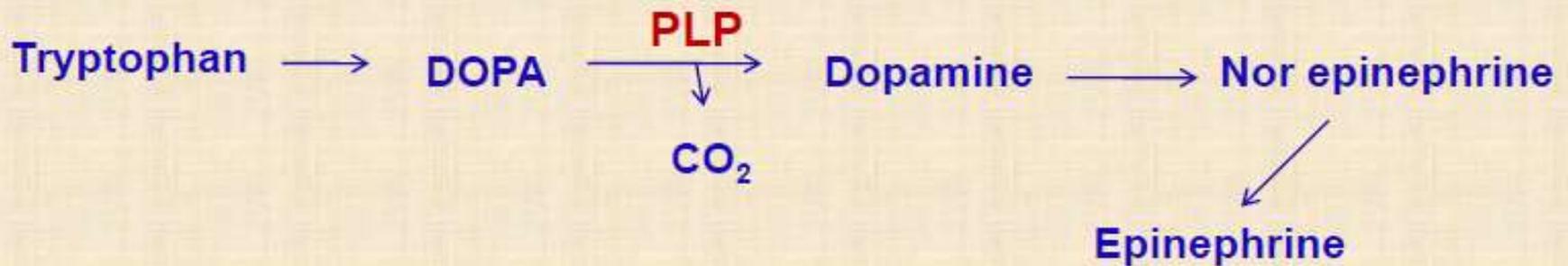
amino acid 1 + keto acid 2  $\rightarrow$  amino acid 2 + keto acid 1

# Decarboxylation

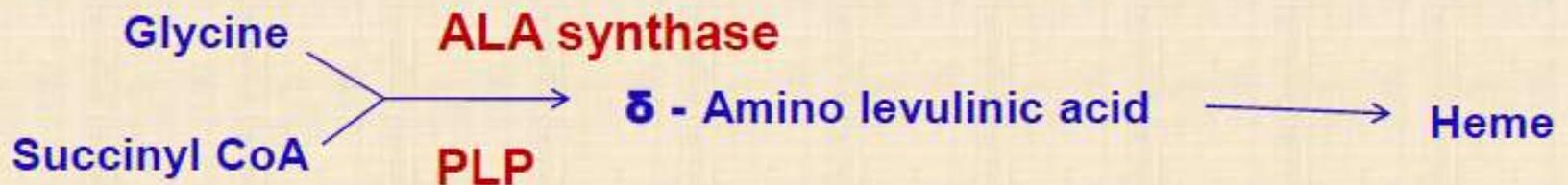
- **α** - Amino acids undergo decarboxylation to form respective amines
- The reaction is carried out by decarboxylases which require PLP
- Serotonin produced from tryptophan is important in nerve impulse transmission
- It regulates sleep, behaviour, blood pressure



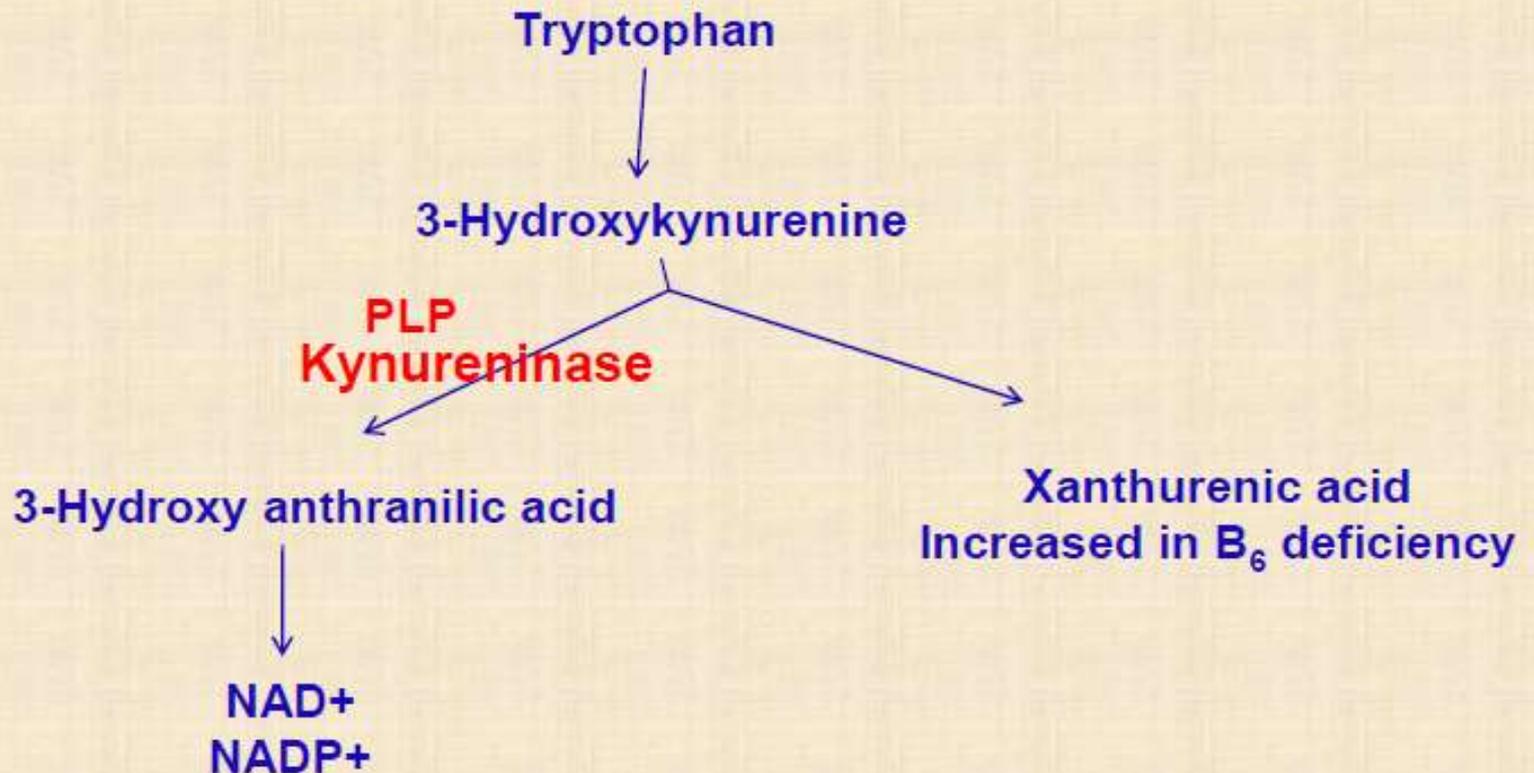
- The synthesis of catecholamines (dopamine, nor epinephrine & epinephrine ) from tyrosine require PLP



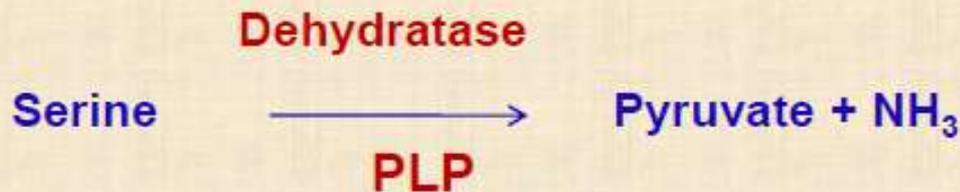
- PLP is required for synthesis of  $\delta$  - amino levulinic acid, the precursor for heme synthesis

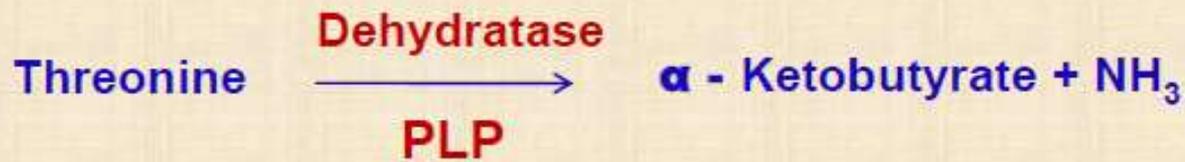


- The synthesis of niacin coenzymes (NAD<sup>+</sup> & NADP<sup>+</sup>) from tryptophan require PLP
- **Kynureninase** require PLP



- PLP Plays an important role in **metabolism of sulfur containing amino acids**
- Transsulfuration from homocysteine to serine occurs in the synthesis of cysteine
- PLP dependent enzyme cystathionine synthase
- **Deamination** of hydroxyl group containing amino acids require PLP





- Synthesis of serine from glycine require PLP.
- Glycogen phosphorylase contains PLP
- It converts glycogen to glucose 1-phosphate
- PLP is needed for the absorption of amino acids from intestine
- B6 is useful to prevent urinary stone formation

- ❖ 80% of the total PLP of body is present in muscle mostly associated with GLYCOGEN PHOSPHORYLASE.
- ❖ This is not released during deficiency but is released during starvation when glycogen reserves are depleted to meet increased demands for gluconeogenesis from amino acids (in liver & kidney).

# DEFICIENCY SYMPTOMS

- Pyridoxine deficiency is associated with-
  - **neurological symptoms such as depression, irritability, nervousness and mental confusion.**
  - Convulsions and peripheral neuropathy are observed in severe deficiency.
- These symptoms are related to the decreased synthesis of biogenic amines (serotonin, GABA, norepinephrine and epinephrine).
- In children, B6 deficiency with a drastically reduced GABA production results in convulsions (epilepsy).

# DEFICIENCY SYMPTOMS

- Decrease in hemoglobin levels, associated with hypochromic microcytic anaemia, is seen in B6 deficiency. This is due to a **reduction in heme production.**
- The synthesis of niacin coenzymes (NAD<sup>+</sup> and NADP<sup>+</sup>) from tryptophan is impaired. **Xanthurenic acid, produced in high quantities is excreted in urine.**
- Dietary deficiency of pyridoxine is rather rare and is mostly observed in women taking oral contraceptives, alcoholics and infants.

# **PYRIDOXINE ANTAGONISTS**

- Isoniazid, deoxypyridoxine and methoxy pyridoxine are the antagonists of vitamin B6.

## **TOXIC EFFECTS OF OVERDOSE VITAMIN B6**

- Excess use of vitamin B6 (2.5 g/day) in the women of premenstrual syndrome is associated with sensory neuropathy.
- Some workers have suggested that vitamin B6 more than 200 mg/day may cause neurological damage.

Thank

You

# VITAMIN B7 (BIOTIN)

- ❖ Biotin (formerly known as anti-egg white injury factor, vitamin B7 or vitamin H) is a sulfur containing B-complex vitamin.
- ❖ Boas (1927) observed that rats fed huge quantity of raw egg white developed dermatitis and nervous manifestations, besides retardation in growth.

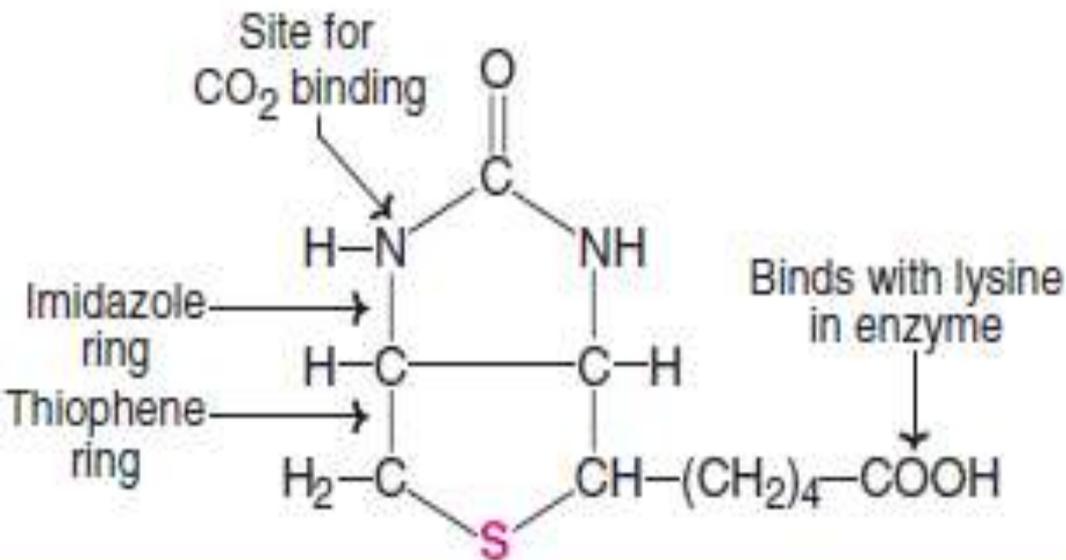
# VITAMIN B7 (BIOTIN)

- The egg-white injury factor was identified as a glycoprotein– avidin and biotin was called as anti-egg white injury factor.

