Senior five notes

Principles of nutrition

Nutrition; this is the study of food, its ingestion, digestion, absorption, utilization what happens if too much is taken in, what happens if too little is taken in and its egestion. This is the scientific study of all processes of growth, maintenance and repair of living bodies which depend on food intake. **OR** Is the study of food and its uses in the body. It's a process of feeding the body with food and involves taking in food (ingestion), food breakdown (digestion), absorption of the digested food (assimilation) absorption of nutrients into the cell constituents and removal of undigested materials from the body (egestion)

Nutrients

These are the chemical substances found in the food which give food its characteristic colour, texture, taste and flavour. They include carbohydrates, proteins, vitamins, fats and mineral salts among others

Dietetics

This is the study of nutrition in relation to the body's health and diseases. It involves the practical applications of nutritional science.

Nutritional science. This is the study of scientific knowledge governing the nutritional needs of humans especially for maintenance, growth, activity and reproduction. It's concerned with the nature and composition of foods, the amounts required by the body, physical and chemical changes brought about by the intake of food.

MAL-NUTRITION

This is a condition that occurs when the body receives wrong amount of nutrients. Its long term diet imbalance brought about when the intake of one / more nutrients is out of proportion to the needs of an individual.
In certain circumstances malnutrition may be brought about when the intake of one / more nutrients is greater / smaller than that required by the body i.e. too much intake of carbohydrates causes obesity and insufficient intake results into Marasmus.

KINDS OF MAL-NUTRITION

1. **Under-nutrition:** This is where the total intake of one / more nutrients is less than required by the body e.g. little intake of proteins causes kwashiorkor.
2. **Over-nutrition:** A situation brought about when the total intake of a nutrient is greater than / goes beyond that required by the body e.g. too much intake of carbohydrates causes obesity.

Diet therapy: Is the use of food in solid / liquid form to prevent, treat, manage / cure diseases.

Diet status: Is the relationship between dietary intake and metabolic requirements of the body.

Metabolism: This refers to the total sum of all chemical processes in the body which sustains life and health. Series of chemical reactions will utilize nutrients for building, repair and maintenance and energy production.

Nutritional status. This is a condition of the body resulting from utilization of essential nutrients available to the body. It can be poor, fair or good status depending on the intake of nutrients and relative need for them plus

the body's ability to use them. Nutritional status of the populace is a good indicator of national prosperity especially in developing countries.

Two kinds of metabolism

(a) **Anabolism;** A process whereby large molecules are formed from smaller ones i.e. manufacture of cells and it involves utilization of energy. Examples of anabolic process in the body include

(b) **Catabolism:** A process whereby large molecules are broken down to form smaller ones i.e. breaking of food evolves energy. Examples of catabolic process in the body include

Optimum nutrition: this is a condition where by the important nutrients are supplied and utilized to maintain health and well being at the highest possible level. I deal nutrition is reflected in a well developed body consisting of ideal weight for body composition, good muscle development, smooth clear skin, clear and bright eyes, good posture and facial expression, normal appetite and digestion.

Good nutrition. This is the feeding in relation to good health which involves good choice of foods in terms of quantity, quality and variety or the food groups eaten and are free from toxic chemicals, microbial contamination and involves foods that meet the body requirements and can easily be digested so that the body can get nourishment from it.

Poor nutrition. This is when one is deprived of food or when one is taking inadequate amounts of essential nutrients required for proper body functioning. Poor nutrition may also refer to excessive intake of nutrients. Borderline nutrition means that one depends on the minimum need from day to day. Such people lack nutrition reserves to meet any added physiological or metabolic demands from injury or sickness. This is due to poor eating habits, low incomes and living in stressed situations like war tone areas.

Balanced diet. This is a diet that provides all the necessary food nutrients in the correct amounts for the body needs at a particular time. Proper nutrition is essential from the time of conception, to birth and up to death.

Diet. This is a mixture of food stuffs which supply nutrients to an organism. It's what we eat or drink each day. Diets must be adjusted at various stages and conditions of life so that the person meets the nutritional requirements.

Food

Food is scientifically defined as any liquid / solid which when eaten or swallowed provides the body with materials enabling it to carry out any of the following:

- growth and repair eg the proteins
- protection and regulation of the body processes eg the vitamins and minerals
- Energy production eg the fats, carbohydrates and proteins

BASIC FUNCTIONS OF FOOD

1. For cell growth and repair
2. Supply of heat and energy
3. To protect and regulate body processes thus preventing diseases.
4. Food is eaten to satisfy hunger.

SOCIAL FUNCTIONS OF FOOD

Whenever there is a social function food is associated with drinking. On many ceremonies and occasions, like religious festivals, cultural festivals are celebrated with feasts.

Food is also a sign of security. When people have enough food to eat they feed more securely free from worry, but if it becomes difficult for them food it turns out to be uneasy.

- **Belonging.** Having friends and relatives gives people a belonging of being accepted and valued by others. Food can create a warm feeling of hospitality when people get together. In such a situation, people find it easier to socialise like on meetings and family get together parties.
- Food satisfies emotional needs. It's used to satisfy feelings like a grandmother to a grandson.
- **Enjoyment and creativity.** Much of the enjoyment from food comes from the sense of taste, smell, sight and touch. Your favourite food is always the one that tastes most delicious to you. Many people prepare and serve food as a way of becoming creative in preparing and serving foods which leads to enjoyment not only to them but also to the people who share the end results.
- **A form of relaxation.** This can be seen on family meals. The meal time is often the only time when the whole family is gathered together and this creates an opportunity to converse and relax.
- **A means of entertaining.** This can be seen on buffets, cocktail parties as many people can be entertained by food and dancing.

STIMULATIONS OF THE BODY'S HUNGER

Hunger is scientifically defined as the empty feeling of the stomach showing the body's need for food. People may have little or no food for long periods of time and their lives are threatened. Hunger is also known as starvation.

Hunger can be explained scientifically using the following body's stimuli.

- **Chemical stimulus**. When there is a fall in blood glucose levels hunger may be stimulated. The fall in the blood sugar levels cause weakness, headaches and laziness. The person is driven to take food immediately. Glucose and fatty acids are known to act as signals that initiate a feeling of satiety.
- **Nervous stimulus.** Contractions of the abdominal walls and the feeling of discomfort in the abdominal cavity signals to the person that the stomach is empty. It therefore initiates the feeling of to eat. In children it's preceded by crying and quest for attention.
- **Thermo stimulus**. When we are cold, we feel hungrier as food is constantly burnt to produce heat for warmth, than when it's hot and the appetite is low.

- In many cases, the brain is believed to act as the central controller of food intake, serving to integrate chemical and nervous signals from many different sources like the sensory signals, and in response, produce control signals that regulate the level of food intake and adjust the balance between food oxidation and storage.
- All in all, food intake is stimulated by hunger but inhibited at an appropriate point by the sensation of satiety. The hypothalamic region of the brain has the feeding centre, which stimulates appropriate voluntary feeding behaviour and a satiety centre which is required to stop feeding once the required amount of food has been taken. Malfunction of the satiety centre leads to binge eating and thus obesity.

CLASSIFICATION OF NATURAL FOODS ACCORDING TO PHYSIOLOGICAL IMPORTANCE

- **Energy giving foods**
- These provide fuel to run our body's physiological and physical activities. These include lipids and carbohydrates and to a certain extent proteins. Foods known to provide such nutrients include cereals, plantain and tubers.
- **Body building foods**
- These build, maintain and repair the tissues. Basically this is a function of proteins. The nutrient is contained in eggs, meat, breast milk and legumes.
- **Protective foods**
- This group include foods which supply vitamins and minerals and marginal amounts of energy and proteins. They are found in fruits and vegetables.

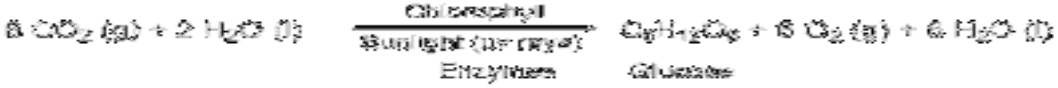
CARBOHYDRATES

A **carbohydrate** is an organic compound with the empirical formula $C_m(H_2O)_n$ that is, consists only of carbon, hydrogen and oxygen with a hydrogen: oxygen atom ratio of 2:1 (as in water). However, there are exceptions to this. One common example would be deoxyribose, a component of DNA, which has the empirical formula $C_5H_{10}O_4$.

Carbohydrates are organic compounds with empirical formula Cn (H2O) n consisting of carbon, hydrogen, and oxygen.

Carbohydrates have been of prime importance in the human diet and provide the major source of heat and energy for the body activity (work) and human development. Animals are unable to synthesis carbohydrates but most plants can manufacture them from water and CO_2 with the help of sunlight in a process known as photosynthesis.

