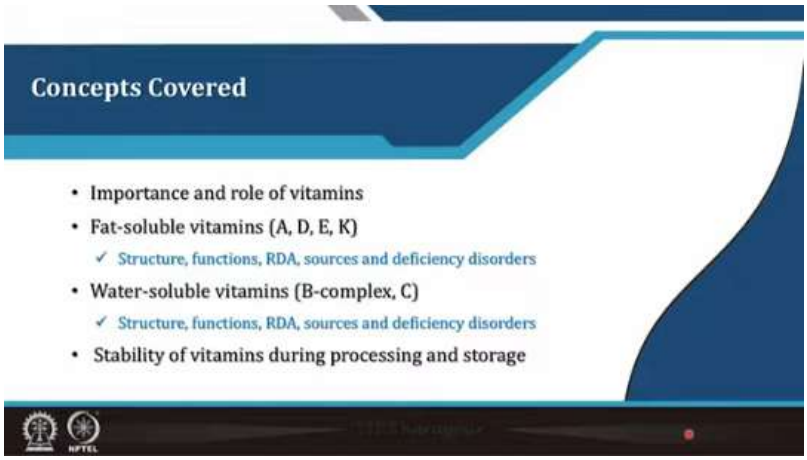
FOOD SCIENCE AND TECHNOLOGY

Lecture26

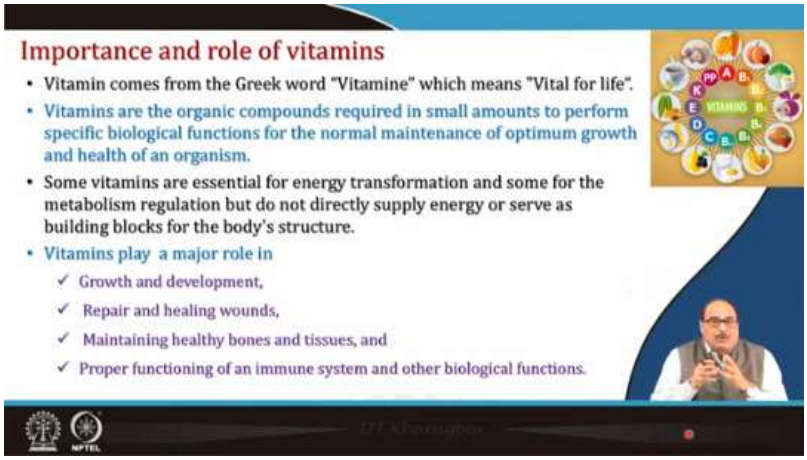
Lecture 26: Vitamins

Hello everyone, Namaskar.

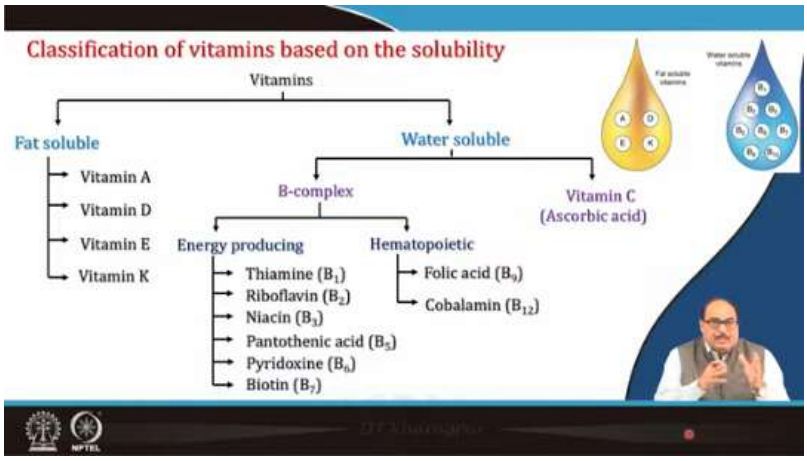
Now, we are in the sixth module of this course, and the next five lectures of this module will be devoted to the micronutrients and bioactive compounds present in food. So, the first lecture of this module, and overall lecture number 26, today we will discuss vitamins.



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.

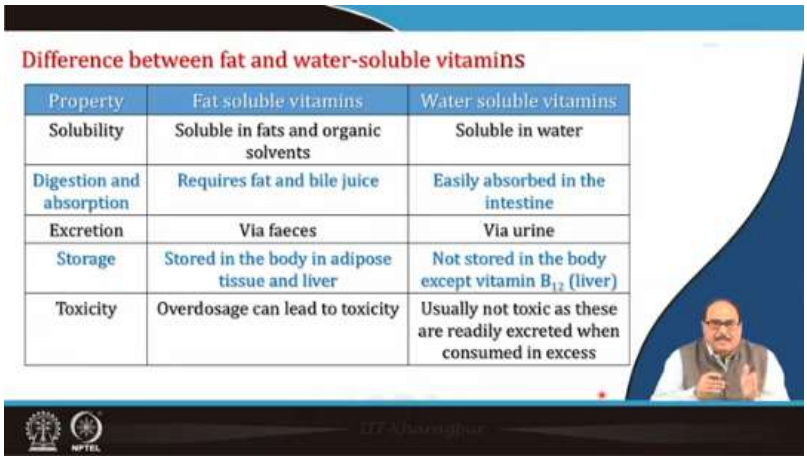


So, let us see how vitamins are important in our daily life. I hope you know that the name vitamin comes from the Greek word "Vitamine", which means vital for life. So, the name itself indicates that vitamins are a very important component; they are vital for our life. Vitamins are organic compounds 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.

