VITAMINS

Definition: Vitamins are organic non-calorigenic substances required by the body in small amounts for certain metabolic functions. Some of them can be manufactured by the body.

Classification of vitamins

Vitamins are classified into the following;

1. **Fat soluble vitamins;** These are vitamins that dissolve in fats and are transported in fat related compounds. These include vitamins A, D, E and K.
2. **Water soluble vitamins;** These are vitamins that dissolve in water and are easily lost from food during food preparation. Examples include B group vitamins and vitamin C.

FAT SOLUBLE VITAMINS

VITAMIN A (Retinol)

Vitamin A (Retinol) is a primary alcohol and mainly occurs in 2 forms i.e. Retinal or retinoic acid and β-carotene or pro-vitamin A. Retinal is the most active in humans and found in animal tissues associated with lipids. B-carotene is found in all the dark coloured (red and yellow) plant tissues and it's converted to the active vitamin A in the body (small intestines).

Characteristics

Vitamin A is a pale yellow fat soluble alcohol; very slightly soluble in water but soluble in lipids; relatively stable to heat and easily destroyed by oxidation.

Functions of vitamin A

1. Vitamin A is important in the formation of rhodopsin (visual purple) and iodopsin (visual violet) light receptor pigment. These are important in the normal vision i.e. allow us to see in bright and dark / dim light and sort out the colours respectively. Retinol combines with opsin protein to form the pigments which are stored in the rods and cones of the retina.
2. Retinol is necessary in the production of glycoproteins which help in lubricating and keeping the integrity of the moist and mucus membranes like the gastro-intestinal tract, bronchial tubes, oral cavities, respiratory tract, urinary tracts, cornea and healthy outer skin covering. This maintains them healthy and in good condition.
3. Vitamin A is required during cell differentiation, stability and growth of bones, nerves, epithelial tissues, cell membranes and other soft tissues. It facilitates the removal (dissolving) of old bone for new bones with the final production of strong skeletal bones and tooth enamel.
4. The pro-vitamin A (β-vitamin A) helps to neutralize free radicals in the cells which might lead to cell damage as one grows older. These free radicals are produced from body metabolites, tobacco smoke, car exhaust fumes, x-rays, uv-rays, etc. these can damage DNA, cell components or kill the cell.
5. Retinol supports the normal functioning of the reproductive system in both males and females. This helps in sexual maturation and prevents sterility.
6. Retinoid also play a role in preventing epithelial cancer.

Digestion, Absorption and Storage of vitamin A

Vitamin A (Retinol) enters the body in 2 forms;

- Retinal/ preformed vitamin A from animal sources
- β-carotene / precursor / pro-vitamin A from plant sources

Bile salts, pancreatic lipase and fats aid the splitting of retinol from lipid fatty foods. The bile salts and acids aid in the absorption of vitamin A as it does for other fat related substances.

Pancreatic lipase helps in the initial hydrolysis of fat emulsion as the fats in the intestines help in the absorption of retinol. In the intestinal mucosa, some of the β-carotene is converted to retinol.

All the retinol from the preformed animal sources and plant carotene is re-esterified or combines with the long chained fatty acids to form retinyl esters. These are incorporated with lipid droplets to form chylomicrons which enter the blood stream via the lymphatic system.

They are then carried to the liver for storage and distribution as needed by the cells.
In the liver, retinyl esters are hydrolyzed to form free retinol. The free retinol is bound to a carrier protein, retinol-binding protein (RBP) for delivery to cells.
However, absorption of the retinol is affected by;

1. Age; in new born babies, especially premature babies, absorption is poor, but with advancing age the rate of absorption increases due to increased growth rate.
2. Chronic use of mineral oil as a laxative hinders retinol absorption.
3. A high level of thyroxine hormone stimulates the conversion of β-carotene to retinol and increases absorption and storage of retinol.
4. Oral contraceptives elevate the level of retinol binding protein and thus absorption of retinol due to the effect of oestrogen.
5. Liver disease like hepatitis, cirrhosis will decrease blood level of both retinol and retinol binding protein.
6. Protein and zinc deficiency will lower serum level of retinol and retinol binding protein.
7. High level of vitamin E affects conversion of β-carotene to retinol.

Storage of vitamin A

The liver is the most efficient storage organ of retinol. It contains about 90% of the body's total quantity of retinol. This amount is sufficient to supply the body's needs for 6 – 12 months and some can go as much as 4 years. However, the liver stores and plasma levels are checked during periods of infectious disease.

Recommended daily intake of vitamin A

Retinol is stored in the liver and so it is not required daily in the diet but the following should be considered

Children	400 – 800 µg
Adults	800 – 1000 µg
Pregnant and Lactating women	1000 – 1200 µg

Effects of vitamin A deficiency

- The skin becomes rough, dry and scaly as the keratinized epithelium blocks the sebaceous glands.
- **Goose-pimple** like follicles appear on the fore arms and spread to the shoulders, abdomen, back, thighs and buttocks.
- Photoreceptor pigmented are not produced which reduces vision in dim light and adjustment to bright light. This is known as **Xerosis**.
- Poor dark adaptation follows and finally colour and night blindness. This is known as **nyctalopia**.
- Itching, dryness, burning and inflammation of the eyelids
- The cornea becomes dry, opaque and inflamed leading to **xeropthalmia**.
- **Keratomalacia** occurs leading to softening of the cornea with permanent blindness. This can lead to death in infants. Keratinization of the epithelial membranes occurs. This involves shrinking, hardening and progressive degeneration of cells. This increases the susceptibility of membranes to severe infections e.g. the eyes, nasal passages, bronchial tubes, urinary tract and throat deteriorate.

Note: Keratin is an insoluble protein that forms dry, scale-like tissue like nails, hair, skin, teeth enamel and horny tissue.

