

FOOD SCIENCE AND TECHNOLOGY

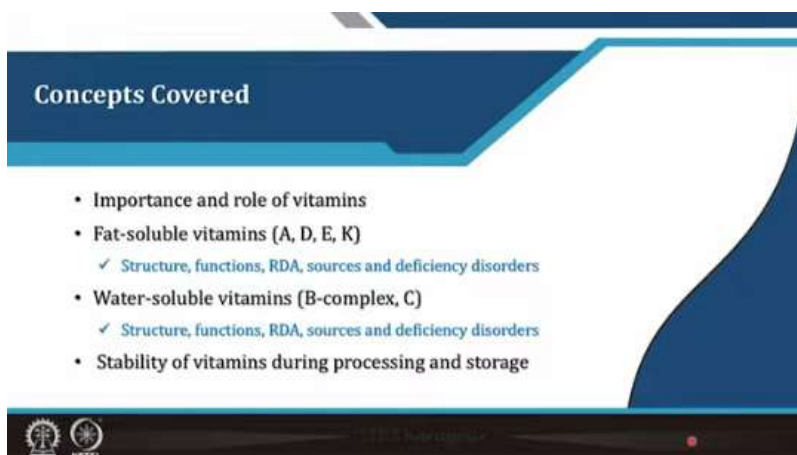
Lecture26

Lecture 26: Vitamins

Hello everyone, Namaskar.





Now, we are in the sixth module of this course, and the next five lectures of this module will be devoted to the micronutrients and bioactive compounds present in food. So, the first lecture of this module, and overall lecture number 26, today we will discuss vitamins.



The concepts which we will cover in this lecture today will include the importance and role of vitamins, structure, functions, RDA, sources, dietary deficiencies, and disorders of fat-soluble vitamins as well as water-soluble vitamins. And towards the end, we will also talk about the stability of vitamins during the processing and storage of foods.

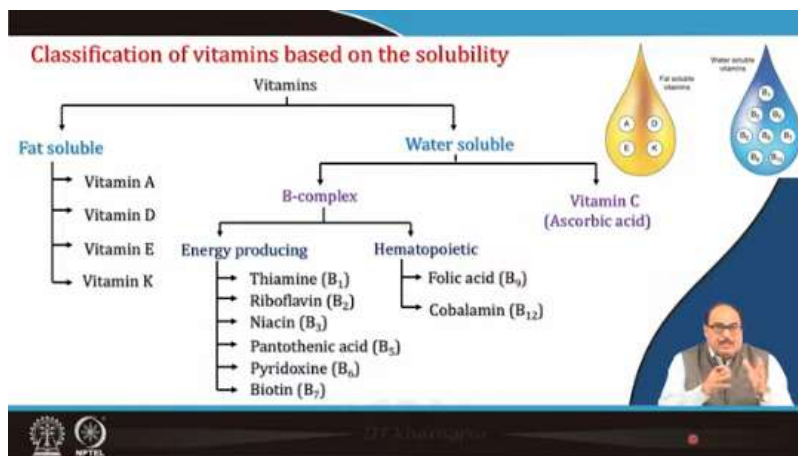
Importance and role of vitamins

- Vitamin comes from the Greek word "Vitamine" which means "Vital for life".
- Vitamins are the organic compounds required in small amounts to perform specific biological functions for the normal maintenance of optimum growth and health of an organism.
- Some vitamins are essential for energy transformation and some for the metabolism regulation but do not directly supply energy or serve as building blocks for the body's structure.
- Vitamins play a major role in
 - ✓ Growth and development,
 - ✓ Repair and healing wounds,
 - ✓ Maintaining healthy bones and tissues, and
 - ✓ Proper functioning of an immune system and other biological functions.

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So, let us see how vitamins are important in our daily life. I hope you know that the name vitamin comes from the Greek word “Vitamine”, which means vital for life. So, the name itself indicates that vitamins are a very important component; they are vital for our life. Vitamins are organic compounds required in small amounts to perform specific biological functions for the normal maintenance of optimum growth and health of an organism. Some vitamins are essential for energy transformation, and some are required for the regulation of metabolism, but they do not directly supply energy or serve as building blocks for the body structure. Vitamins play a major role in growth and development, repair and healing of wounds, maintaining healthy bones and tissues, as well as the proper functioning of the immune system and other biological functions.



Vitamins are classified into two major categories or two major groups based on their solubility. There is one group of vitamins—vitamin A, D, E, and K—which are soluble in fats, and accordingly they are called fat-soluble vitamins. There are other vitamins which are soluble in water, and they include B complex vitamins and vitamin C. The B complex vitamins can be further categorized into two groups: one is the B, energy-producing

vitamins, which are involved in the energy production processes in the body, such as thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, and biotin. The other group of B complex vitamins includes folic acid (B₉) and cobalamin (B₁₂), which are hematopoietic vitamins.