Photosynthesis is the process by which chlorophyll containing plants are able to manufacture carbohydrates from CO_2 in the air and water from the soil. Sunlight is used as energy and it is trapped by chlorophyll pigment.



Oxygen and water are given off during the process as the by-products.

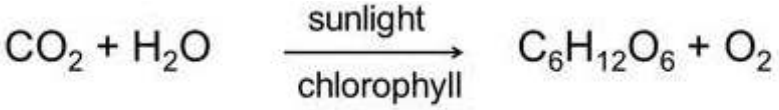
At first a very simple carbohydrate (glucose) is formed but as the process continues the single molecules (monosaccharide) are linked together to form larger molecules (disaccharides) and eventually polysaccharides. These are stored as starch or cellulose in various parts of the plants like the roots, pods, seeds, fruits, stems or leaves. This can be oxidized to produce energy for the plant itself or when eaten for the human body.

Composition and Structure of Carbohydrates

The term carbohydrates refers to the compounds of the hydrates of carbon i.e. they consist of the elements Carbon (C), Hydrogen (H) and Oxygen (O) in the ratio of 1 : 2 : 1.

Elementally carbohydrates are composed of carbon, oxygen and hydrogen. The hydrogen and oxygen are in ratio of 2:1. Chemically carbohydrates are composition of monosaccharide molecules.

NB. Animals are unable to synthesis carbohydrates but most plants can manufacture them from water and carbon dioxide with the help of sunlight in a process known as photosynthesis.



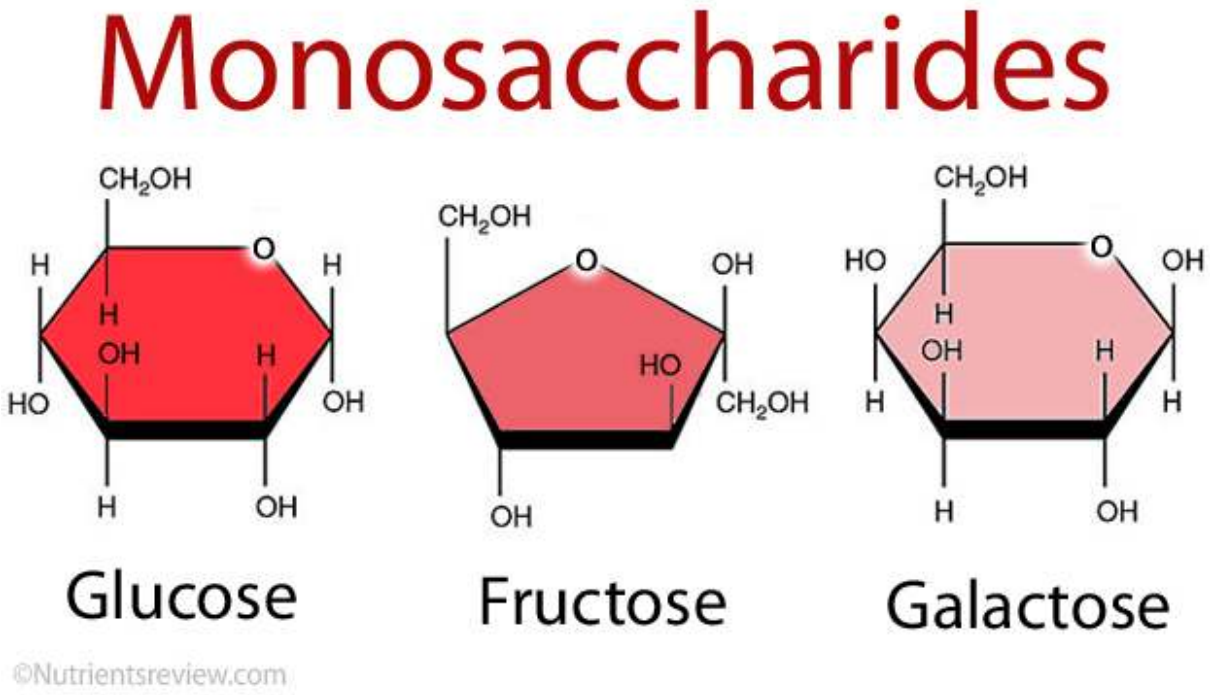
Classification of Carbohydrates

Classification can be done according to the number of single sugar units in the structure. These are monosaccharides, disaccharides, oligosaccharides, and polysaccharides.

According to functional groups; Aldose sugars, ketose sugars.

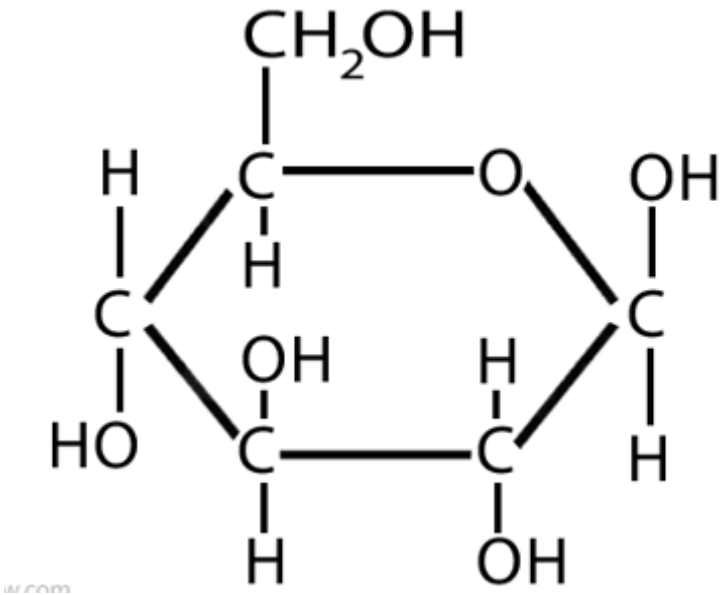
Monosaccharides

Monosaccharides are the simplest form of carbohydrates which cannot be hydrolyzed any further by enzymatic actions. They have the basic carbohydrate structures and are made of 3-7 carbon atoms ie. Trioses(3carbon), tetroses (4 carbon), pentose (5 carbon), hexoses (6 carbon) and heptose (7 carbon). The most important monosaccharides in human nutrition are hexoses which include glucose, fructose and galactose. They all have a sweet taste, dissolve in water, easily broken down and reducing sugars.



Glucose (Dextrose, Grape, Corn sugar)

Glucose is the simplest hexose sugar found in sweet ripe fruits. Glucose is a white moderately sweet crystal obtained from hydrolysis of starch. Glucose is a strong reducing sugar and is the form in which sugar circulates in the blood stream to provide the major energy. 3



Glucose is the simplest hexose sugar found in sweet ripe fruits like grapes, sweet vegetables, maize, roots and onions. Glucose is a white, moderately sweet crystal obtained from the hydrolysis of starch. Glucose is a strong reducing sugar or agent capable of dissolving blue Benedicts / Fehling's solution. It reduces copper from the cupric (Cu) state that is blue to cuprous (Cu^{2+}) state which is colourless. This test is also used for detecting glucose level in urine.

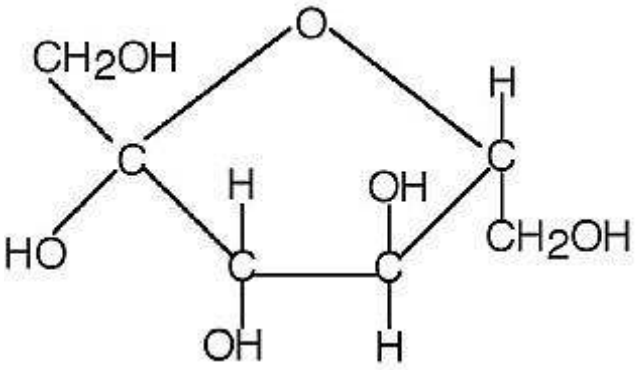
Glucose is the form in which sugar circulates in the blood stream to provide the major energy or fuel source to the body. This sugar or glucose concentration is maintained at 90 mg / dl of blood by insulin hormone. Insufficient level of insulin hormone in blood can lead to diabetes.

Glucose is commercially available in crystalline or powder form, tablets, syrup or colourless liquid. It is often used in confectionary, jam making and brewing industries.

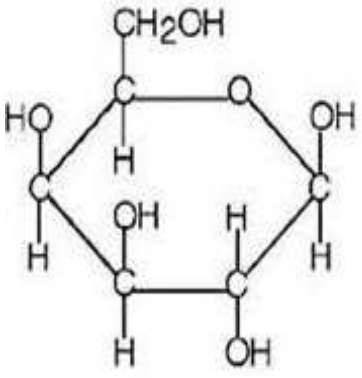
Fructose (Fruit sugar)

Fructose is the sweetest of all the hexose or simple sugars and doesn't crystallize easily. Mainly occurs in sweet fruits, honey and sweet vegetables. It can also be got from the hydrolysis of sucrose. Fructose provides an acceptable nutritive sweetener for use in carbohydrate and calorie modified diets. It is sweet and soluble in both cold and hot water.

