FOOD BIOCHEMISTRY & HUMAN NUTRITION (18BTFT306)

UNIT – 1 METABOLISM OF CARBOHYDRATES

Enable | Enlighten | Enrich
KARPAGAM
ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
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Need of Studying Biochemistry

- Biochemistry is the language of biology. The study of biochemistry is essential to understand the basic functions of the body. This study will give information regarding the functioning of cells at the molecular level.

1. How the food that we eat is digested, absorbed and used to make ingredients of the body?
2. How does the body derive energy for the normal day-to-day work?
3. What is the function of genes?
4. What is the molecular basis for immunological resistance against invading organisms?

Answer for such basic questions can only be derived from a systematic study of biochemistry.

The term “Biochemistry” was coined by Neuberg in 1903 from the Greek words, bios (=life) and chymos (=juice).

Need of Studying Biochemistry

- More than 99% of the human body is composed of 6 elements, i.e. oxygen, carbon, hydrogen, nitrogen, calcium and phosphorous.

- The human body is composed of about 60% water, 15% protein, 15% lipids. 2% carbohydrates and 8% minerals. These biomolecules are covalently linked to each other to form macromolecules of the cells, eg. Glucose to glycogen, amino acids to proteins etc…

- Major complex biomolecules are proteins, polysaccharides, lipids and nucleic acids. The macromolecules associate with each other by noncovalent forces (do not share electrons).

Study of Metabolic Processes

- Our food contains carbohydrates, fats and proteins as principal ingredients. These macromolecules are to be first broken down into small units; carbohydrates to monosaccharides and proteins to amino acids. This process is taking place in the gastrointestinal tract and is called digestion of primary metabolism.
- After absorption, the small molecules are further broken down and oxidized to carbon dioxide. In this process, NADH (reduced form of Nicotinamide Adenine Di-nucleotide) and FADH2 (reduced form of Flavin Adenine Di-nucleotide) are generated. This is named as secondary or intermediary metabolism.
- Finally, these reducing equivalents enter the electron transport chain in the mitochondria, where they are oxidized to water, in this process energy is trapped as ATP. This is termed as tertiary metabolism.
- Metabolism is the sum of all chemical changes of a compound in the body, which includes synthesis (Anabolism) which consumes energy and breakdown (Catabolism) which liberates energy.

Anabolism & Catabolism

What is Anabolism?

- This is the building up or biosynthetic phase of metabolism. Here, the enzymatic biosynthesis of macromolecules of cells, such as proteins, polysaccharides and lipids occur from their simple precursors such as amino acids, monosaccharides, fatty acids and glycerol respectively. This is an energy requiring synthesis and the energy is furnished by the ATP generated during catabolism.

What is Catabolism?

- This is the biodegradative phase of metabolism. Here, breaking down or splitting of complex nutrient molecules such as carbohydrates, lipids, and proteins into simpler molecules such as lactic acid, CO2, ammonia or urea occurs. This process is an energy form the nutrient molecules is followed by its conservation in the form of the energy transferring molecule ATP.
- Anabolism and catabolism take place concurrently and simultaneously in cells, but they are independently regulated.

Digestion of Carbohydrates

- Francis Sylvius (1614-72), who identified the Sylvian fissures (the lateral sulcus separates the frontal lobe from parietal lobe) in the brain, recognized the importance of saliva and pancreatic juice in the digestion of carbohydrates.

- Valenine in 1844, showed the action of pancreatic juice on starch.

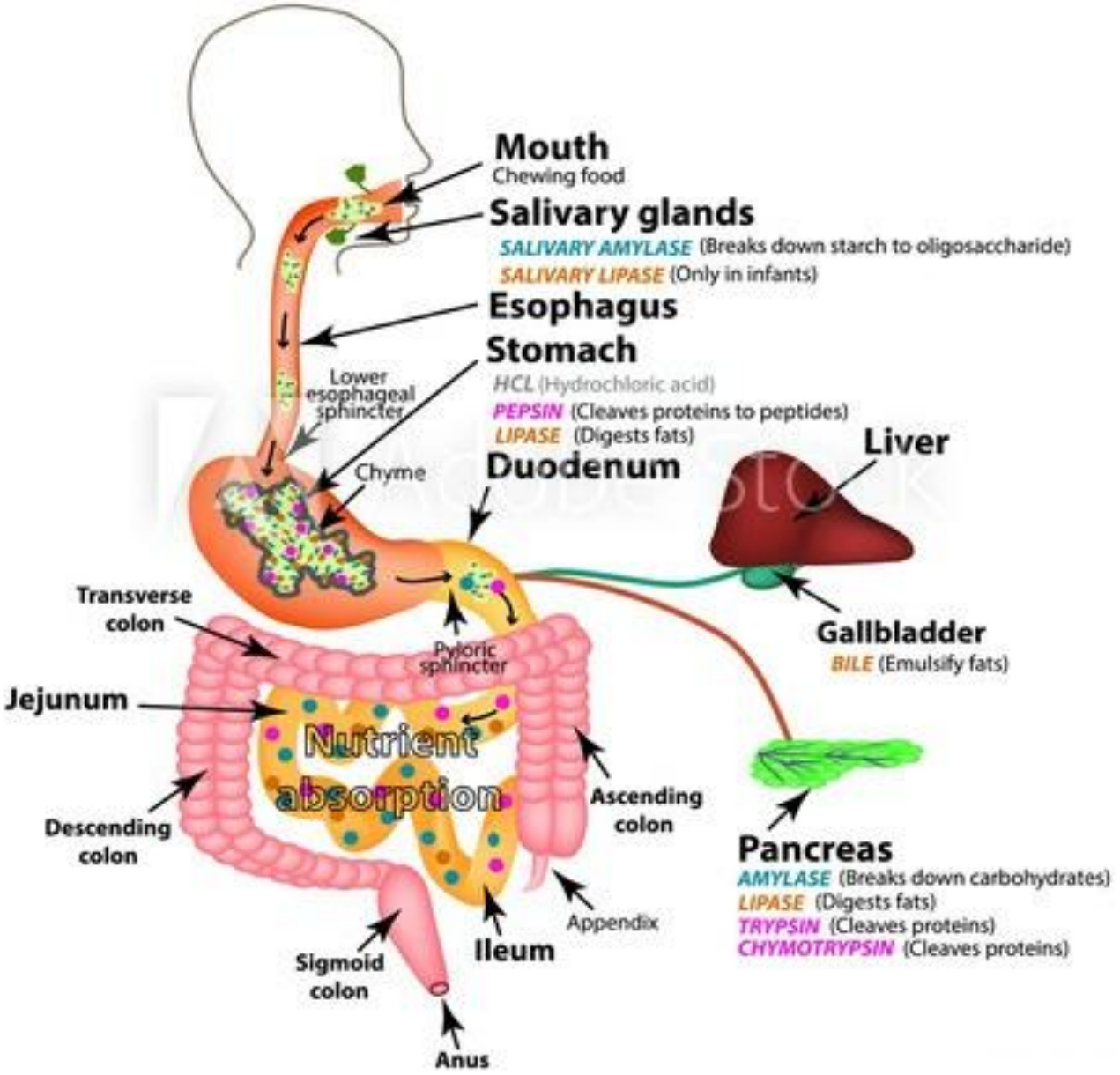
- Salivary amylase (old name: Ptyalin) was isolated by Mailhe in 1845.

- Pancreatic amylase (old name: Amylopsin) by Claude Bernard in 1849.

Digestion of Carbohydrates

- Cooking helps in breaking of glycosidic linkages in polysaccharides and thus makes the digestion process easier.
- In the diet carbohydrates are available as polysaccharides (starch, glycogen), and to a minor, as disaccharides (sucrose and lactose).
- These complex carbohydrates are hydrolyzed to monosaccharide units in the gastrointestinal tract.
- This process of digestion starts in the mouth by the salivary α-amylase.
- However, the time available for digestion in the mouth is limited. The gastric hydrochloric acid will inhibit the action of salivary amylase.
- In the pancreatic juice another α-amylase is available, which will hydrolyze the α-1,4 glycosidic linkages randomly. So as to produce smaller subunits like maltose, isomaltose, dextrins and branched or unbranched oligosaccharides.
- The intestinal juice (Succus entericus) and brush border of intestinal cells contain enzymes, which will hydrolyze disaccharides into component monosaccharides.
- These enzymes are specifically named as sucrase, maltase, isomaltase and lactase, depending on the specific substrates. The monosaccharides are then absorbed.

DIGESTIVE SYSTEM



Lactose intolerance

- This is a comparatively common condition produced by the deficiency of lactase.
- This enzyme hydrolyses lactose to glucose and galactose.
- Lactase is present in the brush border of enterocytes. The deficiency may be due to congenital (primary) or acquired (secondary) causes.
- In this condition, lactose accumulates in the gut. It is acted upon by bacteria to produce organic acids.
- These take up water into bowels by osmotic effect. Irritant diarrhea is produced. Benedicts test will be positive for such stool samples.
- The reason for acquired lactose intolerance may be sudden change into a milk based diet.
- Lactase is an inducible enzyme (normally present in minute quantities within in a cell, but whose concentration increases dramatically when a substrate compound is added).
- Curd is an effective treatment, because the *Lactobacilli* present in curd contains the enzyme lactase.
- Lactase is abundantly seen in yeast, which could also be used in treatment.
- In the case of malnutrition, caution should be taken in giving milk to such children, because milk may cause sever diarrhea and malnutrition may worsen.
- Moreover, a relative deficiency of lactase (Alactasia) is found in Asian population, compared to Western standards.

ABSORPTION

Absorption of carbohydrates

- Only monosaccharides are absorbed by the intestine. Minute quantities of disaccharides that may be absorbed are immediately eliminated through kidneys.
- Absorption rate of galactose is more than glucose; while fructose is absorbed at a lesser rate than glucose.

Absorption of glucose

- Since glucose molecule is polar, it cannot diffuse through the lipid bilayer of the cell membrane.
- Hence, glucose has transporters, which are transmembrane proteins spanning the width of the membrane.

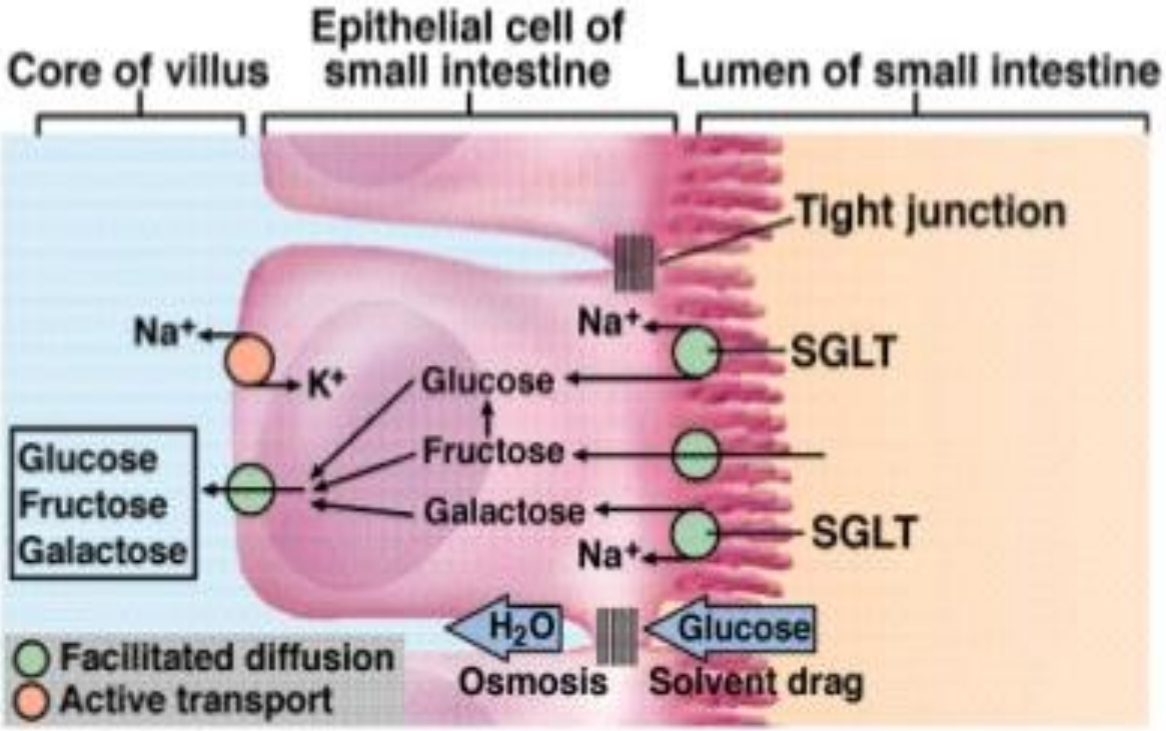
a. Co-transport from lumen to intestinal cell

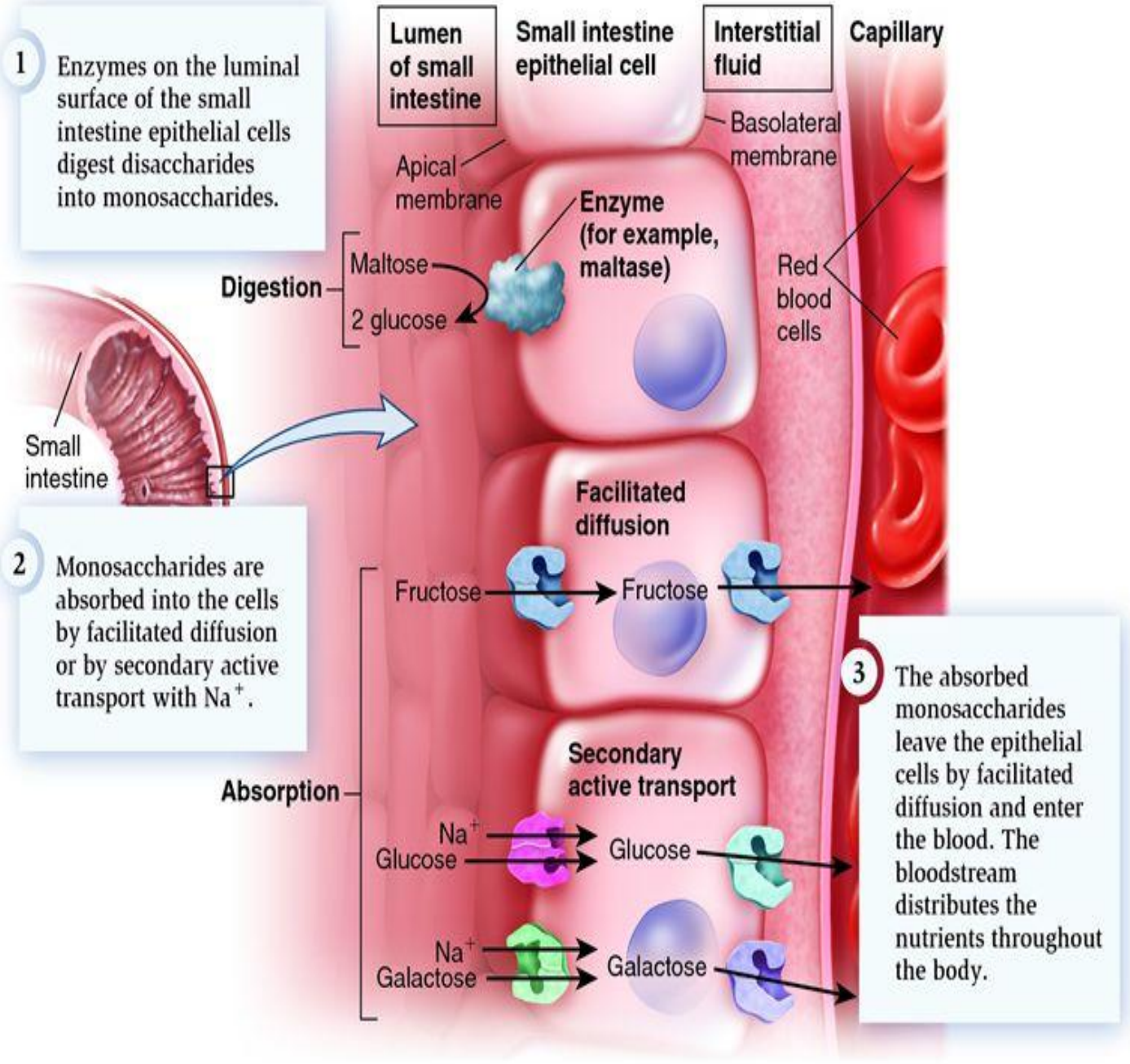
- This process is mediated by sodium dependent glucose transporter-1 (SGluT-1). Absorption from intestinal lumen into intestinal cell is by cotransport mechanism (secondary active transport).
- A membrane bound carrier protein is involved, which carries glucose along with sodium. This sodium is later expelled by the sodium pump with utilization of energy. So energy is needed indirectly.
- The transporter in intestine is named as SGluT-1 and the transporter in the kidney is called SGluT-2. The first one is involved in glucose-galactose absorption.