- Poor teeth enamel which easily break or chip
- Retarded bone growth and development
- Reproductive failure and increased risk of pregnancy complications

Toxicity of vitamin A

Excess vitamin A can be stored in the liver and other tissues. This leads to a condition known as **Hypervitaminosis A**. Effects of Hypervitaminosis A include;

- Joint and muscular pain
- Enlargement of the liver, spleen

- Dry itching skin
- Coarse sparse hair and thinning
- Skin turns yellow with patches – jaundice
- Nausea, headache and irritability
- Cessation of menstruation
- Abnormal births in pregnant women
- Anorexia
- Anaemia

Food sources of vitamin A

Retinal (Animal vitamin A)

- Egg yolk
- Liver
- Milk and milk products (cream, butter, cheese)
- Fish and fish liver oils
- Fortified margarine

β-carotene (Plant vitamin A)

- All the dark and brightly coloured (orange, green, yellow, red) fruits and vegetables e.g. carrots, red chillies, tomatoes, chilli, green pepper
- Pulses
- Cereals

Note: Our bodies are unable to convert all the β-carotene to retinal. For this reason animal sources are much more efficient in the diet.

VITAMIN D (Cholecalciferol)

The naturally occurring vitamin D is called Cholecalciferol and it's formed in the tissues of mammals from pro-vitamin D-7-dehydrocholesterol with the help of the sun's uv light rays. It is a pro-hormone activated to its full form in the body to help utilize calcium and build strong bones and teeth.

Chemical and physical properties

Vitamin D is of 2 forms;

1. **Cholecalciferol** (D_3) formed by irradiation of 7-dehydrocholesterol under the skin with the help of the sun's u.v. light rays. It is also found in fish liver oils.
2. **Ergocalciferol** (D_2) is produced by irradiating ergosterol (plant sterol) by u.v. rays.

Vitamin D forms white yellowish powder; insoluble in fat solvents, very stable to heat, light, oxidation and alkalis; affected by acids and metals.

Absorption, transport and storage of vitamin D

The ingested vitamin D_3 is absorbed with the lipids from the small intestines. Since it's a fat soluble, this absorption is facilitated by the presence of bile salts.

It mixes with intestinal micelles and is absorbed in these lipid packets through the lymphatic system and finally into the blood stream.

The vitamin D_3 synthesized in the skin is transported by its special globulin protein carrier to the liver.

In the liver, an intermediate product known as hydroxyl-cholecalciferol is formed and finally transported to the kidney.

In the kidney, a renal enzyme alpha-hydroxylase forms the physiologically active vitamin D_3, calciferol. It is then stored in the liver, skin, brain, bones and other tissues.

Vitamin D_3 malabsorption diseases like coeliac syndrome, spruce and colitis, indigestion due to diarrhoea, abnormal gas accumulation and discomfort hinder absorption of vitamin D.

Functions of vitamin D

1. Vitamin D (Calciferol) regulates the level of enzyme alkaline phosphatase in blood concerned with the deposition of calcium phosphates in the bones and teeth. It thus promotes the formation of strong bones and teeth (mineralization).
2. It is required for the proper absorption of calcium and phosphorous in the small intestines and its distribution in the body. It initiates the synthesis of calcium and phosphorous binding proteins which increase the absorption of the ions.
3. Vitamin D increases the reabsorption of phosphorous and calcium by the kidneys and thus prevent their excretion in urine. This helps to maintain the calcium-phosphorous level in blood.

4. It also promotes quicker healing of fractures, prevents teeth infections and osteoporosis.

Food sources of vitamin D

Vitamin D is exclusively found in animal foods like;

- Dairy products like milk, butter, cheese, cream
- Eggs especially the egg yolk
- Organ meat like liver, chicken skin, kidneys, brain
- Oily fish, fish liver oil, cod liver oil
- Fortified margarine

Recommended daily requirements (RDA) for vitamin D

Group of people	Daily intake
Children / infants	5 – 10 µg
Pregnant and lactating mothers	5 – 10 µg
Adults (Below 25 years)	0 – 5 µg
Adults (Above 25 years)	0 – 10 µg

Note: Demands increase for growth in childhood, pregnancy and lactation and for people who stay indoors for long like the elderly or those in winter seasons.

Deficiency of vitamin D

Lack of vitamin D leads to inadequate absorption of calcium and phosphorous from the gastro-intestinal tract which in turn faulty mineralization of bone and teeth structures. This leads to inability to withstand the stress of the weight resulting into the following skeletal malformations;

1. **Rickets;** This mainly occurs in children especially premature infants. It results from failure of calcification of the growing portion of the bone. The bones involved will be deformed.

   It presents the following characteristics;

   - Soft, fragile bones leading to widening of the long bones, bow legs, narrowing of the pelvis, projection of the sternum (as in the pigeon chest/breast)
   - Enlargement of the wrists, ankle joints, knees (knock knees)
   - Softening of the skull (craniostanes) leads to bulging / bossing of the forehead giving the head a box-like appearance, delayed closing of the fontanel leading to enlargement of the head.
   - Stunted growth and delayed learning to sit, crawl and walk
   - Poorly developed muscles which results in weakness of the abdominal muscles forming a pot belly and delayed walking
   - Restlessness and nervous irritability
   - Excess sweating
   - Alteration of the teeth structure and formation

2. **Osteomalacia**; This is frequently referred to as Adult Rickets due to failure in calcification to keep up with the rest of the metabolic processes. The following effects take place;

   - General weakness with difficulty in walking especially climbing stairs
   - Pain in the bones of the legs and lower part of the back
   - Spontaneous multiple fractures even after minor falls
   - Softening of the bones which may be so severe that the bones of the legs, spine, and thorax bend into deformities

3. **Dental caries** leading to delayed dentition, slow eruption malformation and poor development of the teeth.

4. **Tetany**; This results from insufficient absorption of dietary vitamin D, calcium and phosphorous ions or disturbance of the parathyroid hormone. It leads to;

   - Muscular twitching, cramps and pain
   - Sharp flexion of the wrists and ankle joints

- Convulsions

Toxicity of vitamin D

Vitamin D builds up easily in the body because it is stored in the body and is slowly released. This mainly develops from large doses of vitamin D supplementation and excessive intake of fortified foods.