Structure



(Fructose)



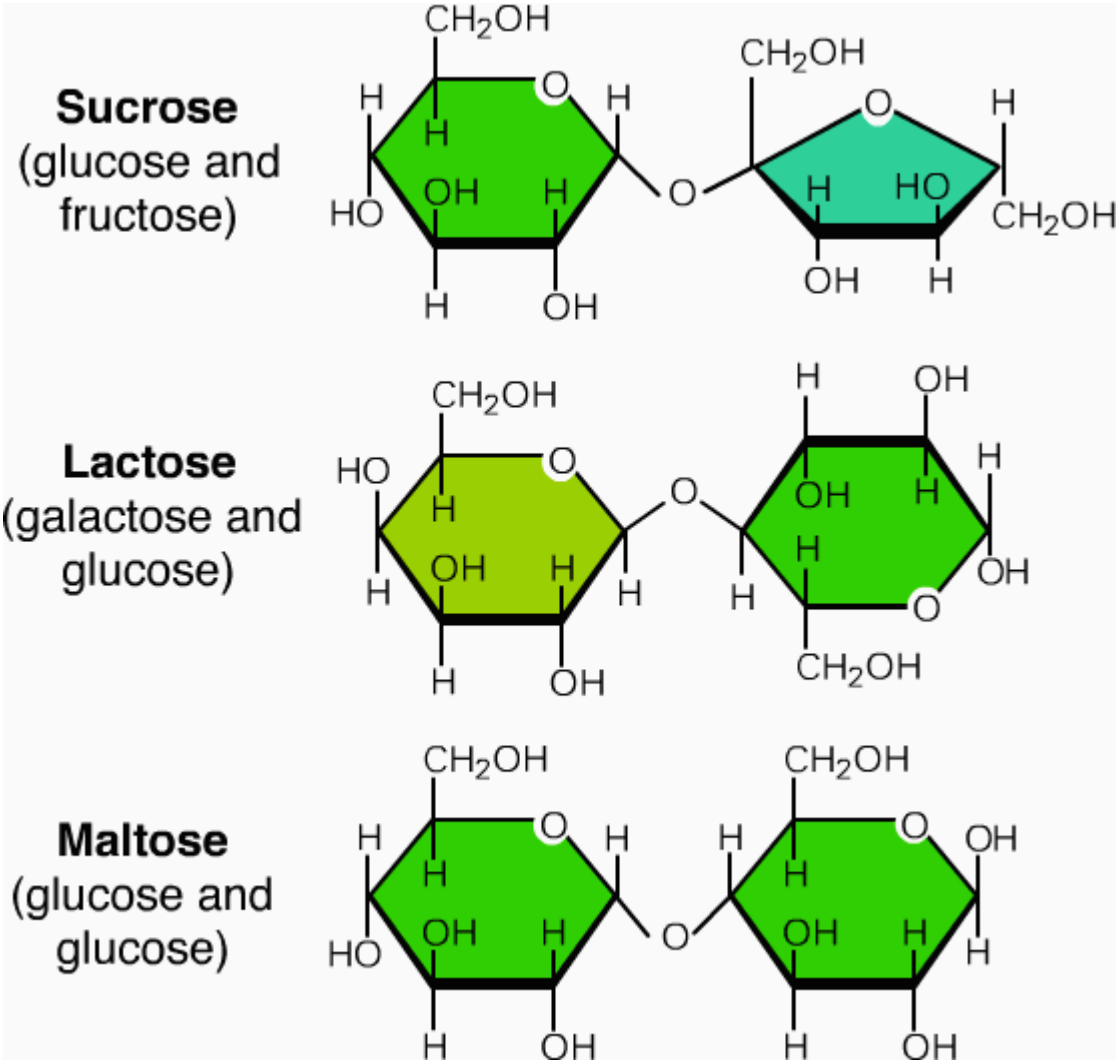
(galactose)

Galactose (Milk sugar)

Galactose results from the hydrolysis of lactose and is changed to glucose in the liver for energy production. The reaction is reversible and during lactation, glucose may be reconverted to galactose for use in breast milk production.

Disaccharides

Disaccharides are also known as double sugars because they are compound of 2 monosaccharide units linked together with the help of a glycosidic bond. Disaccharides are all white solids, water soluble, crystalline and vary in their sweetness and also reducing sugars except sucrose. Disaccharides are formed by condensation reaction of monosaccharides which result to release of water molecule and bonded by 1-4 glycosidic bond.



Sucrose (table sugar)

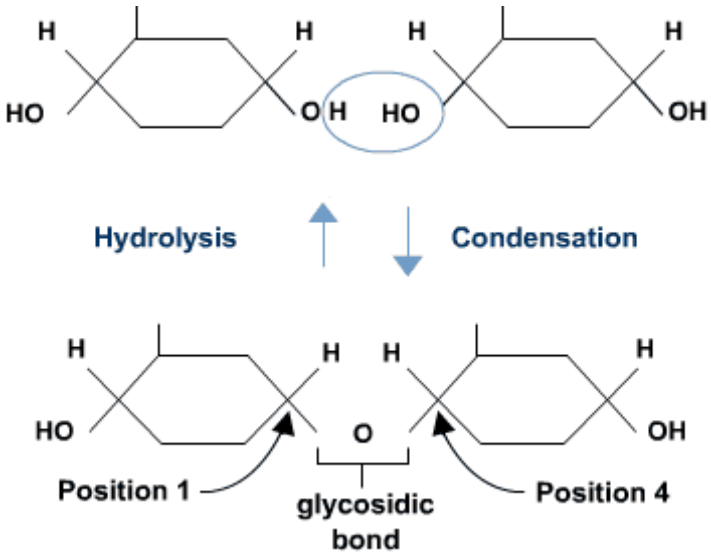
Mainly found in sugar cane, syrup, brown sugar and all the sweet fruits. Formed from condensation of fructose and glucose and it is the sweetest sugar among disaccharides.

Lactose (milk sugar)

It is the least sweet of all disaccharides and formed by condensation of galactose and glucose by 1-4 glycosidic bond with release of water molecule.

Maltose

Made up of two glucose units and occurs in malt products of starch hydrolysis, germinating seeds and cereal grains and starchy materials on action of diastase and maltose enzyme. 5



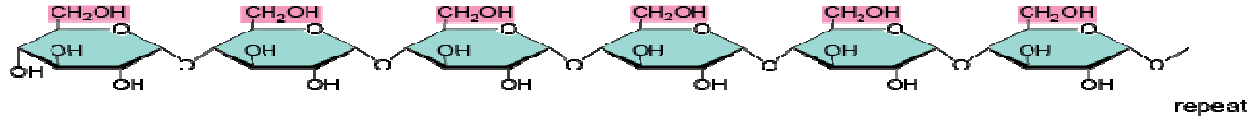
Oligosaccharides

These contain between 3-10 monosaccharide units and they are complex. They are irregular in form and when digested yield few constituent monosaccharide units. Naturally occurring oligosaccharides include starchyose (a tetra-saccharide made of glucose), raffinose (a tri-saccharide of glucose, fructose and galactose). They are usually found in legumes and cannot be digested but provide food for bacteria flora to thrive in the intestinal tract producing gas that can bring abdominal discomfort, pain and embarrassment. Commercially prepared oligosaccharides are used in special infant formulas, on people with gastrointestinal problems and sports drinks since they are easily digested.

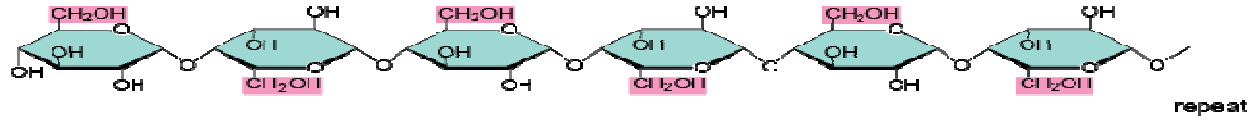
Polysaccharides

These are complex carbohydrates composed of many or several single sugar units bonded by glycosidic bonds at each connection. They contain long chains and branched formations with relatively high molecular weight. Unlike sugars, they are amorphous (non-crystalline), tasteless and generally insoluble in cold water. Examples of polysaccharides include starch, cellulose, glycogen, pectin, dextrin, hemicellulose and gums.