- **Clinical application: common treatment for diarrhea is oral rehydration fluid. It contains glucose and sodium. Presence of sodium and glucose together in oral rehydration fluid allows absorption of sodium to replenish body sodium chloride levels and glucose to provide energy.**

Glucose is absorbed by:

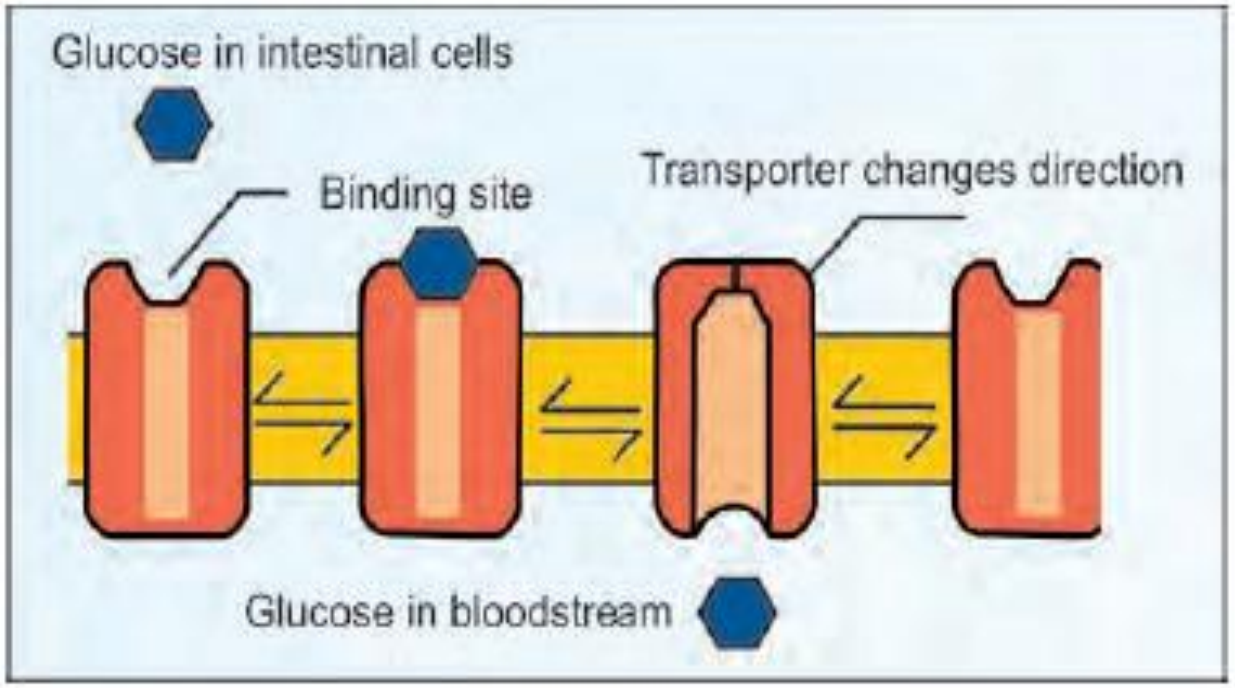
- ***sodium-dependent glucose transporter*** (SGLT).
- solvent drag




1 Enzymes on the luminal surface of the small intestine epithelial cells digest disaccharides into monosaccharides.
Lumen of small intestine
Small intestine epithelial cell
Interstitial fluid
Capillary
Basolateral membrane
Apical membrane
Enzyme (for example, maltase)
Digestion
Maltose
2 glucose
Red blood cells
Small intestine
Facilitated diffusion
Fructose
Fructose
2 Monosaccharides are absorbed into the cells by facilitated diffusion or by secondary active transport with Na+.
Absorption
Secondary active transport
Na+
Glucose
Glucose
Na+
Galactose
Galactose
3 The absorbed monosaccharides leave the epithelial cells by facilitated diffusion and enter the blood. The bloodstream distributes the nutrients throughout the body.

b. Another Uniport System Releases Glucose into Blood

- The same intestinal epithelial cells have a different transport mechanism on the membrane facing capillaries. Intestinal cells release glucose into blood stream by the carrier mechanism called Glucose Transporter Type-2 (GluT2).
- This transporter is not dependent on sodium. It is a uniport, facilitated diffusion system.
- Glucose binds to the transporter on one side of the membrane. When fixed, the complex changes configuration. This leads to the closure of the first binding site. At the same time, the binding site is now exposed on the inner side of the membrane, releasing the glucose. The process is called ping-pong mechanism.
- GluT2 is present in intestinal epithelial cells, liver cells, beta cells of pancreas and kidney.
- Since GluT2 has a high Km for glucose, its presence in beta cells is ideally suited for sensing a high glucose level and releasing insulin. So, this mechanism enables the pancreas to monitor the glucose level and adjust the rate of insulin secretion.



Glucose Transporter (GluT2): Ping-Pong Mechanism

c. Glucose Transporter-4

- GluT4 is the major glucose transporter in skeletal muscle and adipose tissue.
- GluT4 is under the control of insulin. But other glucose transporters are not under the control of insulin.
- **Clinical application: Insulin promotes the translocation of intracellular GluT4 molecules to the cell surface and thus increases glucose uptake. In type-2 diabetes mellitus, membrane GluT4 is reduced, leading to insulin resistance in muscle and fat cells. In diabetes, entry of glucose into muscle is only half of normal cells.**

d. Absorption of other monosaccharides

- Glucose and galactose are absorbed by the same transporter, SGlu T, it is an energy dependent process, against a concentration gradient and therefore absorption is almost complete from the intestine.

- Other monosaccharides are absorbed by carrier mediated facilitated transport. Therefore, absorption is not complete and the remaining molecules in the intestine will be fermented by bacteria.

CARBOHYDRATE METABOLISM

- Carbohydrates are the most important energy source of the body. Glucose is the preferred source of energy for most of the body tissues.
- Brain cells derive the energy mainly from glucose. When the glucose metabolism is deranged, life threatening conditions may occur.
- A minimum amount of glucose is always required for normal functioning of cells.
- Normal fasting plasma glucose level is 75 to 110 mg / dl. After a heavy meal in a normal person, this level rises above 150 mg / dl.

IMPORTANT MILESTONE'S IN CARBOHYDRATE METABOLISM

In 1768, Abbate Spallanzani showed that living tissues take up oxygen and give off carbon dioxide.

In 1860, Louis Pasteur demonstrated the fermentation process of glucose to alcohol by yeast.

In 1893, Gad found out that lactic acid is formed during muscle contraction.

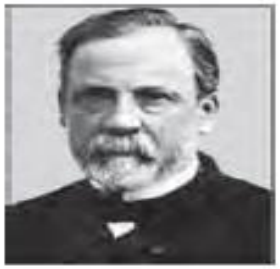
In 1902, Sir Walter Fletcher established that this lactic acid is derived from glycogen in muscle.

In 1914, Gustave Embden studied the lactic acid formation from pyruvate.

In 1915, Chelpin von Euler, Hexokinase enzyme was first identified (Nobel Prize – 1922).

In 1919, Otto Meyerhof enunciated most of the steps of the glycolytic pathway (Nobel Prize – 1922).

Lazzaro Spallanzani 1729–1799



Louis Pasteur 1822–1895

Gustav Georg Embden 1874–1933

von Euler-Chelpin NP 1929 1873–1964

Otto Meyerhof NP 1922 1884–1951

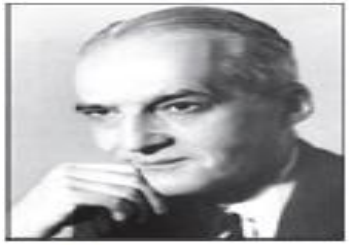
IMPORTANT MILESTONE'S IN CARBOHYDRATE METABOLISM

Other enzymes studied were,

- Phosphofructokinase by Sir Arthur Harden in 1920 (Nobel Prize – 1929).
- Phosphohexoisomerase by Lohmann in 1933.
- Phosphoglucomutase by Leloir in 1938.
- Phsophoglyceromutase by Sutherland in 1942.
- Between 1935 and 1943, all enzymes of glycolytic pathway were crystallized and characterized by Warburg.
- He was awarded Nobel prize in 1931 for his earlier work on iron porphyrins on oxidative process.
- He was awarded Nobel prize for a second time in 1944 for his contributions in glycolysis, but Hitler did not permit him to receive it.

Arthur Harden
NP 1929
1865–1940

Karl Lohmann
1898–1978



Luis Leloir
NP 1970
1906–1987

Otto Warburg
NP 1931
1883–1970

CARBOHYDRATE METABOLISM

Glucose is degraded in the cell by way of a series of phosphorylated intermediates mainly via following metabolic pathways.

1. Glycogenesis – process of biosynthesis of glycogen from glucose
2. Glycogenolysis – process of breakdown of glycogen
3. Glycolysis – process that converts a molecule of glucose into 2 molecules of pyruvic acid.
4. Citric acid cycle / TCA cycle / Kreb's cycle – central pathway for the release of energy from Acetyl CoA, which is produced from the catabolism of carbohydrates, fatty acids and some amino acids.
5. HMP or PP pathway – instead of glucose is going through the glycolytic pathway, the glucose is shunted through this pathway.
6. Gluconeogenesis – synthesis of glucose from noncarbohydrate precursors.

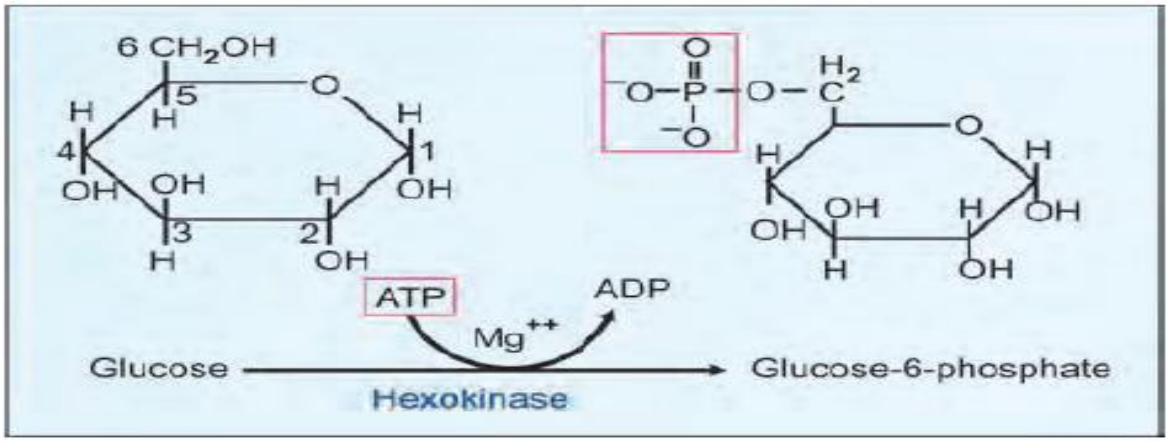
GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Importance of the Pathway

- Glycolysis is derived from the Greek word, (Glyckys = sweet; and Lysis = Splitting).
- In this pathway, glucose is converted to pyruvate (aerobic condition) or lactate (anaerobic condition), along with production of a small quantity of energy.
- All the reaction steps take place in the cytoplasm. It is the only pathway that is taking place in all the cells of the body.
- Glycolysis is the only sources of energy in erythrocytes. Moreover, in strenuous exercise, when muscle tissue lacks enough oxygen, anaerobic glycolysis forms the major source of energy for muscles.
- The glycolytic pathway may be considered as the preliminary step before complete oxidation.
- The glycolytic pathway also provides carbon skeletons for synthesis of certain non-essential amino acids as well as glycerol part of fat.
- Most of the reactions of the glycolytic pathway are reversible which are also used for gluconeogenesis.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

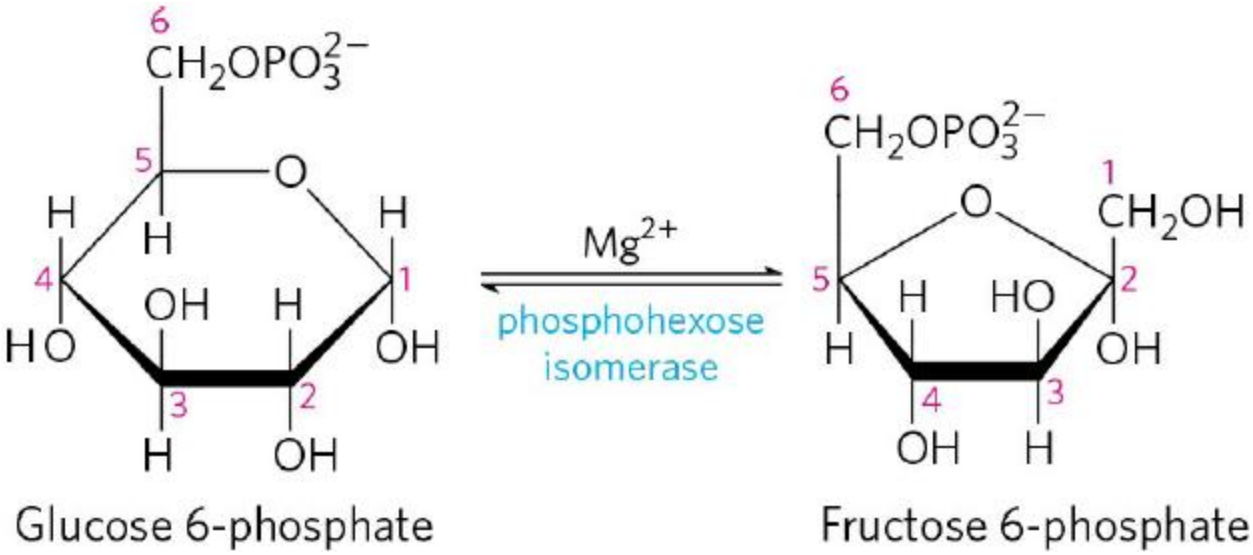
Step-1:



1. Initailly, glucose is activated by phosphorylation to glucose -6-phosphate
2. The enzyme is Hexokinase (HK), which splits the ATP into ADP and the Pi is added on to the glucose
3. The energy released by the hydrolysis of ATP is utilized for the forward reaction.
4. This reaction is irreversible. Mg is required to function the enzyme effectively.
5. Glucose – 6 - phosphate is also called as Robison Ester.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-2

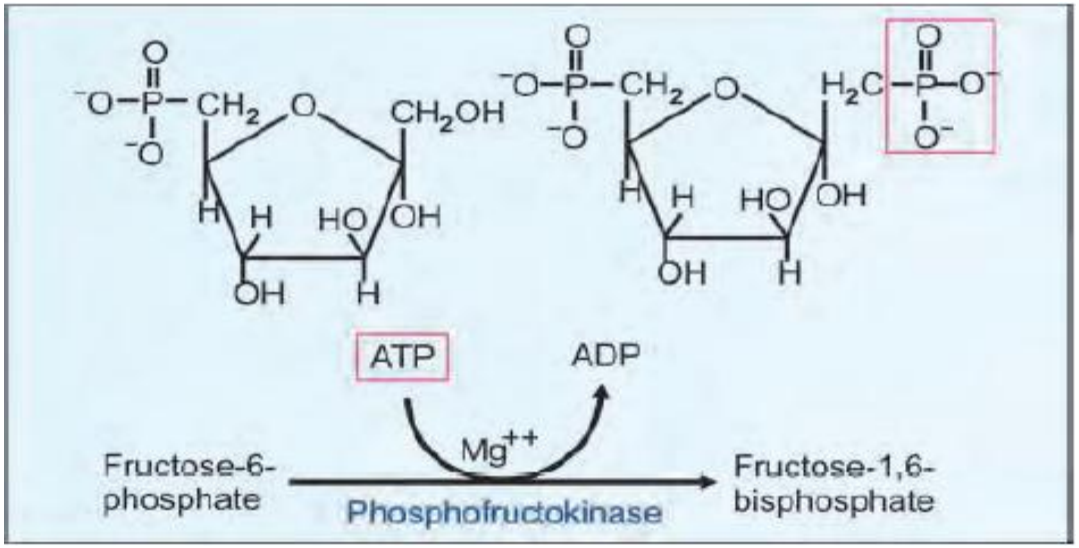


Glucose-6-phosphate is isomerized to fructose-6-phosphate by an enzyme phospho hexose isomerase, actually it is a conversion from aldose sugar to ketose sugar.