Toxicity shows the following effects;

- Progressive body weakness
- Bone and joint pain in adults
- Vomiting and thirst in children
- Hypercalcaemia
- Weight loss
- Loss of appetite (anorexia)
- Irritability and nausea
- Deposition of calcium and phosphorous ions in the skin (adipose tissue) and kidneys
- Failure to grow or thrive in children

VITAMIN E (Tocopherol)

Characteristics

- Tocopherols naturally occur as pale yellow oils in plants like cotton seed, wheat germ
- It's a powerful antioxidant i.e. it oxidizes very slowly
- Vitamin E is insoluble in water i.e. doesn't leach but dissolves in fat solvents
- Its stable with heat, acids but unstable in alkaline and to uv light rays and metals like iron and copper

Absorption, transport and storage of vitamin E

Vitamin E as with other fat-soluble vitamins and fats is absorbed with the aid of pancreatic secretions like lipase and bile salts.

It is transported with other lipids in micelles into the intestinal walls, repackaged in the chylomicrons and carried by way of the lymphatic system into the portal circulation for transport to the liver and circulation to the cells in plasma lipoproteins.

Accumulated intake is stored in the liver and/or in adipose tissue.

In the adipose tissue or cells, vitamin E is held mainly in bulk lipid droplets and mobilization of α-tocopherol from these is slow.

Functions of vitamin E

1. Vitamin E acts as nature's most potent fat-soluble antioxidant which delays the rancidity, bioxidation and deterioration of fats and oils.
2. It also protects the fat-rich cellular organelles, polyunsaturated fatty acids in the cell membranes from oxidative damage. Together with vitamin A and C, vitamin E neutralizes and disrupts the oxidation process of free radicals from cellular metabolism. It takes up much of the oxygen which renders the free radicals harmless. This helps to preserve the tissues integrity and longevity.
3. Vitamin E combines with selenium to form an enzyme gluthione-peroxidase which helps to destroy peroxides before they damage cell membranes.
4. Its reaction with free radicals helps to slow the ageing process and protects against cancer and cardiovascular diseases.
5. It is also important in fertility enhancement, reproduction and prevention of sterility. It is also known as the Anti-sterility hormone/vitamin.

Recommended daily intake

Since vitamin E protects cells and hence tissue health, it is an important nutrient in the diet of pregnant and lactating women, new born infants especially premature infants. Older people also require more vitamin E.

Adults need a daily supply of **10 mg** for men and 8 mg for women

Children need **3 – 8 mg** daily.

Deficiency of vitamin E

1. Oxidative reactions will lead to oxidative damage of the cell membrane and the contents. This leads to destruction and loss of red blood cells which results into haemolytic anaemia especially in premature infants who missed the last 1 or 2 months when stores for vitamins are normally built-up.
2. Pigment degeneration of the retinal pigments of the rods and cones in both children and adults; this is known as pigmentary retinopathy and it leads to blurred vision and finally blindness.
3. Disrupts the making of the protective covering of nerves (myelin sheath); this affects the main nerves, spinal cords and those connecting to the retina. This affects physical activity like walking and vision.

Toxicity of vitamin E

It is the only fat-soluble vitamin with no toxic effects in humans but has been shown to cause sterility in male rats.

Food sources of vitamin E

- Vegetable oils e.g. corn seed oil, wheat germ oil, soya bean oil, cotton seed oil, sunflower oil, peanut oil, palm oil, rapeseed oil
- Milk and milk products like cheese, butter
- Beef, liver, fish, eggs
- Legumes, almonds
- Whole grain and breakfast cereals

VITAMIN K (Quinones)

Vitamin K was discovered as a fat-soluble blood clotting vitamin and this group is known as **Koagulations** vitamins. These include;

1. **Phyllo-quinones (K_1)** mainly found in green leafy vegetables.
2. **Mena-quinone (K_2)** synthesized by intestinal bacteria
3. **Mena-dione (K_3)** synthesized commercially

Characteristics

Vitamin K is stable in the presence of heat, acids and during storage.

It is also soluble in fat and not affected by irradiation.

Absorption, transport and storage of vitamin K

The natural fat-soluble vitamin K1 and K2 require bile salts for absorption and then enter the metabolic system in the small intestines. They are absorbed with other fat related products in form of chylomicrons and then travel through the lymphatic system to the liver.

They are mostly stored as very low density lipoproteins in the liver though in small amounts.

Unlike other fat-soluble vitamins, blood levels of vitamin change rapidly with dietary intake. A moderate restriction of vegetable intake reduces plasma concentration within 10 days. The body thus needs a daily supply to maintain its various activities.

Functions of vitamin K

1. Vitamin K catalyzes the synthesis of blood clotting factors like serum **prothrombin** and plasma **thromboplastin** by the liver. These are in an inactive form and when they are combined with calcium ions, they form **fibrinogen** and **thromboplastin** which are finally converted to **fibrin** and **thrombin** to enable blood to clot properly after an injury.
2. Bone proteins **osteocalcins** as well as the bone matrix are synthesized by vitamin K and calcium ions. These bone proteins bind with calcium to form bone crystals.

Recommended daily allowance of vitamin K

It is quite difficult to determine the daily requirements of vitamin K mainly because;

- Bacterial synthesis in the intestines supplies some of the amount.
- The vitamin is widespread in many sources and thus a normal diet can provide enough.
- The body reserves are small and turnover is rapid.

However the following standard can be followed daily;

Infants (0 – 6 months)	5 µg
Infants (6 – 12 months)	10 µg
Women	65 µg
Men	80 µg

Note: Older adults with chronic infections and persons taking antibiotics need more.
New born infants require vitamin K injections shortly after birth.

Deficiency of vitamin K

In mild deficiency, blood takes long to clot.

In severe cases, blood fails to clot leading to **haemorrhagic anaemia** and death.

Haemorrhagic disease of the new bone baby can occur as the sterile intestinal tract has no bacteria to synthesize vitamin K in the first few days and breast milk or milk has little amounts. A preventive injection or dose of vitamin K is given to the infants after birth.

Excess vitamin K has no health problem to humans.