Difference between fat and water-soluble vitamins		
Property	Fat soluble vitamins	Water soluble vitamins
Solubility	Soluble in fats and organic solvents	Soluble in water
Digestion and absorption	Requires fat and bile juice	Easily absorbed in the intestine
Excretion	Via faeces	Via urine
Storage	Stored in the body in adipose tissue and liver	Not stored in the body except vitamin B ₁₂ (liver)
Toxicity	Overdosage can lead to toxicity	Usually not toxic as these are readily excreted when consumed in excess

Now, let us briefly discuss the major differences in these vitamins. We have already seen that solubility divides them into one group of fat-soluble vitamins. Obviously, they are soluble in fats and other organic solvents, whereas the other group—B complex and C vitamins—are soluble in water. So, accordingly, their solubility also influences their absorption and retention in the body, that is the digestion and absorption of fat-soluble vitamins require, obviously, fat and bile juices. Whereas water-soluble vitamins are easily absorbed in the intestine. Regarding their excretion, the fat-soluble vitamins are excreted through fecal matter, whereas the water-soluble vitamins are excreted through urine. Storage in the body of fat-soluble vitamins is there in the adipose tissues, as well as some of the fat-soluble vitamins are stored in small quantities in the liver as well. The water-soluble vitamins if you take excess, they are not stored in the body, except for vitamin B₁₂, which is stored in a limited amount in the liver; otherwise, the water-soluble vitamins are excreted through urine from the body. So, accordingly, the toxicity of these vitamins, that is, the fat-soluble vitamins, because they are not excreted from the body, they are stored. So, overdoses can lead to several toxicities. Whereas the overdoses of water-soluble vitamins do not create much problem because they are not stored in the body; they are usually not toxic and they are readily excreted when consumed in excess.

Fat soluble vitamins

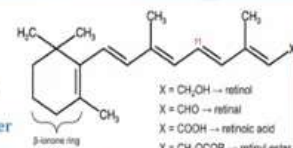
❑ Vitamin A (Retinol)

❖ Structure

- Contains methyl substituted cyclohexenyl ring (β -ionone ring) and a tetraene side chain with a hydroxyl group (Retinol), aldehyde group (Retinal), carboxylic acid (Retinoic acid) or ester group (retinyl ester) at carbon-15.
- Carotenoids act as precursors for vitamin A.


❖ Functions

- Vision:** Essential for the formation of rhodopsin in the retina, which is crucial for vision in dim light and adaptation to changes in light.
- Epithelial health:** Maintains the integrity of mucous-secreting cells in epithelial tissues, preventing keratinization and supporting overall tissue health.
- Immune function:** Helps fight infections by keeping mucous membranes healthy, acting as a barrier to pathogens.



Chemical structure of vitamin A

$X = \text{CH}_2\text{OH} \rightarrow$ retinol
 $X = \text{CHO} \rightarrow$ retinal
 $X = \text{COOH} \rightarrow$ retinoic acid
 $X = \text{CH}_2\text{OOCR} \rightarrow$ retinyl ester





So, let us now come to specific vitamins and discuss their structure, function, and other things. So, first we will start with fat-soluble vitamins and then vitamin A. Its chemical name is retinol. You can see its structure here. It contains methyl-substituted cyclohexanilrin, that is beta-iononrin, and a tetraen side chain with a hydroxyl group that is called retinal. There is an aldehyde side chain that is X here in the structure. It has a retinal or carboxylic acid, retinoic acid, or ester group that is retinyl ester at carbon 15. So, here there are different forms from the structure. You can see that depending upon the X, whether it is alcohol, aldehyde, acid, or ester, that is, you have different forms of vitamin A. The carotenoids, they act as pro-vitamin A. They are basically precursors of vitamin A. So, the functions of vitamin A include being very important in vision. They are essential for the formation of rhodopsin in the retina, which is crucial for vision in dim light and adaptation to changes in light. Also, they are important for the epithelial tissues. They maintain the integrity of mucous-secreting cells in the epithelial tissues, preventing keratinization and supporting overall tissue health and they are also important in immune function, which helps fight infections by keeping mucus membranes healthy, acting as a barrier to pathogens.

Vitamin A (Contd...)

❖ Sources


- Preformed vitamin A**
Fish liver oil, organ meats (such as liver), dairy products, and eggs
- Provitamin - A (Carotenoids)**
Green leafy vegetables, carrot, fruits


❖ Recommended dietary allowance (RDA)

Gender	RDA (µg/day)
Adult men	1000
Adult women	840


❖ Deficiency disorders



Night blindness



Xerophthalmia



Mucous membrane impact

(Source: ICMR-NIN, 2020)

Sources of vitamin A: Vitamins A can be found in fish liver oil or organ meats like liver, dairy products, and eggs, etcetera. Whereas provitamin A, which is a precursor of vitamin A, is converted into vitamin A inside the body. These are the carotenoids, and they are mostly found in green leafy vegetables, carrots, fruits, etcetera. The recommended dietary allowances of vitamin A for adult men include 1000 micrograms per day, whereas for adult women, it is around 840 micrograms per day. This is as per the ICMR NIR recommendations. Regarding the deficiency disorders of vitamin A, if you do not consume the required quantity of vitamin A, there will be problems related to night blindness, xerophthalmia, and mucous membrane impact.

Vitamin D

Structure

- Several forms (vitamers) of vitamin D exist. The two major forms are vitamin D₂ or ergocalciferol, and vitamin D₃ or cholecalciferol.
- Known as an antirachitic factor, sunshine vitamin resembles steroid hormones in structure.