Fructose-6-phosphate is also called as Neuberg Ester

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-3



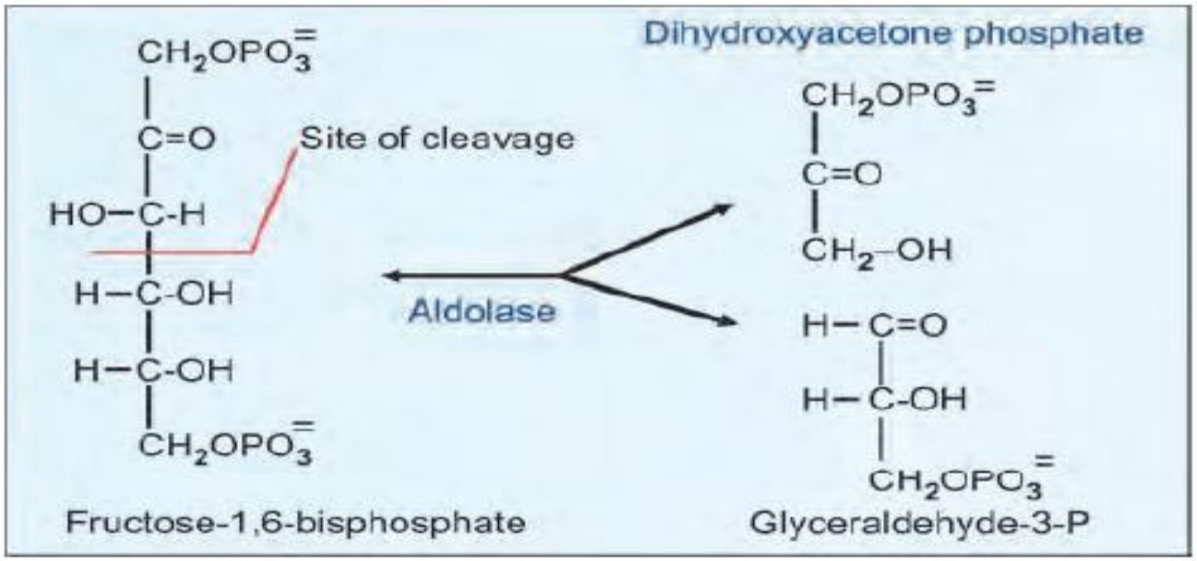
1. Fructose -6-phosphate is further phosphorylated to fructose 1,6-bisphosphate.

2. This enzyme is phosphofructokinase (PFK). This is again an activation process, and the energy is derived by the simultaneous dephosphorylation of ATP. Mg acts as cofactor.

3. This reaction is irreversible and the step 1,2 and 3 termed as Preparatory Phase.
4. Fructose 1,6-bisphosphate is also called as Harden-Young Ester.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-4A

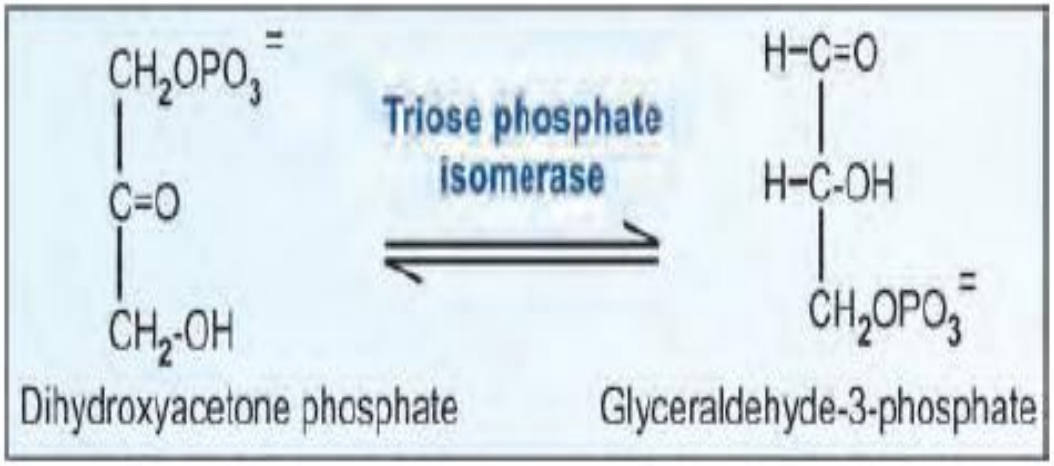


1. Fructose 1,6-bisphosphate is cleaved into two halves, one molecule of glyceraldehyde-3-phosphate and one molecule of dihydroxy acetone phosphate.

2. The enzyme catalyses reaction is Aldolase. This reaction is reversible.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-4B

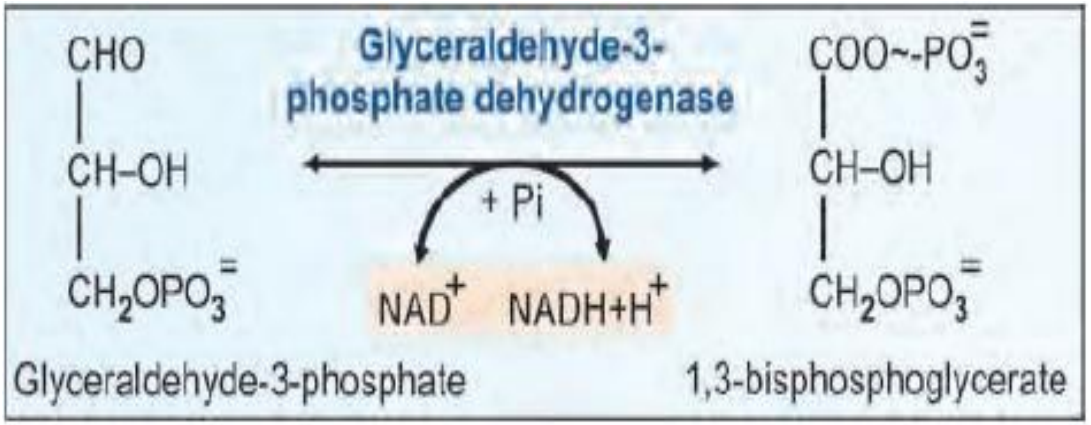


1. Dihydroxy Acetone Phosphate is then isomerized to glycerladehyde-3-phosphate by the enzyme phosphotriose isomerase. It is a reversible process.

2. Thus, net result is that glucose is now cleaved into two molecules of glyceraldehyde-3-phosphate (Fructose is a 6-carbon atom molecule it is equally splitted).

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-5



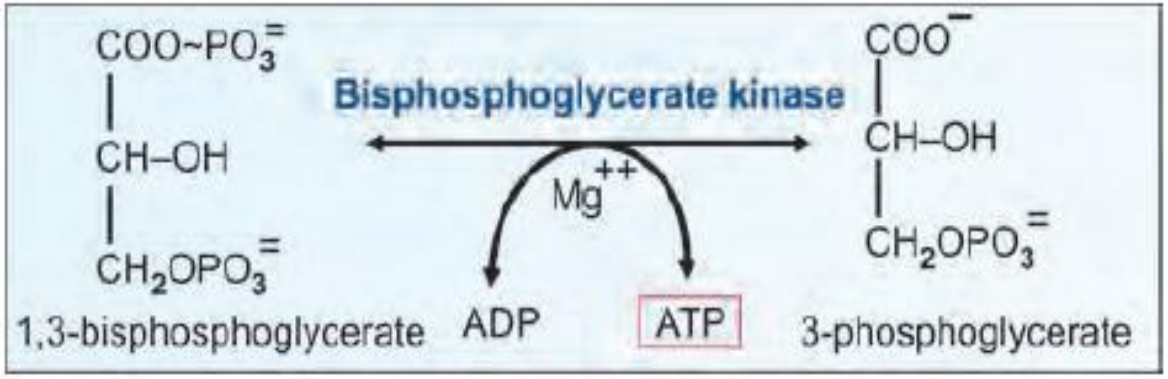
1. In this step, Glyceraldehyde-3-phosphate is dehydrogenated and simultaneously phosphorylated to 1,3-bisphospho glycerate (1,3-BPG) with the help of NAD+.

2. The enyzme is glyceraldehyde-3-phosphate dehydrogenase or phosphoglyceraldehyde dehydrogenase. This is a reversible reaction.

3. NAD+ and NADH + H+ involves in the electron transfer mechanism to produce 1,3-BPG.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-6



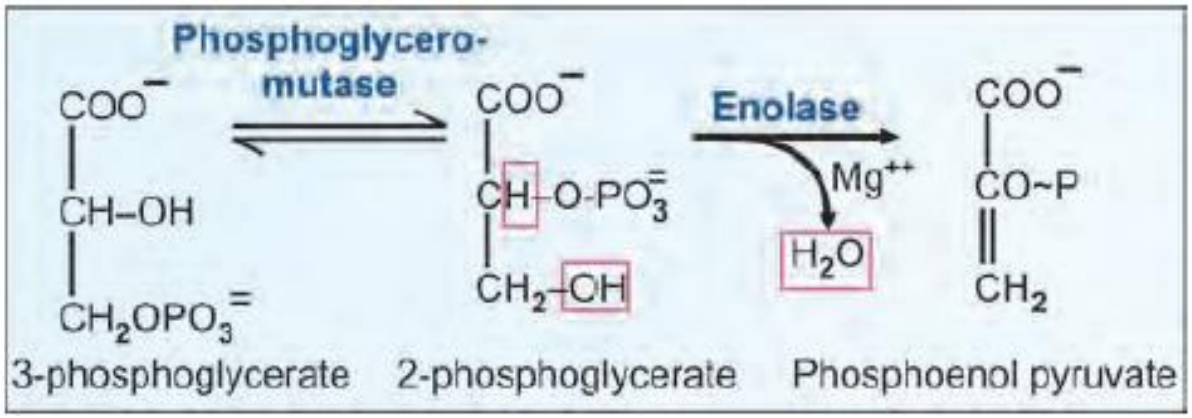
1. The energy of 1,3-BPG is trapped to synthesize one ATP molecule with the help of a kinase.

2. This step is an example of substrate level phosphorylation. Here, 1,3-bisphosphoglycerate had 2-different phosphate groups, one of that phosphate group is cleaved and attached to ADP.

3. Once ADP is attached to phosphate group converted into ATP, by this fashion the substrate is helping to produce ATP, known as Substrate level Phosphorylation.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

Step-7 and 8



Step-7

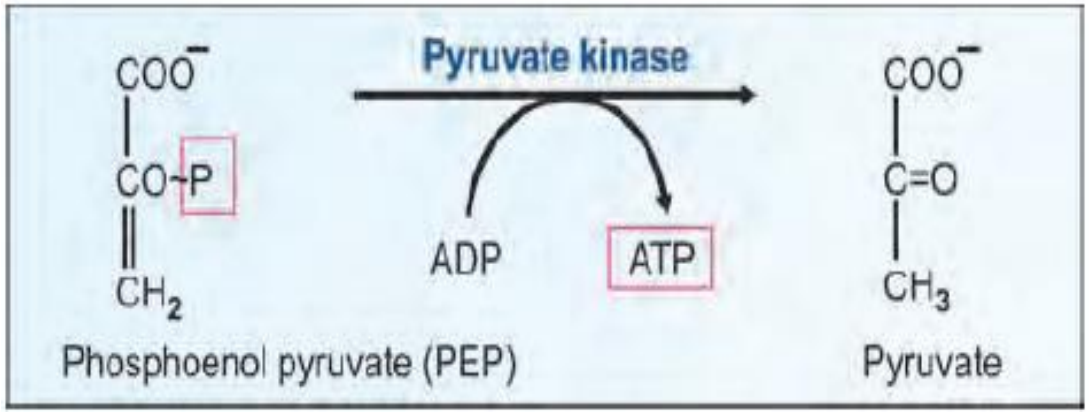
1. 3-phosphoglycerate is mutated to 2-phosphoglycerate by shifting the phsophate groups from 3rd to 2nd carbon atom.
2. This is a readily reversible reaction.

Step-8

1. 2-phosphoglycerate is converted to phosphoenol pyruvate (PEP) by the enzyme enolase by the removal of water molecule.
2. Enolase requirs Mg++ and by removing ions, fluoride will irreversibly inhibit this enzyme.

GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY

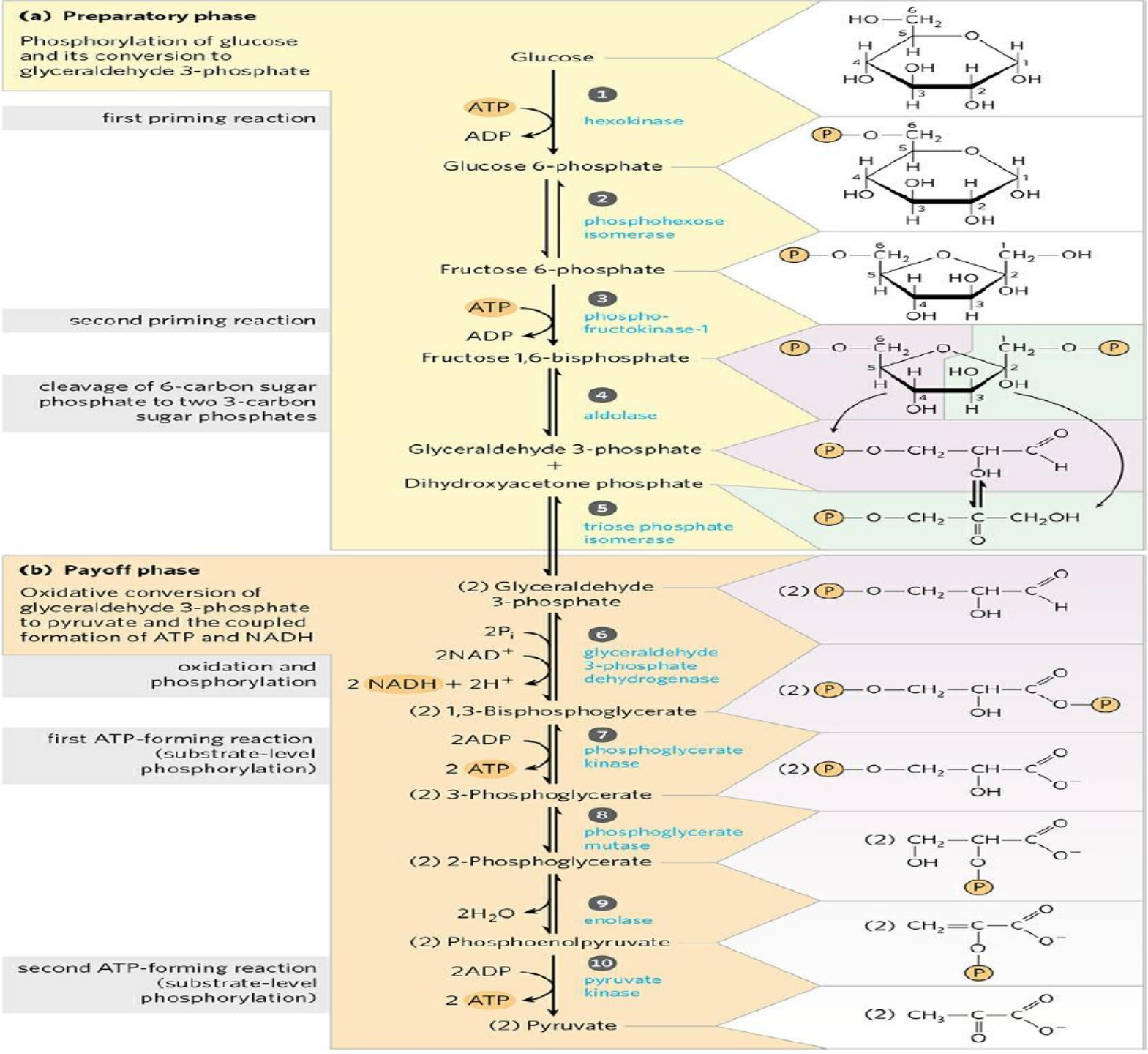
Step-9



1. PEP is dephosphorylated to pyruvate, through a transient intermediate of enol pyruvate.

2. The high energy content of PEP is trapped into ATP by the pyruvate kinase reaction. This is again an example of substrate level phosphorylation.

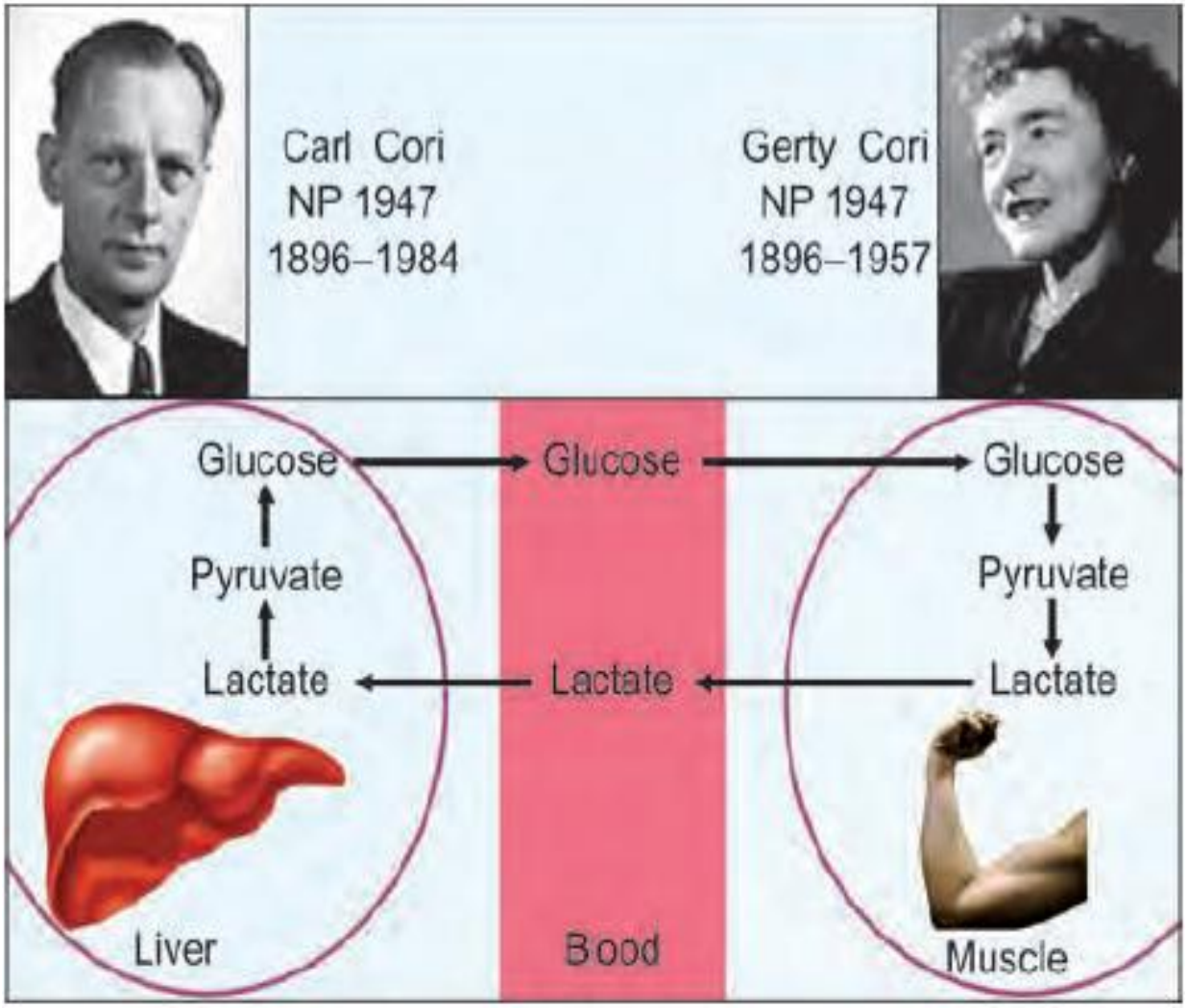
GLYCOLYSIS OR EMBDEN MEYERHOF PATHWAY- summary



CORI'S CYCLE or LACTIC ACID CYCLE

- In an actively contracting muscle, only about 8% of the pyruvate is utilized by the citric acid cycle, and the remaining molecules are, therefore, reduced to lactate.
- The lactic acid, thus generated should not be allowed to accumulate in the muscle tissues.
- This lactate diffuses into the blood. During exercise, blood lactate level is increased considerably.
- Lactate then reaches liver, where it is oxidized to pyruvate.
- It is then taken up through gluconeogenesis pathway, and becomes glucose which can enter into blood and then taken to muscle.
- This cycle is called Cori's cycle, by which lactate is efficiently reutilized by the body.
- Carl Cori and Gesty Cori were awarded Nobel prize in 1947.

CORI'S CYCLE or LACTIC ACID CYCLE



Energy Yield in Glycolysis

Step	Enzyme	Source	No. of. ATP's gained
1	Hexokinase		Minus 1
3	Phosphofructokinase		Minus 1
5	Glyceraldehyde – 3 phosphate dehydrogenase	NADH	2 x 2.5 = 5
6	1,3 – bisphosphoglycerate kinase	ATP	2
9	Pyruvate Kinase	ATP	2
		TOTAL	9 minus 2 = 7 ATP's

Unit - 3

Concepts of food and Nutrition

Food as a Source of nutrients

1. Food is a more basic need of man than shelter and clothing.
2. It provides adequately for the body's growth, maintenance, repair and reproduction.
3. Food furnishes the body with the energy required for all human activities, it provides materials required for the building and renewal of body tissues and the substances that act to regulate body processes.
4. Most foods fulfil more than one function as they are complex mixtures of a number of chemical substances.

Nutrients

1. Foods are composed of dozens or even hundreds of different kinds of substances. "the nutrients" which when consumed in adequate amounts, fulfil all the functions of the body.
2. Six general classes or kinds of nutrients found in all foods are Carbohydrates, fats, proteins, vitamins, minerals and water.

a. Carbohydrates

1. Carbohydrates make up the bulk of our diet. They are our chief source of energy.
2. About 70% of the energy requirements for all body functions is obtained from Carbohydrates.
3. Carbohydrates help in the utilization of proteins and fats.
4. When consumed in excess are converted into fats to be used when needed.
5. The main sources of Carbohydrates are starch and sugars, mostly from cereal grains (wheat, rice, etc) or tubers (potato, sweet potato, Cassava) and those of the latter are Sugarcane and fruits

b. Fats

1. Fats or lipids are the most concentrated form of energy in the food.
2. They furnish more than twice the number of Calories per gram furnished by Carbohydrates and proteins
3. When compared to Carbohydrates, Fats contain a ~~large~~ less percentage of oxygen and more of hydrogen, and consequently on oxidation yield more energy.
4. Generally, 30% of human energy requirements are met by Fats. When excess energy is supplied ~~to~~ to the body, it is stored as fat.
5. The fat content of fruits is poor (except olive and avocado) Fat up to about 15% is present in the germ of cereals. Nuts such as Groundnuts, are rich sources of fats. Butter from milk is an important source of fat.

C. Proteins

1. Proteins are the major source of building material for the body.
2. They play an important role as structural constituents of cellular membranes and function in the maintenance and repair of body tissues.
3. The food value of protein depends upon the nature and content of its amino acids,
4. Proteins are found in both animal and plant tissues. Meat, poultry, eggs cheese, milk and fish are good sources of protein foods from animal sources.
5. Pulses and cereals Contain Considerable amounts of storage proteins. Sogabean Contain over 40% protein on dry weight basis. Nuts and seeds are also good sources of proteins. Starchy vegetables Contain 2% protion, other vegetables and fruits are poor sources of proteins

d. Vitamins

1. Vitamins are "accessory nutrients." They are required for the proper utilization of the bulk food of the diet - Carbohydrates, fats and proteins, and for the maintenance of good health.
2. Vitamins together with minerals are involved in small quantities in the regulation of body processes.
3. They are constituents of enzymes, which function as Catalysts for many biological reactions within the body.
4. Vitamins are found in plant and animal tissues. Their content in plant tissues varies widely depending upon the growing condition, stage of maturity, handling, processing and storage of these food materials.
5. They are not uniformly distributed in plant tissues. vegetables and fruits are good sources of vitamins.
6. Wheat is an excellent source of B-vitamins, but the bran and germ, containing the bulk of these nutrients are usually removed during processing.
7. Since vitamins are simple organic substances they are usually easily synthesized and Synthetic vitamins are therefore added to enrich or supplement those found in food products

e. Minerals

1. acts as Catalysts for many biological reactions within the body. Their other functions include the building of bones, and other structural parts of the body, muscular contraction, transmission of messages through the nervous system and digestion and utilization of nutrients in food
2. Some minerals like Ca, P, Fe, Mg and S are required in huge quantities, others like Zn, Cu, I, Mn, Co etc are required in small quantities
3. Minerals found in foods from animal and plant sources. The mineral content of plant foods varies depending on the medium of cultivation. The distribution of a particular mineral element varies in different tissues. Minerals, as vitamins are added to food to enrich it.

F. Water

1. Water is an important medium for the body, for transporting dissolved nutrients and wastes throughout the body.
2. Apart from the consumption of water as such, body needs of water are supplied by the foods we consume.
3. Some foods contains a high percentage of water. Apart from this, oxidation of Carbohydrates, fats and proteins in the body yields water.

Food Intake and its regulations

All living beings must eat to live and all have mechanisms that direct them to take food.

In almost every case some control is exerted over the amount and kind of food that is taken.

When hungry living beings respond by locating and ingesting foods and eating stops when hunger is satisfied. Thus eating behaviour is a complex interplay between hunger, appetite and satiety.

Hunger, Appetite and Satiety

- Hunger is usually an unpleasant sensation that compels a person to seek food and eat it.
- It is a physiological condition which is associated with the contraction of the stomach.
- The contractions are forceful and occur for a period and then die away as the stomach passes into a resting stage.
- Hunger conditions that subside without eating will reappear later with greater intensity.
- In addition to stomach contraction resulting in tenseness, rumbling and a feeling of emptiness, a hungry person may experience certain general sensations, e.g. weakness, irritability, occasional headache or even nausea.
- Unlike any other being, humans use an external clock in their daily routine, including as when to sleep and when to eat; this external time device triggers our hunger.

- For instance, when the clock say 1 pm :: lunch time, many people feel hungry just because it is lunch time.
- This hunger is triggered by learned behaviour. In addition, the smell, taste, or texture of food also triggers hunger.

Appetite

- Appetite in most people, it is a pleasant sensation that causes a person to desire and anticipate food.
- Appetite exists in all higher life forms, and serves to regulate adequate energy intake to maintain metabolic needs.
- Appetite has physiological components but is basically a psychological state. It is less easily localized than hunger, and is usually felt in the mouth or palate.
- It appears to depend more on the odour and memory of pleasant food.
- Appetite is clearly distinct from hunger, as a person may express a desire for some food at the end of dinner when he is comfortably replete.
- Absence of the desire for food, when it is needed, is an abnormal condition and is known as Anorexia.

Satiety

- It is a sensation accompanying the satisfaction of the desire for food that comes after eating.
- It is not just the opposite of hunger and has far fewer sensations; when hunger builds up slowly, Satiety occurs rapidly.
- The other side of hunger and appetite is Satiety, which is the physiological and psychological experience of fullness that comes after eating / drinking.

Regulation of Hunger

1. The hypothalamus is a small portion of the brain located at its base near the brain stem. This has been identified as the area which evokes the sensation of hunger and satiety.
2. In the central portion of the hypothalamus (the ventromedial hypothalamus), the destruction of a small area causes animals to eat voraciously and become obese, because of the destruction of the satiety centre.
3. Again, the destruction of a small centre in the side region of the hypothalamus (the lateral hypothalamus) results in the opposite effect, that is the animals refuse to eat because of the destruction of the feeding centre and become anorexic.
4. A stimulation of the satiety centre causes organisms to stop eating and that of the feeding centre causes them to eat.
5. The satiety and the feeding centres of the hypothalamus are connected by nerve fibres.
6. When stimulated, the satiety centre sends signals to the feeding centre to inhibit feeding activity. That is, the feeding centre controls the feeding behaviour and the satiety centre regulates it.
7. A number of factors stimulate the satiety centre so that it can regulate the feeding centre. There are sensory, metabolic and hormonal influences controlling the food intake.

a. Sensory influences:

- Stomach contraction results in hunger. But hunger contraction is not the only feature of food intake regulation, as hunger contraction continues even when the main nerve to the stomach is severed.
- However, there are stretch and chemo receptors in the gastro-intestinal system that record the distensions of the stomach and the presence of food after a meal, which relay information to the brain resulting in short-term regulation.
- Sensory stimuli coming from the taste, smell and texture of food are relayed to the cortex of the brain, which are then transmitted to the satiety centre in the hypothalamus, which results in signals to stop or to continue eating.

b. Metabolic factors

- There are glucose receptors in the satiety centre which are receptive to glucose utilization.
- When food is taken, the blood sugar level increases and the rate of utilization of glucose in the tissues rises.
- Then the receptors are stimulated, and the satiety centre signals responses to stop eating.
- Some hours after eating, the blood glucose level falls resulting in a low utilization rate.
- The satiety centre then stops sending signals to the feeding centre. This mechanism of food intake regulation is known as glucostatic regulation.
- The regulation of food intake over a long-term is regulated by the amount of fat stored in the adipose tissues (lipostatic regulation).
- According to this theory, precise information on the fat stores is relayed from the adipose tissues to the nervous control centre.
- If the stores are filled, signals are given to stop eating and when the fat level is reduced, eating continues till the satiety centre is activated.

c. Hormonal Centre :

- A number of hormones, such as insulin, glucagons, etc.. which are involved directly or indirectly in the regulation of the utilization of glucose which can be sensed by the hypothalamus glucose receptors, regulate the intake of food.