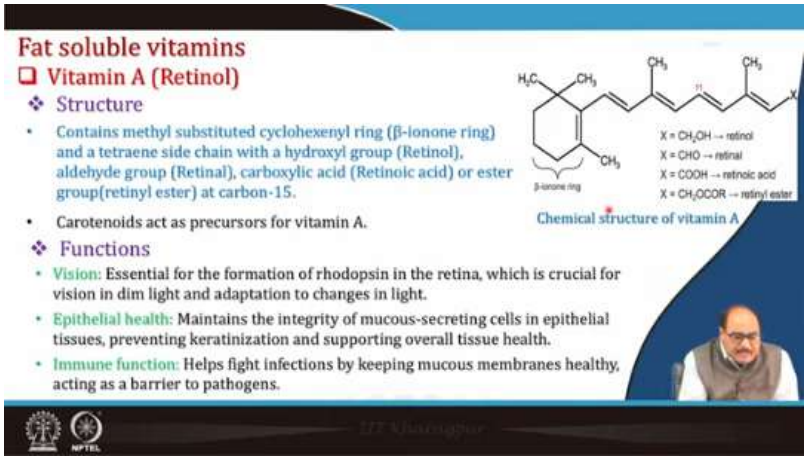


Vitamins are classified into two major categories or two major groups based on their solubility. There is one group of vitamins—vitamin A, D, E, and K—which are soluble in fats, and accordingly they are called fat-soluble vitamins. There are other vitamins which are soluble in water, and they include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

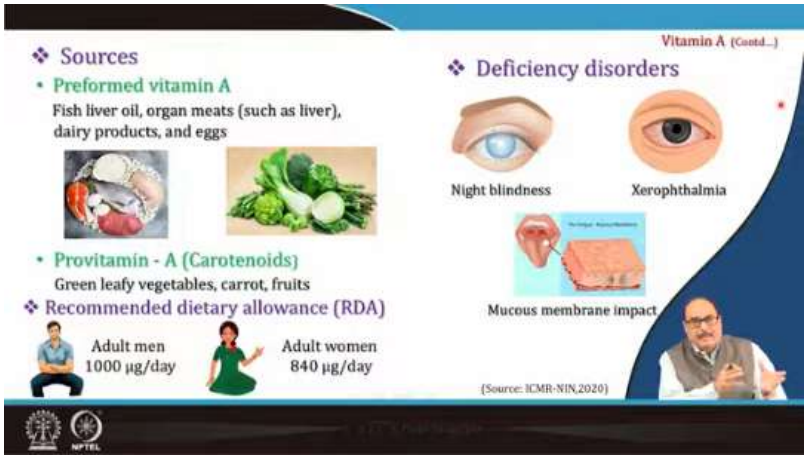
vitamins, which are involved in the energy production processes in the body, such as thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, and biotin. The other group of B complex vitamins includes folic acid (B_9) and cobalamin (B_{12}), which are hematopoietic vitamins.



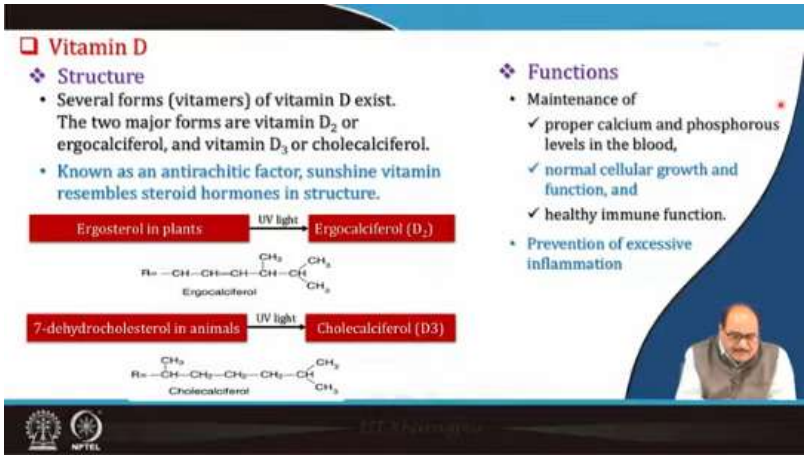
Now, let us briefly discuss the major differences in these vitamins. We have already seen that solubility divides them into one group of fat-soluble vitamins. Obviously, they are soluble in fats and other organic solvents, whereas the other group—B complex and C vitamins—are soluble in water. So, accordingly, 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 B_{12}, 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.



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 tetrain 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.