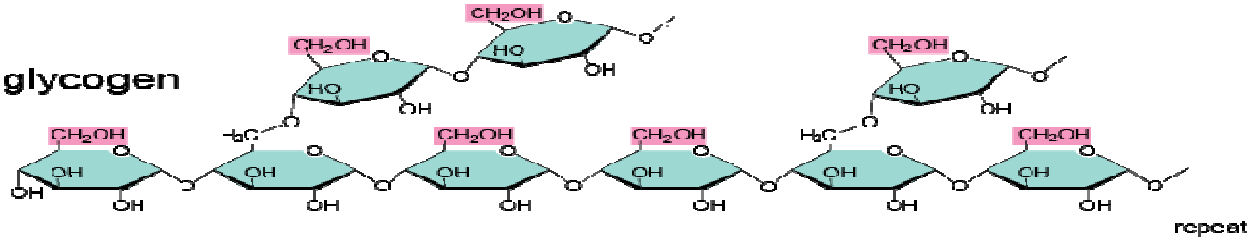
starch



cellulose



glycogen

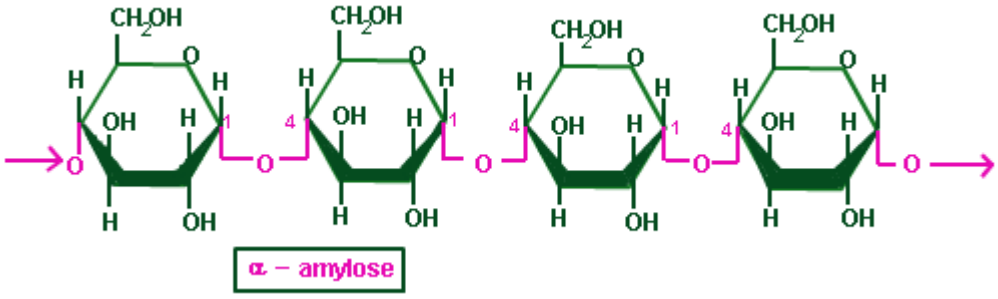


Starch

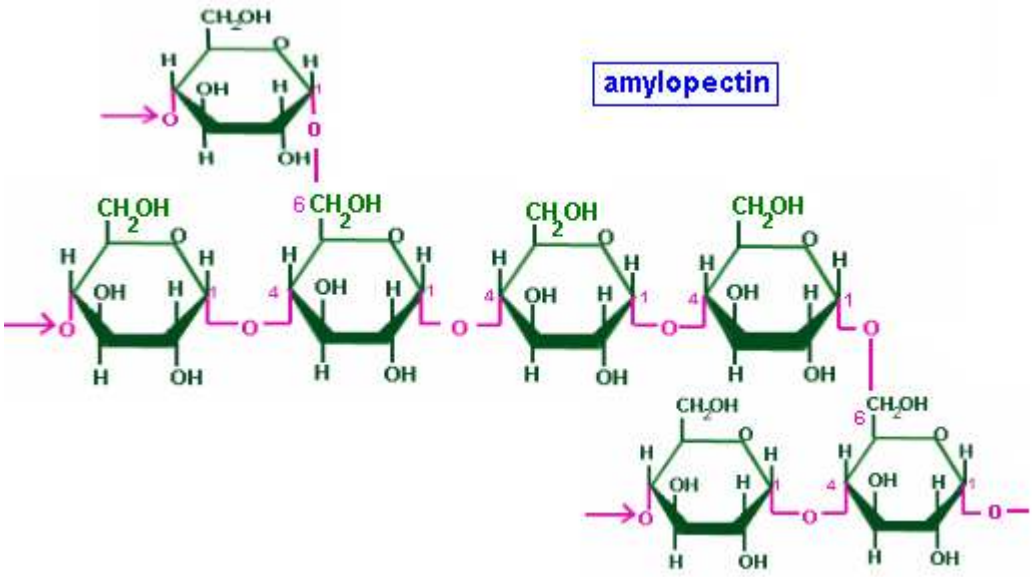
It is a storage form of carbohydrates in plants and thus it's the most significant source of energy in human nutrition. Starch is in two forms i.e. Amylose and Amylopectin.

Amylose, portion of starch made up of long coiled chains of glucose units with 1-4 glycosidic bond and less branching. Forms the outer waring of starch cells which make them insoluble in water. Amylopectin, large portion of starch made up of branching chains with 1-4 and 1-6 linkages at specific points along the chains. It has gel-like properties responsible for the thickening of starch mixture.

Amylose only makes up 20 -30% of the starchportion of starch is made up of long coiled chains of glucose units with α (1,4) glycosidic bonds and less branching. It is responsible for maintaining the normal blood sugar level and forms the outer coating of starch cells which makes them insoluble in cold water but more soluble in hot water than amylopectin without swelling but does not form a gel. With iodine, it stains blue.



Amylopectin is the large portion of starch made of branching chains with 1,4 and 1,6 linkages at specific points along the chains. Less soluble in water, but soluble in hot water with swelling. It has gel-like properties responsible for the thickening of starch mixtures. Turns yellow or orange with iodine.

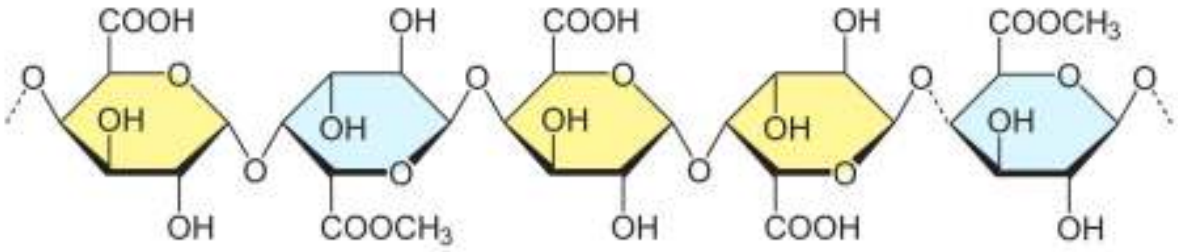


Cellulose

Form the chief cell structures of plants, skin of fruits, covering of seeds and bran layer of cereals. Cellulose is indigestible but are source of bulk in the diet which stimulates peristaltic movement of gut muscles to remove wastes and thus prevent constipation.

Dextrin; These are polysaccharide compounds formed as intermediate produces in starch break down due to action of heat, acid and enzymes. For example, the crusty brown top of bread toast.

Pectin; These are indigestible carbohydrates occurring in ripe fruits and some vegetables. They lack nutritional significance but have the ability to absorb water and form gel. This is used in making of fruit jellies and setting of jam.



Functions of Carbohydrates

Biological functions

- The primary function of dietary carbohydrates is to provide fuel; energy and heat for the body. When oxidized, they release 4kcal/g of energy that is used for proper functioning of the body.
- Excess carbohydrates in the blood stream are converted into body fat which is stored under the skin as a depose tissue.
- This forms the layer which helps in insulating the skin against heat loss but too much can lead to obesity.
- Complex carbohydrates like cellulose, pectin and hemicellulose are useful in stimulating the peristaltic movement of the gastro-intestinal tract.
- Carbohydrates are highly satisfying due to the presence of indigestible carbohydrates like cellulose which are bulky and gives a feeling of satisfaction.

- Dietary carbohydrates have a protein sparing effect hence help to regulate protein metabolism. The body will use carbohydrates preferably as source of energy when they are sufficiently supplied hence sparing proteins for its primary function of tissue building. A constant amount of glucose is necessary for the proper functioning of the brain and central nervous system.
- Glucose is converted to glycogen which acts as an emergency energy reserve for the body. This helps to maintain the normal blood sugar at 90-80mg/dl. This is controlled by insulin and glucagon.
- Glycogen is also an important source of contractile energy for cardiac muscles. Low glycogen stores due to low carbohydrates intake may cause cardiac symptoms.
- Carbohydrates are required for normal fat metabolism. When carbohydrates are severely restricted like during fasting, starvation, excess fats will be metabolized faster so as to provide energy. This leads to accumulation of incompletely oxidized products like ketone and acids that cannot be metabolized.
- Carbohydrates combine with protein to form glycoprotein with help in the formation of cell membrane.
- Oxidation of carbohydrates leads to production of heat energy. This produces warmth to the body.
- Lactose being less soluble than any other sugars, it remains in the intestine for long enough to encourage the growth of intestinal bacteria useful in synthesis of B-groups of vitamins.
- Lactose also enhances the absorption of calcium by forming calcium lactate which is soluble.

Functions of Carbohydrates in Cookery

- Carbohydrates are used as accompaniments to protein and fatty dishes so as to make a balanced diet.
- Sugars are important sweeteners in a variety of dishes like fruit juices, cakes and puddings.
- Sugars are used as preservatives in jam, soft drinks and dried fruits.
- Pectin is an important setting agent in jam and jellies.
- Carbohydrates such as flour act as a base in many baked products like cakes, biscuits, bread and pizza.
- Sugar is a basic ingredient in baking due to its caramelization properties.