Food Groups

According to the food guide, the five food groups are,

1. Pulse - milk - egg - meat - fish group of body - building foods
2. Protective vegetable and fruits group
   a. Green and yellow vegetables and fruits group
   b. Amla - guava citrus fruits group
3. Other vegetables and fruits group
4. Cereals and millets group
5. Oils, fats and sugars group

1oz = 29.57 ml
1oz = 28.35 g

It must be remembered that each group supplies some nutrients and not all nutrients. A combination of items selected from each of the five groups in the right proportion is ideal and will work towards a balanced diet.

1. Pulse - Milk - Egg - Meat - fish Group or Body - Building Foods.

(1 serving = 25 g)
(150 ml = 1 cup)

- The foods included in this group are important for their protein content
- Proteins are highly needed for building of tissues in the body.
- These foods also supply some amount of the B-vitamins such as ~~fat~~ thiamin, riboflavin and niacin.
- Eggs, milk and liver are good sources of iron and milk is a good source of calcium.
- one serving of this group supplies about 5-6g of protein.

The following points should be kept in mind while choosing items from this group.

i. Pulses include all types of dals, (mung dal, tur dal, masur dal etc). Legumes include all dry whole grams, beans, peas, etc. Nuts and oilseeds include sesame seeds. Can be included in daily diet. 25 g of each of these is taken as one serving unit.

Milk includes curds and other preparations containing whole milk (5-6%). An average tea cup or 150 ml is counted as one serving unit.

ii. Egg in a diet means a hen's egg. one egg (40-50g) is considered as one serving

iii. Meat-fish-poultry refer to lean parts of the animal. The protein content of the lean parts is the same but if the adhering fat is not removed, the protein content decreases in the portion of meat

2. a The protective group including vegetables and fruits. half cup (50-75g) 1 serving unit

This group is a rich source of β-Carotene (a precursor of vit-A). It includes the dark green leafy vegetables such as spinach, fenugreek, radish, amaranth, coriander leaves, the light green leafy vegetables such as cabbage, and onion-tops and deep yellow vegetables and fruits such as carrots, orange, red pumpkin, mango, papaya and apricot.

Half a cup or 50-75g of the cooked vegetable or chopped fruit can be counted as one serving unit. whole fruits such as mango, and orange may be counted as one serving.

Almost half a day's need for vitamin A is satisfied by one serving of this group

b. Vitamin-C rich vegetables and fruits 50-75g. 1 Serving unit

This group includes fruits and vegetables such as amla, lemon, ber, gauvas, drumsticks, cabbage, all citrus fruits such as oranges, grapes, and all other fruits such as papaya, pineapple, tomato, strawberries, etc.

Half a cup of fruit or 50-75g of vegetable or a portion as ordinarily served such as slice of papaya or an orange is counted as one serving.

The foods in this group are a rich source of vit-C and fibre. At least one serving of this group must be taken everyday.

3. Other - vegetables and fruits group (2 or more servings)

- There include brinjal, cucumber, pumpkin, bhendi, all ash-gourds, i.e. bottle snake, ridge gourds, etc., all immature beans and peas, beetroot, radish, potatoes, sweat potatoes and yam.
- Other fruits include bananas, apples, melons, grapes, berries, etc.
- Half a cup or 50-75 g of these may be considered as one serving unit. An intake of at least two or ~~three~~ more servings of this group is recommended per day.

4. Cereals and Millets Group (25g - 1S unit) (6 or more servings in a day)

- Foods in this group provide carbohydrates, proteins and calories. The seeds of plants are richer in thiamine than all other portions of the plant.
- Cereals such as wheat and rice may be considered as a good source of thiamine
- The foods ~~are~~ in this group are edible seeds of plants belonging to the grass family.
- They are preparations of rice, wheat, jowar, bajra, maize, ragi and their products such as suji, rice flakes, vermicelli, etc.
- Any preparation containing 25 g of the cereal may be counted as one serving.
  Means half a cup of cooked rice, or one medium chapati, two to three poories, or one small roti, one slice bread, 25 g rice flakes or any ready to eat cereal.
- At least six or more servings may be selected from this group. In order to improve the quality of protein, the meal may include two to more cereals and using a cereal and pulse - legume combination.
  Eg: Khichdi using rice and toor dal, has better protein quality than rice alone.

5. Sugar and Jaggery, Fats and oil group 25 g/day is sufficient. 15g v. oil

Foods in this group mainly supply energy. This group is hence known as the fuel group.

Sugar and Jaggery release energy very easily, while fats and oils are concentrated sources of reserve energy.

Jaggery is the unrefined concentrate obtained from sugarcane juice, good source of minerals & iron.

Sugar mainly used to sweeten beverages like tea and coffee, sherbets and squashes. About 25 g/day is sufficient.

oils and fats are used for seasoning our food, improve flavor, palatability, texture and satiety of food, important in absorbing fat soluble vitamins

oils include groundnut, Sesame, coconut, sunflower, mustard, Safflower, corn, soyabean, palm etc.

Fats include ghee, butter, margarine as well as vanaspati

The RDA / RDI (1988) suggested that fat in the diet should not exceed an amount that can provide 15–20% of the total recommended calorie intake.

fat intake should include at least 15 g of veg. oils in order to meet the requirement of essential fatty acids.

In young children, fat in the diet should provide more than 25% of the total calories of the diet. However for all age groups, about half of this diet will come from invisible fat in the diet.

Five Food Group system

	Food Group	Main Nutrients
1.	Cereals (grains and Products Rice, wheat, Ragi, Ragda, Maize, Jowar, Barley, Rice flakes, wheat flour	Energy, Protein, Invisible fat, vit-B_2, folic acid, Iron, fibre.
2.	Pulses and legumes Bengal gram, Black gram, Green gram, Red gram, Lentil, Lowpea, Peas, Rajmah, Soyabeans, Bean, etc	Energy, protein, Invisible fat, vit-B_1, vit-B_2, folic acid, Calcium, Iron, fibre.
3.	Milk and Milk products Milk, curd, Skimmed milk, Cheese. Meat, chicken, liver, fish, Egg	Protein, fat, vit-B_2, Calcium, Protein, Fat, vit-B_2
4.	Fruits and vegetables. Fruits: Mango, Guava, Tomato ripe, Papaya, orange, Sweet lime, water melon. Vegetables (Green leafy): Amaranth, Spinach, Cuggi, Drumstick leaves, Coriander leaves, Mustard leaves, Fenugreek leaves Other vegetables: Carrot, Brinjal, Ladies finger, Capsicum, Beans, onion, Drumstick.	Carotenoids, vit-C, fibre Invisible fat, Carotenoids, vit-B_2, folic acid, Calcium, Iron, fibre. Carotenoids, Folic acid, Calcium, fibre.
5.	Fats and Sugars Fats: Butter, Ghee, Hydrogenated oils, Cooking oils like Groundnut, Mustard, Coconut Sugars: Sugar, Jaggery	Energy, fat, Essential fatty acids Energy

Calorific value of food

The energy needs of the body are calculated in terms of Calories (Sometimes called the kilocalorie or K(al) or in the metric system, the joule.

One Calorie is equal to 4.184 joules which may be rounded off to 4.2 joules.

The number of ~~foods~~ Calories obtained from a food is its calorific value.

The variation in calorific value of foods is due to the amount of Carbohydrates, Fats and proteins in each of them,

eg. One paratha made of wheat flour and oil gives about 250 Calories, while a glass of Coconut water gives only 45

This is because the former contains a large amount of Carbohydrates, fair amount of proteins and some fat, while the latter contains negligible quantity of Carbohydrates, proteins and fats.

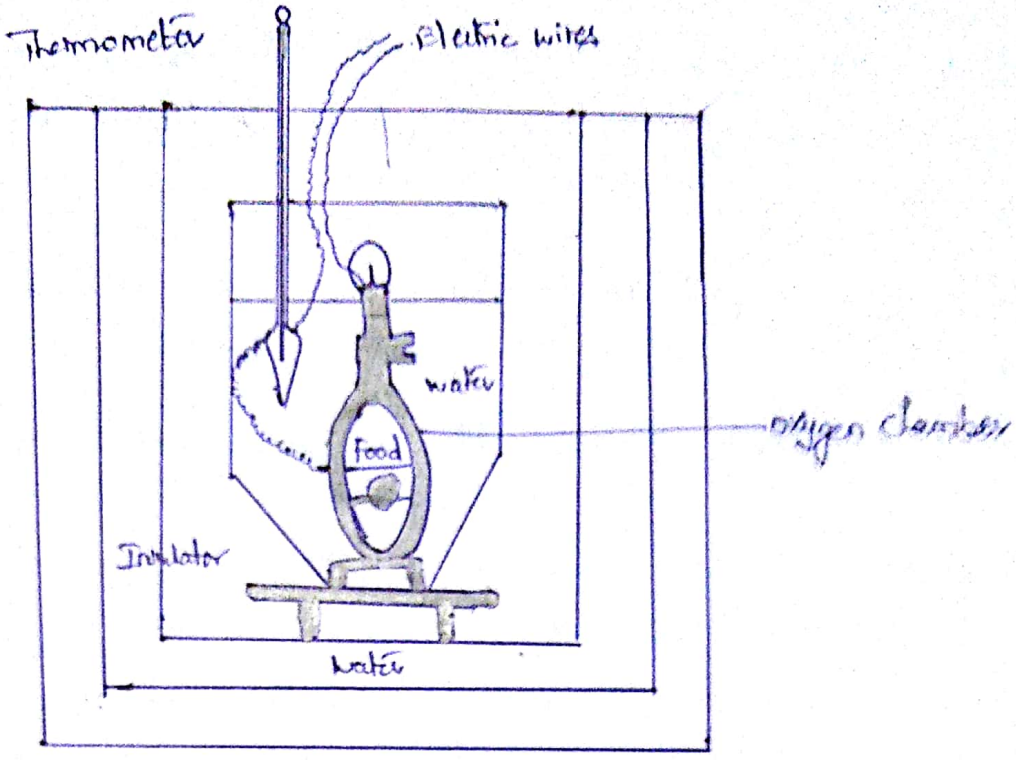
These values are derived with the help of an instrument called bomb Calorimeter. In this instrument, a small elastic spoon holds the sample in the presence of oxygen and catalyst such as platinum. The amount of heat energy released by the complete oxidation of the sample raises the temperature of the surrounding water.

$$\text{Carbohydrate, Protein or fat} + O_2 \xrightarrow{\text{Catalyst}} \text{heat energy} + H_2O + CO_2$$

A similar process takes place in every cell of the human body but with a difference.

The human body always derives less energy than the bomb calorimeter from a given amount of food. This is due to the body's efficiency for utilization of Proteins, fats and Carbohydrates.

This is more true in the case of protein which is not oxidised completely in the body, a fact that limits the energy released and leads to the formation of by-products such as urea and uric acid.



The bomb Calorimeter

From this we can understand that in the body:

1 g of Carbohydrate yields 4.0 Cal or 17 J

1 g of protein also yields 4.0 Cal or 17 J

1 g of fat yields 9.0 Cal or 38 J

Vegetarian Diets

A vegetarian diet consists of only foods of plant origin, and no meat, fish, eggs or other animal products are allowed.

There are four types of vegetarians:

1. **Ovolactovegetarians:**
   This diet consists of plant foods, along with eggs, milk and milk products
2. **Lactovegetarians:**
   This diet is of plant origin, supplemented with milk and milk products
3. **Pure vegetarians or vegans:**
   Eat all foods of plant origin
4. **fruitarians**
   These vegetarians consume raw or dried fruit, nuts, honey and olive oil. They may supplement their diet with grains and legumes.

Problems of Vegetarianism

a. **Energy:**
obtaining Calories is not a problem for adults but for children. Since foods contribute to bulk and are high in fibre

b. **Protein:**
The requirement for body protein needs in plant based foods are not well adequate, its distributed good in animal origin foods. Hence it is necessary to complement foods in such a manner that the limiting a.a of one food will be supplied by another food eaten at the same meal.
The protein content of the diet must contribute about 10% of the total Calorie requirement.
Milk is the preferred choice for children since it is a good source of Calcium which is normally lacking in a vegetarian diet. Skim milk is a richer source of protein than whole milk.
Eggs, another source of good quality protein. Can be used in various forms such as boiled or fried. It is a good source of a wide range of nutrients especially B12 which is absent in vegetarian foods

Curds and buttermilk which are probiotics normally used in Indian dietaries are also a good source of protein.

c- Calcium

If milk is omitted then the calcium in the diet may be marginal. However, dark green leafy vegetables like colocasia, fenugreek are rich in calcium.
Fortified soybean milk, malted ragi may be consumed since they are rich source of calcium.

d. Iron

Plant sources of iron are absorbed less than animal iron. The concentration of iron is also lower.
Therefore, vegetarians must choose good sources of iron as well as ascorbic acid for enhancing the absorption of iron.

e. Zinc

Grains are a good source of zinc but its absorption may be affected due to the presence of phytic acid.
Yeast fermentation lowers phytic acid and increases the availability of zinc and other trace minerals.

f. Vit-D

Rich sources of vit-D are animal sources. Exposure to sunlight may fulfil the requirement of vegetarians but supplementation may be necessary.

g. Riboflavin

Major sources are meats, milk and dairy products. However legumes and whole grains may provide significant amounts.

h. Vitamin - B_{12}

There are no known plant sources of this vit. once a deficiency occurs, effect on the nerves are not always reversible.
vit-B_{12} should be provided by a supplement, by fortified foods such as soybean milk, meat analog, or by yeast grown on a B_{12} enriched media.

Healthful Vegetarian Diets

This requires care in planning and knowledge of the strengths and weaknesses of the various foods.
For this purpose, the following steps should be taken.

1. Reduce substantially all high-calorie, low-nutrient density foods like soft drinks (carbonated beverages). Such foodstuffs have empty calories; use unrefined foods as far as practical.
2. Replace meat with legumes, seeds and nuts
3. Increase the intake of whole grain breads and cereals, legumes, nuts and seeds to maintain energy intake.
4. Use a variety of legumes and whole grains in order to complement the diet
5. Use a variety of fruits and vegetables
6. Eat dry fruits since they contain substantial quantities of several nutrients. Expose the body to Sun's rays to obtain vit-D.
7. Obtain additional food energy from sweeteners such as sugar, and jaggery; margarine; oils and shortenings
8. Eat sufficiently to maintain ideal weight for height
9. Ensure selection of nutritious foods.
10. Use vegetarian cook books and recipes for preparing tasty and nutritious dishes.

Advantages of vegetarianism

- Vegetarians on low total fat and high saturated fatty acid diets show decreased LDL levels and elevated HDL cholesterol levels.
- Addition of eggs to the diet of lacto-vegetarians increases LDL-lipoprotein levels in 3 weeks.
- Improvement in HDL:LDL cholesterol ratio is found in non-vegetarians who are fed lacto-vegetarian diet for six weeks.
- Lacto-vegetarian diet have altered platelet kinetics and arachidonic acid levels in comparison with non-vegetarians.