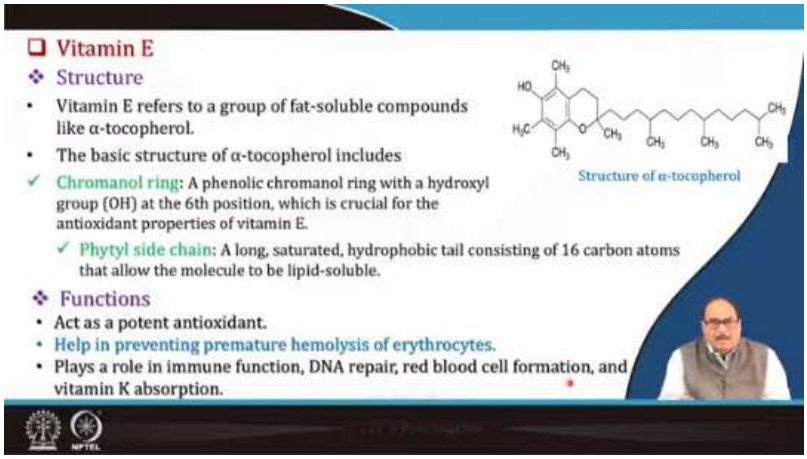


Sources of vitamin A: Vitamins A can be found in fish liver oil or organ meats like liver, dairy products, and eggs, etcetera. Whereas provitamin A, which is a precursor of vitamin A, is converted into vitamin A inside the body. These are the carotenoids, and they are mostly found in green leafy vegetables, 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.



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 D_2, which is ergocalciferol, and vitamin D_3, 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 D_2. Similarly, in animals, there is 7-dehydrocholesterol, which, with the help of sunlight or UV light, is converted into cholecalciferol, which is vitamin D_3. 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.

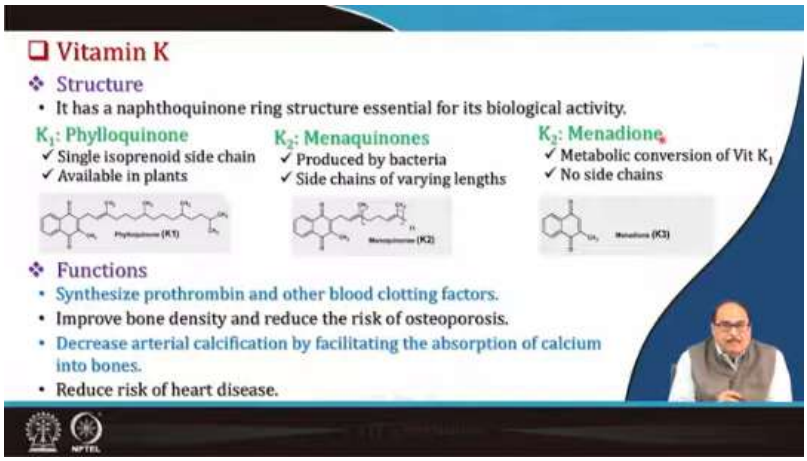
Sources of vitamin D include fish liver oil, eggs, butter, ghee, and full-fat milk. The recommended dietary allowances include 600 international units per day for adult men and the same quantity for adult women as well. Deficiency disorders include reduced bone density, causing osteoporosis and fractures,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



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 phytyl 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.

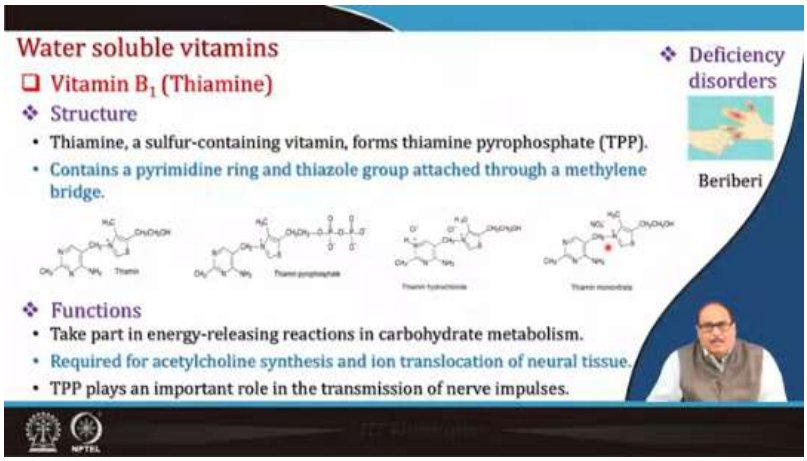
Sources of vitamin E include vegetable oils and fats, nuts and oilseeds, whole cereals, wheat germ oil, millets, fortified oil, and milk. Its recommended dietary analysis as per ICMR and IN includes 7.5 to 10 milligrams per day for adult men and women. Its deficiency disorders include neurological disorders.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



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 K_1 phylloquinone or K_2 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 K_1 and has no side chain as you can see here in the structure. As far

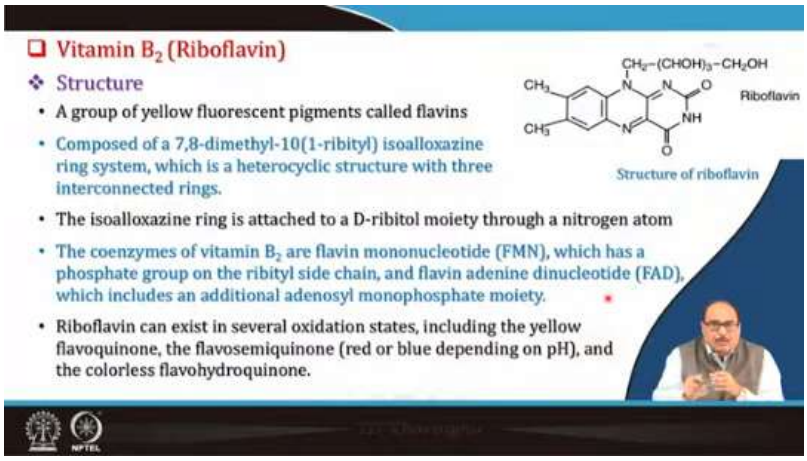
as its function is concerned, it is involved in synthesizing the prothrombin and other blood clotting factors. It improves bone density and reduces the risk of osteoporosis. It decreases artificial calcification by facilitating the absorption of calcium into bones and it reduces the risk of heart diseases.