Ergosterol in plants

UV light

Ergocalciferol (D₂)

$$\begin{array}{c}
 \text{R} - \text{CH} = \text{CH} - \text{CH} = \text{CH} - \text{CH} = \text{CH}_2 \\
 \text{Ergocalciferol}
 \end{array}$$

7-dehydrocholesterol in animals

UV light

Cholecalciferol (D₃)

$$\begin{array}{c}
 \text{R} - \text{CH} = \text{CH} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH} = \text{CH}_2 \\
 \text{Cholecalciferol}
 \end{array}$$

Functions

- Maintenance of
 - proper calcium and phosphorous levels in the blood,
 - normal cellular growth and function, and
 - healthy immune function.
- Prevention of excessive inflammation

Now, vitamin D, in its structure, if you look here again, the structural formula is given as ergosterol and cholecalciferol. These are several forms of vitamin D that exist. There are two major forms: vitamin D₂, which is ergocalciferol, and vitamin D₃, which is cholecalciferol. They are also known as the antirachitic factor, the sunshine vitamin, which resembles steroid hormones in its structure. At these levels, there are ergosterols which are present in plants. When you consume them, in the presence of UV light, these ergosterols are converted into ergocalciferol, which is vitamin D₂. Similarly, in animals, there is 7-dehydrocholesterol, which, with the help of sunlight or UV light, is converted into cholecalciferol, which is vitamin D₃. So, regarding the functions of vitamin D, they are very important and involved in the maintenance of proper calcium and phosphorus levels in the blood, normal cellular growth and function, and healthy immune function. So, these are all maintained by vitamin D in the cell. Also, they are involved in the prevention of excessive inflammation.

Vitamin D (Contd...)

❖ Sources



Fish liver oil Egg, butter, ghee, full-fat milk

❖ Recommended dietary allowance (RDA)



Adult men
600 IU/day



Adult women
600 IU/day

[Source: ICMR-NIN, 2020]

❖ Deficiency disorders



Reduced bone density causing osteoporosis and fractures

Bones become soft and bend in children

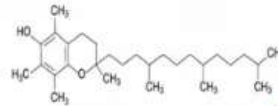
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Sources of vitamin D include fish liver oil, eggs, butter, ghee, and full-fat milk. The recommended dietary allowances include 600 international units per day for adult men and the same quantity for adult women as well. Deficiency disorders include reduced bone density, causing osteoporosis and fractures, etcetera, as you can see here in the figure. Also, bones become soft and bend in children if there is a vitamin D deficiency.

❑ Vitamin E

❖ Structure

- Vitamin E refers to a group of fat-soluble compounds like α -tocopherol.
- The basic structure of α -tocopherol includes
 - ✓ **Chromanol ring:** A phenolic chromanol ring with a hydroxyl group (OH) at the 6th position, which is crucial for the antioxidant properties of vitamin E.
 - ✓ **Phytol side chain:** A long, saturated, hydrophobic tail consisting of 16 carbon atoms that allow the molecule to be lipid-soluble.



Structure of α -tocopherol

❖ Functions

- Act as a potent antioxidant.
- Help in preventing premature hemolysis of erythrocytes.
- Plays a role in immune function, DNA repair, red blood cell formation, and vitamin K absorption.

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The next fat-soluble vitamin is vitamin E, which is tocopherol. Vitamin E refers to a group of fat-soluble compounds like alpha-tocopherol. The basic structure of alpha-tocopherol includes, as you can see here in the structure figure, that it has a chromanol ring, which is a phenolic chromanol ring with a hydroxyl group at the sixth carbon position, which is crucial for the antioxidant properties of these tocopherols or vitamin E. Apart from this, it has a phytol side chain, which is an elongated saturated hydrophobic tail consisting of 16 carbon atoms, as you can see here, and that allows the molecule to be lipid-soluble. This molecule has very good antioxidant properties, which is why vitamin E, tocopherols, etc., are known for their functions as potent antioxidants. There are reports in the literature that while working as an antioxidant, vitamin E's properties get destroyed, reduced, or

sometimes even lost completely. Vitamin E helps in preventing premature hemolysis of erythrocytes. It plays a role in immune function, DNA repair, red blood cell formation, and vitamin K absorption.

Vitamin E (Contd...)

❖ Sources



- ✓ Vegetable oils and fats
- ✓ Nuts and oilseeds
- ✓ Whole cereals,
- ✓ Wheat germ oils
- ✓ Millets
- ✓ Fortified oil and milk

❖ Deficiency disorders



Neurological disorders



Hemolytic anemia



Chronic inflammatory diseases like lupus and rheumatoid arthritis

❖ Recommended dietary allowance (RDA)



Adult men
7.5-10 mg /day



Adult women
7.5-10 mg /day

[Source: ICMR-NIN, 2020]

Sources of vitamin E include vegetable oils and fats, nuts and oilseeds, whole cereals, wheat germ oil, millets, fortified oil, and milk. Its recommended dietary analysis as per ICMR and IN includes 7.5 to 10 milligrams per day for adult men and women. Its deficiency disorders include neurological disorders. Hemolytic anemia, chronic inflammatory diseases like lupus and rheumatoid arthritis, etcetera.

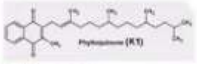
❑ Vitamin K

❖ Structure

- It has a naphthoquinone ring structure essential for its biological activity.

K₁: Phylloquinone

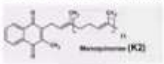
- ✓ Single isoprenoid side chain
- ✓ Available in plants



Phylloquinone (K₁)

K₂: Menaquinones


- ✓ Produced by bacteria
- ✓ Side chains of varying lengths



Menaquinone (K₂)

K₃: Menadione

- ✓ Metabolic conversion of Vit K₁
- ✓ No side chains



Menadione (K₃)

❖ Functions


- Synthesize prothrombin and other blood clotting factors.
- Improve bone density and reduce the risk of osteoporosis.
- Decrease arterial calcification by facilitating the absorption of calcium into bones.
- Reduce risk of heart disease.