- Non-vegetarians show changes in platelet function when saturated fatty acids are decreased.
- Platelet aggregation to thromboxane and clotting activity of platelets is decreased and saturated fatty acids increase thrombin aggregation. Platelet function can be decreased by eating diets.
- Hepatic encephalopathy may be precipitated if a high protein diet is consumed, particularly one that is derived from animal proteins.
- Choline present in foods like wheat germ, soybean, peanuts and skimmed milk, may prevent the formation of a fatty liver.
- overall, there are more advantages in a vegetarian diet than a non-vegetarian one.

Non-nutrient components of food and their importance.

① Naturally several substances occur determine overall food quality

② Several of these compounds designed by nature to protect the plants against predators.

③ These compounds may have pharmacological properties or may have non-nutritional factors or toxins that affect overall nutritional content of the food.

Anti-nutritional factors

They include trypsin inhibitors, phytates, oxalates, tannins, lectins and goitrogens interfere with assimilation of nutrients like protein, iron, zinc, Ca, I.

a- Trypsin inhibitors (protein)

- Proteins widely distributed in legumes, egg white, soybean, lima bean, Kidney bean and duck egg white.
- Trypsin inhibitors in legumes and egg are easily inactivated by autoclaving at 120°C for 15 to 30 mins.
- More drastic heat treatment is needed to inhibit the inhibitors in soya, lima and kidney beans as well as duck egg white.
- Once it is get inactivated, the utilization of protein in that food improves

b- Phytates (iron, Ca, Mg)

- Phytates are hexaphosphate compounds of inositol
- Widely distributed in seeds, unrefined cereals & millets
- bind Fe, Zn, Ca, Mg
- form insoluble complexes with iron in the presence Ca & Mg.
- These complexes affect the absorption of iron in cereal based diets.
- on germination, the phytate content falls down due to enzymatic breakdown of phytate

c. Tannins (iron)

- These are condensed polyphenolic compounds distributed in plants.
- foods rich in tannins are seed coat of most legumes, spices, tamarind, turmeric, certain veg & fruits.
  Millets, ragi, bajra & sorghum.
- Tannins bind with iron forming compounds which are not absorbed in the gut.
- A typical veg diet containing cereals, legumes, veg & spices contains 2 to 3 g of tannin
- In order to reduce tannin content of the diet.
  legumes must be consumed after removing the seed coat, intake of tamarind, turmeric, and tea must be minimized in the diet.
- Tannins also bind protein, reduce their availability.

d. oxalate Calcium

- Oxalic acid is dicarboxylic acid & its salt (oxalate)
- Widely distributed in plant foods, generally act as Calcium Sulphate
- DGLV, green vegetables. some legumes are rich source of oxalate.
- Highest content of oxalate present in horsegram & Kesari dhal.
- oxalate interfere with Calcium salt by forming insoluble Calcium salts.
- Dietary oxalate absorbed and contribute to increased excretion of oxalate in the urine.
- predispose a person to oxalate urinary stone.

e. Goitrogens (Anti-thyroid substances. (Iodine)

- found in plant foods, mainly in Brassica genus
  cabbage, cauliflower, rape, leaves, radish, tapioca, mustard, cress, broccoli, brussel sprouts, turnips.
- chemically they are thiocynate, iso-thiocynate, glucosinolates
- interfere in the uptake of iodine by thyroid gland
- predispose a person to suffer from goitre: especially (65°C - 75°C)
- Suffer from goitre and necessary to suffer by the role of origin.

Toxic agents

- Kesari dhal & broad beans, Cassava contain toxic substances
- Raw ~~Conference~~ Substances may be made fit for consumption with.
- Heat treatment can destroy toxic substances.

phytochemicals

phytochemicals - non-nutritive plant chemicals have protective or disease preventive properties.

(5 to 6 servings)

tomatoes - lycopene,
Soy - isoflavones
fruits & veg - flavonoids.

mostly colourful fruits & veg)

functions

1. Antioxidant. — allyl sulfides (onions, leek, garlic)
   - Carotenoids (fruits & carrots)
   - flavonoids (fruits & veg)
   - Polyphenols (tea & grapes)
2. Hormonal action - Isoflavones - Soy
   reduce menopausal symptoms & osteoporosis.
3. Stimulation of enzymes : Indoles - in cabbages stimulate enzymes
   make estrogen less effective
   - reduce risk for breast cancer.
4. Interference with DNA rep. - Saponins in beans interfere with replication of cell DNA.
   - Preventing the multiplication of cancer cells.
   Capsaicin, in hot peppers protect DNA from carcinogen
5. Antibacterial effect : phytochemical from allicin from garlic.
6. Physical action : Some phytochemicals has bind physically to cell walls, thereby preventing the adhesion of pathogens to human cell walls.

Proanthocyanidins - from cranberry. Consumption reduces the urinary, arterial and vascular infections.

Sources of phytochemicals

1. Foods containing phytochemicals are already part of our daily diet.
2. In fact, most foods contains phytochemicals except for some refined foods such as sugar or alcohol.
3. Some foods, such as whole grains, vegetables, beans, fruits and herbs, contain many phytochemicals.
4. The easiest way to get more phytochemicals is to eat more fruits (strawberries, blueberries, cranberries, cherries, apple) and vegetables (Cauliflower, Cabbage, Carrots)
5. It is recommended that we should take daily at least 5 to 6 servings of fruits or vegetables.
6. Fruits and vegetables are also rich in minerals, vitamins and fibre and low in saturated fat.

List of phytochemicals

Alkaloids
- Caffeine
- Theobromine
- Theophylline

Anthocyanins
- Cyanidin
- Malvidin

Carotenoids
- β-Carotene
- Lutein
- Lycopene

Flavonoids
- Epicatechin
- Quercetin
- Resveratrol
- Kaempferol
- Hesperidin
- Naringin

Isoflavones
- Daidzein
- Genistein

Lignans
- Silymarin

Hydroxycinnamic acids
- Chlorogenic acids
- Coumarin
- Ferulic acid
- Scopoletin

Monoterpenes
- Geraniol
- Limonene

Phenolic acids
- Capsaicin
- Ellagic acid
- Gallic acid
- Tannic acid

Phytosterols
- β-sitosterol
- Saponins

etc **Xanthophylls**
- Astaxanthin
- β-Cryptoxanthin

Common Plants containing phytochemicals

Vegetables
- Broccoli
- Fennel
- Garlic
- Tomato

Fruits & nuts
- Acai
- Almond
- Blueberry
- Black Raspberry
- Blackberry
- Black currant
- Cranberry
- Grape
- Mangosteen
- Olive
- Orange
- Pomegranate
- Red raspberry

Medicinal Plants
- Ginkgo
- Goat's rice
- Opium Poppy
- Passion fruit
- Periwinkle
- Wintergreen

Common Herbs
- Aloe vera
- American Ginseng
- Dandelion
- Hop
- Indian Cress
- Korean Ginseng
- Lemon Balm
- Lemon verbena
- Marigold
- Milk Thistle
- Red Clover
- Rosemary
- Sage
- Tea

Beans
- Cocoa
- Soyabean

Protein - Energy Malnutrition (PEM)

1. PEM is one of the largest public health problems of our country. This condition is a deficiency of protein and Calories in the diet.
2. Strictly speaking, it is not one disease, but a spectrum of conditions arising from an inadequate diet.
3. It affects people of all ages, the results are more drastic in childhood due to the highest requirements in that period.
4. In adults, mild degrees of it results into some wasting, while severe degrees are encountered in famines and wars of long duration.
5. But in infants and children PEM is a major problem, recently, it was assumed that there was always a primary deficiency of proteins associated with varying degrees of energy deficiency, based upon observations in Africa.
6. But, the extensive studies conducted mainly at the National Institute of Nutrition, Hyderabad, India, a different concept has emerged whereby it is a condition, at least in India, primarily due to a deficiency of total dietary energy; the protein deficiency being only secondary.
7. This condition in children embraces at one end of the spectrum the puffed up cases of Kwashiorkor, the shrivelled cases of marasmus; and on the other cases of nutritional dwarfing.

Marasmus

1. The term derived from the Greek word meaning 'to waste' has been in usage in medical literature since old times.
2. It was as common in Europe and North America in 19th century as it is in India today. This is the childhood equivalent of starvation in adults.
3. Clinically, the presentation is of an irritable or apathetic child who fails to thrive, is markedly emaciated and has inveterate diarrhoea.
4. The appetite may be extreme or reduced. There is extreme shrivelling of the body with occasional dehydration, loss of subcutaneous fat, marked wasting of muscles, low body weight and length.
5. The abdomen may be shrunken or distended with gas. There may also be associated vitamin deficiencies like hypovitaminosis A.

Kwashiorkor

1. This term is used by the Ga tribe in and around Accra in Ghana, Africa. means, 'the sickness the older child gets when the next baby is born'.
2. It was adopted for the medical literature by Cicely Williams in 1933.
3. The child is apathetic, anaemic, anorexic, diarrhoeic and oedematous, usually brought to the doctor on account of some infective condition.
4. There is severe growth retardation but on account of oedema, the weight might not be severly subnormal.
5. The oedema may be varying in degree and distribution and associated with ascites and pleural effusions.
6. The skin changes may involve any part of the body, the mote common sites being lower limbs, buttocks and perineum. The skin changes show characteristic areas of desquamation and pigmentation or depigmentation.
7. Cracks appear at folds and ulcers may develop at anal region and over pressure points. The muscular wasting is extreme, and may result in incapability to crawl or walk.
8. The hair is sparse, softer and thinner than normal. Its colour also might change and become reddish, brown or gray (dyschromatichia)
9. There are associated symptoms such as angular stomatitis, cheilosis, and atrophy of the tongue, anaemia, hepatomegaly, and at times, tremors like those in parkinsonism.

Marasmic Kwashiorkor

1. This is a combination of in varying degrees of the features of the two conditions marasmus and kwashiorkor and is found in places where PEM is prevalent.
2. It is the superimposition of Kwashiorkor on any degree of marasmus and is the most common presentation of PEM in India.
3. Clinically, some features of both marasmus and kwashiorkor are present and the picture may be complicated by gastrointestinal or respiratory infections due to which the child is usually brought to medical attention.

Food Fortification

Food fortification is defined by the Codex Alimentarius as the addition of one or more essential nutrient to a food, whether or not it is normally contained in the food.

fortification of foods with micronutrients is an effective strategy to increase the micronutrient intake of a population.

It can be passively targeted to some or all population groups and thus, does not necessitate any cooperation from the individuals who benefit it.

For this an industrial infrastructure is required and the fortified food needs to be well accepted by the targeted population group and must be affordable.

The WHO guidelines identifies three approaches

a. Mass:
- Addition of micronutrients to foods generally consumed by the general public.
- Provides greater population coverage but may satisfy only partially the micronutrient needs of the at-risk subgroups.

b. Targetted:
- fortification that focuses on coverage of specific, at-risk subgroups.
- Delivery can be sufficient to satisfy nutritional requirements.

c. Market-driven.
- where a food manufacturer takes the initiative to fortify products in order to increase sales and profit.
- Has a very small coverage in developing countries.

There is, in addition, a relatively new concept, namely household fortification.

This is the consumption of dietary supplements (usually in powder form) mixed with foods at meals.

In the case of mass fortification, the main advantage over the other interventions is that it uses already existing distribution and trade system, and therefore the cost is basically restricted to the added vitamins, and minerals and the fortification process

The WHO guidelines on food fortification with micronutrients (iron, folic acid, vit-B_{12}, vit-A, riboflavin, copper, zinc) provides detailed information on fortification levels based on safety, and technological and cost constraints. The salient features are

1. Not more than 3 mg of fortificant iron can be added to a 50 g serving portion of a solid food or 250 ml of beverage, contributing a maximum of 22% of a daily iron needs from a diet.
   - fortifying flour with iron has the potential to increase national IQ by 5%, national GDP by 2% and eliminate 60,000 deaths of pregnant women every year.

2. Folic acid as prophylactic intervention is targeted to pregnant women who are at risk of neural tube defects and the dose is 400 µg either given alone, or in combination with iron, and micronutrients. This can significantly reduce the 200,000 cases of NTD's in newborn babies every year.
   - 1.8 mg folic acid / Kg of edible food stuff is the maximum amount that can be added for fortification of staples and a maximum of 27 µg of folic acid / 140 K cal serving of product for other fortified commercial foods.
   - Iron and folic supplementation in malaria-endemic areas is not recommended, since, it shows an increased incidence of adverse effects and death.

3. - Traditional treatment for vitamin-B_{12} deficiency megaloblastic anaemia is a single, intramuscular dose of parenteral cyanocobalamin of 200 µg.
   - Alternatively, oral doses of 1000 µg - 2000 µg of cyanocobalamin have been found to be as effective
   - The upper limit for folate is set to at 1000 µg/day for adults
   - for macrocytic anaemia due to folate deficiency, a daily supplementation course in doses of 500 µg to 5000 µg can be given preferably with vitamin B_{12}.

4. - The upper limit for vit-A has been set at 10000 IU (3,030 µg as retinol) daily.
- Total vit-A exposure should be limited to a cumulative dose that maintains a hepatic vitamin-A concentration of < 300 µg/gm, which considered the threshold of toxicity.
- Regular daily consumption of 30 mg of vit-A in the retinoid form is associated with chronic toxicity.
- The WHO does not specify a safety limit for fortification of food with vit-A, but it should provide 15% of the daily vitamin-A needs but should not exceed 30%.
- for commercial products, the WHO recommends a maximum vit-A addition of 60 µg / 40 Kcal serving.
- It is not recommended that high dose supplements of vit-A to lactating women to support vit-A in milk.

5- Oral dose of appx. 2mg daily are used to treat individuals with hyporiboflavinosis.
- Riboflavin is generally added to multinutrient supplements and in the fortification of staple cereals, where it is added at a concentration of upto 200 mg/kg of cereal flours.

6. Copper deficiency anaemia has been successfully treated with daily doses of copper as cupric sulphate of 1mg - 2mg / day in adults and young children and doses of upto 9 mg / day in divided doses are safe and tolerable in adults.

7. Where high-dose zinc is given, copper should be included in the formulation to prevent distortion of copper nutriture by zinc.

Effects of food processing and preservation on nutritive value of foods

1. Some loss of certain nutrients during food processing is inevitable. The major consideration in evaluating food processing from a nutritional point of view is the balance between increased food availability and the effects that each of the various processing methods has on nutrients and food quality.
2. The net effect of food processing on product quality is positive. The nutritive value of foods may be improved by an increase in nutrient content and / or digestibility of food components.
3. Besides, the aesthetic qualities of food are also improved, resulting in enhanced appeal of the food of the appetite and better nutrient retention through consumption.

a. Processing Loss vs. Natural Differences

1. Variations in the nutrient content of raw food materials may affect the content of vitamins and minerals in the final product
2. Raw foods may vary widely in their vitamin content as a result of genetic differences, climatic or soil conditions, maturity at harvest, handling conditions following harvest and the nutrient intake of the animal in the case of meats, fish and poultry.
3. There may be great variations in the vitamin and mineral content of some fresh fruits and vegetables. Samples of fresh tomatoes and carrots may vary twofold in their concentrations of vit-C and β-carotene
4. Similarly investigators have found a wide range of thiamine concentration in pork depending on the thiamine intake of the animal.

b. Positive and Negative Effects of processing

1. The basic food preservation methods which have been used by early man are still utilized today. An analysis of the processing techniques reveals both favourable and unfavourable effects on nutritional quality.