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.

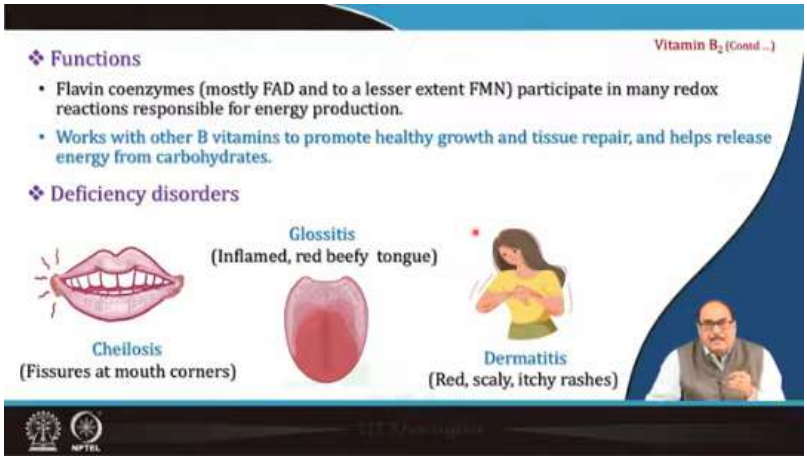


Then now let us talk about water-soluble vitamins and here in the first, we talk about B complex vitamins like vitamin B_1 (thiamine). Its structure is a sulfur-containing vitamin. It

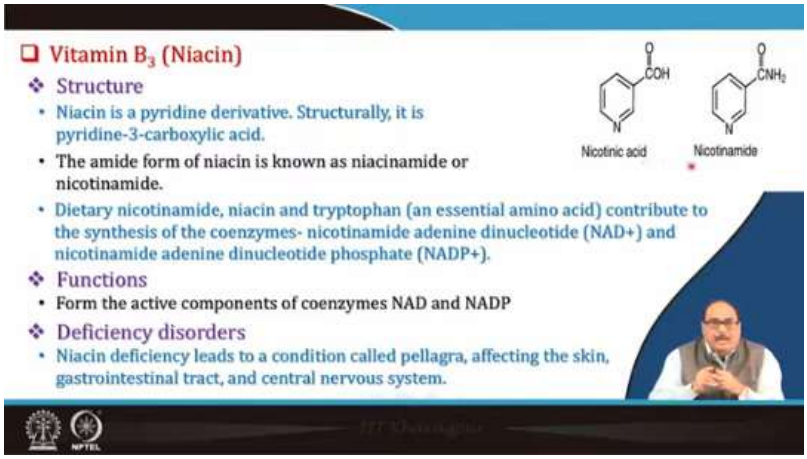
forms thiamine pyrophosphate popularly known as TPP. It contains a pyrimidine ring and a thiazole group attached through a methyl bridge. There is thiamine, thiamine pyrophosphate, thiamine hydroxide, and thiamine mononitrate. The functions of vitamin B_1. It takes part in the energy-releasing reactions 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 B_2, 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 B_2 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.

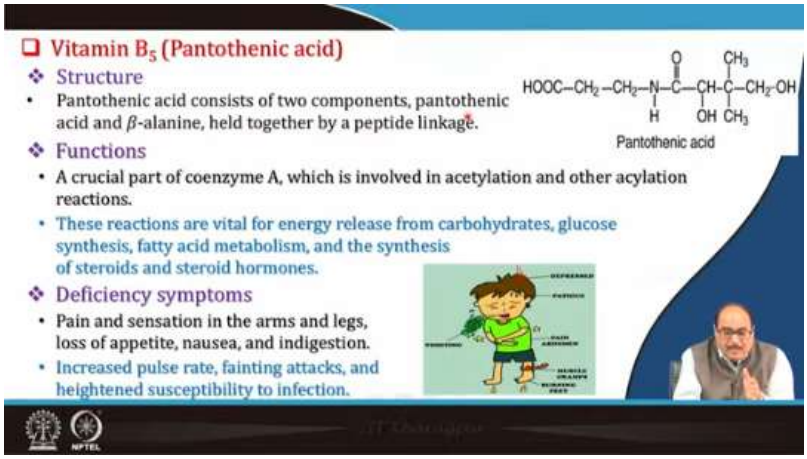


Functions of vitamin B_2 are that flavin coenzymes, mostly FAD, or to a lesser extent even FMN, participate in many redox reactions responsible for energy production. It works with other B vitamins to promote healthy growth and tissue repair, and it helps the release of energy from carbohydrates that is the metabolic reactions which are involved in the energy release process; it helps in those. Regarding the deficiency of vitamin B_2, 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.