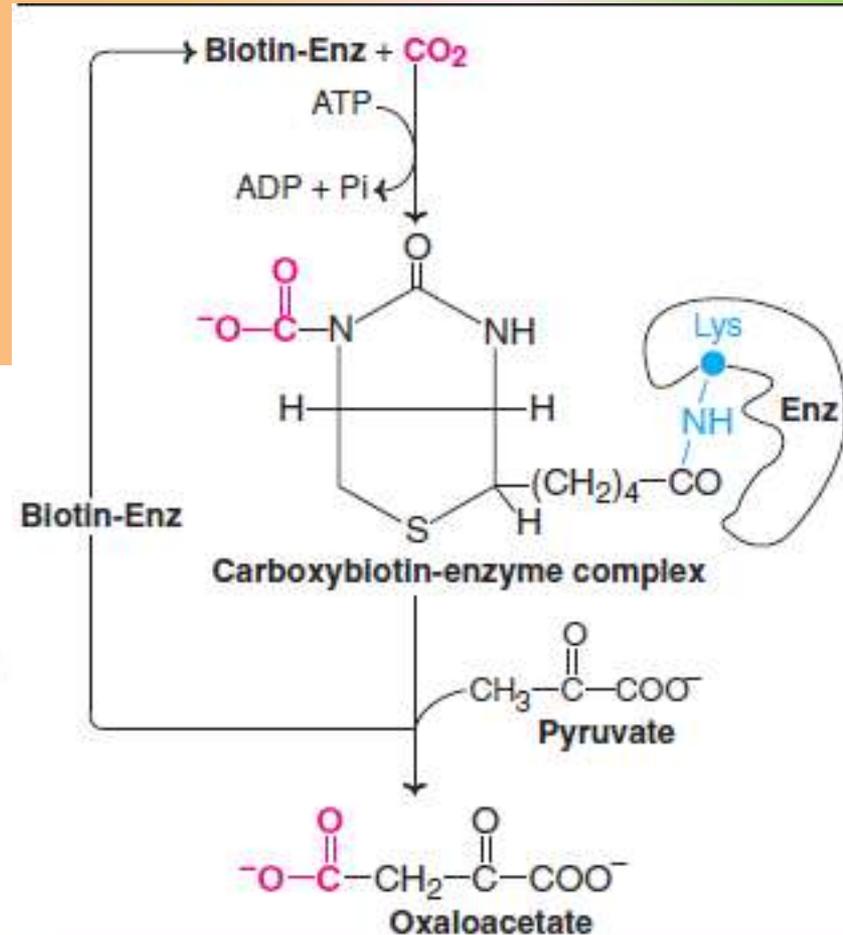
# CHEMISTRY OF VITAMIN B7 (BIOTIN)

- Biotin is a heterocyclic sulfur containing monocarboxylic acid.
- The structure is formed by fusion of **imidazole and thiophene rings with a valeric acid side chain.**
- **Biotin is covalently bound to  $\epsilon$ -amino group of lysine to form biocytin in the enzymes.**
- **Biocytin may be regarded as the coenzyme of biotin.**

# CHEMISTRY OF VITAMIN B7 (BIOTIN)



**Fig. 7.28 :** Structure of biotin with binding sites.



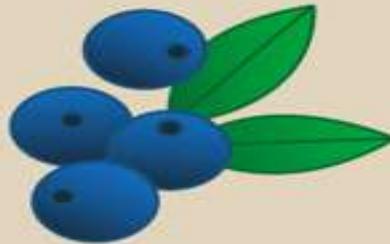
**Fig. 7.29 :** Role of biotin in the carboxylation reaction, catalysed by the enzyme pyruvate carboxylase (Enz-Enzyme).

# DIETARY SOURCES OF VIT B7

## 9 foods high in vitamin H



Avocado



Berries



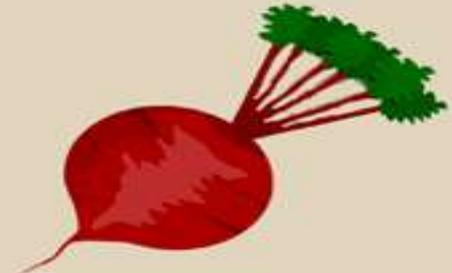
Soy beans



Cauliflower



Carrot



Beetroot



Mushroom



Walnut



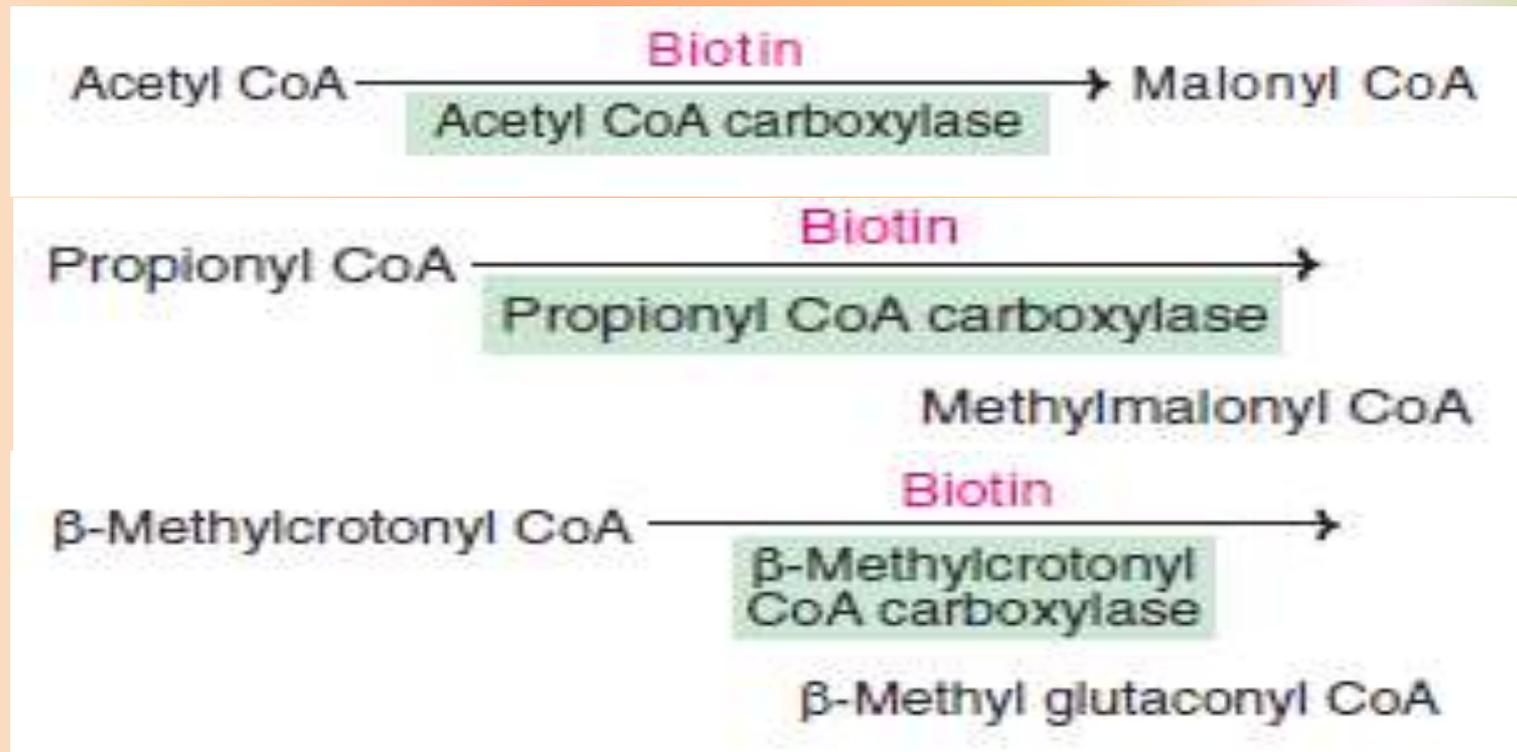
Banana

# RDA OF VITAMIN B7 (BIOTIN)

- A daily intake of about **100-300 mg** is recommended for adults.
- **Children – 50-200 mg.**
- **Infant – 35 mg.**
- In fact, biotin is normally synthesized by the intestinal bacteria.

# FUNCTIONS OF VITAMIN B7 (BIOTIN)

- Biotin serves as a carrier of CO<sub>2</sub> in **carboxylation reactions**.
- **The reaction catalysed by pyruvate carboxylase, converting pyruvate to oxaloacetate.**
- Biotin is involved in the synthesis of fatty acids, isoleucine, and valine, and in gluconeogenesis.



# DEFICIENCY SYMPTOMS

Deficiency symptoms include:

- brittle nails
- conjunctivitis
- depression
- dermatitis
- fatigue

- hair loss
- hallucinations
- loss of appetite
- muscle pain
- nausea
- neurological symptoms
- weakness



# ANTAGONISTS

Desthiobiotin, biotin sulphonic acid are biotin antagonists.

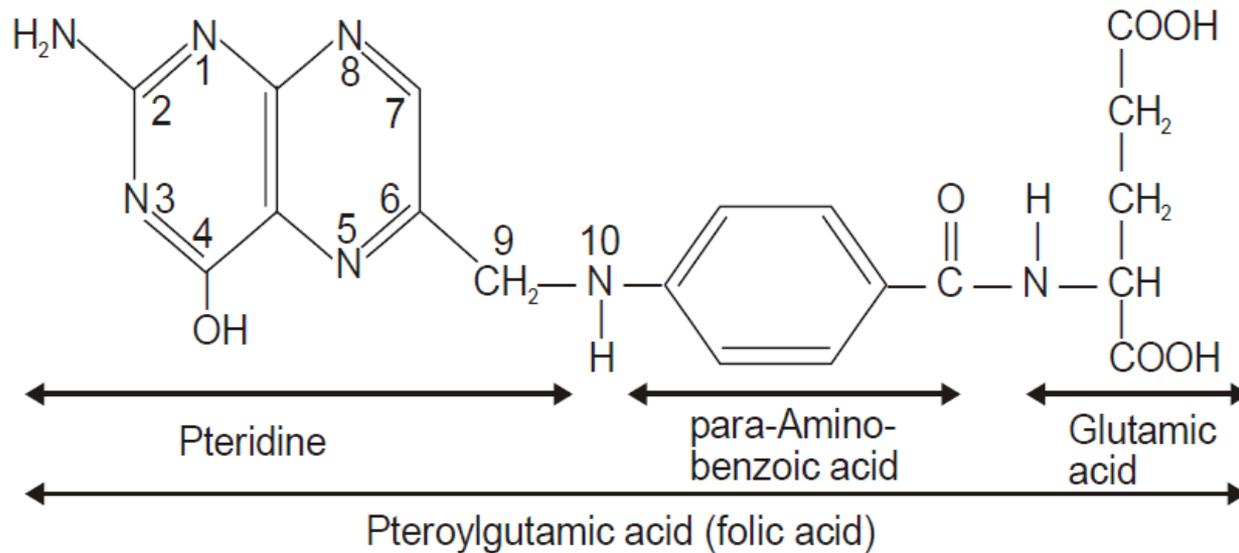


# VITAMIN B9 (FOLIC ACID)

- Folic acid is also known as folacin or pteroylglutamic acid.
- Folic acid usually occurs as polyglutamate derivatives with 2 to 7 glutamic acid residues joined by gamma peptide linkage.
- These compounds are taken up by intestinal mucosal cells & extra glutamate residues removed by glutamate conjugase.
- Free folic acid then reduced to THFA by reductase.

# CHEMISTRY

- Folic acid consists of three components pteridine ring , p-amino benzoic acid (PABA) and glutamic acid (2 to7 residues).

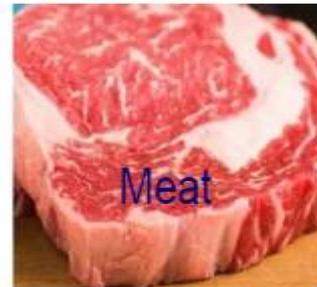


# DIETARY SOURCES

- Folic acid is widely distributed in nature.
- The rich sources are green leafy vegetables, whole grains, cereals, liver, kidney, yeast and eggs.
- Milk is a poor source of folic acid.



Sources of folic acid



# RDA FOR FOLATE

- 200 $\mu\text{g}$ /day for adults
- 400  $\mu\text{g}$ /day in pregnancy
- 300  $\mu\text{g}$ /day in lactation

- **active form** -tetrahydrofolate (THF or FH<sub>4</sub>).
- **Synthesized** from folic acid by the enzyme **Dihydrofolate reductase (DHFR)**.

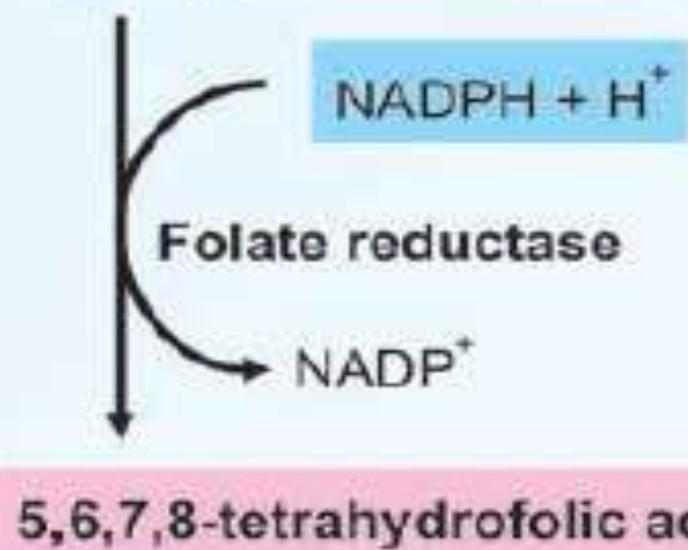
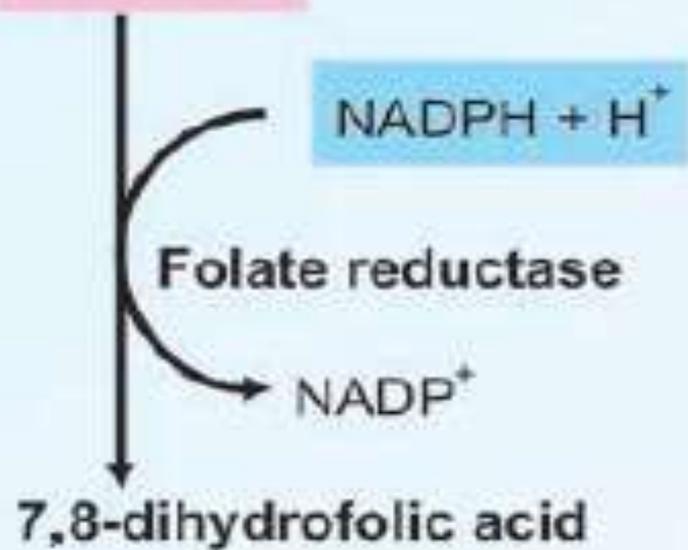
# Synthesis of THFA

Folic acid functions as a coenzyme, tetrahydrofolate ( $H_4$ -folate or  $FH_4$ )

Folate is first reduced to 7,8-dihydrofolate ( $H_2$ -folate or  $FH_2$ )

7,8-Dihydrofolate is, then, reduced to 5,6,7,8-tetrahydrofolate

Folic acid



Gerhard  
Domagk  
NP 1939  
1895-1964



Gertrude  
Elion  
NP 1988  
1918-1999

$H_4$ -Folate is a carrier of one-carbon units

The one-carbon unit may be attached to  $N^5$   
or  $N^{10}$  of  $H_4$ -folate

# Functions of Vitamin B9

- **Formation of RBC** – folic acid in combination with vitamin B12 is essential for formation, maturation.
- **Nerve** – it is necessary for growth & division of all body cells,
- **Hair & Skin** – it is essential for the health of skin & hair
- **Pregnancy** – it is an important nutrient for the pregnant women & her developing fetus.& folic acid improves the lactation.