2. On the positive side, heat processing destroys antidigestive factors such as trypsin and amylase inhibitor in cereal grains, peas and beans, thus improving the digestibility and bioavailability of protein and carbohydrates in these products.
3. Heat processing also destroys thiaminase, which destroys thiamine in fish, shell-fish, and cabbage and it destroys the avidin and other factors in raw egg-white that would otherwise bind biotin and some of the iron present in egg-yolk and make these nutrients biologically unavailable.
4. Heat processing increases the digestibility of starch and protein (by gelatinization and denaturation, respectively), and it increases the bioavailability of niacin, which is present in many cereals in bound form.
5. Heat processing also increases the palatability of food, resulting in an increased appeal and nutrient consumption
6. Vitamins are sensitive to processing and storage. Generally the water-soluble vitamins, especially thiamine, riboflavin and vit-C, are more susceptible to loss due to leaching while washing and blanching.
7. While, the fat soluble vitamins, particularly A, D, E are more sensitive to oxidation during processing and storage. Minerals which are water-soluble are also susceptible to leaching.
8. Certain, water-soluble and fat soluble vitamins are sensitive to high temperatures during processing. water soluble vitamins are more heat sensitive than fat soluble. Vit-C and thiamine are more heat sensitive
9. Minerals are ~~se~~ not sensitive to heat, but their bioavailability may be altered as a result of interaction within the food.
10. Small loses in protein bio-availability as a result of non-enzymatic browning between certain amino acids and sugars may occur. The resultant flavor and color which is the characteristic of this browning reaction is very desirable in some foods.

Heat Processing

1. Ever since the discovery of fire, man has used to heat to cook his food. Inspite of numerous beneficial effats, heat processing also has a detrimental effect on nutrients since thermal degradation of nutrients does occur.
2. Commonly used heat processes are cooking, blanching, pasteurization and commercial sterilization.
3. Carbohydrates, reducing sugars undergo the caramelization reaction and digestibility of starch increases because of gelatinization.
4. Proteins - in the presence of reducing sugars, proteins are degraded via Maillard rxn. The most heat labile amino acids are lysine and threonine.
5. Fats - Some fats degrade at very high temperatures
6. vitamins - The most heat labile vitamins are ascorbic acid, thiamin, vit-D, and pantothenic acid. During canning process, the most significant losses occur in the washing and blanching steps. vit-B6 and pantothenic acid are reduced to 67% and 62%. However, B_1, B_2, B_3 are well retained in canning of tomato juice. Fat soluble vitamins are less heat labile than the water soluble vit.
7. Minerals - Loss of trace minerals occurs in the blanching operation Zinc, copper and manganese retention is of importance in terms of availability and quantity in foods.

Freezing

1. In this method, nutrients are affected at the pre-freezing treatment stage, during freezing, frozen storage and thawing.
2. Although, the retention of sensory attributes and nutritive properties are better than canning or dehydration
3. Carbohydrates, fats, and proteins are not significantly affected but it is well known that significant amounts of some vitamins are lost during freezing process.
4. Freezing does not have any significant effat on the vitamin content of vegetables, fruits and animal tissues

5. During frozen storage, substantial loss of vitamins can occur depending upon the product, pre-freezing treatments, the type of packaging, the type of pack and the storage conditions.

6. Most minerals are lost, although in small amounts, from vegetable during steam blanching than during water blanching. Iron is the only mineral, which shows significant losses during storage.

Freeze drying

1. Amino acids and proteins: in various freeze dried foods such as beef, chicken, egg, fish, green beans, Sweet corn etc. the percentage retention of amino acid ranges from 95% to 100%.

2. Vitamins - about 50% - 70% of ascorbic acid in raw, unblanched food are retained. About 95% or more of vit-A and Carotenoids are retained. Thiamine is retained at a level of 75% or more, while 90% or more of riboflavin remains intact.
Other vitamins such as folic acid, pantothenic acid and B12 are not much affected, except pyridoxine.

3. Fats: About 57% to 100% of PUFA are retained various freeze-dried foods such as beef, chicken, pork and shrimp.

Irradiation

1. Radiation sterilization is comparable to canning or the thermal processing of foods.

2. Carbohydrates: Hexoses are degraded by dehydrogeration and complex polysaccharides exhibit a break in the glycosidic linkage. Effects produced by irradiation continue during storage. Polysaccharides such as cellulose and starch are depolymerised by irradiation.

3. Lipids: Radiation results auto-oxidation of fats, produce hydroperoxides. Animals fats are more susceptible to radiation-induced chemical changes than vegetable fats.
Radiation of lipids involve transformation of some essential fatty acids, there by inducing nutrient deficiency.

4. Fat-Soluble vitamins : The percentage destruction of vit-A is most in fresh milk and less in evaporated milk, butter, cheese and cream.
vit-K is retained from about 20 to 78%. in irradiated foods.
26%. to 85%. of vit-E is destroyed in various irradiated foods.
It must be remembered that vitamin-E is the most sensitive vitamin among fat-soluble vitamins to irradiation.

5. Water-soluble vitamins : 65%. to 95%. of Thiamine destruction
vit-B_2 decreases from about 1.8% to 50%. in various foods such as milk, fruits and beef.
Pyridoxine is retained from 24%. to 82%. in beef, chicken, cabbage.
vit-C is retained between 72%. to 100%. depending upon the food and the radiation dose.

Microwave Cooking

1. This appliance has relatively new meaning for the urban homemaker.
2. In microwave heating, non-ionizing electromagnetic wave vibrating at microwave frequencies create temperature rises when absorbed by certain materials.
3. Vitamins : About 83% to 91%. vit-B_6, is 52%. to 91%. vit-B_1, 73%. to 98%. vit-B_2, 64%. to 100%. vit B_3 is retained in various meat products.
48%. to 98%. of Ascorbic acid is retained in vegetables.
Microwave cooking results higher vitamin retention in foods than those conventionally cooked.
4. Proteins : The protein content and the amino acid content of microwave cooked food is not significantly affected.
5. Minerals : Conventionally cooked food has a significantly higher mineral content, especially phosphorous and iron.

Diet for Diabetes Mellitus

- Diabetes mellitus, commonly known as diabetes, is a disorder of Carbohydrate metabolism characterized by high blood sugar level (hyperglycaemia) and high level of sugar in urine (glycosuria).
- It is accompanied in many cases by secondary alterations of fat and protein metabolism, resulting in an array of physical disorders
- Diabetes, is a metabolic disease. It can be kept well under control and reasonably managed with proper care though it cannot be cured once it occurs.

Causes of diabetes

- Diabetes is the result of lack of effective insulin action. Insulin is a hormone secreted by the β-cells of islets of Langerhans, which are an endocrine portion of the pancreas.
- Some minute quantities of insulin are also known to be secreted by the muscle tissue for its own use. for this reason moderate amount of muscular exercise is always advocated for diabetic persons.
- Lack of insulin may be either absolute or relative.
- Absolute insulin deficiency does not occur normally, it occurs mainly in patients whose pancreas has been operated for the removal of malignant tumor.
- Relative insulin deficiency occurs when the quantity of insulin secreted is insufficient to metabolize the carbohydrates consumed.

Factors Predisposing Diabetes

1. Acquired and Environmental Factors

a. Infection: It may precipitate insulin-dependent diabetes mellitus (IDDM) or non-insulin dependent diabetes mellitus (NIDDM).

b. Direct: Cell-cytotoxicity – Alloxan, Pyrinuron are drugs which damage β-cells and produce diabetes

c. Damaged β-cell function through other mechanisms, such as toxic substances, inadequate protein intake, nitrosamines in foods such as those found in smoked and cured mutton, precipitate diabetes.

2. Changes in lifestyle

a. Over nutrition and obesity

- It is always advised to use the BMI in risk assessment for the diagnosis of diabetes or even response to weight loss.
- BMI is a more accurate measure of total body fat.
- Waist circumference is a helpful index of a normal or overweight person.
- Men whose ~~weight~~ waist circumference is more than 35 inches are at high risk of diabetes, dyslipidemia, hypertension and cardiovascular disease

b. Physical inactivity

c. Malnutrition

d. Severe or prolonged stress

e. Drugs and hormone intake of several oral contraceptives, cause glucose intolerance and in susceptible individuals may induce diabetes.

F. Pancreatic disorders

3. Metabolic and Endocrine disorders

- ACTH (Adrenal-Cortico-trophine Hormone), glycogen and adrenalin are shown to be diabetogenic since they increase the level of blood sugar.

Classification of Diabetes

There are two main clinical groups of diabetes who may be differentiated

a. The Juvenile-Onset type.

- An abrupt onset in patients who are less than 25 yrs old.
- usually underweight
- deficient in insulin in their blood plasma and show no insulin response when fed large amounts of glucose.
- accumulation of ketone bodies in the blood, which in excess amounts can lead to coma and ultimately death
- Hence this type requires insulin therapy for control of the diabetes

b. The maturity - onset type

- This type develops insidiously in middle-aged, usually obese patients.
- They normally ignore their symptoms for several months before counselling help from a doctor.

Symptoms of Diabetes

1. The initial symptoms of diabetes include excretion of large amounts of glucose in urine. In some cases, may goes to 100 g / day. This is termed as Glycosuria.
2. Losing so much solute in urine causes osmotic diuresis and the volume of urine increases (polyuria). Hence diabetic patient urinates frequently.
3. The patient feels very thirsty constantly (poly-dipsia) and drinks large quantities of water.
4. These symptoms which persist for many months cause maturity-onset diabetic to approach a doctor.
5. Tissues receive a liberal supply of glucose from the blood, they are unable to utilize it efficiently in the absence of insulin. Such a diabetic, therefore, feels weak and tired.
6. Carbohydrates cannot be utilized as a fuel, fats are then mobilized. They are transported from the body stores to the liver.
7. Thus, fat content of blood and liver increases. The plasma of such a patient is often opaque and fatty (lipaemia).
8. This disproportionate metabolism of fat in a patient showing lipaemia result in excessive production of ketone bodies such as ~~Ket~~ acetone, aceto-acetic acid, and β-hydroxybutyric acid which cause ketosis, Ketonaemia, and Ketonuria.
9. When Ketosis becomes severe, the patients breath gives a characteristic smell like acetone.
10. By-products of fat metabolism such as aceto-acetic acid, and β-hydroxy acids, produced faster and they can be metabolized, the patient develops acidaemia (acidosis) which gives rise to hyperventilation (air hunger).

11. Along with abnormal Carbohydrate and fat metabolism there is extensive breakdown of protein in order to provide energy. This energy is obtained by deamination of amino acids.
12. At this stage, patients develops lack of appetite (anorexia), nausea, and vomitting.
13. The increased loss of water and electrolytes through urine as well as orally leads to dehydration.
14. The Ketoacidosis is associated with increasing drowsiness and if untreated, the patient may become unconscious (diabetic coma) which can prove fatal.
15. A combination of hyperglycaemia, Ketosis, acidaemia, and dehydration may cause the patients' death.
16. Other possible symptoms include blurred vision, skin irritation or infections.

Acute Complications of Diabetes

Two complications may develop in diabetes mainly arising from severe insulin insufficiency. They are.

① Hypoglycaemia (Insulin shock)

- may take place in patients, who are receiving insulin where there is imbalance between diet and insulin dosage, or it may be caused due to delay in eating, omission of food or loss of food by vomiting and diarrhoea.
- Some patients, excessive exercise may also cause symptoms of insulin shock.
- Such cases, patient becomes pale, nervous, weak and hungry. The person tends to have excessive perspiration and a moist skin.
- He may have uncoordinated movements, nausea, vomiting or convulsions.
- If not treated by giving sugar or fruit juice, the patients may go into coma and even die.

② Diabetic Acidosis and Coma

- Diabetic acidosis or Ketoacidosis as it is known, is also characterized by elevated level of Ketones in the blood, feeling of weakness, headache, anorexia, pain in the abdominal region.
- The skin is hot and flushed while the breathing is painful and rapid
- There may be symptoms as described in insulin shock.
- Emergency treatment involves intake of foods and liquids having sufficient glucose such as fruit juices, kheer, broth etc.

Chronic Complications of Diabetes

① Diabetic Eye disease.

- Prevalence of diabetic retinopathy, especially in middle-aged and elderly people, causing visual disability.
- Risk of blindness especially in older persons which is indicated by deposition of white exudate, and haemmorhage or by oedematous swelling of retinal tissues
- Cataract, and other eye diseases occur earlier and more often in diabetes than in non-diabetes.

② Kidney diseases

- Progressive impairment of renal function, accompanied by urinary protein loss and culminating in end-stage renal failure may be seen in diabetes.

③ Diabetic Neuropathy

- Damage to nerve fibres conducting sensation and blood vessels as well as the viscera is the most common complication of diabetes.

④ Cardio-vascular diseases.

- occurs more frequently in diabetics than in non-diabetics.
- chance of claudication and gangrene in the lower limbs, and for cerebral infarction, stroke and diffused cerebral disease.

⑤ The Diabetic foot.

- Diabetics are affected by a peculiar disability which severely damages the tissues of the foot.
- It is seen in the form of chronic ulceration, sepsis, and gangrene.
- It may necessitate amputation of the foot

3-major factors have been identified which lead to the diabetic foot. They are

a. Chronic diabetic neuropathy
b. Atherosclerotic obstruction of the arteries that supply the lower limbs
c. Bacterial infection

6. Gastroparesis

- Gastroparesis is also called delayed gastric emptying.
- It results in food remaining in the stomach for a longer period of time than normal.
- Normally, the stomach contracts to move food down into the small intestine for digestion and the vagus nerve controls these contractions.
- Gastroparesis may occur when the vagus nerve is damaged and the muscles of the stomach and intestines do not work normally.
- food then moves slowly or, stops moving through the digestive tract.
- Dietary treatment includes dietary changes (mostly fibre rich foods)

Medicinal plants in the use of Diabetes Mellitus.

① Jamun (Syzigium cumini)

- Jamun occurs naturally in India and is also widely cultivated in India for its delicious fruits.
- The fruit has an unusual taste, flavor and odour.
- It is generally purple, and has a sub-acidic to sweet taste.
- The edible portion of the fruit is about 40 to 50 %. of the whole fruit and the seed is large, whereas the skin is thin and edible.
- Ayurvedically, it is recognized that a decoction of the dry leaves of the jamun exhibit hypoglycaemic effects.
- The fruit, bark and seeds have also been found to possess anti-diabetic properties.
- Some studies have also shown that the seeds have hypolipidaemic properties
- Jamun seeds contain quercetin, gallic acid and ellagic acid, which are known antioxidants.

② Fenugreek (Trigonella-foenum graecum Linn.)

- Fenugreek seeds are used as a condiment and the leaves are widely consumed as a green leafy vegetable.
- The leaves are a rich source of calcium, iron, β-carotene and other vitamins. The leaves and the seeds are bitter
- The seed extracts shown to contain, alkaloids (trigonelline), fat, fibre, saponins and proteins. These extracts shown to exhibit hypoglycaemic effects.
- An insulin stimulating substance, 4-hydroxy isoleucine has been identified in fenugreek seeds.
- Blood glucose lowering effects have been reported in diabetes on consumption of 15 gms of fenugreek powder daily.

3. Karela / Bitter Gourd (Momordica charantia Linn.)

- Bitter gourd is cultivated for the use of its unripe fruit as vegetable, locally known as karela.
- It is used as a tonic, emetic and laxative.
- Sometimes, it is used in the treatment of gastroenteritis, diabetes, tumours and some viral infections.
- The juice of the unripe fruit is taken once or twice a day as an anti-diabetic remedy. It helps improve glucose tolerance.