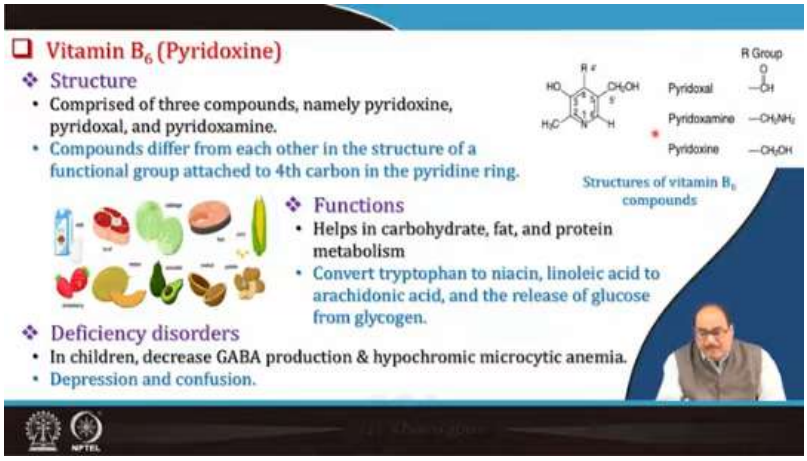


Then, vitamin B_3. Chemical name is niacin, which is a pyridine derivative. You can see a niacin is a pyridine derivative. Structurally, it is a pyridine-3-carboxylic acid. The amide form of niacin is known as nicotinamide or niacinamide. Dietary nicotinamide, niacin, and tryptophan, which is an essential 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 B_3 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.

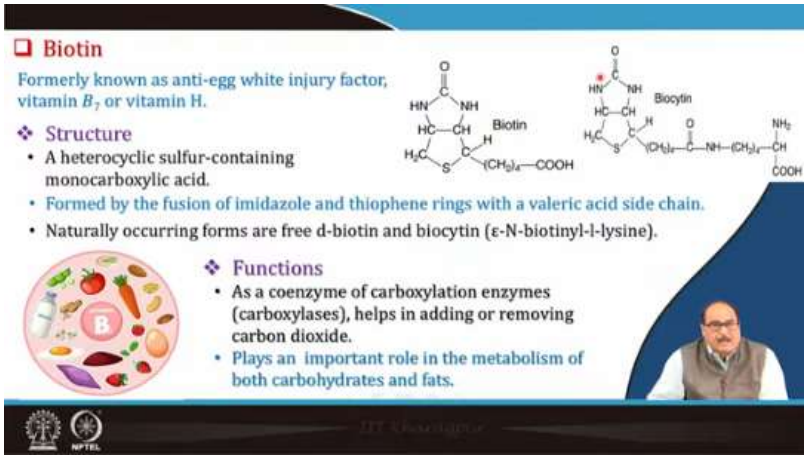


The other vitamins of this B complex group of vitamins is vitamin B_5 (pantothenic acid). Pantothenic acid consists of two components that is, pantothenic acid and beta-alanine, which are held together by a peptide linkage. Its functions include that it is a crucial part of coenzyme A, which is involved 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 B_5 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.

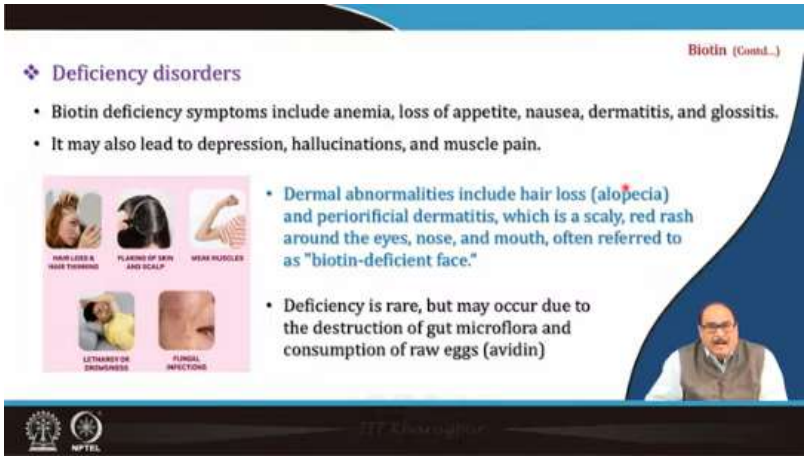


Then, vitamin B_6 pyridoxine, it is composed of three compounds namely, pyridoxine, pyridoxal, and pyridoxamine. You can see here the structure that is the R group here and the R group, depending upon its nature, it may be alcohol, pyridoxamine, or pyridoxine. These compounds differ from each other in the structure of the functional group attached