# Functions of Vitamin B9

- **DNA synthesis**
  - Transfer of single carbon units
  - Synthesis of adenine and guanine
  - Anticancer drug methotrexate
  - Homocysteine metabolism
  - Neurotransmitter formation

# Functions of Vitamin B9

- 1 C groups play a pivotal role in donating carbon atoms for synthesis of different types of compounds.
- Some synthetic pathways require the addition of single carbon groups that exist in a variety of oxidation states, including formyl, methenyl, methylene, and methyl.
- These single carbon groups can be transferred from carrier compounds such as THF and SAM to specific structures that are being synthesized or modified.
- The “one-carbon pool” refers to single carbon units attached to this group of carriers.

# 1 C compounds

Group	Structure	Carried by
Formyl	-CHO	N <sup>5</sup> -formyl-THFA and N <sup>10</sup> -formyl-THFA
Formimino	-CH=NH	N <sup>5</sup> -formimino-THFA
Methenyl	=CH-	N <sup>5</sup> ,N <sup>10</sup> -methenyl-THFA
Hydroxymethyl	-CH <sub>2</sub> OH	N <sup>10</sup> -hydroxymethyl THFA
Methylene	-CH <sub>2</sub> -	N <sup>5</sup> ,N <sup>10</sup> -methylene-THFA
Methyl	-CH <sub>3</sub>	N <sup>5</sup> -methyl-THFA and methyl cobalamin

## H<sub>4</sub>-Folate can:

- Receive one-carbon units from various compounds
- Transfer one-carbon units to various compounds

# Sources of one-carbon units

Tetrahydrofolate may receive one-carbon units from:

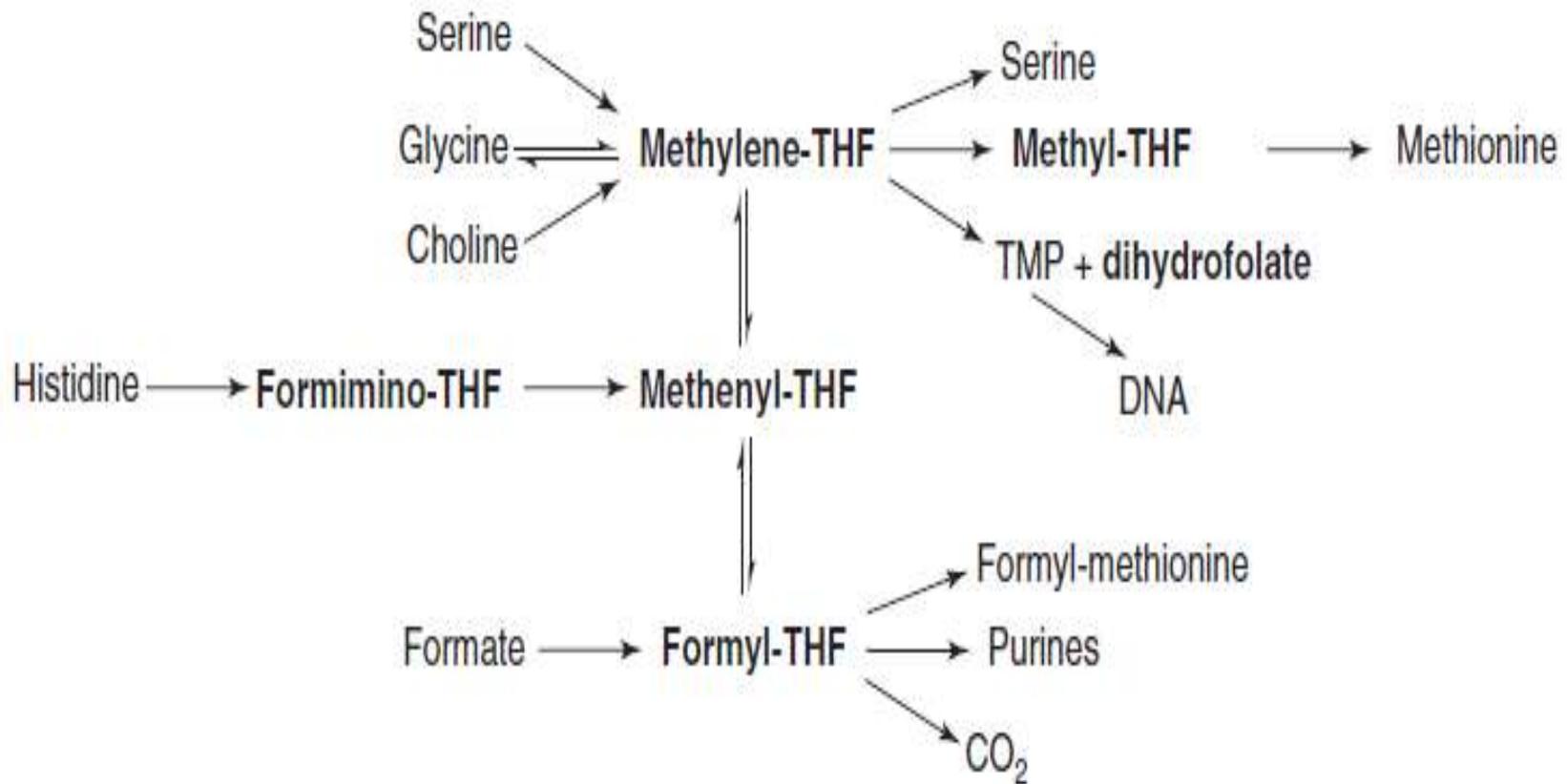
- Formiminoglutamic acid
- Methionine
- Choline
- Thymine
- Serine

Methionine, choline and thymine are the source of methyl groups

Serine can contribute its hydroxymethyl group

Sources of one-carbon units

Synthesis using one-carbon units



**Figure 45-16.** Sources and utilization of one-carbon substituted folates.

# DEFICIENCY MANIFESTATIONS

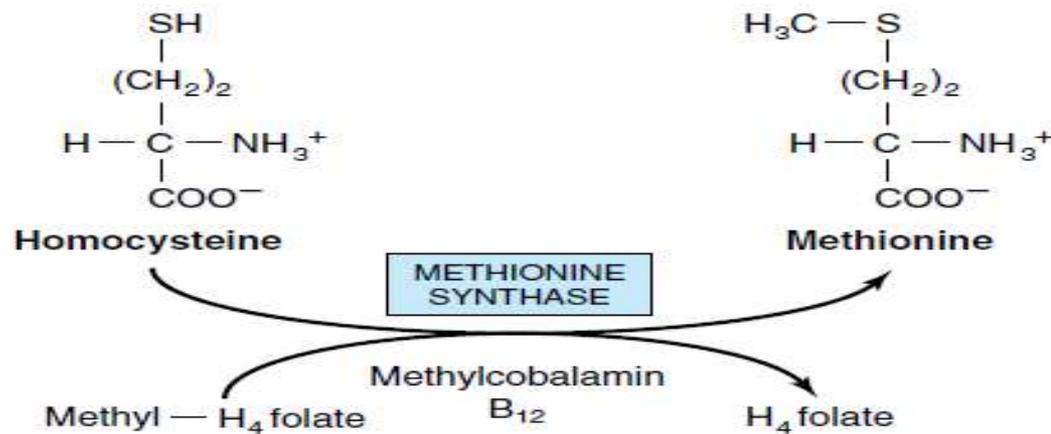
- **Reduced DNA synthesis:-** in folate deficiency , THFA is reduced & thymidylate synthase enzyme is inhibited.

## **Macrocytic anemia:-**

- most common deficiency
- DNA synthesis is delayed but protein synthesis is continued. So Hb accumulated in RBCs
- This asynchrony between maturity of nucleus & cytoplasm is manifested as immature looking nucleus & mature cytoplasm
- Reticulocytes is seen, rapidly destroyed in spleen, leads to decreased generation & increased destruction of RBCs result in anemia.
- So a macrocytic anemia associated with megaloblastic changes in bone marrow.

- Leucopenia & thrombopenia are also manifested.
- So in foal deficiency peripheral blood picture is describe as macrocytic.

- **Hyperhomocysteinemia:**
- due to folate trap, risk factor for atherosclerosis, thrombosis & hypertension



**Figure 45-14.** Homocysteinuria and the folate trap. Vitamin B<sub>12</sub> deficiency leads to inhibition of methionine synthase activity causing homocysteinuria and the trapping of folate as methyltetrahydrofolate.

**Folic acid deficiency** is probably the most common vitamin deficiency.

observed in pregnant women, lactating women, women on oral contraceptives, and alcoholics .

# Causes-

- Inadequate dietary intake
- defective Methyl-tetrahydrofolate reductase
- Defective absorption:- celiac disease, resection of jejunum, gastroileostomy
- Drugs:- phenytoin, phenobarbitone, hydantoin inhibit the intestinal enzymes
- Folate trap

## Folic Acid antagonists

□ Aminopterin and amethopterin (also called as methotrexate) are structural analogues of folic acid. They competitively inhibit dihydrofolate reductase including humans and block the formation of THF .

- has high affinity for rapidly dividing cells (hair, mucosal, RBCs, Leukocytes etc.) used in the treatment of many cancers including leukemia.

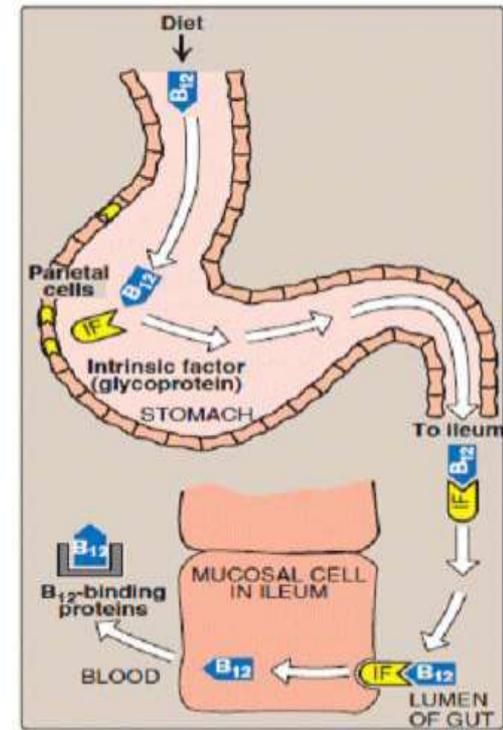


# VITAMIN B12

- Vitamin B12 is also known as **anti pernicious anemia vitamin**.
- **It is a unique vitamin**, synthesized by only microorganisms and not by animals and plants.
- It was the last vitamin to be discovered.
- B<sub>12</sub> is also known as Red vitamin because it exists as a dark red crystalline compound.
- Color is due to **Cobalt** metal ion.



- Synonyms are:-
- Cyanocobalamine
- Anti pernicious anemia factor  
&
- Extrinsic factor of castle



# HISTORICAL MILESTONE

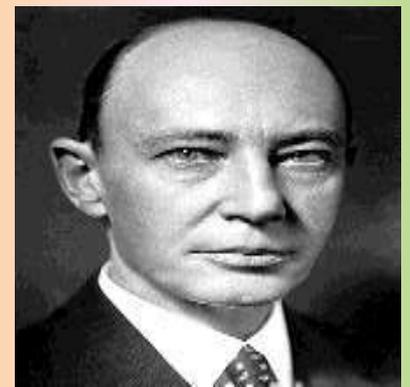
## George Whipple

- B<sub>12</sub>, was first discovered by him



## George Richards Minot and William Murphy

- They also found that an entirely different liver substance cured pernicious anemia in humans which was B<sub>12</sub> Vitamin.



# SOURCES

- As described previously Cobalamin is synthesized solely by microorganisms.
- Ruminants obtain cobalamin from the foregut, but the only source for humans is food of animal origin, e.g. **meat, chicken, fish, eggs, liver and dairy products.**
- Vegetables, fruits, and other foods of non-animal origin are free from cobalamin unless they are contaminated by bacteria.
- Strict vegetarians are at risk of developing B<sub>12</sub> deficiency.

