METABOLIC FUNCTIONS OF VITAMINS

The vitamins are the organic substances present in minute quantities present in foods of animal and plant origin that are required for normal metabolism. Broadly, the vitamins can be classified into water soluble and fat soluble vitamins.

Fat soluble vitamins: Vitamin D, E, K, A.

Water soluble vitamins: Vitamin B complex and C

FAT SOLLUBLE VITAMINS

VITAMIN A

The major role of vitamin A is

- Cellular differentiation
- Tissue growth
- Vision

The form of vitamin A that is component of rhodopsin that facilitates the efficient transfer of photons of light to electrochemical signals. The form of vitamin A involved in vision is retinal and retinol. The retinoic acid form of Vitamin A is required for cellular differentiation tissue growth.

VITAMIN D

There are two types of vitamin D *viz.* Vitamin D_2 (ergocalciferol) and Vitamin D_3 (Cholecalciferol). The active form of vitamin D is 1,25 dihydroxy-cholecalciferol (also called calcitrol). The calcitrol acts as steroid hormone.

Functions:

1. Calcitrol is involved in calcium homeostasis in bone that works along with hormone Paratharmone. It stimulates mobilization of calcium from blood to bone.
2. The calcitrol stimulates the production of calcium binding protein called *calbindin*. The protein calbindin influences the movement of calcium across the intestinal cells.
3. Calcitrol stimulates the production of calcium sodium pump in luminal surface of intestinal cells. This pump facilitates the movement of absorbed calcium from intestine to blood circulation.

VITAMIN E (α-tocopherol)

The vitamin E is mostly noted for last line of defence against lipid oxidation. The oxidation of lipids causes their disintegration. Most prominent effect of lipid oxidation is in biological membranes that are lipid bilayers. The lipid oxidation in membranes causes significant damage to membrane. The enzymes superoxide dismutase, catalase glutahione peroxidase etc prevent oxidation biomolecules. Once they fail to prevent the oxidation, the α-tocopherol is the last line of defence against it.

Functions:

1. Protection against oxidation of lipids.
2. Involved in cell proliferation and platelet aggregation.
3. Helps in cell adhesion and inflammation.
4. Involved in modulation of extra-cellular matrix.

VITAMIN K

The active form of Vitamin K is phylloquinone and its inactive form is menadione. The phylloquinone is synthesized from menadione.

Functions:

1. The phylloquinone stimulates the production of gamma-carboxy-glutamic acid residue (an unusual amino acid) in thrombin and other enzymes that are involved in blood clotting.
2. The gamma-carboxy-glutamic acid is also found in a bone protein called osteocalcin that is involved in new bone growth and formation in newborn animals. Thereby, the vitamin K is involved in bone development in neonates.

WATER SOLUBLE VITAMINS

The water soluble vitamins are vitamin B complex and vitamin C. These vitamins are classified based on their metabolic roles into three classes:

1. Vitamins important for redox reaction: Ascorbic acid, Niacin and Riboflavin
2. Vitamins important for carbohydrate, protein and lipid metabolism: Thiamine, pyridoxine and pentothenic acid.
3. Vitamins involved in single carbon metabolism: Biotin, folic acid and Vitamin B_{12}.

1. VITAMINS IMPORTANT FOR REDOX REACTION

ASCORBIC ACID

The ascorbic acid primarily acts as cofactor for Hydroxylases (mono-oxygenases) and Oxidases. In animals (except primates and Guinea pigs), the Ascorbic acid is synthesized from glucose in liver and kidney. In primates and Guinea pigs, the enzyme L-glucono-lactone oxidase is absent that is needed for ascorbic acid synthesis.

Function:

1. As a cofactor of oxidases and mono-oxygenases (Hydroxylases) it helps in hydroxylation of proline in collagen, elastin, C1q complements (immune factor), and acetyl choline esterases.
2. As a cofactor of oxidases and mono-oxygenases (Hydroxylases) it is involved in biosynthesis of carnitine, catecholamines.
3. As a reducing agent it keeps the metal cofactors in enzymes in reduced state.

