CALCIUM, PHOSPHORUS AND MAGNESIUM

CALCIUM

A total of approximately 1-1.5kg of body weight is made up of calcium where 99% is found in the bones and teeth and remaining 1% is in the ECF and other compartments. Ca^{2+} exists as carbonates or phosphates of calcium within the body, while in the plasma they exist in either the ionized form(which is the physiologically active form), bound to plasma proteins(mainly albumin) or complexes with organic acids, all these forms being in equilibrium with each other.

SOURCES; milk and other dairy products (cheese etc), egg yolk, bone meal, cabbage, nuts, figs etc

ABSORBTION; dietary Ca^{2+} is absorbed mainly from the duodenum and first half of the jejunum under the influence of a carrier protein CALBINDIN – a calcium dependent ATPase against an electrical and concentration gradient. Absorption is affected by certain factors including;

1. Vitamin D- presence of vitamin D in the gut promotes calcium absorption.
2. PH-acidity increases the absorption of calcium salts which are more soluble in these condition, while in alkaline medium decreases absorption by causes the formation of insoluble salts of calcium.
3. Composition of diet-a high protein diet (amino acids particularly Lysine and Arginnine) and organic acids e.g. citric acid increases the solubility of Ca^{2+} salts, fatty acids on the other hand cause formation of insoluble Ca^{2+} salts thereby decreasing Ca^{2+} absorption.
4. Parathyroid hormone through its stimulation of 1, α-hydroxylase which increases the production of Calcitriol (1, 25-$(OH)_2$-D_3), the active form of vitamin D, increases calcium absorption.
5. Calcitonin decreases the absorption of Ca^{2+}
6. Glucocorticoids diminish intestinal transport of Ca^{2+} hence its absorption.
7. Phytic and oxalic acids- presence of phytates and oxalates especially in cereals (phytates) and vegetables (oxalates) cause the formation of insoluble calcium salts which are excreted in feces and decrease Ca^{2+} absorption.
8. Presence of other minerals such as phosphates, phosphorus, iron and magnesium decrease Ca^{2+} absorption.

FUNCTIONS

1. Ca^{2+} is involved in calcification or mineralization of bones and teeth.

2. Also involved in coagulation of blood as factor IV causing the chelating of prothrombin to form thrombin in the clotting cascade.
3. Plays a role in neuromuscular transmission of impulses particularly at the pre and post synaptic junctions.
4. It is actively involved in muscle contraction and relaxation that produces body movement.
5. It in addition regulates microfilament mediated processes such as degranulation,cell motility etc
6. It activates regulatory kinases with or sometimes without binding to the regulatory protein Calmodulin.
7. It is needed for the excitability of nerves.
8. It plays a role in permeability of gap junctions
9. It acts as a secondary and tertiary messenger in signal transduction and hormone action
10. It mediates secretion of hormones
11. It's involved in systolic myocardial contraction and general excitability of heart.
12. Affects (decreases) vascular permeability hence reduces allergic exudates.

REGULATION AND EXCRETION

Levels of calcium in the body and particularly in the blood are strictly regulated by vitamin D- Calcitriol,and hormones such as Parathyroid hormone and Calcitonin. Excess Ca^{2+} is normally excreted in urine with little amounts also excreted in stool.

Calcitriol increases blood levels of calcium by increasing its absorption from the intestine while parathyroid hormone which is secreted by the parathyroid gland acts at three principal sites- the bones, kidneys and intestines also to increase blood levels of Ca^{2+} the hormone causes demineralization of bone leading to the release Ca^{2+} into blood, increased absorption of Ca^{2+} from the intestines and reabsorption of the filtered ions from the glomerular filtrate at the kidneys.

Calcitonin is a peptide hormone secreted by the thyroid gland; it decreases blood Ca^{2+} concentration by inhibiting the resorbtion of bone having an opposite effect to parathyroid hormone together with which it causes remodeling of bone to achieve proper bone growth and development. Secretion and activities of these two hormones that regulate calcium blood

conc. is under feedback regulation depending on the levels of blood Ca^{2+} and this influences quantity excreted.