# SOURCES



# SOURCES



**B<sub>12</sub> IN LIQUID FORM**



**B<sub>12</sub> IN PILL FORM**

# RDA

- **1-2  $\mu\text{gms/day}$**  in adults
- **0.5- 1.5  $\mu\text{gms/day}$**  in children
- **3-4  $\mu\text{gms/day}$**  in pregnancy & lactation

# CHEMISTRY OF VIT. B<sub>12</sub>

- Cobalamin is analogous to heme in its structure having as its base a tetrapyrrole ring.
- Instead of iron as a metal cofactor for heme, cobalamin has **cobalt in a coordination state of six with**
- **The four equatorial positions coordinated by the nitrogen of the four pyrrole groups and,**
- **5<sup>th</sup> position is occupied with benzimidazole group &**
- **The sixth position occupied by either a deoxyadenosine group, a methyl group or a CN–group**

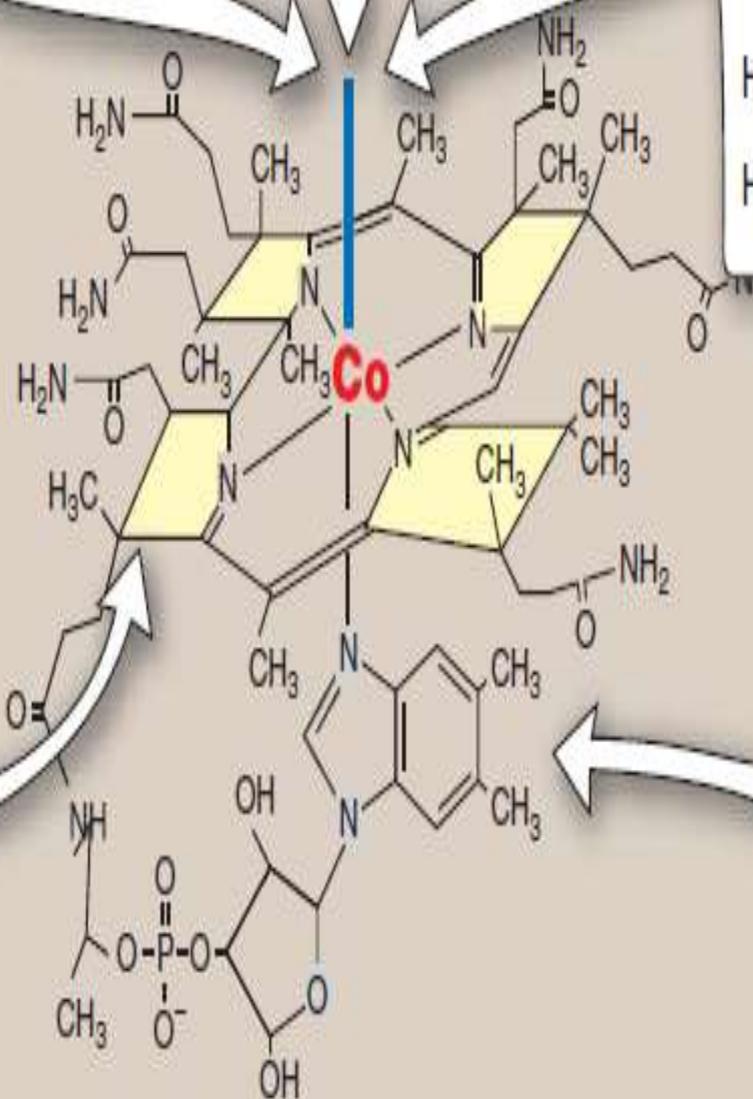
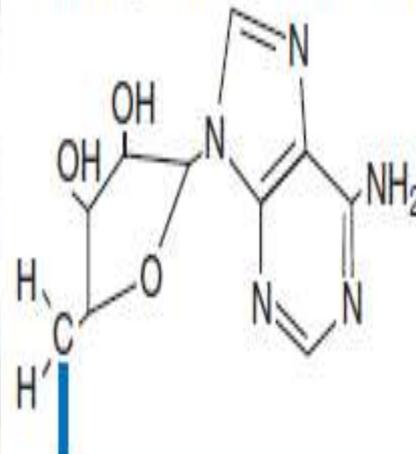
Methylcobalamin



Cyanocobalamin

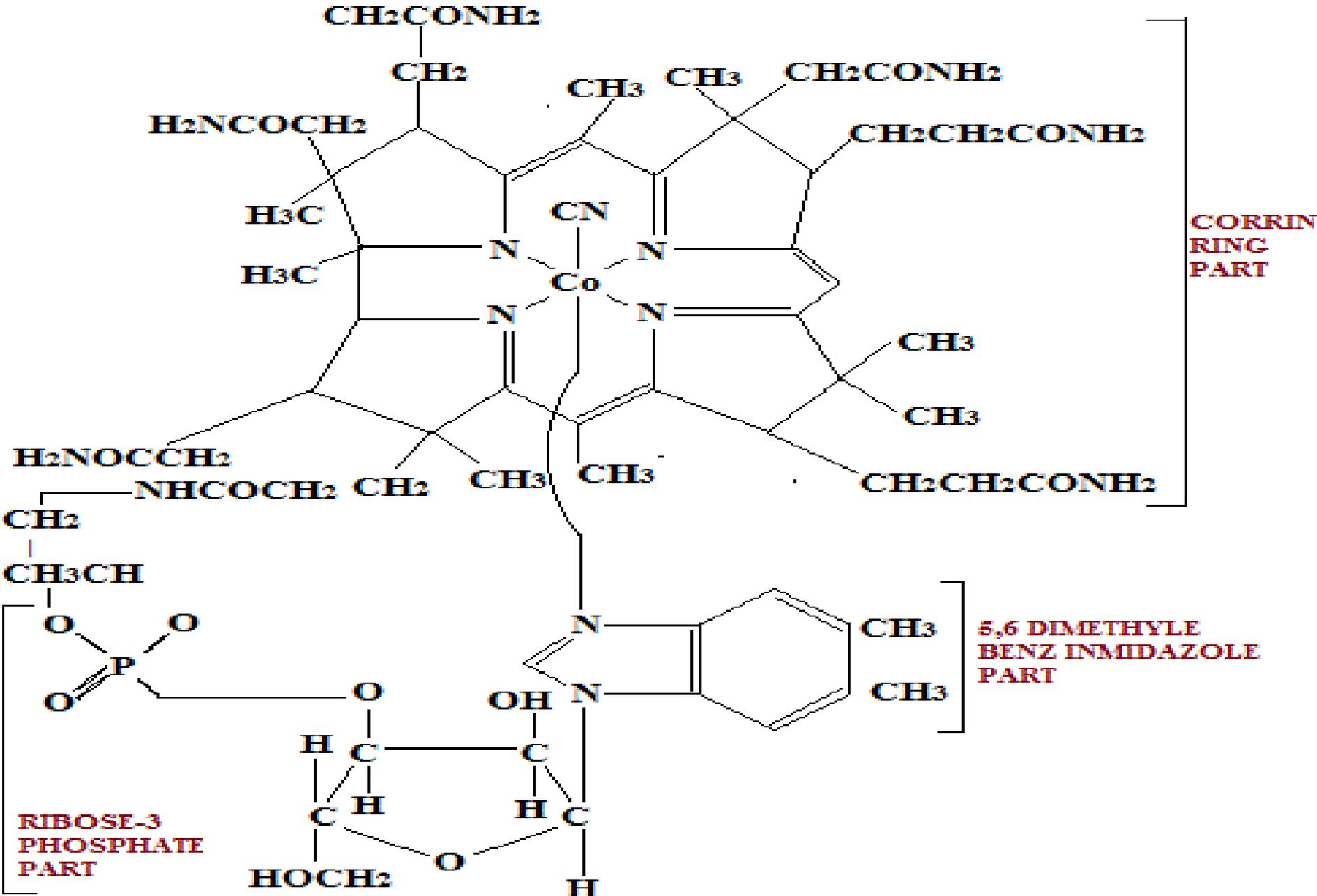


5'-Deoxyadenosylcobalamin



Corrin ring

Dimethylbenzimidazole



**VITAMIN B12  
(CYANOCOBALAMIN)**

# FORMS OF VIT. B<sub>12</sub>

- **Cyanocobalamin:-** when cyanide is added at R position. (present in supplements, more stable) Has no physiological function. Used as oral preparation.
- **Hydroxycobalamin:-** when OH group is added, natural form, produced by bacteria, used in supplementation tablets and injections
- **Adenosylcobalamin:-** adenosyl is added, active form & major storage form in liver.
- **Methylcobalamin:-** methyl group is added, major circulatory form in blood.
- **Ado-12 & methyl B<sub>12</sub>** are the functional co-enzyme in the body

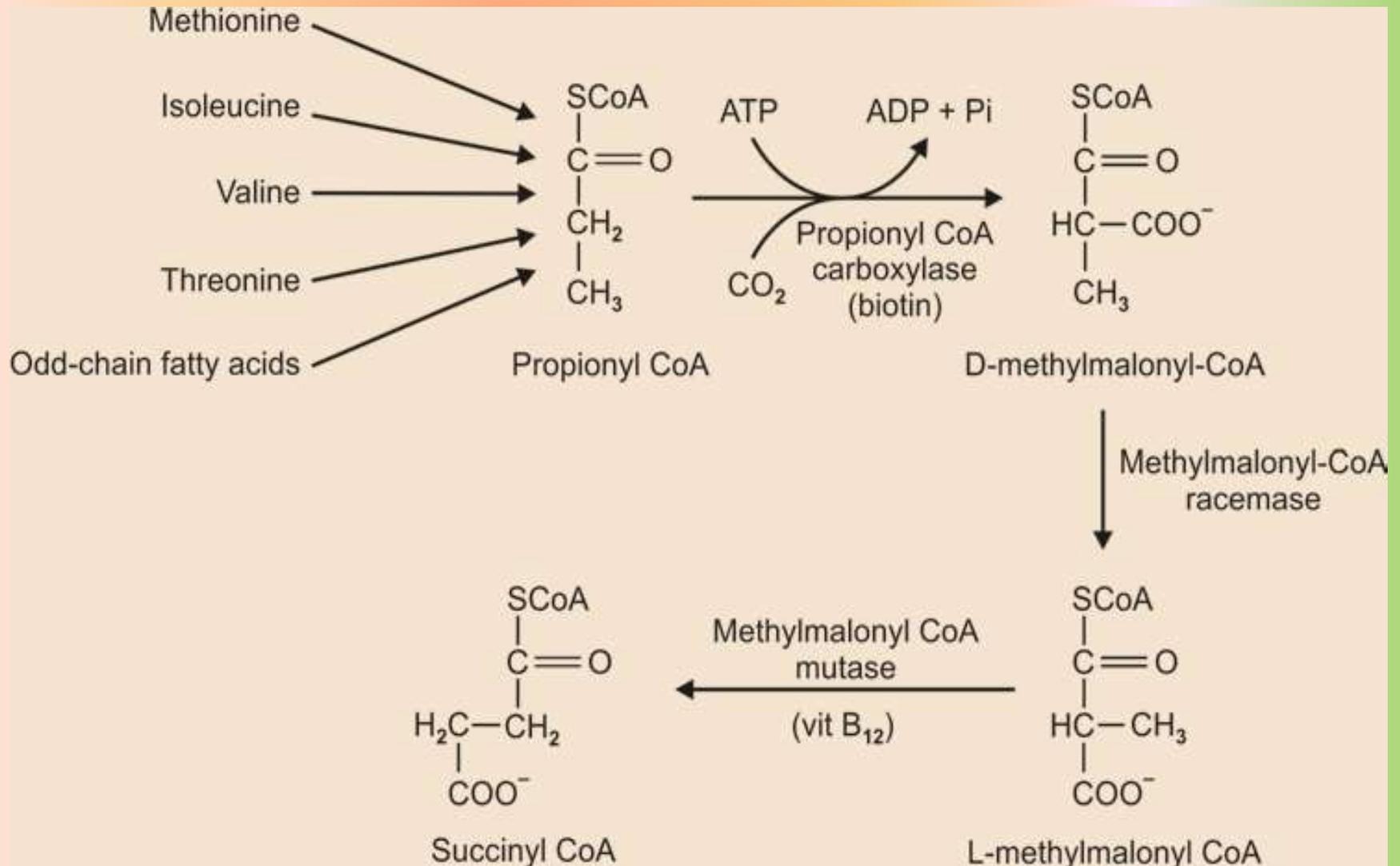
# BIOCHEMICAL OR METABOLIC FUNCTIONS OF VIT. B<sub>12</sub>

- Methionine synthase
- Methylmalonyl CoA mutase

# Metabolic Role of Cobalamin

- Cobalamin plays a vital role in the catabolism of odd-chain fatty acids, threonine, methionine, and the branched chain amino acids (leucine, isoleucine, and valine).
- The degradation of each of these compounds produces the same metabolite, **Propionyl CoA**.

# Fate of Propionyl CoA



# Fate of Propionyl CoA in B<sub>12</sub> deficiency

- Cobalamin deficiency leads to decrease utilization of propionyl co A, leading to an accumulation of methylmalonyl- CoA in serum, which has been suggested as a possible source of neurologic defects seen in cobalamin deficiency.

- B<sub>12</sub> deficiency is associated with Demyelination due to accumulation of methylmalonyl CoA in two ways:-
  1. Methylmalonyl CoA is a competitive inhibitor of malonyl CoA in fatty acid synthesis, severe inhibition of F.A. biosynthesis will lead to degeneration of myelin sheath.
  2. Methylmalonyl CoA can substitute for malonyl CoA in fatty acid synthesis leading to synthesis of branched chain F.A., which may disrupt the membrane structure.
- Excess methylmalonyl-CoA in B<sub>12</sub> deficiency gets excreted in urine causing **methylmalonic aciduria**

# Role of cobalamin in methionine metabolism

- Cobalamin is required for the conversion of homocysteine into methionine.
- Cobalamin must first undergo methyl transfer to form methyl cobalamin.
- It receives the methyl group from N5 methyltetrahydrofolate thus regenerating tetrahydrofolate to participate in other one carbon transfers in purine metabolism or pyrimidine remodeling.