Food sources of vitamin K

- Fresh green leafy vegetables
- Liver especially pigs liver, eggs
- Cereals like rice, wheat
- It is also synthesized by bacteria in the intestines
- Low amounts are found in dairy products

WATER SOLUBLE VITAMINS

VITAMIN C (Ascorbic Acid)

Characteristics

Of all the water soluble vitamins, vitamin C is the most unstable easily destroyed by heat, light, acids, oxygen and alkalis. Care must thus be taken during food preparation to preserve vitamin C. These include;

- Vitamin C forms white crystals with a sweet sour taste
- It readily dissolves in water
- It readily reacts with metallic ions like copper and iron
- Ascorbic acid is a strong reducing agent i.e. easily oxidized to a useless form
- It is sensitive to alkalis but fairly stable in acidic solution. In this way alkalis like bread soda should be avoided when preparing vegetables.
- Vitamin C is easily destroyed by heat
- In the presence of light, vitamin C is oxidized by oxidase enzyme

Vitamin C can't be stored within the body and any excess is slowly excreted in urine. Hence both adults and children need daily supplies. It is also easily lost when food is cooked; all the vitamin C can be destroyed by overcooking or keeping food in a hot place.

Functions of vitamin C

1. Ascorbic acid is particularly required for the synthesis, building and maintenance of bone matrix, cartilage, dentine, collagen and connective tissue. This helps to keep body structures like skin, bones, teeth muscles, tendons and cornea in a healthy condition.
2. Vitamin C is required during growth of infants, pregnancy and lactation to supply demands for foetal growth and maintenance of maternal tissues.
3. It assists in the maintenance of the elasticity of vascular tissues enabling them to easily contract and relax. Vascular tissue is weakened without sufficient vitamin C supply.
4. Ascorbic acid helps to maintain resistance against infections like colds, influenza, bleeding of gums, skin infections and fever.
5. It is important in the release of stress relieving hormones like adrenaline and norepinephrine from the adrenal glands. This prevents the body from fatigue and stress especially that brought by injury, general illness, overworking or shock.
6. It enhances the absorption of iron from the small intestines by converting it from the ferric (Fe^{3+}) state to the ferrous (Fe^{2+}) state which is more soluble.
7. Vitamin C also influences the removal of iron from ferritin, the protein-iron-phosphorous complex in which iron is stored in the liver, spleen and bone matrix. This makes iron easily available for synthesis of haemoglobin and red blood cells and thus prevent anaemia.
8. Along with vitamin A and E, vitamin C acts as an antioxidant. It is a scavenger / takes up free oxygen radicals from cellular metabolism. This protects low density lipoproteins (LDLPs) and other polyunsaturated fatty acids (PUFAs) in plasma, cell membranes and the whole cell against oxidative damage.
9. Vitamin C is important in tissue regeneration and wound healing especially after cuts, bruises and surgery.
10. It is also involved in a variety of metabolic reactions which take place in the active tissues like the liver, brain, spleen, kidneys, adrenal glands and pancreas where vitamin C is found in large amount. Some of them include;
    - Hydroxylation of the aminoacids proline and lysine to the stable forms of hydroxyproline and hydroxylysine
    - Synthesis of carnithine which transports long-chained fatty acids to the mitochondria for energy production
    - Synthesis of peptide hormones like norepinephrine
    - Conversion of folic acid to the more active folinic acid in the liver
    - Metabolism of phenylalanine, tyrosine aminoacids and their metabolites

Food sources of vitamin C

1. Fresh fruits like oranges, mangoes, grapes, tomatoes, melons, lemons, strawberries, blackcurrants
2. Fresh vegetables e.g. green pepper, spinach, amaranthus, lettuce, cabbage, onions, peas, parsley

Note: It is not widely distributed in foods i.e. found only plant foods and can be easily lost from food during food preparation. Therefore, a daily supply is thus important in our diet.

Recommended daily allowances of vitamin C

Body stores of ascorbic acid vary directly with intake and when the intake isn't continuous, the amount taken is poorly held in the liver. There are variable losses in food handling, processing, preparation and storage.
The current RDI is as follows;

Infants (below 6 months)	30 mg/day
Adults	60 mg/day
Pregnant and Lactating mothers	70 mg/day

Note: Beyond 6 months, the RDI of infants is gradually increased t the adult level.
Cigarette smoking reduces the desired level of vitamin C and thus regular smokers should take in an additional 100 mg/day to maintain the level.

Deficiency of vitamin C

The following effects are shown after several months of ascorbic acid deprivation to the body;

- Poor wound healing because collagen synthesis doesn't take place especially after surgery.
- Irritability
- Growth retardation
- Malabsorption of iron leading to mild anaemia
- Teeth become loose
- Swelling of gums
- Increased susceptibility to infections like colds, flu
- Pin-point haemorrhage of the skin from slight bleeding of the hair follicles

Long term shortage will result into **Scurvy** in adults. It has the following signs and symptoms;

- Swelling of the legs, thighs and hands leading to tenderness
- Bleeding and swelling of the gums (gingivitis)
- Breakdown of blood tissue leading to anaemia
- Pain in the limbs
- General body tiredness (fatigue)
- Teeth become loose and eventually fallout
- Skin becomes thick, dry, rough and scaly
- As the disease progresses, the slightest injury produces excessive bleeding
- Weak and painful muscles
- Blood escapes from the weak walls of the blood vessels and appears as small red spots under the skin

In infants;

- Pain, tenderness and swelling if limbs
- Loss of weight
- Diarrhoea and frequent vomiting
- The child is pale, irritable and cries a lot when handled
- If teeth are present, the gums are likely to swell become tender and bleed

Vitamin C losses

Vitamin C is easily oxidized and it is very unstable and can be lost through the following ways;

- All plant cells contain oxidase enzyme released during chopping of fruits and vegetables.
- Reheated or warmed food loses more of the vitamin content.