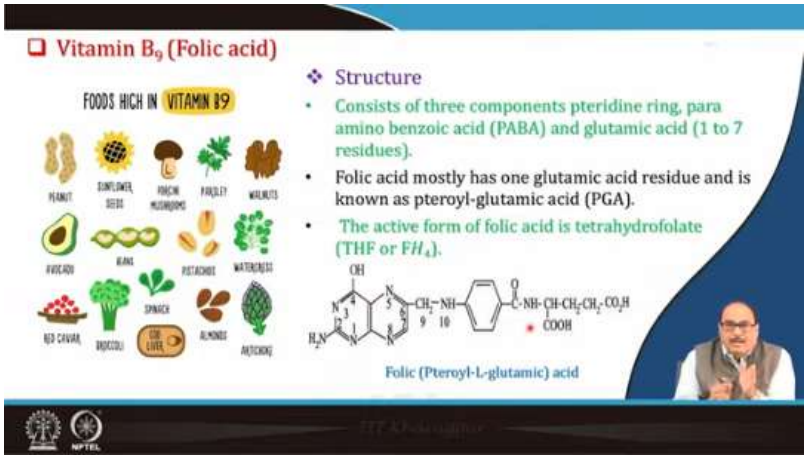
to the fourth carbon. So, their functions include helping in carbohydrate, fat, and protein metabolism, converting tryptophan to niacin, linoleic acid to arachidonic acid, and the release of glucose from glycogen. Its deficiency disorders, particularly in children, its deficiency results in decreased GABA production and hypochromic microcytic anemia, that is, there may be depression and confusion-related issues if the vitamin B6 deficiency is there.



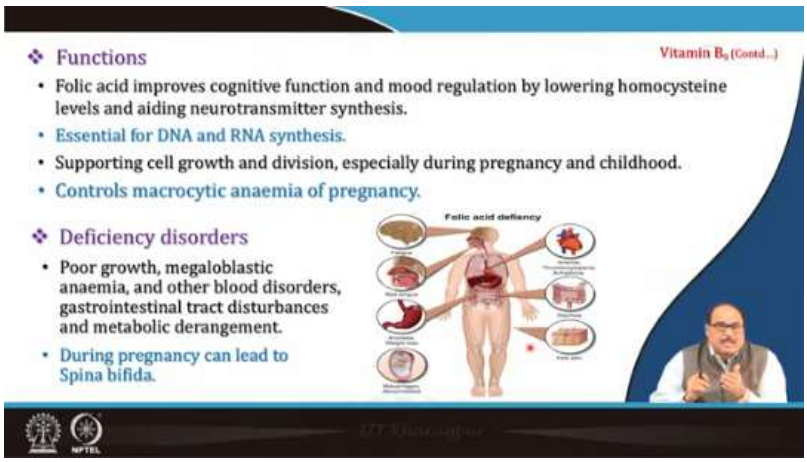
Then another important water-soluble vitamin of the B complex group is biotin. It was formerly known as anti-egg white injury factors, vitamin B_7, or vitamin H as well. So, you can see its structure is given here. It is a heterocyclic sulfur-containing monocarboxylic acid. It is formed by the fusion of imidazole and thiophene with a valeric acid side chain. Naturally occurring forms of this vitamin are free d-biocytin, which is the sigma N biotinyl L-lysine. It functions as a coenzyme of carboxylation enzymes, that is, carboxylase, and helps in adding or removing carbon dioxide. It plays an important role in the metabolism of both carbohydrates and fats.



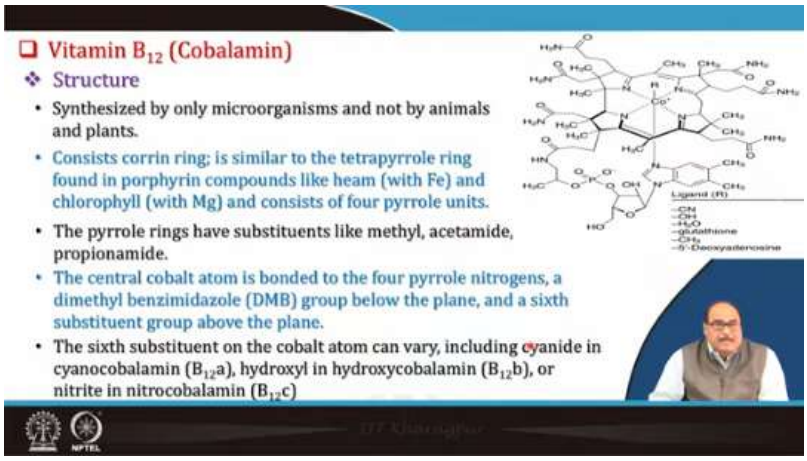
Its deficiency disorders include symptoms like anemia, loss of appetite, nausea, dermatitis, and glossitis. It may also lead to depression and muscle pain, etcetera. Dermal abnormalities include hair loss and periorifacial dermatitis, which is a scaly red rash around the eyes, nose, and mouth, often 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.