N5-methyl-THFA (-CH<sub>3</sub>)

THFA

Vitamin B<sub>12</sub>

Methyl cobalamin

Methionine

Homocysteine

ATP

PPi + Pi

Adenosine

S-adenosyl-methionine (SAM)

S-adenosyl-homocysteine (SAH)

+ CH<sub>3</sub>

Methyl acceptor

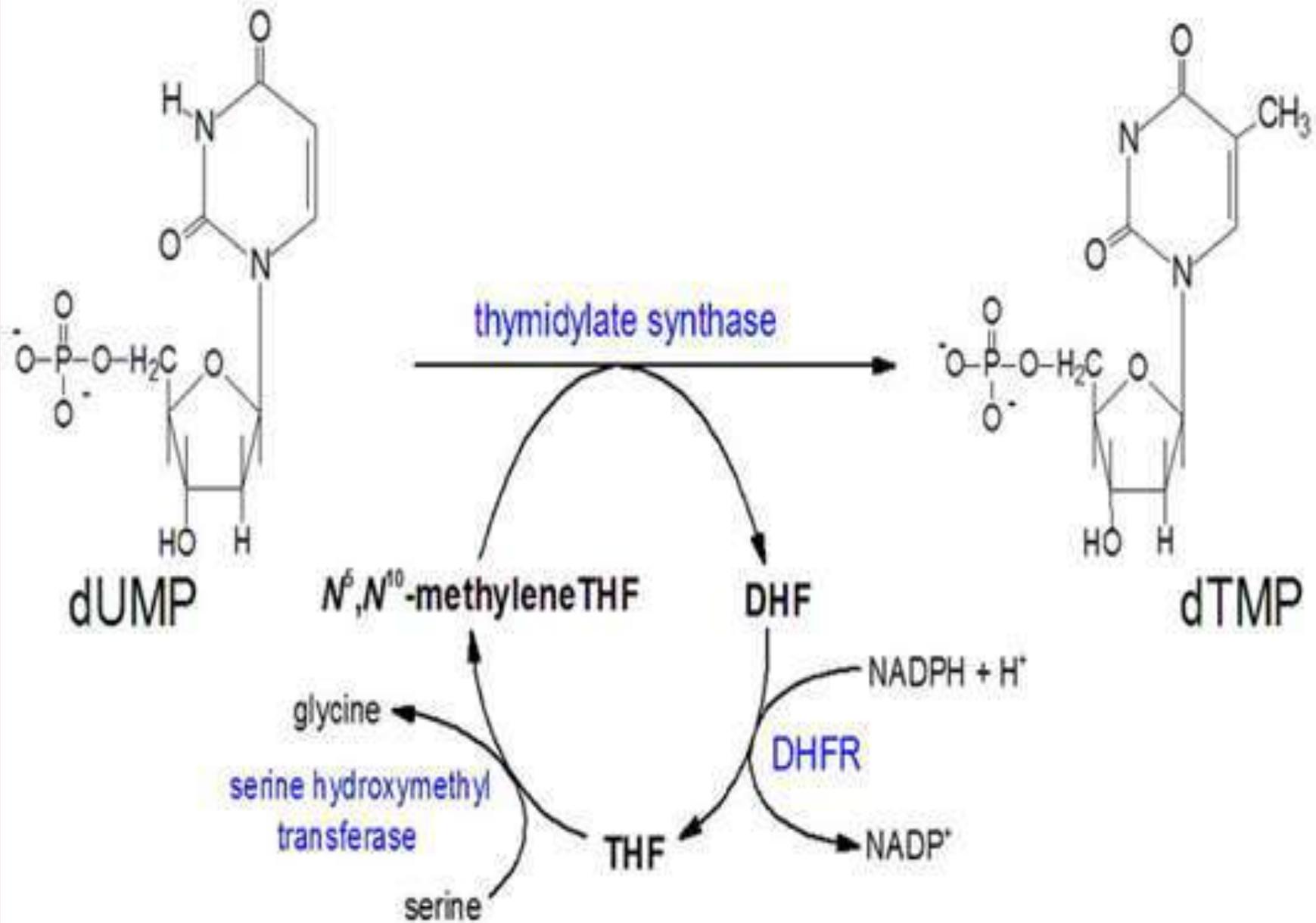
Methylated product

# Folate trap

- In cobalamin deficiency, the methionine synthase reaction cannot occur, N5-methyltetrahydrofolate accumulates and the other C-1 donor forms of tetrahydrofolate cannot be formed.
- The methionine synthesis from homocysteine ceases allowing the “trapping” of the folate pool as N5- methyltetrahydrofolate, diminishing levels of N5, N10- methylenetetrahydrofolate.

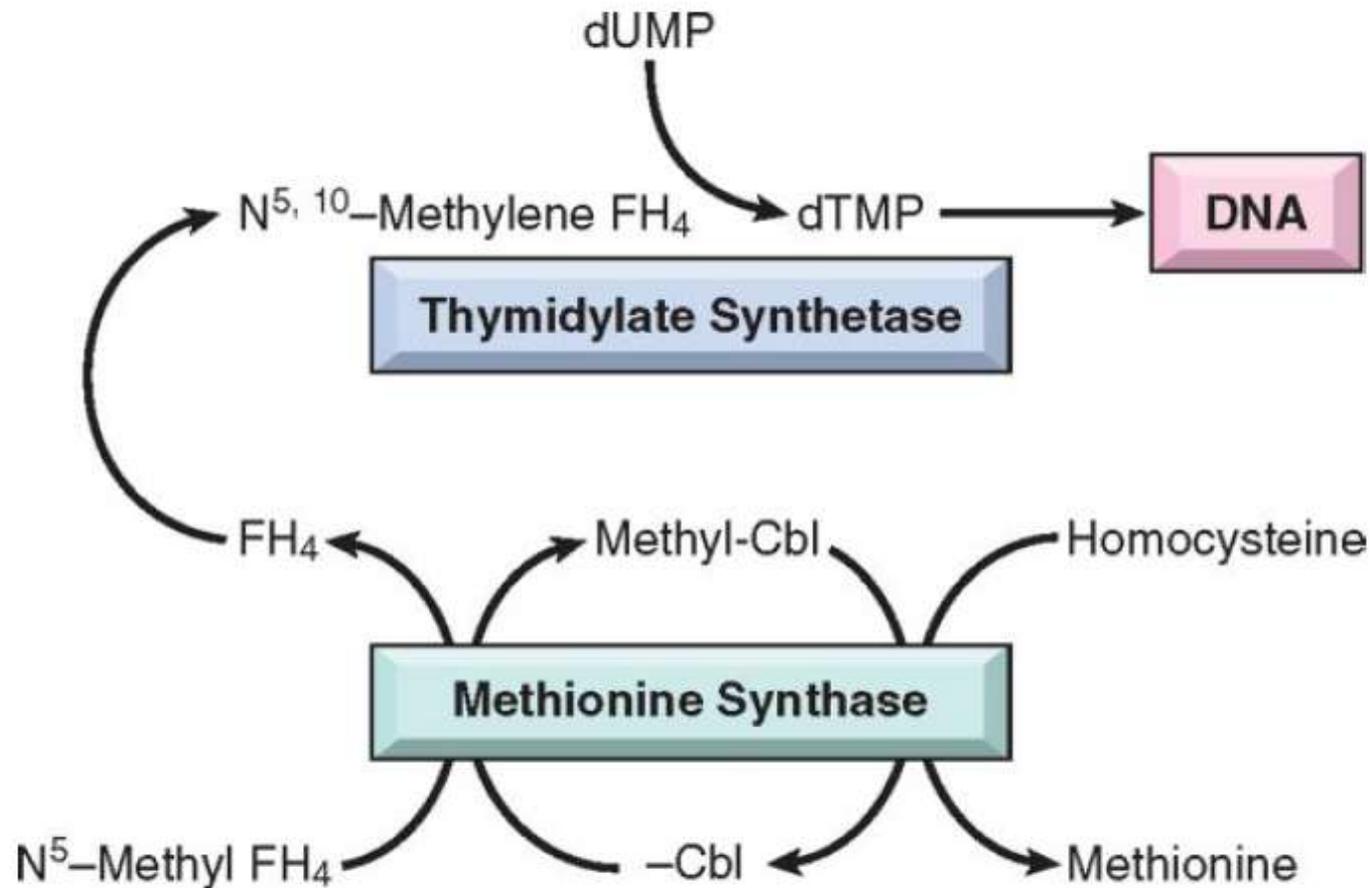
## **Role of cobalamin in DNA synthesis and the biochemical basis of Megaloblastic anemia**

- The cause of megaloblastic anemia seen in strict vegetarians is attributed to the effects of cobalamin deficiency on DNA synthesis, specifically the thymidylate synthase reaction which converts dUMP → dTMP.



- N<sup>5</sup>,N<sup>10</sup>-methylene tetrahydrofolate, is required for the methylation of dUMP to dTMP, thus in its deficiency, the thymidylate synthase reaction is slowed and dTMP levels drop and hence DNA synthesis is also slowed down due to non availability of deoxy ribonucleotides.

# Role of cobalamin and folic acid in methionine metabolism



# Absorption and digestions

- Dietary cobalamin is released from protein complexes by enzymes in the stomach, duodenum, and jejunum.
- It combines rapidly with a salivary glycoprotein that belongs to the family of **cobalamin-binding proteins known as haptocorrins (HCs)**.
- In the intestine, the haptocorrins are digested by pancreatic trypsin and the cobalamin transferred to **intrinsic factor(IF)**.

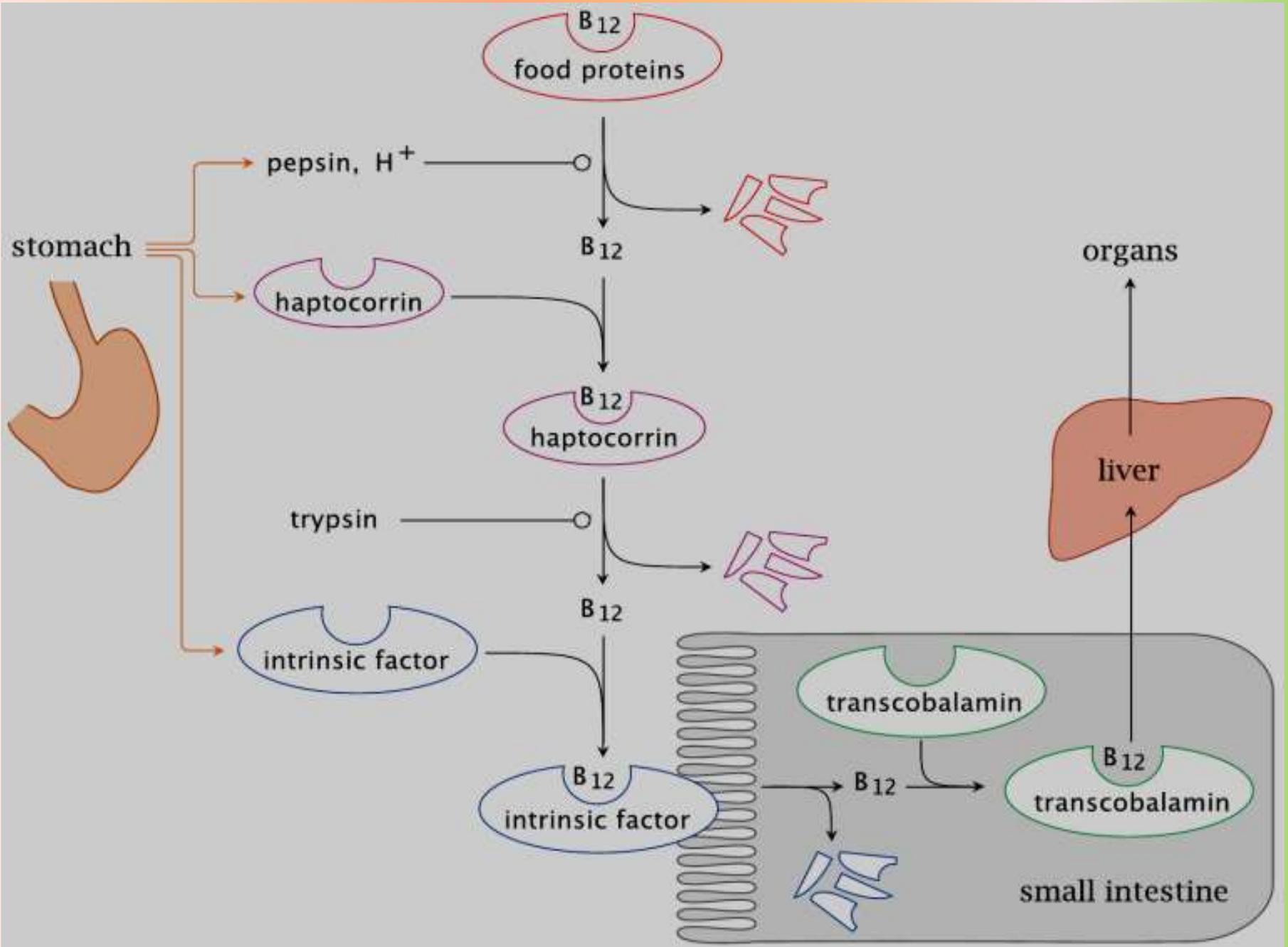
- Intrinsic factor (IF) is produced in the gastric parietal cells of the fundus and body of the stomach, its secretion parallels that of hydrochloric acid.
- The IF-cobalamin complex passes to the ileum, where IF attaches to a specific **receptor (Cubulin)** on the microvillus membrane of the enterocytes.
- Cubulin with its ligand IF-cobalamin complex is endocytosed.
- The cobalamin-IF complex enters the ileal cell where IF is destroyed.

# Transportation of Cobalamin

- Three plasma transport proteins have been identified.
- **Transcobalamine I and III** (differing only in carbohydrate structure) are secreted by white blood cells.
- Although approximately 90 percent of plasma vitamin B12 circulates bind to these proteins, only **transcobalamine II is capable of** transporting vitamin B12 into cells.