Then, the next fat-soluble vitamin is vitamin K. It is a naphthoquinone ring structure essential for the biological activity of this vitamin and there are many different forms like K₁ phylloquinone or K₂ menaquinone and menadione. This phylloquinone has a single isoprenoid side chain. It is available mostly in plants, whereas the menaquinones are produced by bacteria and have side chains of varying length. Menadione is a metabolic conversion of vitamin K₁ and has no side chain as you can see here in the structure. As far

as its function is concerned, it is involved in synthesizing the prothrombin and other blood clotting factors. It improves bone density and reduces the risk of osteoporosis. It decreases artificial calcification by facilitating the absorption of calcium into bones and it reduces the risk of heart diseases.


Vitamin K (Contd...)

❖ Sources



- ✓ Green leafy vegetables
- ✓ Cabbage
- ✓ Broccoli
- ✓ Avocado
- ✓ Nuts

❖ Deficiency disorders




Hypothrombinemia

- ✓ Impaired blood clotting
- ✓ Prolonged bleeding on minor injuries
- ✓ Easy bruising
- ✓ Slow blood clot formation

❖ Recommended dietary allowance (RDA)



Adult men
55 µg/day



Adult women
55 µg/day

[Source: ICMR-NIN, 2020]

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Its sources include green leafy vegetables, cabbage, broccoli, avocado, nuts, RDA of vitamin K for adult men and women is about 55 micrograms per day. Regarding deficiency, although it is very rare, vitamin K deficiency is very rare, but still it may result in hypothrombinemia if there is a deficiency like impaired blood clotting. There will be a delay in blood clotting and there will be more blood circulation. If there is any cut or wound, there may be prolonged bleeding and minor injuries, easy bruising, and slow blood clot formation, etcetera, and all these things together can be called hypothrombinemia. So, that is the major problem of vitamin K deficiency.

Water soluble vitamins

❑ Vitamin B₁ (Thiamine)

❖ Structure

- Thiamine, a sulfur-containing vitamin, forms thiamine pyrophosphate (TPP).
- Contains a pyrimidine ring and thiazole group attached through a methylene bridge.

Cc1nc(Cc2c(C)nn(C)c2)c(C)c1
 Thiamine

Cc1nc(Cc2c(C)nn(C)c2)c(C)c1COP(=O)([O-])OP(=O)([O-])[O-]
 Thiamine pyrophosphate


Cc1nc(Cc2c(C)nn(C)c2)c(C)c1COP(=O)([O-])OP(=O)([O-])N
 Thiamine hydrochloride

Cc1nc(Cc2c(C)nn(C)c2)c(C)c1COP(=O)([O-])OP(=O)([O-])N
 Thiamine monophosphate

❖ Functions

- Take part in energy-releasing reactions in carbohydrate metabolism.
- Required for acetylcholine synthesis and ion translocation of neural tissue.
- TPP plays an important role in the transmission of nerve impulses.

❖ Deficiency disorders



Beriberi

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Then now let us talk about water-soluble vitamins and here in the first, we talk about B complex vitamins like vitamin B₁ (thiamine). Its structure is a sulfur-containing vitamin. It

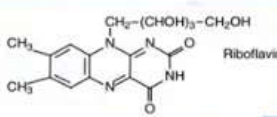
forms thiamine pyrophosphate popularly known as TPP. It contains a pyrimidine ring and a thiazole group attached through a methyl bridge. There is thiamine, thiamine pyrophosphate, thiamine hydroxide, and thiamine mononitrate. The functions of vitamin B₁. It takes part in the energy-releasing reactions in carbohydrate metabolism. It is required for acetylcholine synthesis and iron translocation in neural tissues. TPP plays an important role in the transmission of nerve impulses. Its deficiency disorder is very severe. Deficiency of vitamin B results in a popular disease known as beriberi.

Vitamin B₂ (Riboflavin)


Structure

- A group of yellow fluorescent pigments called flavins
- Composed of a 7,8-dimethyl-10(1'-ribityl) isoalloxazine ring system, which is a heterocyclic structure with three interconnected rings.
- The isoalloxazine ring is attached to a D-ribitol moiety through a nitrogen atom
- The coenzymes of vitamin B₂ are flavin mononucleotide (FMN), which has a phosphate group on the ribityl side chain, and flavin adenine dinucleotide (FAD), which includes an additional adenosyl monophosphate moiety.
- Riboflavin can exist in several oxidation states, including the yellow flavoquinone, the flavosemiquinone (red or blue depending on pH), and the colorless flavohydroquinone.

Structure of riboflavin



Structure of riboflavin




Vitamin B₂, its chemical name is riboflavin, is a group of autofluorescent pigments called flavins. It is composed of 7,8-dimethyl-10-(1'-ribityl) isoalloxazine ring system, which is a heterocyclic structure with three interconnected rings, as you can see here. The isoalloxazine ring is attached to a D-ribitol moiety through a nitrogen atom. The coenzymes of vitamin B₂ are flavin mononucleotide, commonly known as FMN, which has a phosphate group on the ribityl side chain, and flavin adenine dinucleotide, that is FAD, which includes an additional adenosyl monophosphate moiety. So, riboflavin can exist in several oxidation states, including the alloflavocanone and the flavosemucanone which is red or blue depending on the pH, and the colorless flavohydroquinone.

Vitamin B₂ (Contd ...)


❖ **Functions**

- Flavin coenzymes (mostly FAD and to a lesser extent FMN) participate in many redox reactions responsible for energy production.
- Works with other B vitamins to promote healthy growth and tissue repair, and helps release energy from carbohydrates.


