Basic Nutrition

(FSN11301T)

Dr. Md. Abdul Mojid Mondol
Associate Professor
School of Science and Technology
Bangladesh Open University

Introduction to this Module

Among the modules of B.Sc (Hons) in Food Science and Nutrition program, Basic Nutrition (FSN11301T) is one of them. This module covers: the definition of food and nutrition, the food sources of basic nutrients (carbohydrates, proteins, fats, vitamins and minerals), the functions of nutrients in our body and deficiency diseases. Basic Nutrition (FSN11301T) module is different from traditional books used in the class. The learners can understand this module just studying at home without attending in class. Please read carefully the instructions to understand the lessons clearly.

Arrangement of Module

There are 24 lessons in this module. The lessons of this module have been arranged in such a way that a learner can understand about the content just after reading the heading of the lesson. Every lesson has been started with objectives followed by content. To understand the content, some pictures have been added. At the end of each lesson, the learners have been subjected to evaluate their merit.

How to read this module?

Before reading the main text, first read objectives with care. A learner how much understood the objectives of the lesson, will be evaluated at the end of the lesson. If necessary, a learner has to read again and again main test to under the objectives clearly. When a learner will understand objectives clearly, then he/she will write the answer of the exercise.

Audio-video program and tutorial service

Learners may easily understand some lessons of this module just after reading but some may not. Those hard lessons will be made easily understandable through audio-video programs and tutorial services. Audio-video programs will be broadcasted through Bangladesh Betar and BTV at specified date and time. Before broadcasting audio-video programs, learners are advised to sit in front of Betar or TV with book, note book and pen so that necessary notes can be written down. Learners will get chance to solve any part of any lesson and audio-video programs which are hard and not easily understandable from tutor in tutorial class. Keep in mind, tutorial class is not like traditional class where tutor will only help learners to understand those hard portions of this module. So, learners are advised to mark hard portions of the lessons according to the tutorial class schedule before coming to the class so that it can be discussed with tutor to solve. After all, tutor as well as Bangladesh Open University respective teachers will help the learners to complete this module successfully.

Lesson 1: Food, nutrition, nutrients and calorie

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define food and nutrition;
- Classify foods and nutrients;
- Describe functions of food and nutrients;
- Calculate the energy of foods.

1.1 Food

Food has been a basic part of our existence. The term ‘food’ refers to anything that we eat and which nourishes our body. In short, food is the raw material from which our bodies are made. It includes solids, semi-solids and liquids. Intake of the right kinds and amounts of food can ensure good nutrition and health, which may be evident in our appearance, efficiency and emotional well-being. Thus, two important features for any item to be called food are:

(i) It should be worth eating, that is, it should be ‘edible’.

(ii) It must nourish the body.

1.1.1 Classification of foods

Foods can be classified based on-

1. Origin: such as

i. Animal foods: milk, meat, eggs, fish, shrimps, snails, crabs, etc.

ii. Plant foods: vegetables, whole grains, nuts, seeds, legumes, fruits, oils, etc.

Animal Foods

Plant Foods

2. Predominant functions: such as

i. Body building foods: This group of foods allows us to grow and repair tissues such as meat, milk, poultry, fish, eggs, pulses, etc.

ii. Energy giving foods: This group of foods gives energy to our body such as cereals, sugars, fats, oils etc.

iii. Protective foods: This group of foods protects our body from diseases such as vegetables, fruits, milk, etc.

Bodybuilding foods

Energy giving foods

Protective foods

1.2 Functions of Food

1. Social and religious function

Foods function as an integral part in different social occasions (e.g., naming, birthday, putting rice to a child's mouth for the first time, marriage ceremony, get-togethers, meeting etc) and religious functions (e.g., circumcision, Eid, Christmas, Pooja, etc).

2. Physiological function

There are three physiological functions performed by food. These are (i) providing energy, (ii) building body, (iii) regulating body processes and providing protection against diseases and germs.

3. Psychological function

Our metal satisfaction or dissatisfaction is sometimes related with the serving foods irrespective of nutritional value; even you may not satisfy with a nutritionally balanced meal if the foods included are unfamiliar or distasteful.