# Storage of Cobalamin

- The liver contains 2000 to 5000 mcg of stored vitamin B12.
- Since daily losses are 1 to 3 mcg/day, the body usually has sufficient stores of vitamin B12 so that vitamin B12 deficiency develops more than 3 years after vitamin B12 absorption ceases.



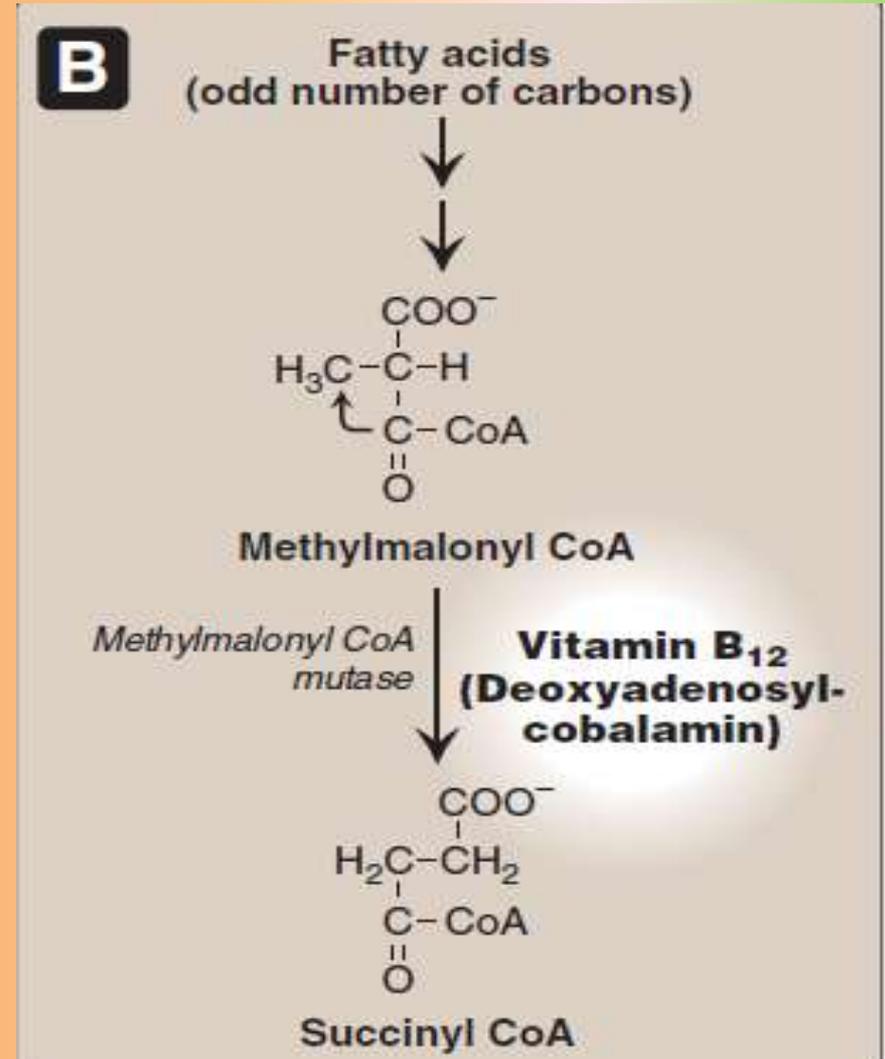
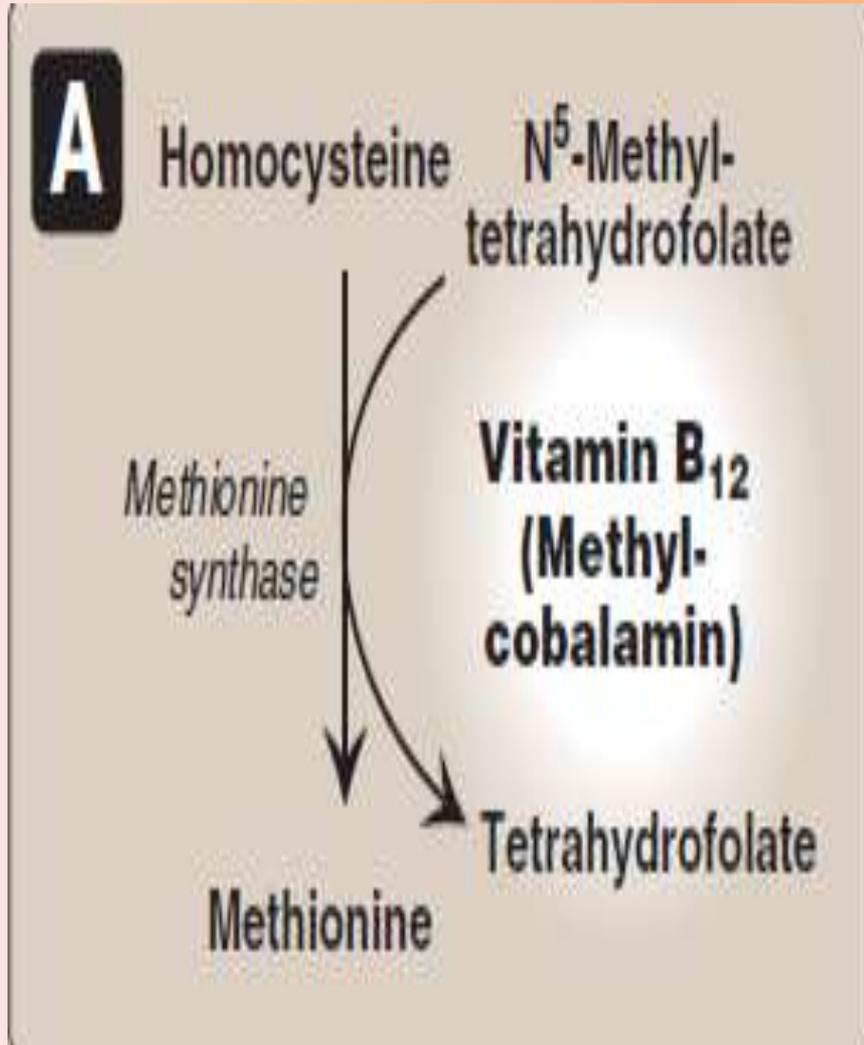
# Proteins associated with vitamin B12 metabolism

- R protein ( Haptocorrin or TCN I )
- Intrinsic factors
- Cubilin receptors
- Transcobalamin II
- Cell surface receptors for TCNII-B12 complex
- Enzymes involved in formation of- adenosyl and methyl cobalamin forms.

# Intrinsic factor

- **Gastric intrinsic factor (GIF) is a** glycoprotein produced by the parietal cells of the stomach. It is necessary for the absorption of vitamin B12.
- Encoded by the *GIF gene located at 11q12.1* chromosome.
- IF deficiency may be due to defect in GIF gene or GIF antibodies

# Biochemical or Metabolic functions of Vit. B12



# Haptocorrin

- Haptocorrin (HC) also known transcobalamin-1 (TC-1) or R-protein is encoded by the TCN1 gene located on 11q12.1 near GIF gene.
- Glycoprotein - 433 amino acids (48KDa) and 30% carbohydrates.
- The essential function of haptocorrin is protection of the acid sensitive vitamin B12 while it moves through the stomach.

# Cubilin receptor

- Also known as Intrinsic Factor-Cobalamin Receptor.
- Cubilin protein and aminonless (AMN) protein forms a Cubam complex which helps in vitamin B12 absorption. Cubilin recognizes the IF-B12 complex and AMN helps in receptor mediated endocytosis.
- Cubilin is a co-transporter protein having 3623 amino acids (398 KDa) and
- transportation requires calcium. Apart from B12 it also facilitates uptake of lipoprotein and Iron.

# Transcobalamin II

- In enterocyte B12 is liberated from IF and appears in blood bound to TC2 (holotranscobalamin) which carries B12 to various cells.
- 20% of total B12 is present in holotranscobalmin form which is supposed to be the form available for cellular uptake.

# Cell surface receptors for TCNII-B12 complex

- Vitamin B12-TCII complex is transported to target cells and undergoes receptor-mediated endocytosis using the transcobalamin II receptor (TCII-R), a specific vitamin B12 cell surface receptor.

# Deficiency symptoms

- The most important disease associated with vitamin B12 deficiency is **pernicious anemia**. It is characterized by low hemoglobin levels, decreased number of erythrocytes and neurological manifestations. One or more of the following causes are attributed to the occurrence of pernicious anemia.
- Autoimmune destruction of gastric parietal cells that secrete intrinsic factor. In the absence of IF, vitamin B12 cannot be absorbed.
- Hereditary malabsorption of vitamin B12.
- Partial or total gastrectomy – these individuals become intrinsic factor deficient.

# Deficiency symptoms

- Insufficient production of IF and/or gastric HCl, occasionally seen in older people.
- Dietary deficiency of B12 is seen among the strict vegetarians of low socioeconomic group in the developing countries (India, Srilanka etc.).

# Deficiency symptoms

- Methyltransferase step is also suppressed due to non availability of active methionine, so methylation of phosphatidyl ethanolamine to phosphatidylcholine is not done, this leads to deficient formation of myelin sheath of nerves , leads to neurological lesions.
- The symptoms include paresthesia (numbness and tingling) of fingers and toes.
- In advanced stages, confusion, loss of memory and even psychosis may be observed.

# Deficiency symptoms

- The biosynthesis of fatty acids, required for myelin formation, is impaired.
- This is because, **methylmalonyl CoA acts as a competitive inhibitor of malonyl CoA in fatty acid synthesis.**



# VITAMIN C (ASCORBIC ACID)

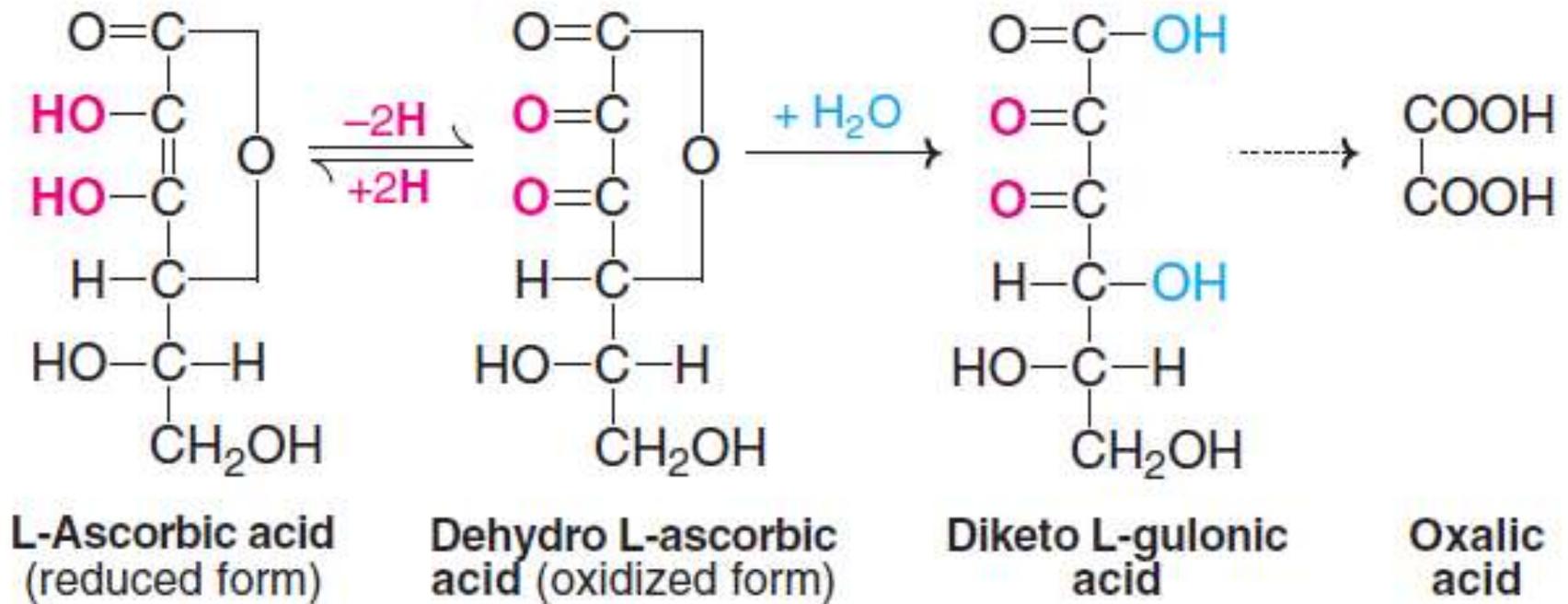
- It is also called **ascorbic acid** and **antibiotic vitamin**.
- it is the most active reducing agent.
- it is powerful antioxidant
- Synthesized by most animals (not by human)



# Chemistry

- Ascorbic acid is a hexose derivative and closely resembles monosaccharides in structure.
- The acidic property of Vitamin C is due to the enolic hydroxyl group. It is a strong reducing agent.
- L- ascorbic acid undergoes oxidation to form dehydroascorbic acids and this reaction is reversible.