- Storage of fruits and vegetables in a warm temperature of about 45^0C and above leads to loss of about 90% of the vitamin.
- Storage of vitamin C containing foods in copper cans will render it inactive.
- Excessive of alkalis like salt, bread soda during food preparation

Ways to reduce vitamin C losses

- Use fresh fruits and vegetables as wilted ones contain little vitamin C.
- Wash fruits and vegetables under running water and avoid soaking as it results into leaching/dissolving of vitamin C in the water.
- Store vitamin C containing foods in a cool and dark place to avoid oxidation.
- Prepare (sort, chop or cut) fruits and vegetables just before cooking in order to minimize action of oxidase enzyme.
- Use minimum amount of water when cooking as these nutrients are highly water soluble.
- The liquid used for cooking should be used for making other dishes like soup, gravy and sauces instead of being poured away.
- Wash fruits and vegetables before chopping or cutting to avoid leaching.
- Cut or chop fruits and vegetables with a sharp knife to avoid excessive cell damage which can expose cells to oxidase enzyme.
- Crushing, chopping and grated should be limited to reduce exposure of oxidase enzyme to the cells.
- Blanch vegetables and fruits before use. The high temperature (850c) will destroy oxidase enzyme and conserve vitamin C. bring the water to the boil before adding the foods. Boiling water has no oxygen and this will reduce oxidation.
- Cover all the cut, chopped and cooked food immediately.
- Cook foods as quickly as possible in a saucepan with a tight fitting lid to avoid the escape of volatile nutrients.
- Avoid the use of alkalis like bread soda to soften food and maintain colour as it reduces vitamin C.
- Avoid overcooking and reheating of vegetable dishes as this will destroy any remaining vitamin C.
- Food should be served and eaten immediately.
- Peel a thin layer of fruits and vegetables as most of the vitamins and minerals are beneath the skin. If possible avoid peeling.
- Use methods of cooking which minimize loss of water soluble nutrients such as steaming
- If possible eat foods especially fruits and vegetables when raw in order to increase vitamin C intake.
- Store fruits and vegetables in plastic or stainless steel containers; avoid storing in containers made from catalytic metals like copper, lead or iron which reduce vitamin C.
- Use opaque and airtight containers or those with tight fitting lids.

Toxicity of vitamin C

This mainly develops due to intake of a lot of supplements or tablets of vitamin C. It shows the following;

- Diarrhoea
- Haemolytic anaemia
- Increase in the kidney and bladder stores leads to their failure
- Gout development (gout is a form of arthritis: smaller bones of feet, episodes of acute pain, red & tender joints)

VITAMIN B COMPLEX

The B group of vitamins contains 8 different water-soluble vitamins each one unique and having significant metabolic functions in health and general human nutrition. They (together with vitamin C) share 4 characteristics significant in human nutrition. These are;

- All are water soluble
- All are synthesized by plants and are therefore provided in the diet by plant foods (and some animal foods)

- All have no stable storage form in the body and must thus be provided daily in the diet
- They all serve as essential coenzyme factors in many cell enzyme reactions like energy release and utilization.

The important members include vitamin B_1 (thiamine), vitamin B_2 (riboflavin), vitamin B_3 (niacin or nicotinic acid or nicotinamide), vitamin B_6 (pyridoxine), vitamin B_{12} (cyano-cobalamin), vitamin H (biotin), pantothenic acid and folic acid or folacin / folate. Other unpopular ones include choline, inositol, bioflavonoids and lipoic acid.

VITAMIN B_1 (Thiamine)

Characteristics

- It contains a thiazole ring, sulphur molecule and amino group in its structure.
- It forms white crystalline solids which occur as thiamine hydrochloride.
- Thiamine is very soluble in water but acidic solutions promote its stability
- Vitamin B_1 is unstable to dry heat, oxygen and rapidly destroyed in neutral and alkaline solutions
- It is easily oxidized by metals, reducing agents and use of sulphur dioxide as a preservative

Functions of vitamin B_1

1. Thiamine combines with phosphorous to form co-enzyme **thiamine pyro-phosphatase** (**TPP**). This is required in the decarboxylation of pyruvate to form acetyl CoA in glucose metabolism and removal of keto-acids after fatty acid metabolism.
2. It forms thiamine triphosphates important in neuromuscular activity and building healthy nervous system (brain and nerves). This prevents the nervous disease beriberi.
3. Due to its role in energy metabolism, thiamine will thus promote a normal and good appetite.
4. It also required in maintenance of normal muscle tone (strength) of the gastro-intestinal tract and vascular tissue. This enables normal peristaltic movements which aid digestion and prevent constipation. If the smooth muscles don't receive enough glucose due to insufficient supply of thiamine, there will be lack of muscle tone / strength.

Recommended dietary allowances

This depends on the amount of carbohydrate metabolism and total calorie intake. However, a minimum of 1.0 mg/day is required especially for adults.

The following conditions will require an increase in thiamine supply to the body;

- Alcoholism
- Presences of infections like fever which increase energy requirements especially in elderly people with chronic illnesses
- Periods of normal growth and development like in infancy or childhood and adolescence. As the body grows, there is an increase in tissue volume or cells which needs more energy thus an increase in thiamine requirements.
- Pregnancy and lactation to cater for the increased needs of the foetus, increased metabolic rate and larger body during pregnancy and also milk production.

Deficiency of vitamin B_1

Deficiency may occur due to any of the following

- Chronic alcoholism; an individual who drinks a lot of alcohol
- High carbohydrate intake
- Inadequate supply of foods rich in thiamine; this leads to primary thiamine defieciency
- Indigestion leads to gastro intestinal disturbances like diarrhoea and vomiting
- Pregnancy and lactation due to the increased demand for the rapid foetal development and milk production

Mild effects of deficiency include;

- Fatigue (feeling of tiredness)
- Loss of appetite
- Indigestion leading to diarrhoea and constipation

- Depression, anger and anorexia
- Insomnia (lack of sleep)
- Forgetfulness (defective memory)
- Cramping of the calf muscle, heaviness or weakness in legs
- Breathlessness and cardiac failure
- Burning sensations in the feet

Severe cases can lead to beriberi.

Beriberi is the disease of the peripheral nerves characterized by the following signs and symptoms;

- Gastro-intestinal disturbances
- Pain and prickly sensations in the muscles
- Weakness in the muscles of the legs, feet, calf and thighs
- Growth failure in children
- Oedema leading to swelling of the feet and knees
- Emanciation or thinness of the body
- Neuritis (pain and swelling of the nerves)
- The heart becomes enlarged leading to acute cardiac failure and even death.

The different signs and symptoms lead to the 2 types of beriberi i.e.