1.3 Different types of foods

1. Whole foods

Whole foods are those foods which directly obtain from nature. Examples include milk, eggs, meats, poultry, fish, fruits, vegetables, dried beans and peas, and grains. Many whole foods are also considered fresh foods. Fresh foods are raw foods that have not been processed (such as canned or frozen) or heated. Fresh foods also do not contain any preservatives.

2. Organic foods

Organic foods are foods that have been grown without most conventional pesticides, fertilizers, herbicides, antibiotics, or hormones and without genetic engineering or irradiation. Organic farmers use, for example, animal and plant manures to increase soil fertility and crop rotation to decrease pest problems.

3. Enriched foods

A food is considered enriched when nutrients are added to it to replace the same nutrients that are lost in processing. For example, when whole wheat is milled to produce white flour, nutrients are lost. By law, white flour must be enriched with several vitamins and iron to make up for some of these lost nutrients.

4. Fortified foods

A food is considered fortified when nutrients are added that were not present originally. For example, orange juice does not contain calcium, and so when calcium is added to orange juice, the product is called calcium-fortified orange juice. Similarly, salt is fortified with iodine, cooking oil is fortified with vitamin A etc.

5. Processed foods

The foods that are prepared using a certain procedure such cooking, freezing (frozen dinners), canning (canned vegetables), dehydrating (dried fruits), milling (white flour), culturing with bacteria (yogurt) are called processed foods. In some cases, processing removes and/or adds nutrients.

1.4 Whole grains vs. Refined/Processed grains

Whole grain products, such as whole wheat bread, brown rice, and oatmeal contain the entire kernel of the grain, including the bran, germ, and endosperm. Refined grain products, such as white bread and white rice, are made by removing the bran and the germ to produce a more uniform product. Removing the bran and germ, however, also removes most of the fiber and reduces the amounts of many of the vitamins and minerals. So, whole grain products are more nutritious than refined grain products.