❖ **Deficiency disorders**



Cheilosis
(Fissures at mouth corners)



Glossitis
(Inflamed, red beefy tongue)



Dermatitis
(Red, scaly, itchy rashes)

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Functions of vitamin B₂ are that flavin coenzymes, mostly FAD, or to a lesser extent even FMN, participate in many redox reactions responsible for energy production. It works with other B vitamins to promote healthy growth and tissue repair, and it helps the release of energy from carbohydrates that is the metabolic reactions which are involved in the energy release process; it helps in those. Regarding the deficiency of vitamin B₂, it is a disease called glossitis, which is an inflamed red, beefy tongue, as you can see here in the body. It may also result in cheilosis which is the fissures at the corners of the mouth, or dermatitis, which is red, scaly, itchy rashes etcetera, might be there.

❑ **Vitamin B₃ (Niacin)**

❖ **Structure**


- Niacin is a pyridine derivative. Structurally, it is pyridine-3-carboxylic acid.
- The amide form of niacin is known as niacinamide or nicotinamide.
- Dietary nicotinamide, niacin and tryptophan (an essential amino acid) contribute to the synthesis of the coenzymes- nicotinamide adenine dinucleotide (NAD⁺) and nicotinamide adenine dinucleotide phosphate (NADP⁺).

❖ **Functions**


- Form the active components of coenzymes NAD and NADP

❖ **Deficiency disorders**

- Niacin deficiency leads to a condition called pellagra, affecting the skin, gastrointestinal tract, and central nervous system.



Nicotinic acid



Nicotinamide

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Then, vitamin B₃. Chemical name is niacin, which is a pyridine derivative. You can see a niacin is a pyridine derivative. Structurally, it is a pyridine-3-carboxylic acid. The amide form of niacin is known as nicotinamide or niacinamide. Dietary nicotinamide, niacin, and tryptophan, which is an essential amino acid, contribute to the synthesis of the coenzymes nicotinamide adenine dinucleotide, that is NAD plus, and nicotinamide adenine dinucleotide phosphate, NADP plus. The functions of vitamin B₃ include that it forms the active compounds of coenzymes NAD and NADP. Its deficiency disorders include that

niacin deficiency leads to a condition called pellagra, which affects the skin, gastrointestinal tract, and central nervous system.

Vitamin B₅ (Pantothenic acid)

- Structure**
 - Pantothenic acid consists of two components, pantothenic acid and β -alanine, held together by a peptide linkage.
- Functions**
 - A crucial part of coenzyme A, which is involved in acetylation and other acylation reactions.
 - These reactions are vital for energy release from carbohydrates, glucose synthesis, fatty acid metabolism, and the synthesis of steroids and steroid hormones.
- Deficiency symptoms**
 - Pain and sensation in the arms and legs, loss of appetite, nausea, and indigestion.
 - Increased pulse rate, fainting attacks, and heightened susceptibility to infection.

Chemical Structure of Pantothenic acid:

$$\text{HOOC}-\text{CH}_2-\text{CH}_2-\text{N}(\text{H})-\text{C}(=\text{O})-\text{CH}(\text{OH})-\text{CH}(\text{CH}_3)_2$$

Diagram: A cartoon illustration of a boy holding a green plant, with a list of deficiency symptoms: numbness, tingling, muscle weakness, fatigue, loss of appetite, nausea, indigestion, and increased pulse rate.

Speaker: A man in a grey vest and white shirt is speaking.

The other vitamins of this B complex group of vitamins is vitamin B₅ (pantothenic acid). Pantothenic acid consists of two components that is, pantothenic acid and beta-alanine, which are held together by a peptide linkage. Its functions include that it is a crucial part of coenzyme A, which is involved in acetylation and other acetylation reactions. These reactions are vital for energy release from carbohydrates, glucose synthesis, fatty acid metabolism, and synthesis of steroid and steroid hormones. Deficiency of vitamin B₅ results in pain and sensation in the arms and legs, loss of appetite, nausea, indigestion, increased pulse rate, and fainting attacks and heightened susceptibility to infections.

Vitamin B₆ (Pyridoxine)

- Structure**
 - Comprised of three compounds, namely pyridoxine, pyridoxal, and pyridoxamine.
 - Compounds differ from each other in the structure of a functional group attached to 4th carbon in the pyridine ring.
- Functions**
 - Helps in carbohydrate, fat, and protein metabolism
 - Convert tryptophan to niacin, linoleic acid to arachidonic acid, and the release of glucose from glycogen.
- Deficiency disorders**
 - In children, decrease GABA production & hypochromic microcytic anemia.
 - Depression and confusion.

Chemical Structures of Vitamin B₆ compounds:

Pyridoxal: $\text{R} = \text{CHO}$

Pyridoxamine: $\text{R} = \text{CH}_2\text{NH}_2$

Pyridoxine: $\text{R} = \text{CH}_2\text{OH}$

Diagram: A cartoon illustration of a boy holding a green plant, with a list of deficiency symptoms: numbness, tingling, muscle weakness, fatigue, loss of appetite, nausea, indigestion, and increased pulse rate.

Speaker: A man in a grey vest and white shirt is speaking.

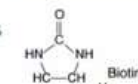
Then, vitamin B₆ pyridoxine, it is composed of three compounds namely, pyridoxine, pyridoxal, and pyridoxamine. You can see here the structure that is the R group here and the R group, depending upon its nature, it may be alcohol, pyridoxamine, or pyridoxine. These compounds differ from each other in the structure of the functional group attached

Biotin

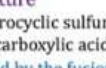
Formerly known as anti-egg white injury factor, vitamin B₇ or vitamin H.