- Starch, sugar and maltose are important raw materials during fermentation process to give alcohol.
- They add variety of food in diet since can be cooked in various ways.
- Starch is used as a thickening agent of liquids like soup, gravies and sauces.
- Carbohydrates are the cheapest foods available which make the to be eaten in larger amounts by any group of people

Effects of Heat on Carbohydrates

Moist and dry heat affects the physical and chemical properties of carbohydrates differently as shown below;

Moist heat

- Starch; Starch grains absorb water, swell, softens and burst releasing the starch cells and amylopectin (gel) which thickens the liquid e.g when making porridge, white sauces, millet bread(kalo) and soup. This process is called Gelatinization.
- Cellulose; Moist heat causes cell walls of fruits and vegetables to soften and become more digestible. If over cooked, they will disintegrate.
- Sugar; moist heat causes sugar to dissolve more easily to form syrup.
- Further heating causes the syrup to darken in color
- Sugar will burn or carbonize at 160 c

Dry heat

- Dry heat causes the starch grain to burst eg pop corns, maize.
- Surface or outside starch grains are converted to pale brown compounds known as dextrins. This improves the flavor and appearance of food. This process is known as dextrinization.
- Excess or overheating leads to burning or blackening.

- Overheating will develop bitter unpleasant flavor.
- Further heating will lead to burning and form charcoal (carbon).

Digestion of Carbohydrates

1. Mouth

- Digestion of carbohydrates starts off with mastication by the teeth to breakdown food into small particles.

- Food is then mixed with saliva which contains salivary amylase (ptyalin) enzyme.

- Salivary amylase converts cooked starch to maltose. Salivary amylase has no action on un cooked starch, therefore cooking helps to rapture the starch cell walls to ease action of enzymes. Food is then pushed to the stomach.

2. Stomach

- Food is mixed with gastric juice which contains gastric or hydrochloric acid.

- Hydrochloric acid stops the action of the alkaline ptyalin and no further digestion of carbohydrates takes place in the stomach since the enzyme is inactive in acid medium. Peristaltic action pushes food into the duodenum and small intestines.

3. Duodenum

- Food is mixed with pancreatic juice from the pancreas which contains pancreatic amylase.

- Pancreatic amylase converts the remaining starch to maltose. Food is pushed to the small intestines.

4. Small Intestines

The intestinal glands produce 3 enzymes to complete carbohydrates digestion. These include;
- Maltase which converts maltose to glucose

- Sucrose/ invertase which converts sucrose to glucose and fructose.

- Lactose converts lactose to galactose and glucose.

- Indigestible polysaccharides may undergo partial breakdown of the intestinal bacteria.

5. Absorption

- CHO are absorbed from the small intestines through the villi and into the blood stream inform of glucose with some fructose and galactose. The villi increase surface area for absorption.
- Fructose and galactose are converted into glucose for the final absorption. These travel through the hepatic portal vein to the liver where they are either oxidized to produce energy and heat, combined with phosphate and potassium to form glycogen and stored in the liver for future use.
- The excess is converted to fats and stored as a depose tissue.
- The rest is eliminated as feaces.

Questions

i) Why is energy required in the body? The body uses chemical energy, heat energy, electrical energy (nerve and muscle)

- Cell activity including metabolism and synthetic reactions
- Physical activity including voluntary movement
- Heart and nerve activity
- Temperature regulation
- Digestion and absorption
- The brain uses 25% of the energy
- Growth is energy intensive

ii) Describe the factors which affect metabolic rate of an individual

- Age. Adolescent have a higher metabolic rate than adults as they need energy for growth and activity
- Sex. Men tend to have more lean tissue than women which translates to more respiring cells that make and need energy.
- Body composition and size. Some people have more or less lean tissue than others of the sane sex and age. Fat short people will therefore have a lower metabolic rate that tall learner people.
- Lactation is energy intensive
- Disease. The body's metabolism may be lowered by disease and reduced activity but as the patent recovers, energy requirements for healing go up.

- Pregnancy and lactation. Because of the demand for energy and nutrient for the foetus, metabolic rate is always high.
- Physical activity. More active people have a higher demand for energy as they utilise what has been made all the time. Therefore sports man, manual workers among others will Have a higher metabolic rate than sedentary workers of the same size, sex, weight etc,
- Climate. In cold climates more heat energy is lost and required to warm the body which is the reverse in hot climates. The metabolic rate is higher for people living in Iceland than those in deserts
- Drugs and medication. Many steroids and steroid medicines increase metabolic rate and resulting metabolites are usually stored as fat leading to weight gain.
- Endocrine related disorders such as hypothyroidism and hyperthyroidism largely affect the hormone thyroxine which controls metabolism

c) Discuss the factors which affect digestion of food nutrients.

- Nutrient requirement. When the body's need for a given nutrient is high, it stimulates a mechanism for this nutrient to be taken up e.g. by stimulating hunger for energy metabolism, production of enzymes for break down and absorption.
- Presence of inhibitors. Many inhibitors combine with nutrients such as vitamins and minerals forming complex compounds that are insoluble or make the nutrient unavailable e. g. when iron reacts with phytates forming iron phytate.
- Presence of enhancers. These on the other hand work to encourage digestion by emulsifying e.g. bile, affecting pH, release of enzymes etc.
- Diseased gastro intestinal tract or diseased digestion involved organ.A diseased organ such as the liver or pancreas affects the production and release of digestive juices. If any area in the gut is impaired e.g. the stomach, it will still inhibit digestion.
- Enzymes and enzyme activators. Presence of enzymes ensure chemical digestion to be efficient and effective. Protein deficiency for example greatly impairs enzyme production leading to low appetite and indigestion.
- Amount of food and the amount of chewing
- Temperature and pH of the digestive tract. Enzymes work best at specific temperature and pH and if this id altered they do not perform their function.
- Activity of individuals

Diabetes Mellitus.

It is a chronic metabolic disorder characterized by the absence or inadequate insulin hormone which leads to increased glucose level.

This condition can be hereditary but also common with overweight, obese and elderly people.

Diabetes mellitus is mainly caused by the following;

- Genetic factors which lead to inheriting of altered or mutated genes responsible for production of insulin. This makes insulin un available.

- Failure of defective B-cells of the pancreas to secrete any insulin.

- Obesity and hypertension which increases the sensitivity of tissues to insulin hormone.

METABOLISM OF CARBOHYDRATES (Glucose)

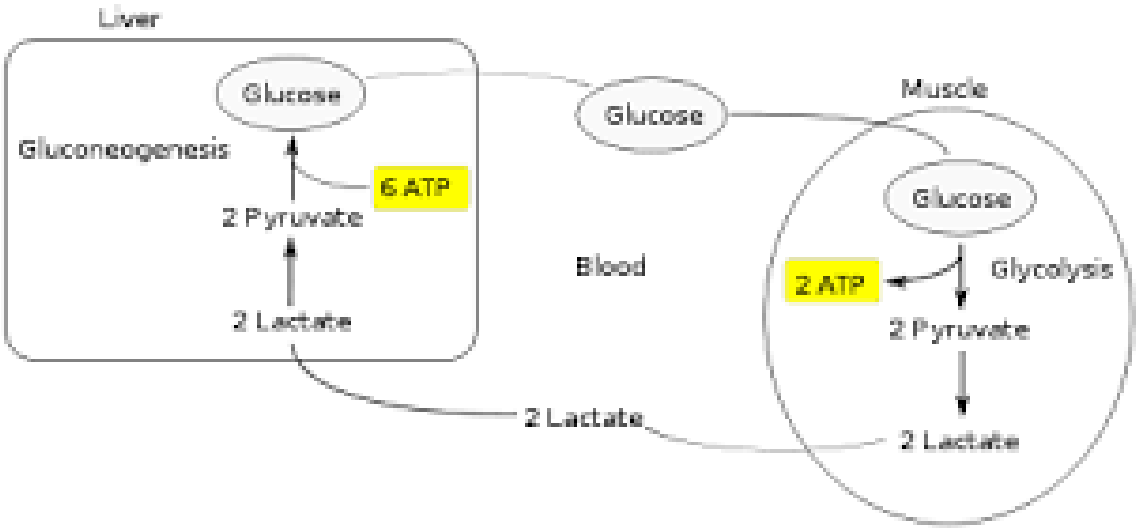
- The main aim of carbohydrate or glucose metabolism is to extract energy from glucose the end product of carbohydrate digestion and absorption. This goes on in all the cells but the major sites are the liver, adipose tissue, muscle tissue and renal or kidney tissue.
- The initial step is known as glycolysis (sugar-splitting).
- Glycolysis refers to the splitting apart of simple hexose sugars like glucose into 2 molecules of a 3 carbon compound known as pyruvate / pyruvic acid and finally into Acetyl CoA. This takes place in the cell cytoplasm as follows;
- Glucose is phosphorylated by addition of a phosphate molecule to form the more reactive glucose-6-phosphate.
- This is further phosphorylated and reorganized to form fructose-1,6-diphosphate.
- It's eventually split into two 3 carbon molecules known as glyceraldehyde and di-hydroxyl acetone phosphate. This process utilizes 2 ATP molecules.
- Two pairs of phosphate molecules are lost from the compounds to form 4 ATP molecules.
- The compounds are then finally converted to two 3 carbon compounds known as pyruvate / pyruvic acid.
- A total of 10 ATP molecules are produced in this step.
- The hydrogen atoms released are taken up by the Hydrogen ion receptor molecules.
- The pyruvate is oxidized by combining with coenzyme A (CoA) to form Acetyl CoA and 2 carbon compound with the release of CO_2. This reaction is catalyzed by pyruvate dehydrogenase enzyme and it produces 6 ATP molecules. $2Pyruvate + 2NAD^+ + CoA \rightarrow 2Acetyl\ CoA + 2NADH + H^+ + CO_2 + Energy$
- Acetyl CoA now enters the Kreb's cycle
- This is the final stage of carbohydrate metabolism and it takes place in the Kreb's or Tri-carboxylic acid (TCA) or Citric Acid Cycle. It occurs in the cristae of the mitochondria. The Kreb's cycle is a cyclic sequence of 8 reactions with the final dual purpose of energy production. This occurs as follows;