Other factors that may influence blood Ca^{2+} conc. includes levels of Phosphorus ion which decreases Ca^{2+} (Ca and P ions have almost completely reciprocal relationships with respect to regulation and excretion from the body), pregnancy which places greater demands on blood Ca hence reduce total amount in blood, presence and absence of serum proteins, Ph of the blood with alkalosis decreasing Ca blood level through its facilitation of complexing of Ca with organic compounds in the blood.

PHOPHORUS

P levels in the body represent about 1kg of total body eight with 80% of this quantity found in the bones and teeth and about 10% in the muscles is found mainly intracellular, it occurs in either the organic (nucleic acids, phospholipids etc) or inorganic form.

SOURCES; milk,cereals, nuts, meat etc

Absorption; asorption is mainly from the jejunum and is influenced by Calcitriol which increases it. P in blood is mainly protein bound the skeleton is the major reservoir of P.

FUNCTIONS.

1. It is involved in the formation of bones and teeth.
2. It is an energy source as high energy phosphate bonds in ATP and other high energy compounds (CTP,GTP and CP) that maintain muscle contractility, neurological functions, electrolyte transport etc
3. It is a constituent of cyclic adenine and guanine nucleotides,cGMP,cAMP .
4. Composition of nucleoside coenzymes e.g. NAD,NADP
5. Involved in DNA and RNA synthesis
6. Forms physiologically important phosphate esters such as Phospholipids, Phosphoproteins, Glucose-6-phophate,Nucleic acids etc.
7. It also helps to maintain the critical intracellular concentration and provides substrate for bone mineralization.
8. It is also the source of the phosphate buffer system of the blood.
9. It helps in the activation of some enzymes by phosphorylation and is involved in the activities of several enzyme systems e.g. adenylate cyclase and 1, α-25-hydroxy vitamin D-hydroxylase.

REGULATION

Serum levels of P depends on levels from diet and on its excretion and reaborbtion from the kidney tubules which is under the influence of parathyroid hormone and calcitonin.

MAGNESIUM

This is the fourth most abundant cation in the body of animals and is second to potassium inside the cell. 60% of the body Mg is located in bones, 20% in skeletal muscles, 19% in other cells and 1% in ECF. It is an alkaline earth metal distinct from other transition elements in that it interacts with other chemical species with a stronger electrostatic bonding component and prefers oxygen to N atoms.

SOURCES; vegetables, cereals, nuts, beans, Bone Meal, dairy products etc.

20-30% of ingested Mg is absorbed from the small intestine, and this is influenced by malabsorbtion syndromes and other factors that affect passage of food. Other minerals such as Ca and Phosphates also decrease Mg absorption, while presence of proteins, lactose and vitamin D increases Mg absorption.

FUNCTIONS

1. It chelates important intracellular anionic ligands especially ATP. (Convert adenosine triphosphate (ATP) to adenosine pyrophosphoric acid (ADP), with the subsequent release of energy.)

2. It catalyses and activates more than 300 enzymes-being an essential cofactor for enzymes concerned with respiration,glycolysis and transmembrane transport of other cations e.g. Na and Ca. Mg affects enzyme activity by binding to the active sites of enzymes, ligand binding or induction of conformational changes during catalytic process as well as promotion of aggregation of multiple enzyme complexes

3. It helps to maintain low resting concentration of intracellular calcium by competing with Ca for binding sites on proteins (troponin molecule found at regular intervals along actin filaments) and membranes hence sequestering Ca into the sarcoplasmic reticulum. Magnesium acts to relax muscles after calcium stimulates contraction

4. It helps maintain normal muscle and nerve function.

5. Mg is known to play a crucial role in the maintenance of cell integrity such that deficiencies of Mg lead to development of cancer. Glutathione requires magnesium for its synthesis. Low magnesium is associated with dramatic increases in free radical

generation without the cleaning and chelating work of glutathione (magnesium), cells begin to decay as cellular filth and heavy metals accumulate.

6. Magnesium has an effect on a variety of cell membranes through a process involving calcium channels and ion transport mechanisms. Magnesium is responsible for the maintenance of the trans-membrane gradients of sodium and potassium.

   The major excretory pathway for Mg is through the kidneys, but60-80% orally taken Mg is lost through feces while up to 0.75mEq/l is lost through sweat.