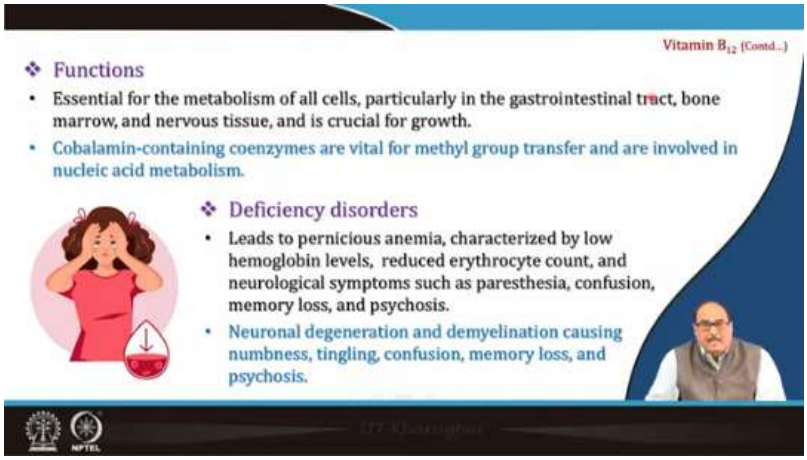
Then, vitamin B_9, which is folic acid, is a very important vitamin. It consists of three components: a pteridine ring, para-amino benzoic acid and glutamic acid (1 to 7 residues). Folic acid mostly has one glutamic acid residue and is known as pteroyl-glutamic acid or abbreviated as PGA. The active form of folic acid is tetrahydrofolate, or THF or FH_4, and its structure is shown here.



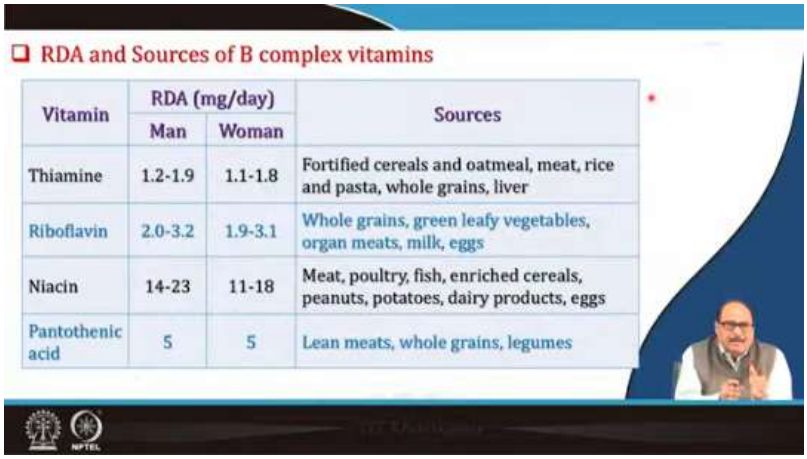
The functions of folic acid include improving cognitive functions and mood regulation by lowering homocysteine levels and aiding neurotransmitter synthesis. It is essential for DNA and RNA synthesis. It supports cell growth and division, especially during pregnancy and childhood. It is very essential, and it controls macrocytic anemia during pregnancy. The deficiency disorders of vitamin B_9 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 B_{12}, 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_{12}a or hydroxyl in the hydroxycobalamin, which is B_{12}b, or nitrite in the nitro cobalamin, which is B_{12}c. So, accordingly, there may be different forms depending upon the specific substituent and the cobalt atom, such as cyano cobalamin or vitamin B_{12}a, B_{12}b, or B_{12}c.

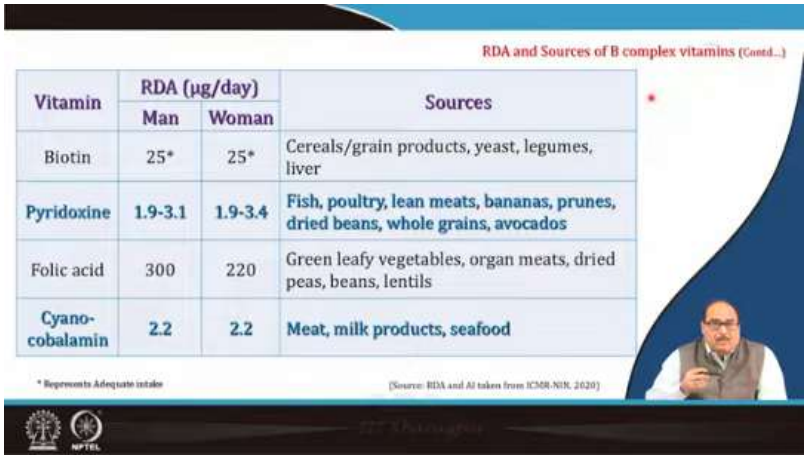


Functions of vitamin B_{12} include its essential role in the metabolism of all cells, particularly in the gastrointestinal tract, bone marrow, and nervous tissues, and it is crucial for growth. Cobalamin-containing coenzymes are vital for methyl group transfer, and they are involved in nucleic acid 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.

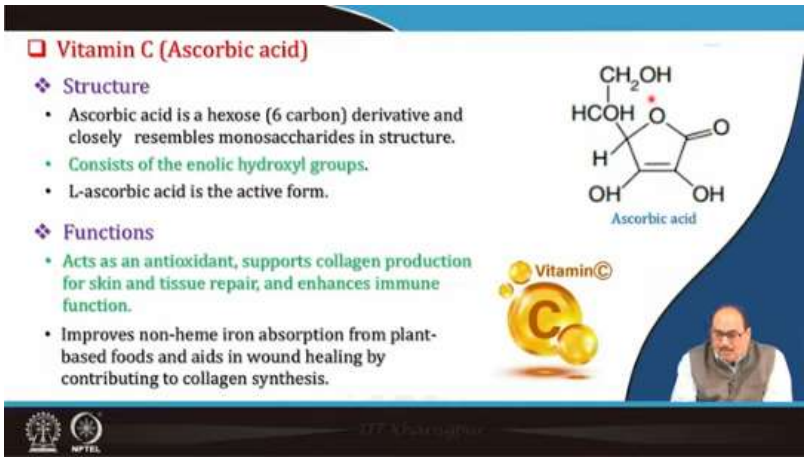


So, in this table, I have tried to provide you with the RDAs for men and women of important B complex vitamins like thiamine, riboflavin, etcetera. Generally, you can see here they are required in very small quantities, maybe in the 1.2 to 1.9 per day, thiamine 2.0 to 3.2 milligrams per day, riboflavin,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