- Acetyl CoA combines with a 4 carbon oxaloacetic acid (oxaloacetate) to form a 6 carbon citric acid (citrate).
- This then goes through a series of reactions which involve progressive loss of 2 molecules of CO_2 with final generation of the 4 carbon oxaloacetic acid.
- This links up with another Acetyl CoA molecule to continue the cycle.
- Hydrogen atoms are produced from the Kreb's cycle and are taken up by hydrogen ion (H^+) receptors. The hydrogen atoms produced are taken to the Electron Transport System (ETS) or Respiratory Chain.
- The ETS is a means by which hydrogen atoms released during glycolysis and the Kreb's cycle are converted into ATP or energy molecules. The ETS is made up of electron carriers and hydrogen acceptor molecules like FAD, NAD, Coenzyme Q (Ubiquinone) and Cytochrome b, c and a. These capture hydrogen atoms as they are released from the cycle and separate them into constituent electrons and protons.
- The electrons pass through the ETS from carrier to carrier with the subsequent formation of 3 ATP molecules from each electron. This leads to a total production of 24 ATP molecules from 8 hydrogen atoms. This is known as Oxidative phosphorylation.
- The hydrogen protons and electrons from the ETS combine with oxygen to form water with the help of cytochrome oxidase enzyme. $2e^- + 2H^+ + \frac{1}{2} O_2 \rightarrow H_2O$
- A total of 40 ATP molecules are produced and net gain of 38 ATP molecules.

Glycolysis without oxygen

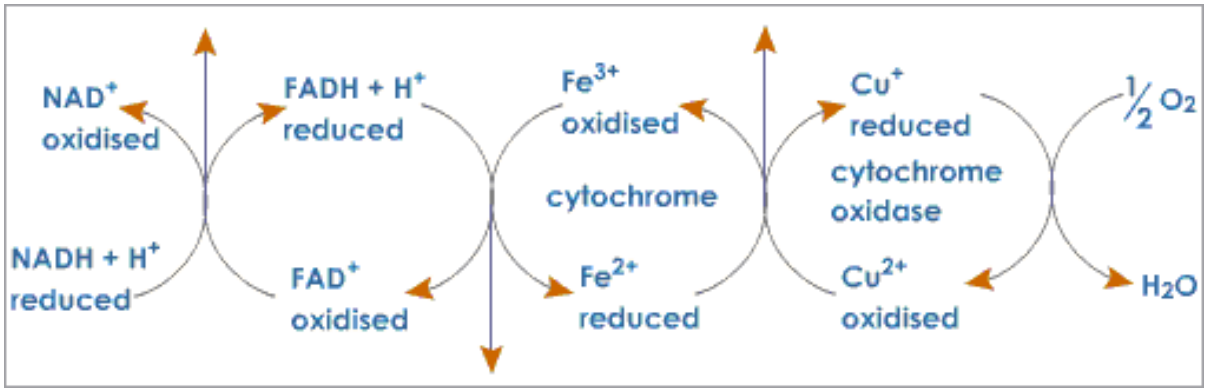
- When oxygen supply is insufficient, typically during intense muscular activity, energy must be released through anaerobic metabolism. Lactic acid fermentation converts pyruvate to lactate by lactate dehydrogenase. Most importantly, fermentation regenerates NAD^+, maintaining the NAD^+ concentration so that additional glycolysis reactions can occur. The fermentation step oxidizes the NADH produced by glycolysis back to NAD^+, transferring two electrons from NADH to reduce pyruvate into lactate. (Refer to the main articles on glycolysis and fermentation for the details.)
- Instead of accumulating inside the muscle cells, lactate produced by anaerobic fermentation is taken up by the liver. This initiates the other half of the Cori cycle. In the liver, gluconeogenesis occurs. From an intuitive perspective, gluconeogenesis reverses both glycolysis and fermentation by converting lactate first into pyruvate, and finally back to glucose. The glucose is then supplied to the muscles through the bloodstream; it is ready to be fed into further glycolysis reactions. If muscle activity has stopped, the glucose is used to replenish the supplies of glycogen through glycogenesis.[3]

- Overall, the glycolysis part of the cycle produces 2 ATP molecules at a cost of 6 ATP molecules consumed in the gluconeogenesis part. Each iteration of the cycle must be maintained by a net consumption of 4 ATP molecules. As a result, the cycle cannot be sustained indefinitely. The intensive consumption of ATP molecules indicates that the Cori cycle shifts the metabolic burden from the muscles to the liver.
- lactate produced by anaerobic glycolysis in muscles moves to the liver and is converted to glucose, which then returns to the muscles and is metabolised back to lactate.



Energy transformation to ATP though the electron system.

This is the site for oxidative phosphorylation. The NADH and succinate generated in the Krebs cycle are oxidised, providing energy carried by ATP. It involves transfer of electron from donors to electron accepters in reduction and oxidative reactions as well as transfer of protons (H^+ions) across the membrane



d) Name two carbohydrates related diseases and suggest possible control for each.

Glucose homeostasis

- This is the way how glucose can be maintained at a normal blood glucose level in the circulation. Low carbohydrate intake or decreased blood glucose will lead to the secretion of a number of blood glucose raising hormones. These include;
- Glucagon hormone from the α-cells of the pancreas acts in opposition to insulin to increase breakdown of liver glycogen into glucose (glycogenolysis).
- Thyroxine hormone from the thyroid gland increases formation of glucose from carbohydrates and production of epinephrine hormone.
- Epinephrine hormone from the adrenal glands stimulates the breakdown of muscle glycogen to glucose.
- Somatostanin hormone produced from the delta cells of the pancreas and the hypothalamus suppresses the action of insulin and increases the action of glucagon. It also modulates the related metabolic activities.
- Other steroid hormones like growth hormone, glucocorticoids and adrenocorticoids also stimulate the conversion of glucose from other sources like fats and proteins and also delays uptake of glucose by muscles.
- They can also increase the absorption of glucose from the gastro intestinal truct.
- Extreme cases of low dietary carbohydrates will lead to depletion of glucose and glycogen stores as in cases of actual starvation leading to marasmus.
- if glucose is more in the blood, it will be broken down to give energy by the action of insulin which increases the cells permeability of glucose for oxidation, the remainder can be converted to glycogen in a process called glycogenesis if carbohydrates are still in the body, will be converted to fats a process called lipogenegesis and stored as adipose tissue but the excess will be passed out in urine.

Food sources of Carbohydrates

Food sources of Sugar

- All sweet fruits and vegetables like bananas, apples, mangoes, melons, beet roots, cherries
- Bee honey
- Jam, Sugar canes
- Sweetened food products like soft drinks

Food sources of Cellulose

- Skins of fruits and vegetables
- Whole grain cereals like maize, wheat, oats and barley

Food sources of Starch

- Cereals e.g. wheat, maize, rice, barley, millet
- Root vegetables like cassava, yams, potatoes, carrots
- All types of flour i.e. wheat flour, maize flour, millet flour

Deficiency of Carbohydrates

- Insufficient supply of carbohydrates in the diet is very rare as it is the cheapest food available but can occur in cases of actual starvation and can lead to marasmus.
- Marasmus is a protein energy malnutrition (PEM) disease mainly due to lack of a number of nutrients but especially carbohydrates. It has the following signs and symptoms;

- Extreme body thinness (muscle wasting)
- Lack of energy (body weakness)
- General body fatigue (tiredness)
- Low body weight
- Retardation of growth especially in children
- Constipation and diarrhoea
- Dryness of the skin and mucous membranes
- Little or no body fat

Effects of excess Carbohydrates

- Too much or excess carbohydrates in the body can lead to the following;
- Tooth decay (dental caries) due to eating of too much of sweet and sticky sugary foods
- Accumulation of fats under the skin and abdomen which can lead to obesity
- Fat deposition around the body organs like the kidney, pancreas and the liver can lead to insensitivity of body organ which causes diabetes mellitus (type II)
- Accumulation of fats in blood vessels can leads to cardiovascular problems like atherosclerosis, high blood pressure and heart attacks.