   Deficiency of Mg manifests as impairment of neuromuscular functions such as hyperirritability, tetany, convulsions and electrocardiographic changes. In cattle an endemic disease called grass staggers or grass tetany characterized by restlessness and convulsions followed by death frequently occurs.\

TRACE ELEMENTS

Trace elements occur in the human and animal body in milligrams per kilograms amount or less as against major elements which occur in gram per kg. Essential elements are elements required for life, whose deficient intake results in impairment of vital functions and only intake of physiologic amounts of the element can alleviate or prevent such a disturbance in function. Certain T.Es exists in the body whose exact role is not known such includes Arsenic, Mercury, and Cyanide etc

GENERAL CHARACTERISTICS OF TRACE ELEMENTS

1. Amplification; a very small amount of the element is necessary for optimal performance in the whole organism, hence a lack of such elements even in small quantities can result in disturbances. Trace elements are constituents of or interact with enzymes or hormones and regulate the metabolism of large biochemical substrates.
2. Specificity; they are specific in their functions and are most times not replaceable by even similar compounds.
3. Homeostasis; There exists mechanisms that regulate to achieve optimal body distribution of these T.Es including their absorbtion,storage and excretion e.g. the rate of absorption of T.Es generally decreases with its increasing concentration in the intestinal lumen or associated tissues. Active transport mechanisms have been suggested for Fe, Zn, and Cu. Excretions of T.Es is mainly through feces.
4. There are interactions between two or more T.Es, such as an overabundance of one element interfering with the metabolic activities of another one present in normal or marginal concentrations.

SULPHUR

Sulfur represents about 0.25 percent of our total body weight, similar to potassium. The body contains approximately 140 grams of sulfur-mainly in the proteins, although it is distributed in small amounts in all cells and tissues. Approximately half of the total of body sulphur is found in the Muscles, skin and bones, as well as concentrated amounts in hair and nails. A multivalent non-metal, it is an essential element for life as it is a building block of proteins, enzymes and vitamins. Sulfur is present in four amino acids: methionine (an essential amino acid) and in the non-essential cystine and cysteine, which can be made from methionine and taurine (used in production of bile acid for digestion).

SOURCES; “organic” sulphur is found in foods such as meat, fish, poultry, grains, legumes and vegetables such as Brussels sprouts, broccoli, onions and garlic.

FUNCTIONS

1. It plays an important function in the formation of amino acids. It is a component of keratin, the main protein of hair and nails. Sulfur is also present in the fur and feathers of animals. It also makes up collagen and elastin, the main proteins found in skin and connective tissue. And is involved in repairing damaged skin and maintaining healthy detoxification of the skin.
1. Organic sulphur can add flexibility to cell walls and allows easier passage of fluids. This may aid in eliminating pain, softening tissues and help movement.
2. Sulphur is also a component of the B vitamin Biotin and therefore contributes to fat metabolism. Sulphur is essential for insulin and thiamine production and therefore plays a role in carbohydrate metabolism.
3. Sulphur is a major component of joint tissue where it functions in the formation of cartilage, tendons and ligaments
4. Plays a role in detoxification of heavy metals in conjunction with the transport of oxygen across the cell membrane.
5. It is important in cellular respiration, as it is needed in the oxidation-reduction reactions that help the cells utilize oxygen, which aids brain function and all cellular activities.

ABSORPTION

It is generally believed that the sulphate ion is poorly absorbed. Sulfur is absorbed from the small intestine primarily as the four sulfur-containing amino acids or from sulfates in water or fruits and vegetables. Sulfur is stored in all body cells, especially the skin, hair, and nails. Excess amounts are eliminated through the urine or in the feces.

IODINE

The body contains about 25 mg of iodine. A small percentage of this is in the muscles, 20% is in the thyroid, and the rest is in the skin and bones.
Iodine is well absorbed from the stomach into the blood. About 30 percent goes to the thyroid gland, depending on the need. Iodine is eliminated rapidly. Most of the remaining 70 percent is filtered by the kidneys into the urine.
Iodine's main role in animal body is as constituents of the thyroid hormones, *thyroxine* (T4) and *triiodothyronine* (T3). These are made from addition condensation products of the amino acid tyrosine, and are stored prior to release in an iodine-containing protein called thyroglobulin. T4 and T3 contain four and three atoms of iodine per molecule, respectively. The thyroid gland actively absorbs iodide from the blood to make and release these hormones into the blood, actions which are regulated by a second hormone TSH from the pituitary. Thyroid hormones are phylogenetically very old molecules which are synthesized by most multicellular organisms, and which even have some effect on unicellular organisms. The thyroid hormones, thyroxine and triiodothyronine, are also needed for normal growth and development, protein synthesis, and energy metabolism
Sources; Iodized salt -- table salt with iodine added -- is the main food source of iodine. Seafood is naturally rich in iodine. Cod, sea bass, haddock, and perch are good sources. Kelp is the most common vegetable seafood that is a rich source of iodine. Dairy products also contain iodine. Other good sources are plants grown in iodine-rich soil.