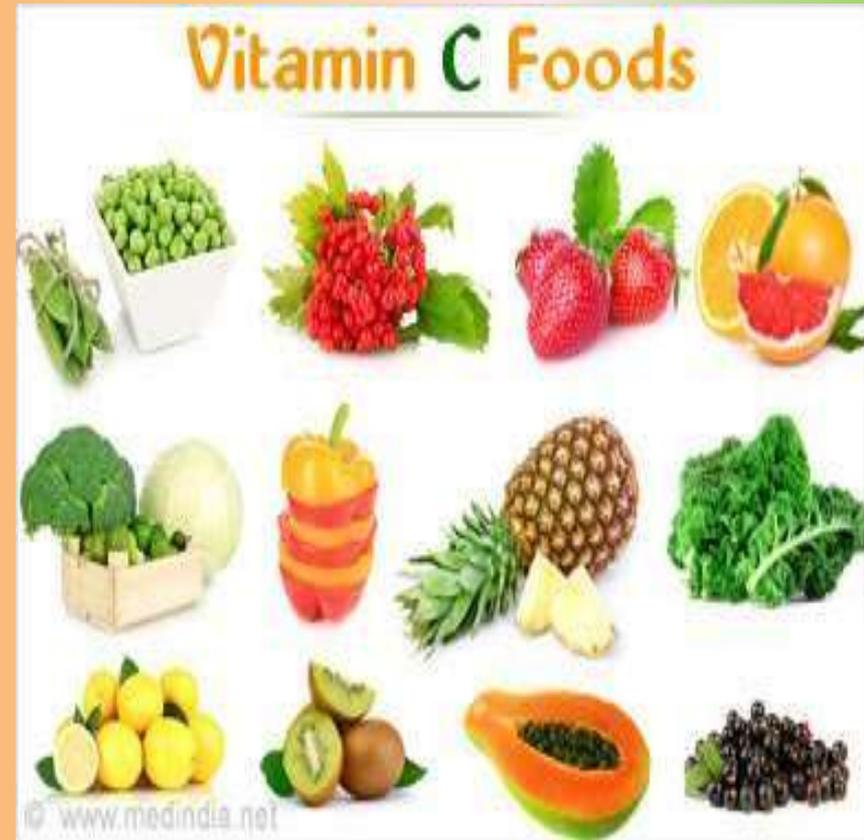
- Both these form are biologically active.
- D-Ascorbic acid is inactive.
- The plasma and tissues predominantly contain ascorbic acid in reduced form.
- Oxidation of ascorbic acid is rapid in the presence of copper, hence vitamin C becomes inactive if the foods are prepared in copper vessels.



*Fig. 7.15 : Structures of vitamin C (ascorbic acid) and its related compounds.*

# DIETARY SOURCES OF VITAMIN C

- Citrus fruits, gooseberry (amla), guava, green vegetables (cabbage, spinach) tomatoes, potatoes (particularly skin) are rich in ascorbic acid.
- Milk is poor source of vitamin C.
- Easily lost through cooking
- Sensitive to heat
- Sensitive to iron , copper, oxygen.



# RDA

- 60-90 mg/day for adults
- Additional 20%-40% for lactating & pregnant females
- +35 mg/day for smokers
- Body is saturated at intake of 100 mg/day above this is excreted in urine
- High doses may reduce the duration & severity of common cold

# Biosynthesis and metabolism.

- Many animals can synthesise ascorbic acid from glucose.
- Man, other primates guinea pigs and bats cannot synthesize ascorbic acid due to the deficiency of a single enzyme namely **L-gulono-lactone oxidase**.

- Vitamin C is rapidly absorbed from the intestine. It is not stored in the body to a significant extent.
- Ascorbic acid is excreted in urine as such or as its metabolites di ketogulonic acid and oxalic acid.

# BIOCHEMICAL FUNCTIONS

## As coenzymes

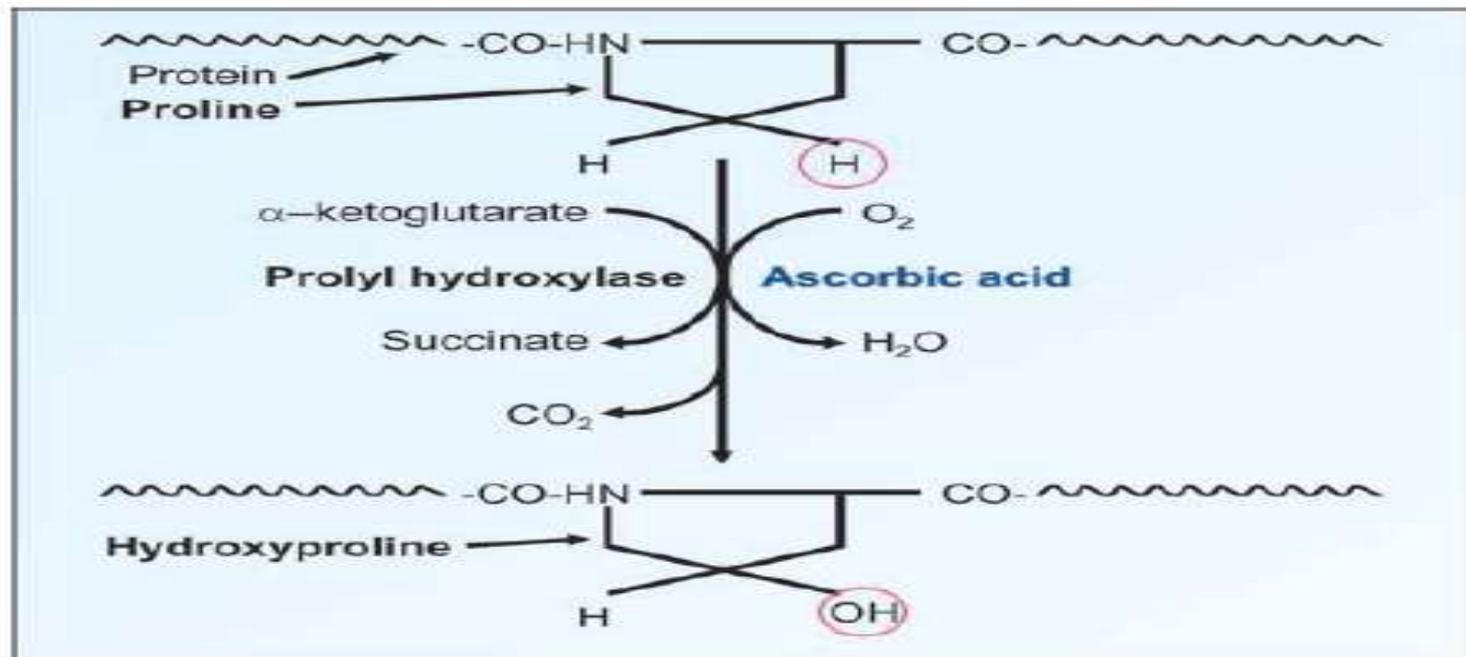
- **in cu-containing hydroxylases** eg-dopamine  $\beta$  hydroxylase,peptidylglycine hydroxylase
- **$\alpha$ -ketoglutarate linked iron containing hydroxylase** eg-proline & lysine hydroxylases, aspartate  $\beta$ -hydroxylase , vit –K dependent proteases, trimethyl lysine&  $\gamma$  -butyrobetaine hydroxylases
- Increases activity of other enzymes

## NON enzymic roles-

reducing agent

oxygen radical quencher

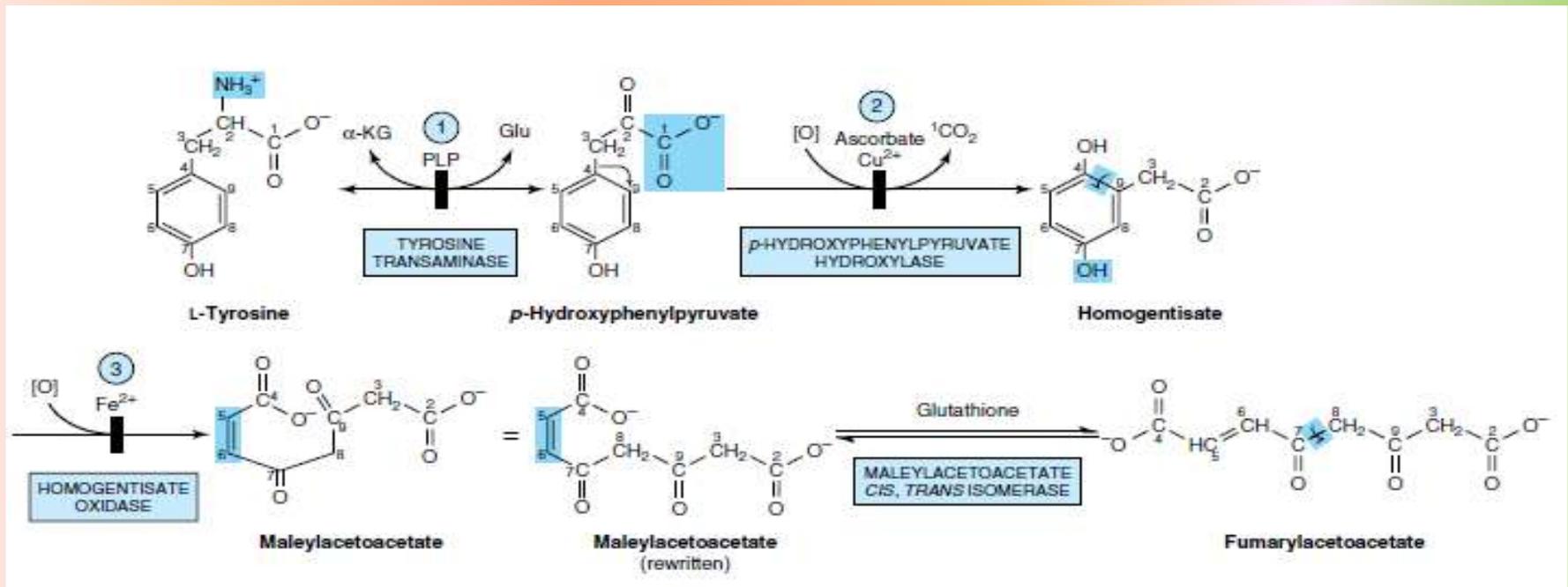
**Collagen formation:** vitamin C plays the role of a coenzyme in hydroxylation of proline and lysine while procollagen is converted to collagen. In this way, Vitamin C is necessary for maintenance of normal connective tissue and wound healing.

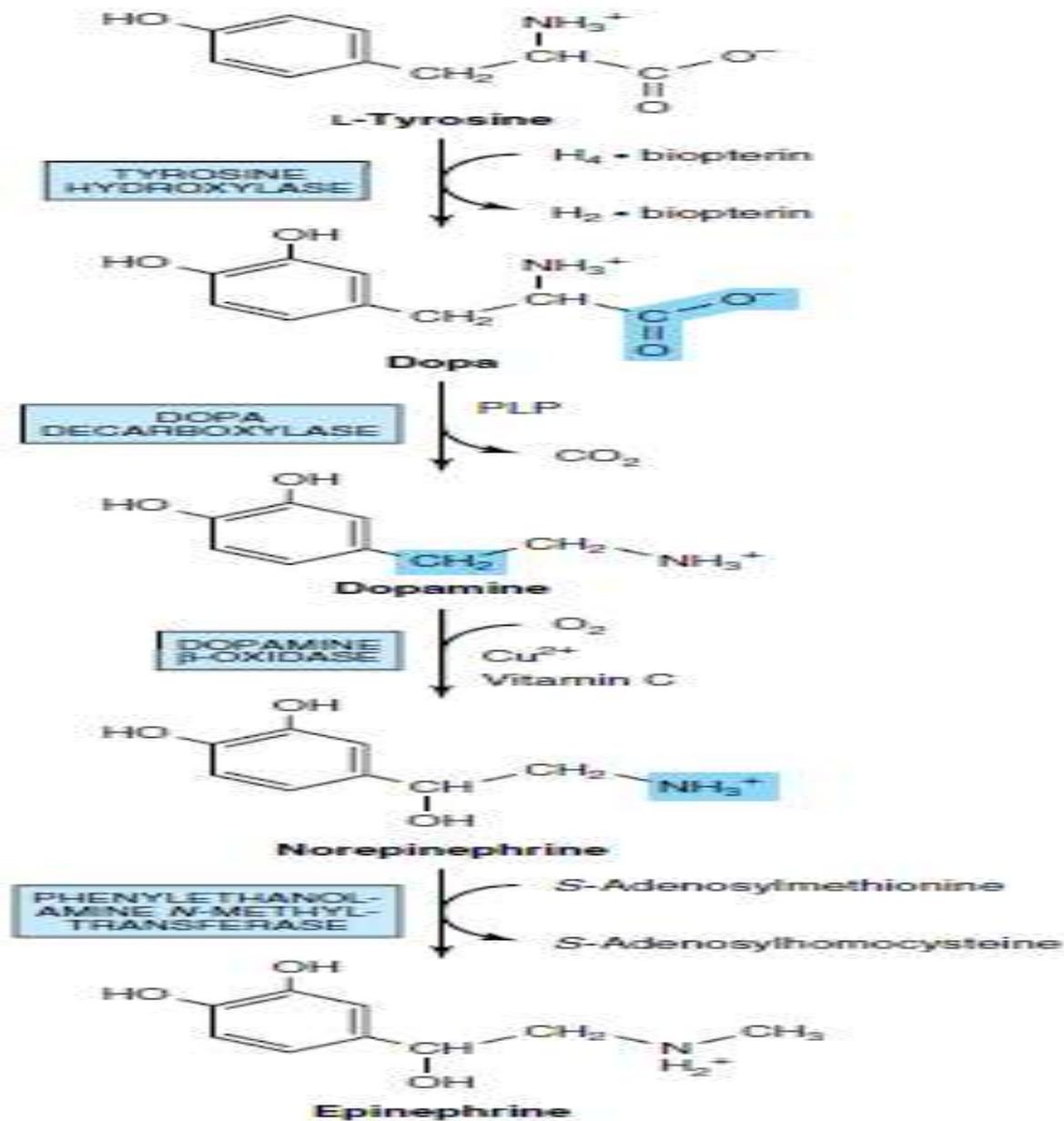


**Fig. 34.29.** Hydroxylation of proline to hydroxyproline needs ascorbic acid

- **Tryptophan metabolism: tryptophan hydroxylase** for the hydroxylation of tryptophan to hydroxy-tryptophan in the synthesis of serotonin.