HYPOGLYCAEMIA

- This is a condition when the level of blood glucose falls to below 70 mg / dl of blood. This level of glucose is too low to meet the body's needs. It is a metabolic disorder caused by any of the following; habbits
- Pancreas disease or tumors which lead to excessive insulin production
- Rapid conversion of glucose into glycogen after eating a meal rich in simple sugars
- Liver damage which makes it unable to store enough glycogen and release it when required
- Hyperthyroidism leads to excessive thyroxine hormone production which uses up all the glycogen stores.
- Alcohol intoxication which blocks glucose production by the liver
- People with hypo-glycaemia show the following signs and symptoms;
- Body weakness and fatigue
- Excessive perspiration

- Mental confusion leading to brain damage
- Blurred vision
- Palpitations and convulsions
- Faintness
- Inability to speak clearly
- Always feel hungry
- Light headaches, nervousness and irritability
- Shakiness
- Hunger and nausea
- Tingling or numbness in the lips or tongue
- Sleepiness
- Lack of coordination
- Seizures
- Unconsciousness

HYPER GLYCAEMIA

This occurs when the blood glucose level rises too high above 180 mg / dl of blood. Too much glucose will be found in blood and if not taken up by the cells it will lead to diverse effects. Hyper-glycaemia can be caused by the following;

- Excessive intake of carbohydrate foods which are rapidly changed into simple sugars (glucose)
- Overproduction of thyroxine hormone which increases glucose production
- Insufficient supply of insulin hormone due to defects of the β-cells of the pancreas
- Normally, increased dietary supply of carbohydrates will lead to secretion of insulin which lowers the blood glucose level. Insulin regulates blood glucose level through the following ways;
- Conversion of glucose to glycogen in the liver for a constant energy reserve (glycogenesis)

- Conversion of glucose and other metabolites to fats for storage in adipose tissue and around other body organs like intestines, blood vessels, kidneys
- Inhibits fat and protein breakdown to avoid glucose production
- Enhances glucose transport through the cell membrane and uptake by muscle tissue allowing glucose to be oxidized to supply energy
- Influences phosphorylation which increases activity of the enzymes responsible for glycolysis and gluconeogenesis
- Promotes uptake of amino acids by the skeletal tissue and thus increasing protein synthesis
- Excessive secretion of insulin can cause reduction of glucose to such an extent that the brain cells are deprived of glucose. This can lead to stroke, shock, fainting and even coma. It can also increase fat deposition leading to accumulation of fats in the body.
- However, insufficient supply of insulin can lead to increased blood glucose and its excretion in urine. This can progress to diabetes (to pass through) mellitus (honey/sweet nature of urine).

FORMS OF DIABETES MELLITUS.

- **Type-1 or insulin dependent diabetes mellitus (IDDM)**

- This form of diabetes develops more rapidly due to failure of the B-cells of the pancreas to secrete insulin hormone which controls blood glucose level and other metabolic activities. It develops from genetic factor and immunological action of the B-cells of the pancreas. IDDM develops 1.1 the age of 6-11 years and at any age less than 40 years. It can also be known as Juvenile diabetes mellitus.
- Type 1 is difficult to manage and can only be controlled by injection of insulin. It mainly leads to excessive urination, thirst, hunger, weight loss and ketoacidosis.
- These can lead to comma and death.

Type II or Non-dependent diabetes mellitus (NIDDM)

- This type develops more slowly due to the presence of some amount of insulin in the body. It occurs due to the insulin resistance or insensitivity by the cells. This develops from physical inactivity, obesity and hypertension. The condition is milder, stable and mainly occurs in adults usually above 40years and 80% of these are obesity. It can also be known as adult or obesity diabetes mellitus.
- Type II mainly leads to increased thirst, body fatigue, blurred vision, vascular and neural complications like atherosclerosis and paralysis ketoacidosis is less common as some insulin is available to present fat breakdown but loss of fluids(dehydration) and electrolytes are common which can lead to comma and death.
- Type II patients improve with weight loss, exercise and nutritional therapy.

Effects of Diabetes Mellitus

The following occur during the initial onset or its uncontrolled state;

- Increased blood glucose (hyperglycemia)
- Excretion or presence of glucose in urine (glycosuria)
- Increased thirst (polydipsia)
- Increased urination (polyphagia)
- Weight loss in type I and obesity and type II

More serious causes can lead to;

- Mental instability, forgetfulness and confusion.

- Blurred vision, Joint pain, Skin irritation, Body sores which fails to heal , General body weakness. Severe causes can lead to;

- Brain damage

- Fluid and electrolyte imbalance which leads to edema and body dehydration.

- Ketoacidosis occurs due to disturbance of the acid base balance from ketone bodies accumulating from excessive fat breakdown. The hydrogen on concentration increases and these appear in urine. This leads to formation of acid urine and renal failure.

- Coma and death.

Diet During Diabetes Mellitus

- The diet for any person with diabetes mellitus is always based on normal nutritional requirements or needs of that individual. Too little carbohydrates could cause hypo glycaemia (faintness and comma) and too much can lead to hyper glycaemia (excretion of glucose in urine and body dehydration). The following can be considered;
- Doctors' advice should be followed especially if a special diet is prescribed.
- The diet is basically of low carbohydrates.
- Sugar is completely cut out and can be replaced by sweeteners like fructose, saccharin and sorbitol with no energy value.
- High fibre food like cereals, fruits and vegetables should be increased.
- Consumption of bread, sweets, biscuits and milled cereals is reduced.
- Increased protein intake and favorable foods include lean, boiled or roasted beef, eggs, fish and chicken.
- Meals should be regularly served and never be missed.
- Salt intake should be minimized to reduce risks of hypertension.
- Exercises and increased physical activities should be included on the dietary plan to reduce body weight.

- Severe cases need daily insulin injections usually before the meal to keep the level.

Diabetes Insipidus

- Diabetes insipidus is a condition or specific injury of the pituitary gland which produces insufficient antidiuretic hormone (ADH) or vasopressin, a hormone that helps the kidney to reabsorb adequate amount of water.
- This leads to copious output of non-sweet urine, great thirst and sometimes a large appetite, large quantities of dilute non-sweet urine may be excreted. This can be as high as 5 t0 30 litres per day.
- The condition can be controlled by daily injection of posterior pituitary extract.

DIETARY FIBER

Dietary fiber is a type of carbohydrate that cannot be digested by our bodies' enzymes. It is found in edible plant foods such as cereals, fruits, vegetables, dried peas, nuts, lentils and grains.

CLASSIFICATION OF FIBRES

Fiber is grouped by its physical properties and is called soluble, insoluble or resistant starch.

Soluble fiber ;which dissolves in water is readily fermented in the colon into gases and physiologically active by-products, such as short-chain fatty acidsproduced in the colon bygut bacteria; it is viscous, may be called prebiotic fiber, and delays gastric emptying which, in humans, can result in an extended feeling of fullness. Examples include; arabinoxylan, fructans, inulin, alginicacids, raffinose

Insoluble fiber; which does not dissolve in water – is inert to digestive enzymes in the upper gastrointestinal tract and provides bulking. Some forms of insoluble fiber, such as resistant starches, can be fermented in the colon. Bulking fibers absorb water as they move through thedigestive system, easing defecation. Examples of insoluble dietary fiber include; cellulose, Chitin, hemicellulose, hexoses, pectose, lignin, xanthan gum, resistant starch.

Physicochemical properties

Dietary fiber has distinct physicochemical properties. Most semi-solid foods, fiber and fat are a combination of gel matrices which are hydrated or collapsed with microstructural elements, globules, solutions or encapsulating walls. Fresh fruit and vegetables are cellular materials.

- The cells of cooked potatoes and legumes are gels filled with gelatinized starch granules. The cellular structures of fruits and vegetables are foams with a closed cell geometry filled with a gel, surrounded by cell walls which are composites with an amorphous matrix strengthened by complex carbohydrate fibers.
- Particle size and interfacial interactions with adjacent matrices affect the mechanical properties of food composites.
- Food polymers may be soluble in and/or plasticized by water. Water is the most important plasticizer, particularly in biological systems thereby changing mechanical properties.
- The variables include chemical structure, polymer concentration, molecular weight, degree of chain branching, the extent of ionization (for electrolytes), solution pH, ionic strength and temperature.
- Cross-linking of different polymers, protein and polysaccharides, either through chemical covalent bonds or cross-links through molecular entanglement or hydrogen or ionic bond cross-linking.
- Cooking and chewing food alters these physicochemical properties and hence absorption and movement through the stomach and along the intestine.

Dietary fiber in the digestive system

in the upper gastrointestinal tract

Following a meal, the stomach and upper gastrointestinal contents consist of

- food compounds
- complex lipids/micellar/aqueous/hydrocolloid and hydrophobic phases

- hydrophilic phases
- solid, liquid, colloidal and gas bubble phases.