MANGENESE

Mn is usually bound to proteins in the body either in the =2 or +3 valency states, it is associated with formation of connective tissue and bony tissue, growth reproduction as well as lipid and carbohydrate metabolism.

Sources; include cereals, vegetables, fruits nuts, liver, kidney etc
FUNCTIONS

1. It functions as a constituent of metalloenzyme and as an enzyme activator
2. It binds directly to substrates e.g. ATP or protein causing conformational changes that lead to enzyme activation. Some of the enzymes activated are non specific hence this can mask Mn defieciency, however Mn activation of glycosyltransferase, phosphoenol pyruvate carboxykinase and glutamine synthetase are specific.
3. Arginase, pyruvate carboxylase and Mn superoxide dismutase are examples of enzymes composed of Mn, while hydrolases, kinases and decarboxylases are examples of enzymes that can also be activated by Mn.

Mn within the cells are concentrated in the mitochondria and the body stores are located within the skeleton, absorption of Mn is poor especially in increased intake of the same. Ca and P also decrease its absorption. Absorbed Mn is bound to plasma proteins in blood and then transported to the liver from where its excess are removed via the kidney, as well as in bile and pancreatic secretions.

COPPER

Copper is distributed widely in the body and occurs in liver, muscle and bone. Cu is an important trace element associated with some metalloproteins. It is present both in the +1 and +2 valency states within the body and is involved mainly in oxidation-reduction reactions. It is an important constituent of many compounds and enzymes including Ceruloplasmin, Cytochrome C Oxidase, Super oxide Dismutase, Tyrosinase (necessary for pigmentation of skin via the production of melanin) etc. most of these copper containing enzymes bind to and react directly with molecular oxygen.

It in addition plays a significant role in iron metabolism- Cu deficiency impairs Fe absorption and is accompanied by anemia.

Sources; meat, lequmes, nuts and cereals etc.

FUNCTIONS

1. In addition to its enzymatic roles, copper is used for biological electron transport. Blue copper proteins participate in electron transport and include Azurin and Plastocyanin.

Duodenum is the site of maximum absorption of Cu; it may also be absorbed in the stomach. Within the intestinal mucosa Cu reacts with metallothionein (a sulphurhydyl group rich protein that binds Cu) which can be competed with by other metal ions. The amount of ingested Cu that is eventually absorbed depends on sex (females have been shown to absorb more), chemical form of the ingested compound, other dietary constituents like trace elements, and the amount ingested.

Cu is stored in the liver after being transported as Cu- albumin or Cu –histidine complexes from blood as metallothionein like Cuproproteins, ceruloplasmin, from where it is transported to other cells to be used in Cu containing enzymes. It is excreted in feces after being secreted from bile into the intestine.

Deficiency of Cu results in weight loss, bone disorders, anemia and myocardial atrophy.

ZINC

Zn is the second most abundant trace element in the body with about 1.4-2.3g of it occurring in a matured animal body.

Prostrate, semen, liver, retina, bone and muscle tissues are rich in Zn. It is found in the +2 valency state and is an essential component of many metalloenzyme involved in all aspects of metabolism.

Sources; meat, fish, dairy products are good sources of available Zn.

FUNCTIONS

1.) It is an integral part of nearly 300 enzymes, contributing to their structural stability, in different species of life e.g. superoxide dismutase, carbonic anhydrase, alkaline phosphatase, RNA and DNA polymerases, thymidine kinase, caboxypeptidase, alcohol dehydrogenase etc
2.) It also plays a role in protein synthesis and is involved in gene expression e.g. Zn finger proteins.
3.) It stabilizes the structures of proteins and nucleic acids
4.) Zn has been shown to be an important element in wound healing as it is necessary factor in the biosynthesis and integrity of connective tissue
5.) It is involved in normal fetal development and influences pregnancy outcome
6.) It is also involved in insulin secretion
7.) Biosynthesis of mononucleotides
8.) Vitamin A metabolism (stimulate the release of vitamin A into the blood).