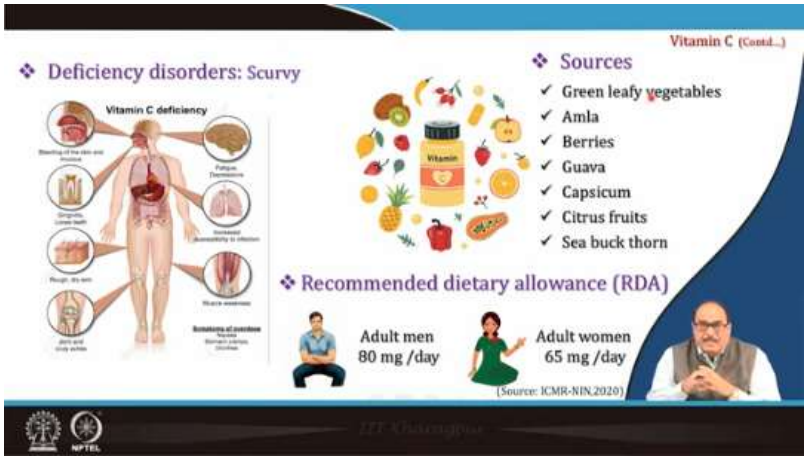
Here, the production you can see is a requirement; the recommended daily allowance is 1.9 to 3.1 micrograms per day in men, as well as 1.9 to 3.4 micrograms per day in women, and it is found in fish, poultry, lean meat, etcetera.



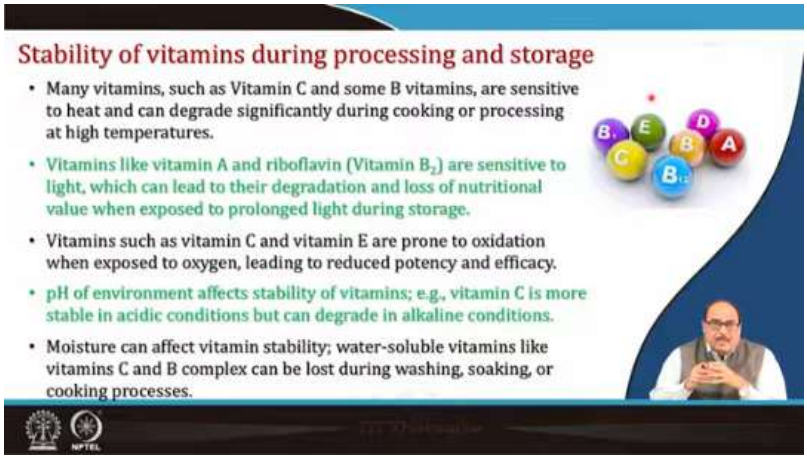
Cyanocobalamin is 2.2 micrograms per day for both men and women, and it is found only in animal sources, that is meat, milk products, seafood, etcetera; it is not found at all in plant foods. Similarly, biotin's requirement is 25 micrograms, that is 25 micrograms per day; it represents the adequate intake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



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.

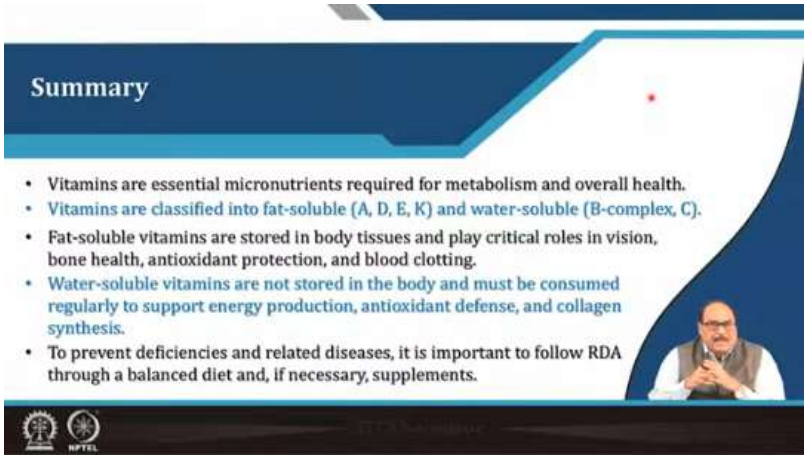


Food sources of vitamin C include green leafy vegetables, amla, which is popularly known as Indian gooseberries, citrus fruits, berries, guava, capsicum, and even sea buckthorn. The sea buckthorn is the richest source of vitamin C. The recommended dietary allowances include 65 milligrams per day for 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.



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.



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.