Micelles are colloid-sized clusters of molecules which form in conditions as those above, similar to the critical micelle concentration of detergents .In the upper gastrointestinal tract, these compounds consist of bile acids and di- and monoacyglycerols which solubilize triacylglycerols and cholesterol.

Two mechanisms bring nutrients into contact with the epithelium:

1. intestinal contractions create turbulence; and
2. convection currents direct contents from the lumen to the epithelial surface.

The multiple physical phases in the intestinal tract slow the rate of absorption compared to that of the suspension solvent alone.

1. Nutrients diffuse through the thin, relatively unstirred layer of fluid adjacent to the epithelium.
2. Immobilizing of nutrients and other chemicals within complex polysaccharide molecules affects their release and subsequent absorption from the small intestine, an effect influential on the glycemic index
3. Molecules begin to interact as their concentration increases. During absorption, water must be absorbed at a rate commensurate with the absorption of solutes. The transport of actively and passively absorbed nutrients across epithelium is affected by the unstirred water layer covering the microvillus membrane.
4. The presence of mucus or fiber, e.g., pectin or guar, in the unstirred layer may alter the viscosity and solute diffusion coefficient.

Adding viscous polysaccharides to carbohydrate meals can reduce post-prandial blood glucose concentrations. Wheat and maize but not oats modify glucose absorption, the rate being dependent upon the particle size. The reduction in absorption rate with guar gum may be due to

the increased resistance by viscous solutions to the convective flows created by intestinal contractions.

Dietary fiber interacts with pancreatic and enteric enzymes and their substrates. Human pancreatic enzyme activity is reduced when incubated with most fiber sources. Fiber may affect amylase activity and hence the rate of hydrolysis of starch. The more viscous polysaccharides extend the mouth-to-cecum transit time; guar, tragacanth and pectin being slower than wheat bran

Fiber in the colon

The colon may be regarded as two organs,

1. the right side (cecum and ascending colon), a fermenter. The right side of the colon is involved in nutrient salvage so that dietary fiber, resistant starch, fat and protein are utilized by bacteria and the end-products absorbed for use by the body
2. the left side (transverse, descending, and sigmoid colon), affecting continence.

The presence of bacteria in the colon produces an 'organ' of intense, mainly reductive, metabolic activity, whereas the liver is oxidative. The substrates utilized by the cecum have either passed along the entire intestine or are biliary excretion products. The effects of dietary fiber in the colon are on

1. bacterial fermentation of some dietary fibers
2. thereby an increase in bacterial mass
3. an increase in bacterial enzyme activity
4. changes in the water-holding capacity of the fiber residue after fermentation

Enlargement of the cecum is a common finding when some dietary fibers are fed and this is now believed to be normal physiological adjustment. Such an increase may be due to a number of factors, prolonged cecal residence of the fiber, increased bacterial mass, or increased bacterial end-products. Some non-absorbed carbohydrates, e.g. pectin, gum arabic, oligosaccharides and resistant starch, are fermented to short-chain fatty acids (chiefly acetic, propionic and n-butyric),

and carbon dioxide, hydrogen and methane. Almost all of these short-chain fatty acids will be absorbed from the colon. This means that fecal short-chain fatty acid estimations do not reflect cecal and colonic fermentation, only the efficiency of absorption, the ability of the fiber residue to sequestrate short-chain fatty acids, and the continued fermentation of fiber around the colon, which presumably will continue until the substrate is exhausted. The production of short-chain fatty acids has several possible actions on the gut mucosa. All of the short-chain fatty acids are readily absorbed by the colonic mucosa, but only acetic acid reaches the systemic circulation in appreciable amounts. Butyric acid appears to be used as a fuel by the colonic mucosa as the preferred energy source for colonic cells.

Dietary fiber and cholesterol metabolism

Dietary fiber may act on each phase of ingestion, digestion, absorption and excretion to affect cholesterol metabolism such as the following:

1. Caloric energy of foods through a bulking effect
2. Slowing of gastric emptying time
3. A glycemic index type of action on absorption
4. A slowing of bile acid absorption in the ileum so bile acids escape through to the cecum
5. Altered or increased bile acid metabolism in the cecum
6. Indirectly by absorbed short-chain fatty acids, especially propionic acid, resulting from fiber fermentation affecting the cholesterol metabolism in the liver.
7. Binding of bile acids to fiber or bacteria in the cecum with increased fecal loss from the entero-hepatic circulation.

An important action of some fibers is to reduce the reabsorption of bile acids in the ileum and hence the amount and type of bile acid and fats reaching the colon. A reduction in the reabsorption of bile acid from the ileum has several direct effects.

1. Bile acids may be trapped within the lumen of the ileum either because of a high luminal viscosity or because of binding to a dietary fiber

2. Lignin in fiber adsorbs bile acids, but the unconjugated form of the bile acids are adsorbed more than the conjugated form. In the ileum where bile acids are primarily absorbed the bile acids are predominantly conjugated.

3. The enterohepatic circulation of bile acids may be altered and there is an increased flow of bile acids to the cecum, where they are deconjugated and 7alpha-dehydroxylated.

4. These water-soluble form, bile acids e.g., deoxycholic and lithocholic are adsorbed to dietary fiber and an increased fecal loss of sterols, dependent in part on the amount and type of fiber.

5. A further factor is an increase in the bacterial mass and activity of the ileum as some fibers e.g., pectin are digested by bacteria. The bacterial mass increases and cecal bacterial activity increases.

6. The enteric loss of bile acids results in increased synthesis of bile acids from cholesterol which in turn reduces body cholesterol.

The fibers that are most effective in influencing sterol metabolism (e.g. pectin) are fermented in the colon. It is therefore unlikely that the reduction in body cholesterol is due to adsorption to this fermented fiber in the colon.

1. There might be alterations in the end-products of bile acid bacterial metabolism or the release of short chain fatty acids which are absorbed from the colon, return to the liver in the portal vein and modulate either the synthesis of cholesterol or its catabolism to bile acids.

2. The prime mechanism whereby fiber influences cholesterol metabolism is through bacteria binding bile acids in the colon after the initial deconjugation and dehydroxylation. The sequestered bile acids are then excreted in feces.

3. Fermentable fibers e.g., pectin will increase the bacterial mass in the colon by virtue of their providing a medium for bacterial growth.

4. Other fibers, e.g., gum arabic, act as stabilizers and cause a significant decrease in serum cholesterol without increasing fecal bile acid excretion.

Functions

a. Increases food volume without increasing caloric content to the same extent as digestible carbohydrates, providing satiety which may reduce appetite.

b. Attracts water and forms a viscous gel during digestion, slowing the emptying of the stomach and intestinal transit, shielding carbohydrates from enzymes, and delaying absorption of glucose, which lowers variance in blood sugar levels

c. Lowers total and LDL cholesterol, which may reduce the risk of cardiovascular disease

d. Regulates blood sugar, which may reduce glucose and insulin levels in diabetic patients and may lower risk of diabetes.

e. Speeds the passage of foods through the digestive system, which facilitates regular defecation

f. Adds bulk to the stool, which alleviates constipation

g. Balances intestinal pH and stimulates intestinal fermentation production of short-chain fatty acids

h. Fiber does not bind to minerals and vitamins and therefore does not restrict their absorption, but rather evidence exists that fermentable fiber sources improve absorption of minerals, especially calcium. Some plant foods can reduce the absorption of minerals and vitamins like calcium, zinc, vitamin C, and magnesium, but this is caused by the presence of phytate (which is also thought to have important health benefits), not by fiber

SOURCES OF DIETARY FIBER ACCORDING TO CLASSIFICATION

Some plants contain significant amounts of soluble and insoluble fiber. For example, plums and pruneshave a thick skin covering a juicy pulp. The skin is a source of insoluble fiber, whereas soluble fiber is in the pulp. Grapes also contain a fair amount of fiber.

WATER SOLUBLE DIETARY FIBER

- legumes (peas, soybeans, lupins and other beans)
- oats, rye, chia, and barley
- some fruits (including figs, avocados, plums, prunes, berries, ripe bananas, and the skin of apples, quinces and pears)
- certain vegetables such as broccoli, carrots, and Jerusalem artichokes
- root tubers and root vegetables such as sweet potatoes and onions (skins of these are sources of insoluble fiber also)
- psyllium seed husks (a mucilage soluble fiber) and flax seeds
- nuts, with almonds being the highest in dietary fiber

Sources of **insoluble fiber** include:

a. whole grain foods
b. wheat and cornbran
c. legumes such as beans and peas
d. nuts and seeds
e. potato skins
f. lignans
g. vegetables such as green beans, cauliflower, zucchini (courgette), celery, and nopal
h. some fruits including avocado, and unripe bananas

i. the skins of some fruits, including kiwifruit, grapes and tomatoes.