Wet beriberi is characterized by;

1. Swelling of the legs due to fluid retention in the tissues (oedema)
2. Enlargement of the cardiac and vascular tissue; this is followed by dilation of blood vessels, chest pain, rapid heartbeat, cardiac failure and death.
3. Neuritis (pain and inflammation of the nerves)
4. The patient looks reasonably healthy (not thin)

Dry beriberi which shows;

1. Muscular wasting and extreme thinness
2. Loss of the sensation of the skin which leads to paralysis of the limbs
3. Neuritis also occurs
4. Difficulty in walking, running and squatting
5. Bed sores and wounds which don't heal also occur
6. There is no oedema or swelling of limbs

Toxicity of vitamin B_1

Any excess or unused thiamine is constantly excreted in the urine but if it's over retained in the metabolically active organs it can lead to constant headache, delayed responses, irritability of the nerves and muscles

Food sources of vitamin B_1

- Milk and milk products
- Fruits especially mangoes, raisins and avocado
- Vegetables especially potatoes, lentils, asparagus
- Whole and enriched cereals, bread, breakfast cereals, whole meal flour, oatmeal
- Legumes like green peas, soya beans, groundnuts, peanuts cashew nuts
- Pork, bacon, liver, beef and chicken also provide some amounts

Ways to reduce vitamin B_1 (thiamine) losses

The vitamin is very soluble in water, easily leached and destroyed at high temperature and exposure to alkaline solution for example in food processing, baking and milling will lead to 70% loss. Due to the great loss in food processing synthetic vitamins are usually added. Consider the following to prevent vitamin B_1 losses;

- Avoid soaking / steeping food in water for a long time.
- Use dry heat methods of cooking to avoid contact with moisture
- Use little water when cooking
- Avoid overcooking, reheating and warming of leftover food.
- Boil potatoes and other vegetables with their skin.
- Use whole meal flour and enriched cereal products instead of milled flour.
- If possible eat fruits and vegetables when raw.

VITAMIN B_2 (Riboflavin)

This is one of the most heat stable B group vitamins and it has several names like vitamin G, lactoflavin, ovalflavine, hyperflavine and yellow flavine but it's presently called Riboflavin. It gets its name from the yellowish brown crystals (flavins) it forms and presence of the D-ribose sugar in its structure.

Absorption occurs in the small intestines. Its phosphorylated and then transported to the liver

Characteristics

- It forms yellowish-brown, orange yellow needle shaped bitter tasting fluorescent crystals.
- It is sparingly soluble and will leach in cooking water so losses may occur in food preparation.
- Vitamin B2 is easily destroyed by uv light rays, visible light and alkalis. In this why care must be taken to avoid standing of milk and other foods in sunlight.
- It's relatively stable to heat, oxidation and acids

Functions of vitamin B_2

1. Riboflavin is an important constituent of flavor-protein co-enzymes like **flavine mononucleotide** (**FMN**) and **flavine adenine dinucleotide** (**FAD**) required in the deamination of aminoacids and oxidation of fatty acids with the subsequent release of energy in the TCA cycle or chain.
2. Flavo-protein coenzymes act as one of the carrier molecules in H+ transfer after cellular oxidation. They accept H ions from the electron transport system and combine them with oxygen to form water as the end product.
3. It promotes normal tissue maintenance of the mucus membranes like linings of the mouth, lips, tongue, skin, nasal linings and digestive system.
4. They are also essential components of all living cells as it forms material that bind cells together in conjunction with vitamin C. it is thus essential for cellular growth especially in children.

Recommended dietary allowances of vitamin B_2

The body's riboflavin requirement is related to the total needs, body size, metabolic rate and rate of growth. All these are also related to protein intake and other B group vitamins. The lower their intake (protein and B group vitamins), the higher riboflavin is excreted or lost since they act in combination.

Increased requirements occur during;

- Pregnancy and lactation due to the increased metabolic rate and total needs
- Growth periods
- Presence of fever and other chronic illnesses
- Stress of injury or illness
- Gastrointestinal disorder which lead to indigestion, diarrhoea, vomiting and poor appetite
- Poor feeding habits

Deficiency of vitamin B_2

Lack of riboflavin leads to a condition known as **Ariboflavinosis** with the following signs and symptoms;

- Lips become swollen and crack easily especially in the corners of the mouth a condition known as **cheilosis**.

- Cracks and irritations develop in the nasal cavity with swelling of the nose.
- The tongue becomes red and swollen a condition known as **glossitis**
- Skin becomes scaly and greasy especially in the skin folds
- Eyes become sensitive to light, easily fatigued (sleepy) leading to blurred vision. This is known as **photophobia**.
- Extra blood vessels (capillaries) develop in the cornea and eyes become blood shot red, burn, itch and also teary. This is known as **corneal vascularization**.
- The membranes lining the eyes harden and crack. This is called **conjunctivitis**.
- Minor injuries easily become aggravated and may not heal quickly.

Food sources of vitamin B_2

- Fresh, canned or dried milk is the best source of riboflavin
- Whole and enriched cereal grains
- Organ meat like kidney, liver and the heart are good sources.
- Some riboflavin is manufacture by bacteria in the intestines.

VITAMIN B_3 (Niacin / Nicotinic acid / Nicotinamide)

This is also known as the **Anti-pellagra vitamin** and is one of the few vitamins which can be manufactured from the amino acid tryptophan in the small intestines. It is found in both animal and plant tissue and both are of equal biological activity.

Characteristics

- Forms white needle like bitter or sour tasting crystals
- It is moderately soluble in hot water but slightly soluble in cold water
- Niacin is very stable to heat, alkalis, light, acids and oxidation. It is thus the most stable of all the B group vitamins and can't be destroyed by normal cooking temperatures.

Functions of vitamin B_3 (Niacin)

1. Niacin is a component of 2 co-enzyme i.e. **nicotinamide adenine dinucleotide (NAD)** and **nicotinamide adenine dinucleotide phosphate (NADP)**. These are responsible for the utilization of energy from glucose, synthesis of fats and other oxidation reduction reactions in the cell respiratory chain.
2. Sufficient amounts of niacin lower elevated levels of cholesterol and thus combat cases of cardiovascular diseases.
3. It can also act as a vasodilator to increase blood flow in pharmacologic (clinical) use.
4. Vitamin B_3 is also important in the normal functioning and maintenance of nerves, membranes, skin and the brain.