20-30% of ingested Zn is absorbed mostly in the duodenum and early p

Art of jejunum by active energy dependent transport. This absorption is varied and depends on certain factors such as presence of dietary Ca, P, Fe, and Cu (which decrease Zn absorption); however diets rich in protein have the opposite effect.

Zn is transported in the blood bound to albumin (mainly) α-macroglobulin, transferin and free amino acids. It is mainly excreted in feces smaller amounts are excreted in urine and sweat.

MOLYBDENUM

It is a component of about 3 metalloenzymes in animals and man including Xanthine oxidase, Aldehyde oxidase and Sulfite oxidase.

Sources; cereals and dry legumes

FUNCTIONS

1.) Xanthine oxidase is involved in degradation of purines to uric acid.
2.) Aldehyde oxidase is involved in oxidation of aldehydes
3.) Sulfite oxidase is involved in final oxidation of sulphur containing amino acids.

Presence of Mo helps in the utilization of Cu while excessive amounts may result in Cu deficiency.

It is absorbed mainly in the stomach and small intestine, and stored in the liver small amounts are retained in the kidney and a skeleton.

Excess are excreted from kidneys and some from bile.

CHROMIUM

Cr is a transitional element that occurs mainly in the +3 and +6 valency state in biological systems. It is widely distributed throughout the body.

Sources; meat, whole grain products and yeast.

FUNCTIONS

It helps in the control of glucose, protein and lipid metabolism i.e. it is a potentiator of insulin action.

It is absorbed poorly from the upper small intestine and is bound to β-globulin fraction of serum proteins (transferin). It is excreted via the kidneys and it is found mainly in the liver-mitochondria, microsomes and cytosol.

Deficiency results in impaired glucose tolerance secondary to parenteral nutrition.

SELENIUM

It is a constituent of glutathione peroxidase and iodothyronine deiodinases and thioredoxin reductase (selenoproteins). It is present in tissues as selenocysteine and selenomethionine which serves as a store for Se which is released in cases of dietary insufficiencies.

The biologically active form of Se is selenocysteine and it is present in the selenoproteins.

Sources; plant (grown on Se rich soils) and animal tissues.

FUNCTIONS

It helps to defend the body against oxidative stress and is also involved in the synthesis and metabolism of thyroid hormones.

GSH (reduced glutathione) catalyses the breakdown of H_2O_2 , phospholipid hydroperoxides etc, it is present in RBC. Thioredoxin reductase is thought to have an immunological function and plays a role in reproduction.

Se is well absorbed in the GIT and may not be regulated homeostasis of Se is achieved by regulation of its excretion via the urine, however high intake of Se leads go exhalation of volatile forms.

COBALT

Co is an integral part of the B vitamin B12- cyanocobolamine which is required for the maturation of RBCs.

Sources; animal tissues.

FUNCTIONS

As a cofactor for some enzymes e.g. glcyl-glycine dipeptidase, invoved in bone marrow development for RBC maturation and in the formation of cobamide enzyme (adenosyl co-enzyme).

FLOURINE

It is obtained mainly from drinking water other sources include tea, salmon, sardine and mackerel. It is present in calcified tissues like bones and teeth.

It is absorbed from intestine and excreted mainly in the urine.

FUNCTIONS

It helps in tooth development-i.e. normal maintenance and hardening of enamel and prevention of dental caries. It also helps in the normal bone development as catalytic mounts of F is required for the conversion of phosphates and Ca hence helps prevent osteoporosis (softening of the bones).

Toxic levels of F in the body result in fluorosis characterized by mitochondrial damage, certain enzyme inhibition and negative effects on protein, steroid and collagen synthesis.

NICKEL

This occurs in trace amounts in humans and animal tissues. Dietary intake is poorly absorbed and it is excreted mainly in feces.

Ni plays an important role in some enzyme activities e.g. Arginase, carboxylase, trypsin and acetyl CoA synthetase.

It is also required for growth and reproduction.