B.TECH FOOD TECHNOLOGY **2018-2019**

Semester-III

18BTFT303 FOOD BIOCHEMISTRY AND HUMAN NUTRITION 4H-3C

Instruction Hours/week: L:3 T:1 P:0 **Marks:** Internal**:40** External**:60** Total**:100**

End Semester Exam:3 Hours

Course Objectives

- Explain the digestion, absorption and metabolic pathways of carbohydrates
- Describe the digestion, absorption, synthesis and metabolic pathways of fatty acids, proteins, and amino acids
- Outline the important aspects of food relating to nutrition
- Summarize the diets suitable for managing specific nutritional disorders
- Categorize the nutrients for different age groups, and sports people

Course Outcomes

1. Illustrate the structure of ATP and identify the major class of macromolecules to which ATP belongs.
2. List the stages in the catabolism of food molecules and describe what occurs during each stage.
3. Outline the biochemistry process, basic concept of human nutrition and the relationship of the consumption of foods to nutritional status and health
4. Evaluate the biological functions of foods for health in addition to nutritional values
5. Report the dietary management system for nutrition and disorder with organs and inborn errors
6. Design and develop new range of food products and nutritional supplements for different age group people, pregnancy and other.

UNIT I –METABOLISM OF CARBOHYDRATES

Carbohydrate – Digestion and absorption, Glycolysis (EMP) pathway, CORI's cycle, Energy yield from glycolysis, TCA cycle – Energetics, HMP or PP pathway, Gluconeogenesis, Glycogenolysis, Glycogenesis

UNIT II-METABOLISM OF FATTY ACIDS AND PROTEINS

Fatty acids – Digestion and absorption, Synthesis of TAG's, Metabolism of adipose tissue – fatty liver and lipotropic factors, Cholesterol – biosynthesis and metabolism

Proteins – Digestion and absorption, General metabolism of amino acids – transdeamination, transamination and oxidative deamination, Urea cycle, Metabolism of serine, cysteine, valine, leucine, isoleucine, tryptophan

UNIT III-CONCEPTS OF FOOD AND NUTRITION

Food as a source of nutrients, Food intake and regulations, Food groups, Utilization of nutrients and digestion process, calorific value of food, dietary need and recommended dietary allowances, Vegetarian diet – health, problems and advantages, Nutrition in phytochemicals and non-nutrient components, Malnutrition – PEM, Food fortification, Effect of processing on nutritive value of foods, vitamins and storage of nutrients, Food allergy, intolerance and sensitivity, Nutrigenomics

UNIT IV-NUTRITIONAL DISORDERS

Dietary management – Fever, overweight, under weight and obesity, burns, CVD, cancer, skin care, diabetes, inborn errors of metabolism

UNIT V-SPECIALIZED NUTRITION

Nutritional requirement for infants, preschool and school children, adolescence, geriatric, sports and fitness, adults, pregnancy and lactation

SUGGESTED READINGS

1. Nelson DL and Cox MM. (2017).Lehninger Principles of Biochemistry. 7th Edition. W.H. Freeman Company.
2. Voet D, Voet JG and Pratt CW. (2016). Fundamentals of Biochemistry Life at the Molecular Level. 5th Edition.John Wiley and Sons.
3. Martin Eastwood. (2003). Principles of Human Nutrition. 2nd Edition. Blackwell Publishing Company.
4. Sunetra Roday. (2012). Food Science and Nutrition. 2nd Edition. Oxford Higher Education/ Oxford University Press.
5. Shubhangini AJ. (2015). Nutrition and Dietetics. 4th Edition. McGraw Hill education.

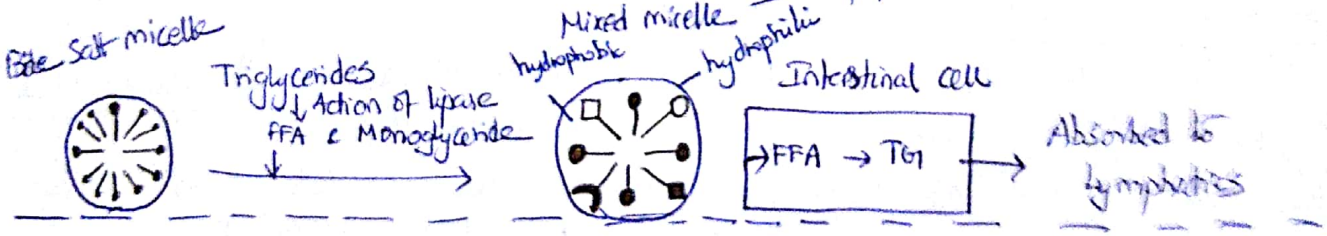
Absorption of lipids

Glycerol as well as small chain and medium chain fatty acids (chain length less than 14 Carbons) are directly absorbed from the intestinal lumen into the portal vein and taken to the liver and are immediately utilised for energy

Micellar formation

Micelle - An aggregate of molecules in a colloidal solution

- Long chain fatty acids (≥ 14 C) are absorbed by forming micelles with the help of bile salts
- The theory proposed by Bergstrom is summarized below.
- The products of digestion, namely 2-monoglycerides, long chain fatty acids, cholesterol, phospholipids and lysophospholipids are incorporated into molecular aggregates to form mixed micelle.
- The micelles are spherical particles with a hydrophilic exterior and hydrophobic interior core.
- The micellerisation helps in disposing the fatty acid molecules in the aqueous medium of intestinal lumen.
- Due to their amphipathic nature, the bile salts tend to form micellar aggregates
- Minimum concentration of bile salts required for micellerisation is 4 mmol/L



- 2 monoglyceride
- Phospholipid
- Free fatty acid
- Cholesterol
- Bile salt

Micelle formation

Enterohepatic Circulation of Bile salts

- In this micellar form, the products of digestion of dietary lipids are presented for absorption at the microvillous surface of the jejunal mucosa.
- Fatty acids, 2-MAG, and other digested products passively diffuse into the mucosal cell
- The remaining bile salts are mostly reabsorbed from the ileum, and returned to the liver to be re-excreted (enterohepatic circulation).
- About 98% of dietary lipids are normally absorbed.

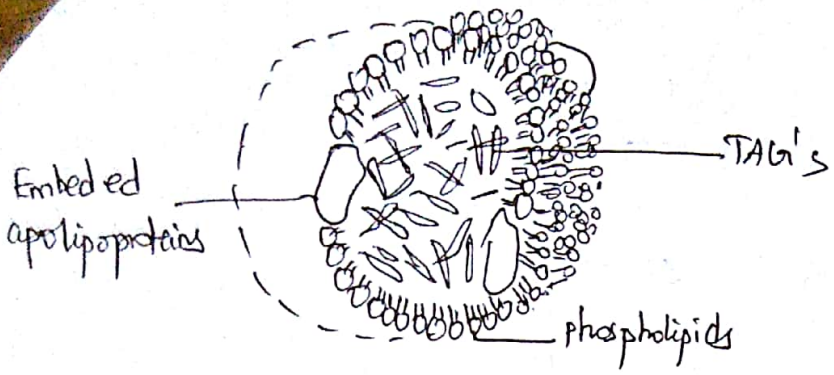
Re-esterification inside Mucosal cell

- Once inside the intestinal mucosal cell, the long chain fatty acids are re-esterified to form TAG's.
- First fatty acids are activated to fatty acyl CoA by the enzyme acyl CoA Synthetase.
- This needs lysis of two high energy bonds. Two such activated fatty acids react with monoacyl glycerol to form the TG.
- Free glycerol absorbed from intestinal lumen directly enters into the blood stream. So free glycerol is not available for re-esterification.
- But the cells can convert glucose to glycerol phosphate, and then add three molecules of acyl groups to synthesise TAG.

Chylomicrons (Lipoproteins) (Droplet of fat)

- The TAG, Cholesterol ester and phospholipid molecules along with apoproteins B48, and apo-A are incorporated into chylomicrons
- The chyle (milky fluid) from the intestinal mucosal cells handed with chylomicrons are transported through the lacteals into the thoracic duct and then emptied into systemic circulation.
- The serum may appear milky after a high fat meal due to the presence of chylomicrons in circulation.
- Normally the lipemia clears within a few hours by the uptake of chylomicrons by tissues.

Chylomicrons



SCFA - Absorption is different

SCF and MCF do not need re-esterification and can directly enter into the blood vessels.

Their absorption is rapid. They are better absorbed than long chain fatty acids.

Synthesis of Triglycerides (TAG)

Liver and adipose tissue are the major sites of TAG synthesis

The TAG synthesis in adipose tissue is for storage of energy whereas in liver it is mainly secreted as VLDL and is transported.

TAG is synthesized by esterification of fatty acyl CoA with either glycerol-3-phosphate or DHAP.

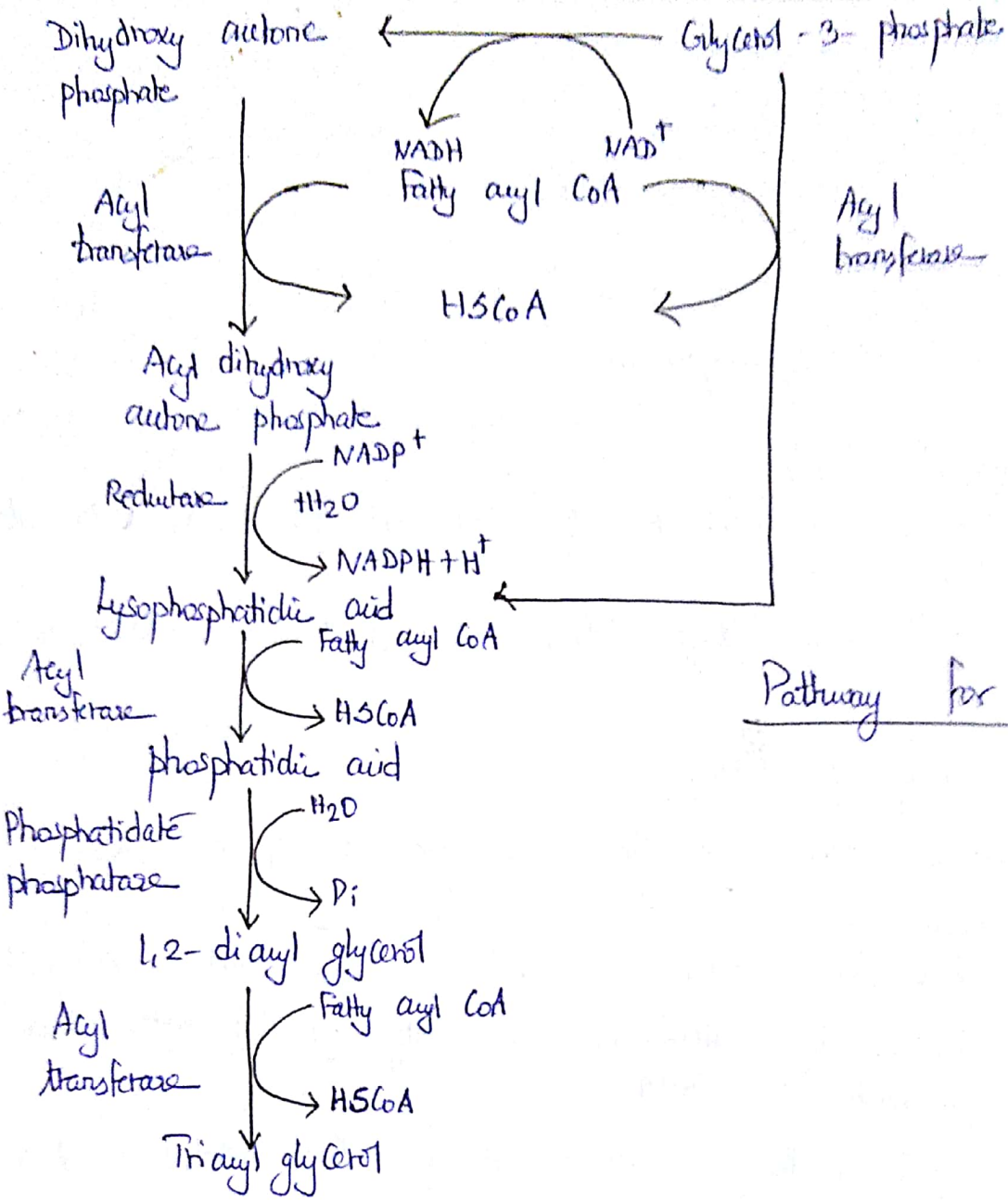
The glyceral part of the fat is derived from the metabolism of glucose.

DHAP is an intermediate of Glycolysis. Glyceral-3-phosphate may be formed by phosphorylation of glycerol or by reduction of DHAP.

Step-1

DHAP reacts with an enzyme Acyl transferase to produce Acyl dihydroxy acetone phosphate

Simultaneously, another enzyme fatty acyl CoA derives / liberates thioester along with CoA.



Pathway for TAG Synthesis

Step-2

- Acyl DHAP reacts with an enzyme Reductase ($NADP^+ \rightarrow NADPH+H^+$) to form Lysophosphatidic acid.
- Also, Glyceraldehyde-3-phosphate forms directly lysophosphatidic acid reaction with enzyme Acyl transferase.

Step-3

Lysophosphatidic acid forms phosphatidic acid, by an enzyme Acyl transferase,
The fatty acyl CoA molecules transfer the fatty acid to the hydroxyl groups of glycerol by specific acyl transferases.

Step-4

phosphatidic acid forms 1,2 - diacyl glycerol, enzyme Phosphatide phosphatase which liberates phosphate molecule.

Step-5

1,2 - diacyl glycerol converted into TAG, by MAG pathway by Acyl transferase, Fatty acyl CoA transfers / liberates thioester to enzyme A. to form TAG

Effective Hydration for fitness and Sports

1. Water is the most essential component of the human body as it plays an important role in the functioning of cells.
2. More than half weight of the human body is make up of water and it is impossible to sustain life without it.
3. Some important functions of water include transports of nutrients, elimination of waste products, regulation and maintenance of body temperature through sweating, maintenance of blood circulation and pressure, lubrication of joints, body tissues and facilitation of digestion.
4. Dehydration is the loss of fluids and salts essential to maintain normal body function.
5. Dehydration occurs when the body loses more fluids than it consumes. Symptoms of dehydration include muscle fatigue, loss of coordination, inability to regulate body temperature, muscle cramps, decreased energy and athletic performance.
6. Normally, exercise increases body temperature, which depends on the intensity and duration of exercise, environmental conditions, clothing worn and metabolic rate.
7. Exercise can cause heavy loss of water and electrolytes from sweat leading to dehydration especially among athletes.
8. If these losses are not replaced, the performance and overall health of the athlete will be adversely affected.
9. To check the hydration status, an athlete must weigh himself before and after exercise.
10. Based on this, drinking enough fluids to replenish these losses will maintain hydration.
11. As a rule of thumb, loss in body weight over 1% indicates dehydration and over 5% indicates serious dehydration.
12. Thirst is not a good indicator of hydration and should not be used to monitor hydration status.
13. Another indicator of hydration status is the colour of urine. A large amount of light coloured urine indicates good hydration. As the level of dehydration increases, the colour of the urine becomes darker.

14. Intake of alcohol increases urine output and decreases hydration. Palatability of fluid can be improved with added flavour, salt (sodium) and by cooling it (15-21°C)
15. As sports beverage helps replenish the glycogen stores and its electrolytes help in rehydration.
16. Sports beverages generally contain 4-8% Carbohydrates, 20-30 meq/L Sodium and 2-5 meq/L potassium; Sports drink should not exceed 8% Carbohydrates.
17. Ideally half to one litre of a sports drink should be ingested each hour to maintain hydration.
18. Over hydration or water intoxication can result in behavioural changes, confusion, drowsiness, nausea, vomitting, hyponatremia, weight gain, muscle cramps, weakness, paralysis and risk of death.