Recommended dietary allowances of niacin

As with other B group vitamins, niacin requirements increase whenever the rate of metabolism is accelerated during i.e. growth and increased physical activity, pregnancy and lactation, presence of infections, stress from injury, surgery and work or tissue trauma, hyperthyroidism (disturbance of the thyroid gland) leading to excess secretion of thyroxine hormone which controls metabolism. The following RDI can be considered;

Children (Below 9 years)	6 – 14 mg
Children (Above 10 years)	15 – 22 mg
Adults	13 – 20 mg
Pregnancy and lactation	20 mg

Deficiency of vitamin B_3

General or mild deficiency can lead to;

- Body weakness
- Indigestion leading to diarrhoea
- Painful skin eruptions develop especially on the neck and hands

- Inflammation (pain and swelling) of the tongue
- Dizziness and mental confusion
- Anorexia
- Apathy, disorientation and neuritis develop

Severe cases lead to a deficiency disease known as pellagra

Pellagra is a disease common in areas where maize and other cereals are the staple foods. These lack the essential amino acid tryptophan required for niacin formation. The disease can also develop due lack of thiamine, riboflavin and pyridoxine and sufficient protein (aminoacids) important in niacin formation.

Pellagra mainly affects the gastrointestinal tract, skin and nervous system characterized by the 4D's i.e. diarrhoea, dermatitis, dementia and death. Effects include;

- Early signs include fatigue, headache, backache, loss of weight, poor appetite and poor health
- Sore tongue, mouth and throat extending to the gastrointestinal tract
- Tongue and lips become abnormally red and swollen. This is known as **glossitis**.
- Nausea and vomiting occur followed by diarrhoea.
- The skin covering the hands, fore arms, elbows, feet, legs, knees and neck become swollen, red, tender resembling mild burns.
- They become rough, cracked, scaly and ulcerated. This condition is known as **dermatitis**.
- Neurological symptoms include mental confusion, dizziness, poor memory, anxiety, irritability, muscle weakness, delusion of perception and other nervous disorders because there is no energy for the nervous system. This condition is known as **dementia**
- Loss of weight (emaciation)
- Loss of the normal menstrual cycle (amenorrhoea)
- If untreated, it can lead to death.

Food sources of niacin

- Meat, fish and poultry are the major sources
- Yeast, peanuts, peanut butter, beans, peas, groundnuts are the richest sources
- Egg and dairy products are good sources

Note: Whole grain cereals are fair sources but milling leads to 80% loss. Enriching and fortification would increase the content.

VITAMIN B_6 (Pyridoxine)

In nature vitaminB6 mainly occurs in 3 forms i.e. pyridoxine, pyridoxamin and pyridoxol.

Characteristics

- It forms white, crystalline, odourless, bitter-tasting solids.
- Its water soluble, fairly heat stable and sensitive to uv light rays and alkalis.

Pyridoxine is absorbed in the upper part of the small intestines and is found throughout the body tissues which shows its essentiality in metabolic activities especially protein metabolism.

Functions of vitamin B_6

1. Pyridoxine forms a potent coenzyme **pyridoxal phosphatase (PLP)** which is important in the synthesis, breakdown and interconversion of amino acids such as active transport of amino acids, haemoglobin synthesis, conversion of tryptophan to niacin, deamination, transamination, decarboxylation of glutamic acid and histidine, trans-sulphuration, formation of pyruvate from alanine, etc. It is thus important in protein metabolism.
2. PLP also participates in the conversion of linoleic acid to arachidonic acid.

Recommended dietary allowances

Deficiency is unlikely because the amounts present in the general diet are large. The need also varies with dietary protein need and intake since vitamin B6 is involved in protein metabolism. However the RDI standard is as follows;

Children (Below 1 year)	0.5 mg
Children (Between 1 – 10 years)	1.5 mg
Adults – Men	1.5 – 2.0 mg
– Women	1.6 – 2.0 mg
Pregnant and lactating mothers	2.5 – 3.0 mg

Deficiency of vitamin B_6

The effects of vitamin B6 deficiency are mainly observed during the following conditions;

- Infants with impaired growth
- Hypochromic anaemia (low heamoglobin)
- Low intake of vitamin B_6
- Pregnancy (due to the foetal growth and increased maternal metabolic activity)
- Convulsions and brain tumors or damages
- Large urinary excretion of vitamins due to kidney failure and infections
- Women on contraceptives; there will be an increased need for amino acid tryptophan and less will be used for niacin synthesis
- Tuberculosis treatment, the drug for TB, Isoniazid has an antagonist / inhibiting role to pyridoxine and will inhibit the formation of glutamic acid the only amino acid used by the brain. This will lead to neuritis.

The signs and symptoms include;

- Loss of appetite
- Nausea and vomiting
- Soreness of the lips, tongue, hands and feet
- Dermatitis and neuritis occur
- Hypochromic anaemia occurs even in the presence of high level of iron
- Central nervous system (CNS) disturbances like irritability, convulsions and neuritis.

Toxicity of vitamin B_6

Toxic effects are rare; however, when taken in large doses like as therapy for pre-menstrual syndrome (PMS) and increased supplementation, the following effects can take place;

- Lack of muscular coordination
- Severe nervous damage
- Irritability

Food sources of vitamin B_6

- Good sources include whole grain cereals especially wheat germ
- Liver, kidney and meat
- Milk and milk products, eggs and green leafy vegetables provide small amounts

VITAMIN B_9 (Folic Acid / Folacin / Folates)

Folic acid is made up of 3 acids i.e. pteroic acid, glutamic acid and para-amino benzoic acid. Animals are unable to synthesize any of these folic acid producing compounds/acids and the vitamin can only be extracted from plants and synthesized by some bacteria in the gut. Leafy vegetable are the main food sources of folic acid.

Characteristics

Forms bright yellow crystals, slightly soluble in water but stable in acidic solutions and sunlight

Functions of folic acid

1. Activated folic acid is important in the formation of the haeme portion (iron containing non-protein portion) of haemoglobin and thus it is important in the formation of red blood cells.
2. Folates participate in the synthesis of nitrogen containing compounds like purines, pyrimidine and nucleoproteins used in the production of nucleic acids (RNA and DNA).
3. Since nucleoproteins, purine and pyrimidine are important in rapid cellular growth and reproduction especially in infants and adolescents, folates are, therefore, essential in normal cellular growth.
4. They are also important in the metabolism of amino acids tyrosine, glutamic acid and phenyl amine with the final release of energy.