Structure

- A heterocyclic sulfur-containing monocarboxylic acid.
- Formed by the fusion of imidazole and thiophene rings with a valeric acid side chain.
- Naturally occurring forms are free d-biotin and biocytin (ε-N-biotinyl-L-lysine).



The chemical structure of biotin shows a fused imidazole-thiophene ring system. The imidazole ring has a carbonyl group (=O) at position 2. The thiophene ring has a sulfur atom at position 4. A valeric acid side chain, -(CH₂)₅-COOH, is attached to the 3-position of the thiophene ring.



A circular collage of various food items including eggs, milk, carrots, and fruits, with a large letter 'B' in the center, representing dietary sources of biotin.

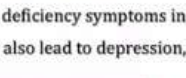
Functions

- As a coenzyme of carboxylation enzymes (carboxylases), helps in adding or removing carbon dioxide.
- Plays an important role in the metabolism of both carbohydrates and fats.

Biotin (Contd...)

❖ **Deficiency disorders**

- Biotin deficiency symptoms include anemia, loss of appetite, nausea, dermatitis, and glossitis.
- It may also lead to depression, hallucinations, and muscle pain.



HAIR LOSS & HAIR THINNING


FLAKING OF SKIN AND SCALP


WEAK MUSCLES

LETHARGY OR DISCHARGES

FUNGAL INFECTIONS

- Dermal abnormalities include hair loss (alopecia) and periorificial dermatitis, which is a scaly, red rash around the eyes, nose, and mouth, often referred to as "biotin-deficient face."
- Deficiency is rare, but may occur due to the destruction of gut microflora and consumption of raw eggs (avidin)






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Its deficiency disorders include symptoms like anemia, loss of appetite, nausea, dermatitis, and glossitis. It may also lead to depression and muscle pain, etcetera. Dermal abnormalities include hair loss and periorifacial dermatitis, which is a scaly red rash around the eyes, nose, and mouth, often referred to as biotin-deficient face and of course, the deficiency of biotin is rare, but it may occur due to the destruction of gut microflora as well as the consumption of raw eggs. You know that raw eggs contain avidin, and this avidin binds to biotin and makes the biotin unavailable for its normal functions in the body. So, therefore, if a person is taking regularly a large amount of raw eggs, they are bound to suffer from biotin deficiency.

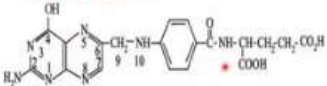
Vitamin B₉ (Folic acid)

FOODS HIGH IN VITAMIN B₉



Structure

- Consists of three components pteridine ring, para amino benzoic acid (PABA) and glutamic acid (1 to 7 residues).
- Folic acid mostly has one glutamic acid residue and is known as pteroyl-glutamic acid (PGA).
- The active form of folic acid is tetrahydrofolate (THF or FH₄).



Folic (Pteroyl-L-glutamic) acid

Then, vitamin B₉, which is folic acid, is a very important vitamin. It consists of three components: a pteridine ring, para-amino benzoic acid and glutamic acid (1 to 7 residues). Folic acid mostly has one glutamic acid residue and is known as pteroyl-glutamic acid or abbreviated as PGA. The active form of folic acid is tetrahydrofolate, or THF or FH₄, and its structure is shown here.


Functions

- Folic acid improves cognitive function and mood regulation by lowering homocysteine levels and aiding neurotransmitter synthesis.
- Essential for DNA and RNA synthesis.
- Supporting cell growth and division, especially during pregnancy and childhood.
- Controls macrocytic anaemia of pregnancy.

Deficiency disorders

- Poor growth, megaloblastic anaemia, and other blood disorders, gastrointestinal tract disturbances and metabolic derangement.
- During pregnancy can lead to Spina bifida.

Folic acid deficiency



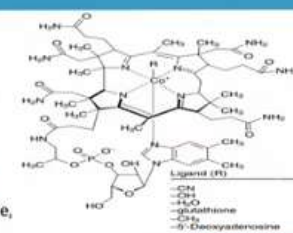
Vitamin B₉ (Contd...)


The functions of folic acid include improving cognitive functions and mood regulation by lowering homocysteine levels and aiding neurotransmitter synthesis. It is essential for DNA and RNA synthesis. It supports cell growth and division, especially during pregnancy and childhood. It is very essential, and it controls macrocytic anemia during pregnancy. The deficiency disorders of vitamin B₉ may include poor growth. Megaloblastic anemia and other blood disorders, gastrointestinal tract disturbances, and metabolic deregulation. During pregnancy, its deficiency can lead to spina bifida.