NIACIN

The niacin is the source of two important coenzymes viz. NAD and NADP that acts as electron carrier. Virtually all the cells are capable of converting niacin to NAD. The enzymes that require NAD are mostly dehydrogenases. Most of the cells utilize NAD for catabolic pathway and NADP for anabolic pathway.

Functions:

1. The NAD acts as electron carrier in catabolic pathways.
2. The NADP acts as electron carrier in anabolic pathways.
3. NAD performs the phosphoribosylation in nucleus that is required for DNA repair. The deficiency of niacin hampers this reaction as a result the DNA damage caused by UV rays is not repaired causing the condition Pellagra.
4. NAD participates in regulation of intracellular Ca^{2+} level.

RIBOFLAVIN

It is present in tissues and flavine adenine dinucleotide and mono-nucleotide (FAD and FMN). The FAD and FMN are the cofactors of oxidases in aerobic environment and of dehydrogenases. The enzymes that contain flavin nucleotide as coenzymes are called flavoproteins.

Functions:

1. Transfers electrons from substrates to complex II of electron transport chain.
2. FAD of some flavoprotein enzymes can transfer electrons directly to molecular oxygen.

2. VITAMINS IMPORTANT FOR CARBOHYDRATE, PROTEIN AND LIPID METABOLISM

THIAMINE

Thiamine in cells is present in thiamine pyrophosphate (TPP) or as a thiamine tri-phosphate (TPPP). TPPP predominates in neural tissues.

Functions:

1. The TPP participates in decarboxylation of α-keto acids and in pentose phosphate pathway.

2. TPPP is involved in sodium gating process that influences the flux of sodium ions across neuronal cell membranes. Its deficiency can lead to impairment of neuro-muscular control.

PYRODOXINE

The pyridoxine is an essential vitamin for amino acid metabolism and Glycogenolysis.

Functions:

1. Coenzyme for trans-aminases that catalyze the trans-amination reactions in amino acid metabolism.
2. Coenzymes for amino acid decarboxylases.
3. Coenzyme for enzymes carrying out aldole reactions in amino acids. E.g. conversion of serine to glycine.
4. Coenzyme for glycogen phosphorylase that catalyzes the Glycogenolysis.

PANTOTHENIC ACID

Pantothenic Acid is an component of Coenzyme A (CoA) and acyl-carrier proteins.

Functions:

1. The CoA is the principle moiety for transport of acyl and acetyl groups in synthetic and catabolic reactions.
    a. β-oxidation of fatty acids.
    b. Oxidation of glucose.
    c. Oxidation of amino acids.
    d. TCA cycle.
    e. Cholesterol synthesis.
2. Post translational modification of regulatory proteins.
3. ACP is involved in fatty acid biosynthesis.

3. VITAMINS INVOLVED IN SINGLE CARBON METABOLISM

A. BOITINE

Biotin is the coenzyme for enzyme carboxylases.

Function:

1. Coenzyme of Acetyl CoA carboxylase- fatty acid biosynthesis.
2. Propionic CoA carboxylase- participates in odd chain fatty acid metabolism.
3. Pyruvate carboxylase- important obligatory step in gluconeogenesis.

B. FOLIC ACID and VITAMIN B_{12}

The completely reduced form of folic acid is present as tetrahydrofolic acid that participates in thymidylate synthesis. The Vitamin B_{12} regenerates the tetrahydrofolic acid being utilized in thymidylate synthesis. The second reaction utilizing Vitamin B_{12} is enzyme methyl-malonyl-CoA mutase that participates in β-oxidation of odd chain fatty acids.

Students are advised to study the books for details.

Recommended book is TEXTBOOK OF VETERINARY BIOCHEMISTRY, R.S DHONOTIA