Deficiency of folic acid

Early effects of deficiency include;

- Growth failure
- Gastrointestinal disturbances like diarrhoea, intestinal lesions (ulcers). Malabsorption defects

Serious defects include;

1. **Spina bifida**
   This occurs due to lack of folic acid in early pregnancy leading to permanent disability of a new born child. It defects the closing of the neural tube (spinal code) in the foetus leaving it open and exposed to damages. So, pregnant and lactating mothers are advised to take at least 400µg of folic acid daily.
2. **Megalo-blastic anaemia;**
   This is characterized by faulty production of abnormally large immature red blood cells which can't give up oxygen properly to the body cells. This leads to;
   - Extreme tiredness
   - Diffuse bleeding
   - Malabsorption syndrome like diarrhoea,
   - Glossitis (red sore tongue and bleeding of the gum)
   - Pale skin

Note: Since tissue growth requires an additional folic acid intake, this deficiency is a risk factor in pregnant women, infants, young children and adolescents.

Toxicity hasn't been detected as excess dietary levels are excreted in both urine and feaces.

Food sources of folic acid

Good sources include liver, yeast, green leafy vegetables, whole grain cereals, legumes, green leafy vegetables.

Few amounts are found in fruits, lean beef and pork.

VITAMIN B_{12} (Cobalamine / Cyano-cobalamine)

Vitamin B_{12} occurs as a protein complex in food, so it's found in animal tissues except for small amounts synthesized by soil microorganisms and intestinal bacteria.

Characteristics

- This occurs as a large deep red complex crystalline solid
- It is a high molecular weight compound with a single cobalt atom at the centre of its structure.
- It's soluble in water, stable at 100^0c but affected by strong acids, alkalis and u.v. light rays.

Absorption and transport

The intestinal absorption of vitamin B_{12} takes place in the colon. Cobalamine is split is split from its protein complex by gastric acid (hydrochloric acid) and then bound to a specific glycoprotein intrinsic factor secreted by the gastric mucosal cells. This cobalamine-intrinsic factor complex moves to the intestines where it is absorbed by special receptors. The intrinsic factor is then released and the vitamin is then picked up by another protein binding carrier trans-cobalamine for its transport to the receptive cells. Vitamin B_{12} is then stored in the active body organs like the liver, kidney, heart, spleen, muscles, testes, brain and bone marrow.

Functions of vitamin B_{12}

1. It is essential for the proper formation and maturation of red blood cells (heamotopoiesis) in the bone marrow by providing an activated form of folic acid.
2. Vitamin B_{12} is important in the formation of methyl groups and their transfer in various metabolic reactions (methylation) like in the synthesis of amino acid methionine from cysteine, energy release, genetic makeup of cells, etc.
3. It is also involved in purine metabolism, synthesis of nucleic acids and nucleoproteins.

Recommended dietary allowances

The amount of dietary vitamin B_{12} needed for normal metabolism i.e. maintenance of normal blood level and body storage is likely small. Daily intake varies with increasing body size. However, adults need 2.0 µg daily and people with pernicious aneamia need a daily dose of 0.5 – 5 µg of vitamin B_{12}.

Deficiency of vitamin B_{12}

Serious cases of deficiency lead to insufficient red blood cells which can lead to pernicious anaemia because inadequate heamoglobin is produced.

Pernicious aneamia is a macrocytic (abnormally large red blood cells) anaemia occurring mostly after the age of 40 years due to absence of intrinsic factor in gastric juice for absorption of vitamin B_{12}

Signs and symptoms of pernicious aneamia include;

- Degeneration of the nervous system leading to nervous disorders
- Sore mouth and tongue
- Loss of normal menstrual cycle
- Burning and prickly sensation in the feet and palms
- Adult coeliac disease due to malabsorption which leads to diarrhoea and other abdominal problems
- Pale skin complexion

Toxicity of vitamin B_{12} has not been observed even in oral intake of up to 100 µg

Food sources of vitamin B_{12}

Dietary cobalamine is supplied by animal food products like liver, eggs, kidney, lean meat, milk and milk products like cheese.

Note: Vitamin B_{12} isn't present in plant foods for this case deficiency can occur in strict vegetarians

PANTOTHENIC ACID

This vitamin is found in all forms of living tissue which accounts for it's as an essential component of the widespread co-enzyme Acetyl Co-A.

Characteristics

- It is yellow viscous oil that is widely distributed in food.

- Occurs in the body as calcium pantothenate which is a white crystalline, slightly bitter tasting, odourless compound
- Water soluble and rapidly destroyed by treatment with dry heat, alkalis and acids
- Stable in only in neutral solution
- Non-toxic – neither deficiency nor toxicity of pantothenic acid have been observed.

Functions of pantothenic acid

Pantothenic acid is an essential constituent of Acetyl Coenzyme A involved in many metabolic processes involving acetylation (addition or removal of an acetyl group [–CO–CH2]) such as synthesis of haemoglobin, phospholipids and steroid hormones, oxidation of pyruvic acid, fatty acid breakdown, ketogenic and glycogenic reactions.

It is also important in the excretion of antibiotics (sulfonamides) from the blood circulation.

Deficiency and **toxicity** have not been observed in natural diets, so the RDA hasn't been established. There is also widespread occurrence of pantothenic acid in the body and plant tissues so deficiency is unlikely. However, intake needs to be increased during severe illnesses, injury and stress and after antibiotics intake

Food sources of pantothenic acid

Rich sources include liver, kidney and other animal tissues

Smaller amounts are found in milk, fruits and vegetables

BIOTIN (Vitamin H / Coenzyme R)

Biotin is an essential sulphur containing vitamin that can be synthesized by intestinal bacteria. However, this can be interfered by antibiotics and avidin – a glycoprotein found in raw eggs that prevents its absorption.

Characteristic

Biotin is soluble in water, stable to heat, susceptible to oxidation by alkalis and strong acids.

Functions of biotin

Biotin is an important co-enzyme in cell enzymes involved in the process of carboxylation. It partners with acetyl CoA in carbondioxide fixation reactions like synthesis of fatty acids, formation of purines and pyruvate metabolism.

Food sources of biotin

Biotin is widely distributed in liver, kidney, milk, egg yolk, yeast, soya flour, cereals and bananas