Vitamin B₁₂ (Cobalamin)

❖ **Structure**

- Synthesized by only microorganisms and not by animals and plants.
- Consists corrin ring; is similar to the tetrapyrrole ring found in porphyrin compounds like heme (with Fe) and chlorophyll (with Mg) and consists of four pyrrole units.
- The pyrrole rings have substituents like methyl, acetamide, propionamide.
- The central cobalt atom is bonded to the four pyrrole nitrogens, a dimethyl benzimidazole (DMB) group below the plane, and a sixth substituent group above the plane.
- The sixth substituent on the cobalt atom can vary, including cyanide in cyanocobalamin (B_{12a}), hydroxyl in hydroxycobalamin (B_{12b}), or nitrite in nitrocobalamin (B_{12c})







Dr. Khairul Hossain

Vitamin B₁₂, a very important vitamin, is also chemically called cobalamin. It is synthesized only by microorganisms and not by animals and plants. So, it is a very complex structure. You can see here in this structure; it consists of a corrin ring. It is similar to the tetrapyrrole ring found in porphyrin compounds like heme with iron and chlorophyll with Mg magnesium and consists of four pyrrole units. You can see here in this structure. The pyrrole rings have substituents like methyl, acetamide, and propionamide groups. The central cobalt atom is bonded to the four pyrrole nitrogen which is a dimethyl benzimidazole group below the plane and a sixth substituent group above the plane. The sixth substituent on the cobalt atom can vary, as you can see here in the structure. It can include cyanide in the cyano cobalamin B_{12a} or hydroxyl in the hydroxycobalamin, which is B_{12b}, or nitrite in the nitro cobalamin, which is B_{12c}. So, accordingly, there may be different forms depending upon the specific substituent and the cobalt atom, such as cyano cobalamin or vitamin B_{12a}, B_{12b}, or B_{12c}.



Vitamin B₁₂ (Contd..)

❖ **Functions**

- Essential for the metabolism of all cells, particularly in the gastrointestinal tract, bone marrow, and nervous tissue, and is crucial for growth.
- Cobalamin-containing coenzymes are vital for methyl group transfer and are involved in nucleic acid metabolism.

❖ **Deficiency disorders**

- Leads to pernicious anemia, characterized by low hemoglobin levels, reduced erythrocyte count, and neurological symptoms such as paresthesia, confusion, memory loss, and psychosis.
- Neuronal degeneration and demyelination causing numbness, tingling, confusion, memory loss, and psychosis.





Dr. Khanna

Functions of vitamin B₁₂ include its essential role in the metabolism of all cells, particularly in the gastrointestinal tract, bone marrow, and nervous tissues, and it is crucial for growth. Cobalamin-containing coenzymes are vital for methyl group transfer, and they are involved in nucleic acid metabolism. Its deficiency disorders include pernicious anemia, which is characterized by low hemoglobin levels, reduced erythrocyte count, and neurological symptoms such as paresthesia, confusion, memory loss, and psychosis, etcetera. Another important deficiency disorder may be neural degeneration and demyelination, causing numbness, tingling, confusion, memory loss, and psychosis, etcetera.

❑ **RDA and Sources of B complex vitamins**

Vitamin	RDA (mg/day)		Sources
	Man	Woman	
Thiamine	1.2-1.9	1.1-1.8	Fortified cereals and oatmeal, meat, rice and pasta, whole grains, liver
Riboflavin	2.0-3.2	1.9-3.1	Whole grains, green leafy vegetables, organ meats, milk, eggs
Niacin	14-23	11-18	Meat, poultry, fish, enriched cereals, peanuts, potatoes, dairy products, eggs
Pantothenic acid	5	5	Lean meats, whole grains, legumes



Dr. Khanna

So, in this table, I have tried to provide you with the RDAs for men and women of important B complex vitamins like thiamine, riboflavin, etcetera. Generally, you can see here they are required in very small quantities, maybe in the 1.2 to 1.9 per day, thiamine 2.0 to 3.2 milligrams per day, riboflavin, etcetera, and their sources are also available, and the ICMR recommended values are there, and you can refer to those ICMR guidelines as well.

Here, the production you can see is a requirement; the recommended daily allowance is 1.9 to 3.1 micrograms per day in men, as well as 1.9 to 3.4 micrograms per day in women, and it is found in fish, poultry, lean meat, etcetera.

RDA and Sources of B complex vitamins (Contd...)

Vitamin	RDA ($\mu\text{g/day}$)		Sources
	Man	Woman	
Biotin	25*	25*	Cereals/grain products, yeast, legumes, liver
Pyridoxine	1.9-3.1	1.9-3.4	Fish, poultry, lean meats, bananas, prunes, dried beans, whole grains, avocados
Folic acid	300	220	Green leafy vegetables, organ meats, dried peas, beans, lentils
Cyano-cobalamin	2.2	2.2	Meat, milk products, seafood

* Represents Adequate intake
(Source: RDA and AI taken from ICMR-NIN, 2020)

Cyanocobalamin is 2.2 micrograms per day for both men and women, and it is found only in animal sources, that is meat, milk products, seafood, etcetera; it is not found at all in plant foods. Similarly, biotin's requirement is 25 micrograms, that is 25 micrograms per day; it represents the adequate intake of biotin.

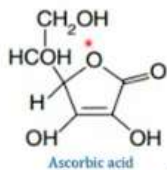
Vitamin C (Ascorbic acid)

❖ **Structure**


- Ascorbic acid is a hexose (6 carbon) derivative and closely resembles monosaccharides in structure.
- Consists of the enolic hydroxyl groups.
- L-ascorbic acid is the active form.

❖ **Functions**

- Acts as an antioxidant, supports collagen production for skin and tissue repair, and enhances immune function.
- Improves non-heme iron absorption from plant-based foods and aids in wound healing by contributing to collagen synthesis.



Ascorbic acid



Now we will talk about another very important group of water-soluble vitamins, that is vitamin C, ascorbic acid. You can see its structure here. It is a hexose, a 6-carbon derivative, and closely resembles monosaccharides in structure. It consists of enolic hydroxyl groups. L-ascorbic acid is the active form of this vitamin. It acts as an antioxidant, supports collagen production for skin and tissue repair, and enhances immune functions. It improves non-heme iron absorption from plant-based foods and aids in wound healing by contributing to collagen synthesis.