**Tyrosine metabolism:** p-OH pp hydroxylase, homogentisate oxidase





**Figure 31-5.** Conversion of tyrosine to epinephrine and norepinephrine in neuronal and adrenal cells. (PLP, pyridoxal phosphate.)

**For peptidyl glycine hydroxylase-cu** containing  
eyz- required for hydroxylation of terminal  
carboxyl group (derived from glycine residues) of  
some peptide hormones

**Synthesis of corticosteroid hormones:** vitamin  
C is necessary for the hydroxylation reactions in  
the synthesis of corticosteroid hormones.

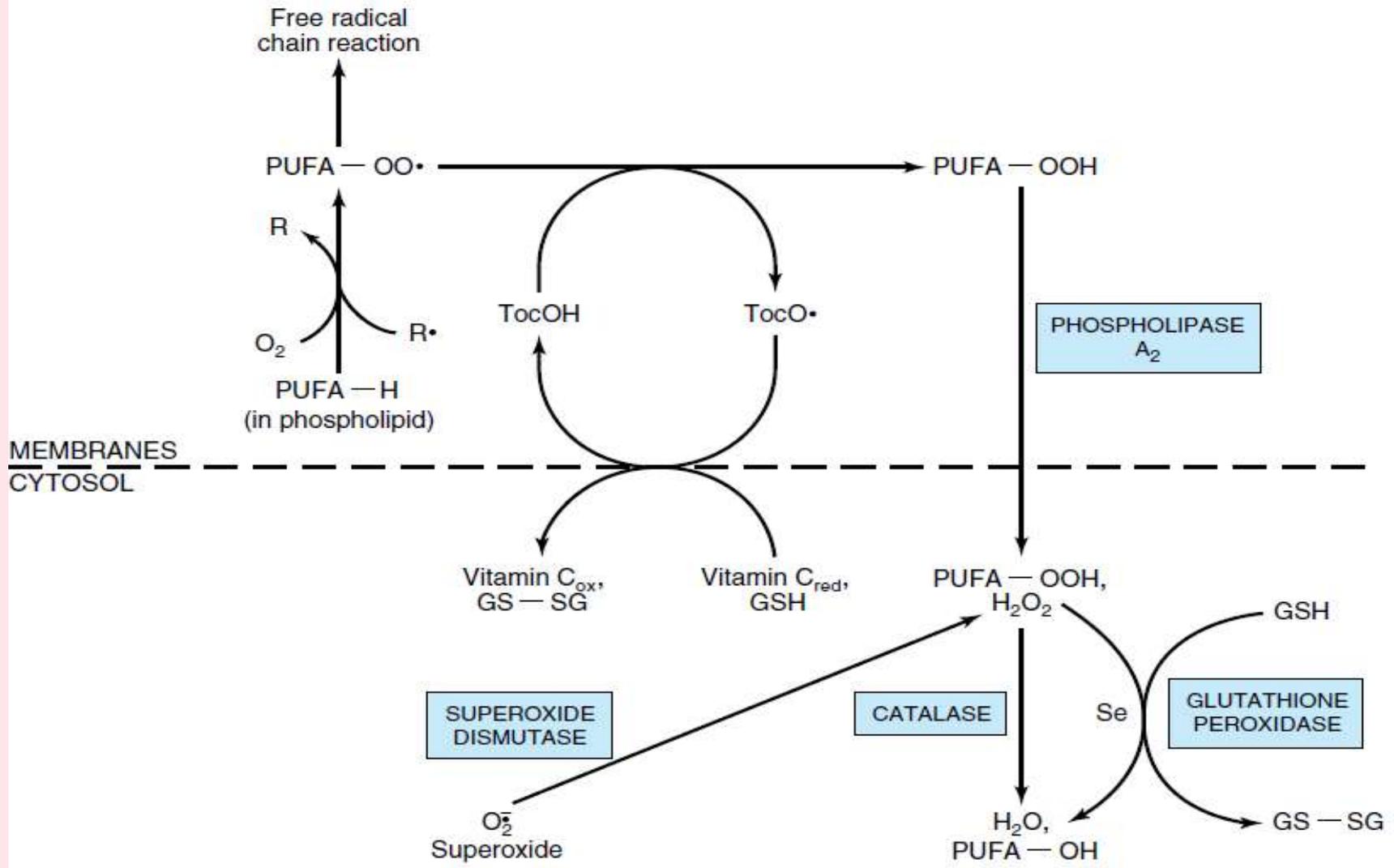
**7 $\alpha$ -hydroxylation of cholestrol** –for bile acid  
synthesis

**Strong antioxidant.**

It spares vitamin A, vitamin E and some B-  
complex vitamins from oxidation.

Prevent oxidative damage to DNA, proteins

Reduce lipid peroxidation



**Figure 45-6.** Interaction and synergism between antioxidant systems operating in the lipid phase (membranes) of the cell and the aqueous phase (cytosol). ( $R\cdot$ , free radical;  $PUFA-OO\cdot$ , peroxy radical)

- **Bone formation:** vitamin C is required for bone formation. Proline hydroxylase is required for the synthesis of OSTEOCALCIN & C1q component of complement
- **Iron and hemoglobin metabolism:** Ascorbic acid enhances iron absorption by keeping it in the ferrous form. This is due to reducing property of Vitamin C. It help in the formation of ferritin (storage form of iron) and mobilization of iron from ferritin.
- **Reconversion of methemoglobin to hemoglobin.**
- Degradation of hemoglobin to bile pigments requires ascorbic acid.

- **Aspartate  $\beta$ -hydroxylase** is required for post synthetic modification of the precursor protein C
- **Vitamin K dependent proteases** that hydrolyses activated factor V in blood clotting cascade
- **Trimethyllysine &  $\gamma$ -butyrobetaine hydroxylase** for synth of carnitine
- **-Folic acid metabolism:** Ascorbic acid is involved in the formation of the active form of folic acids. Also involved in maturation of erythrocytes.

- **Immunological function:** vitamin C enhances the synthesis of immunoglobulins (antibodies) and increases the phagocytic action of leucocytes.
- Required for formation of C1q component of complement.
- **Preventive action on cataract:** vitamin C reduces the risk of cataract formation.
- **Preventive action on chronic diseases:** as an antioxidant, vitamin C reduces the risk of cancer, cataract, and coronary heart diseases.
- **Lowers the incidence of cancers:** in high doses it can prevent the conversion of nitrites & secondary amines to carcinogenic nitrosamines.

# Vitamin C Deficiency

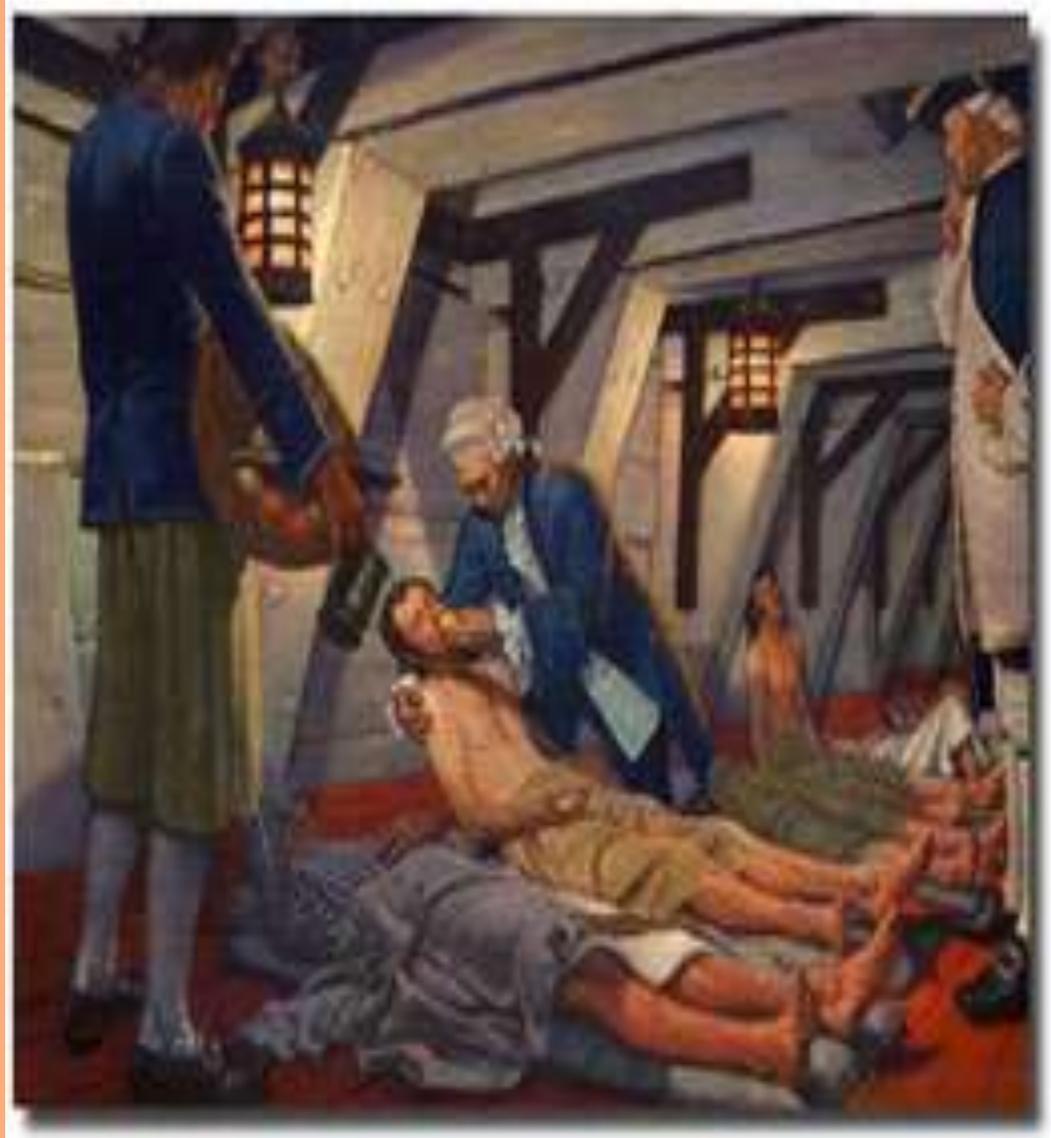
- In alcoholic persons with poor diets.
- Older persons who eat poorly (no fresh fruits and vegetables).

# Vitamin C Deficiency: History of Scurvy

- Sailors on long sea voyages suffered horribly from scurvy
- Jacques Cartier and his exploring party suffered from scurvy in Canada during the winter of 1535-6. Local Indians showed them how to brew a tea from evergreens
- On Vasco da Gama's voyage to the East Indies in 1497, 100 out of 160 men were lost from the disease.
- Scurvy was also seen in the Great Potato Famine, in soldiers during the Civil War, and in California Gold Rush communities

# Scurvy in the British Royal Navy

- James Lind published his Treatise on the Scurvy in 1754. Lime juice was made mandatory on British Navy sailing ships 40 years later



# Deficiency symptoms

**Scurvy:** deficiency of vit C leads to defective collagen synthesis .

- Spongy ,swollen and sore gums which bleed easily.
- capillaries also become fragile and bleed easily, leading to subcutaneous bleeding under the skin.
- Small dot like patches **k/a petechiae.**
- Large patches **k/a ecchymoses**
- Larger accumulation of blood under subcutaneous tissues-**HAEMATOMA**

In severe cases-**epistaxis,retinal haemorrhage ,haematuria ,malena.**



Scorbutic gums. Unlike other lesions of the mouth, scurvy presents a symmetrical appearance without infection.



Pinpoint hemorrhages. Small red spots appear in the skin, indicating spontaneous bleeding internally.

# Scurvy



Follicular  
Hemorrhages

- **WEAK BONES-k/a SCORBUTIC BONES**  
due to defective ground substance formed by osteoblasts.

Bones become weak & fracture easily with slightest trauma or pressure.

- **SCORBUTIC ROSARY**-sternum sink inwards at the costo -chondral junctions .
- **POOR WOUND HEALING**
- **ANAEMIA** -due to low Fe absorption & loss due to scurvy.

**Treatment- 500 mg /day of vit C**

# Scorbutic Rosary



JD MacLean McGill Centre for Tropical Disease

# Vitamin C Excess

- Hemochromatosis
  - Vitamin C enhances iron absorption
- Oxalate kidney stones
- Erodes tooth enamel

# Vitamin-Like Compounds

- Choline
- Carnitine
- Inositol
- Taurine
- Lipoic acid
- Synthesized in the body at the expense of amino acids and other nutrients



# Choline

- Newest essential nutrient
- All tissues contain choline
- Precursor for acetylcholine (neurotransmitter)
- Precursor for phospholipids eg-lecithin ,lung surfactant
- Sphingomyelin ,component of nerve sheath.
- Some role in homocysteine metabolism

# Food Sources of Choline

Widely distributed

- Milk
- Liver
- Eggs
- Peanuts
- Lecithin added to food
- Deficiency rare



# Requirement for Choline

- Adequate Intake is 550 mg/day for adult males
- Adequate Intake is 425 mg/day for adult females
- Normal consumption is ~700-1000 mg/day
- High doses associated with fishy body odor, vomiting, salivation, sweating, hypotension, GI effects
- Upper Level is set at 3.5 g/day (3500 mg/day)

## Deficiency-

- **Demyelinating disease**-due to defective sphingomyelin synthesis.
- **Fatty liver** – due to defective synthesis of phospholipids required for lipoprotein formation to transport lipids → accumulation of TAG in liver      liver enlargement & cirrhosis.

# Lipoic acid

- **Chemically** is 6,8 dithio-octanoic acid.
- **Functions**-take part in the **oxidative decarboxylation** reactions-
- Pyruvate Dehydrogenase Complex
- Alpha –keto glutrate dehydrogenase complex
- It acts as a carrier and undergoes interconversion b/n reduced & oxidised form.