Vitamin C (Contd...)

❖ Deficiency disorders: Scurvy

Vitamin C deficiency

- Bleeding of the skin and mucus
- Fatigue
- Depression
- Increased susceptibility to infections
- Rough dry skin
- Joint and body aches
- Light nausea
- Stomach cramps, diarrhea

❖ Sources

- ✓ Green leafy vegetables
- ✓ Amla
- ✓ Berries
- ✓ Guava
- ✓ Capsicum
- ✓ Citrus fruits
- ✓ Sea buck thorn

❖ Recommended dietary allowance (RDA)

 Adult men 80 mg /day	 Adult women 65 mg /day
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[Source: ICMR-NIN, 2020]

Dr. Khanna

Food sources of vitamin C include green leafy vegetables, amla, which is popularly known as Indian gooseberries, citrus fruits, berries, guava, capsicum, and even sea buckthorn. The sea buckthorn is the richest source of vitamin C. The recommended dietary allowances include 65 milligrams per day for adult women. 80 milligrams per day for adult men. Vitamin C deficiency leads to a disease popularly known as scurvy, and it may lead to bleeding of the skin and mucus, fatigue, depression, increased susceptibility to infections, rough dry skin, joint and body aches, light nausea, and stomach cramps, diarrhea and all these things may lead to the symptoms of vitamin C deficiency, that is, scurvy.

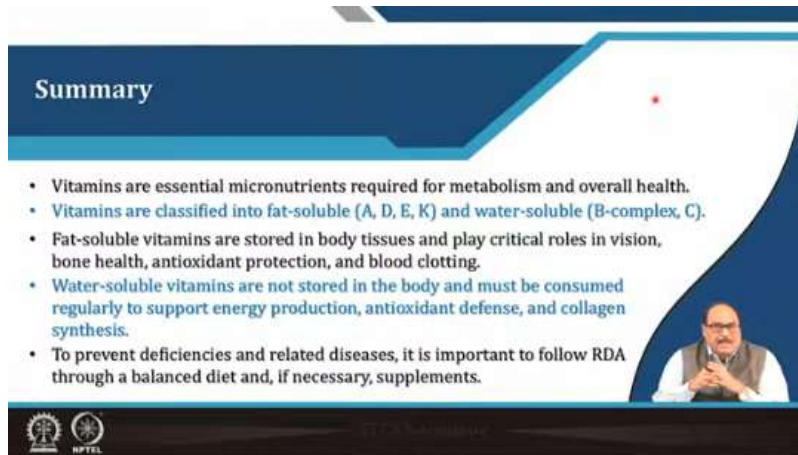
Stability of vitamins during processing and storage

- Many vitamins, such as Vitamin C and some B vitamins, are sensitive to heat and can degrade significantly during cooking or processing at high temperatures.
- Vitamins like vitamin A and riboflavin (Vitamin B₂) are sensitive to light, which can lead to their degradation and loss of nutritional value when exposed to prolonged light during storage.
- Vitamins such as vitamin C and vitamin E are prone to oxidation when exposed to oxygen, leading to reduced potency and efficacy.
- pH of environment affects stability of vitamins; e.g., vitamin C is more stable in acidic conditions but can degrade in alkaline conditions.
- Moisture can affect vitamin stability; water-soluble vitamins like vitamins C and B complex can be lost during washing, soaking, or cooking processes.

Dr. Khanna

Now, let us talk about the stability of vitamins during processing and storage, and many vitamins like C and B vitamins are sensitive to heat, and they can degrade significantly during cooking or processing at high temperatures. Vitamins like A and riboflavin are sensitive to light which can lead to their degradation and loss of nutritional value when exposed to prolonged light during storage. Vitamins like C and E are prone to oxidation, and when exposed to oxygen they lead to reduced potency and efficacy. The pH of the environment affects the stability of vitamins. Vitamin C is more stable in acidic conditions

but can degrade in alkaline conditions. Moisture can also affect vitamin stability. Water-soluble vitamins like vitamin C and B complex can be lost during washing, soaking, or cooking processes.



Summary

- Vitamins are essential micronutrients required for metabolism and overall health.
- Vitamins are classified into fat-soluble (A, D, E, K) and water-soluble (B-complex, C).
- Fat-soluble vitamins are stored in body tissues and play critical roles in vision, bone health, antioxidant protection, and blood clotting.
- Water-soluble vitamins are not stored in the body and must be consumed regularly to support energy production, antioxidant defense, and collagen synthesis.
- To prevent deficiencies and related diseases, it is important to follow RDA through a balanced diet and, if necessary, supplements.

Logos: Anna University, NPTEL

Now, I will summarize the whole lecture by saying that these vitamins are essential micronutrients required for metabolism and overall health. Vitamins are grouped into two major categories: fat-soluble and water-soluble vitamins. Fat-soluble vitamins are stored in the body tissues and play critical roles in vision, bone health, antioxidant production, and blood clotting. Water-soluble vitamins are not stored in the body and must be consumed regularly to support energy production, antioxidant defense, collagen synthesis, and to prevent deficiencies and related diseases. It is very important to follow RDAs, recommended dietary allowances, through a balanced diet. And if necessary, sometimes we can go for the supplementation or fortification of these foods, etcetera, by these vitamins, etcetera. But we must ensure that the daily required amount of these vitamins is provided and taken in the proper quantity. So, we have to remain fit and healthy.



These are the references used in today's lecture.



Thank you very much. Thank you.