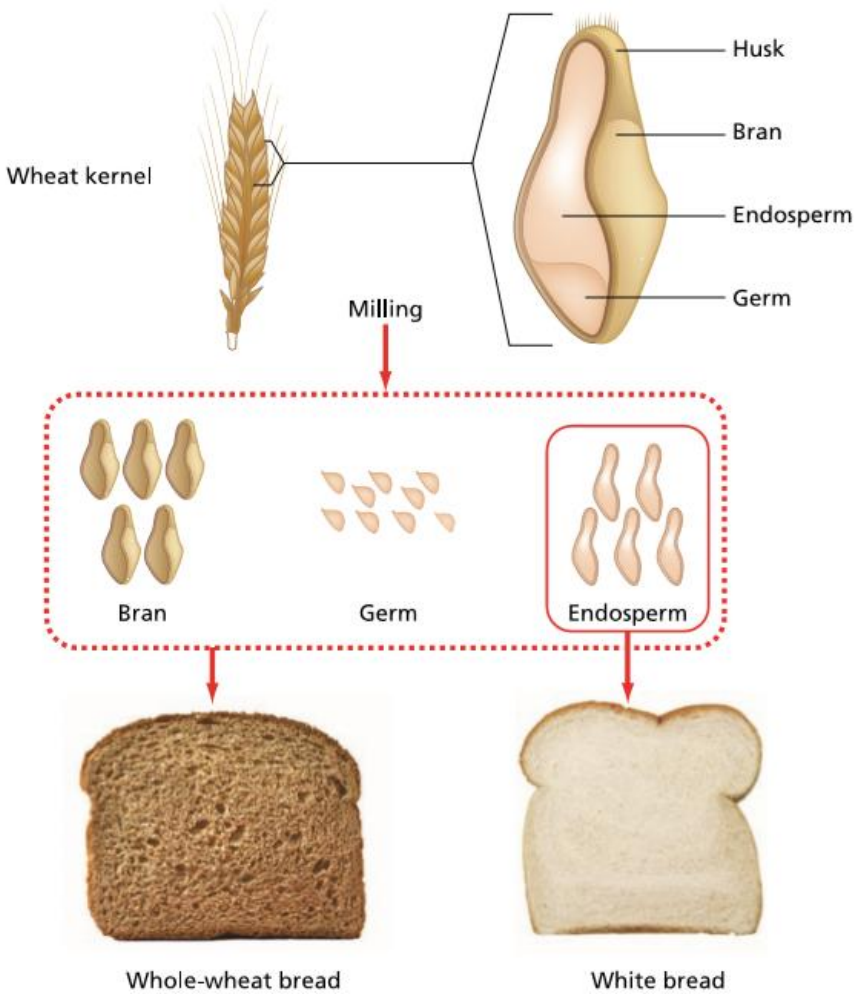


Figure 1.1: Parts of a whole wheat grain

The nutrient compositions of a whole grain (e.g., wheat) are given in the following table-

Parts	Nutrient content
Bran	Fatty acids (omega-3 and omega-6 fatty acid), vitamins (B_1, B_2, B_6, niacin, folate, B_5, E, K), minerals (Mg, Mn, P, Fe, Cu, Zn, Ca), proteins, carbs, dietary fibers
Endosperm	Carbs (starch), some proteins
Germ	B vitamins (folate, niacin), minerals (Mg, P, Mn, K, Se, Na, Zn, Fe), proteins, carbs, fibers, omega-3/6 fatty acid
Outer husk	Inedible part of a grain

1.5 Nutrient-Dense foods and empty-calorie foods

Nutrient-dense foods are those that contain a high amount of healthy nutrients but a low amount of energy, or calories per weight. Nutrient-dense foods are rich in vitamins, minerals, fiber, lean protein and healthy fats. Examples of **nutrient-dense foods** include fruits and vegetables, whole grains, low-fat or fat-free milk products, seafood, organ meats, lean meats, eggs, peas, beans, lentils and nuts.

Empty-calorie foods (opposite to nutrient-dense foods) are those that contain a high amount of calories but fewer amounts of healthy nutrients per weight. Examples of empty-calorie foods include soft drinks, baked goods, processed foods, ice cream, cookies, cake, chips, pizza, beer etc. Small amount of empty-calorie foods add a lot of calories in our diet opposite to nutrient-dense foods.

For example, if one compares the protein content of isocaloric portions of *dal*, bread and milk, one can see that *dal* has the highest nutrient density for protein, milk next and bread the least.

Food	***Calories***	***Protein (g)***
Dal	85	5.5
Milk	85	4.0
Bread	85	2.4

Thus nutrient density is an important aspect to be considered in selection of foods, especially for diet of children, pregnant women, nursing mothers and in therapeutic diets for patients.

1.6 Nutrition

All of us eat food. Food provides nourishment to the body and enables it to stay fit and healthy. The food that we eat undergoes many processes, like, first the food is digested, and then it is absorbed into blood and transported to various parts of the body where it is utilized. The waste products and undigested food are excreted from the body

NUTRITION = Eating → Digestion →Absorption →Transportation →Utilization

Nutrition is the process which includes consumption and digestion of foods, absorption of nutrients and finally utilization of absorbed nutrients for growth, development, and maintenance of a healthy life.

1.7 Optimum nutrition or Adequate nutrition

When all the essential nutrients (that body cannot synthesize) (details given below) are present in right proportion and in sufficient amount as required by our body is called optimum nutrition or adequate nutrition. Optimum nutrition is required to maintain good health. When almost all essential nutrients are present in the body below the required level, the condition is known as under-nourished. An under-nourished person manifests symptoms of deficiency diseases and feels unwell.

1.8 Nutrients

We enjoy eating foods because of its taste, smell, pleasure and filling hunger. But we do not think usually what chemicals foods actually contain. Foods contain different types of chemical substances; some of which are not important but others are critical to the body. Nutrients are chemical substances present in food that are needed for the cells of body for growth, maintenance, and repair. The six groups of nutrients found in foods are:

1. Carbohydrates
2. Lipids (including fats and oils)
3. Proteins
4. Vitamins
5. Minerals
6. Water

1.9 Classification of nutrients

Nutrients can be classified in several ways such as-

1. Based on functions
2. Based on chemical nature
3. Based on importance
4. Based on the amount required daily

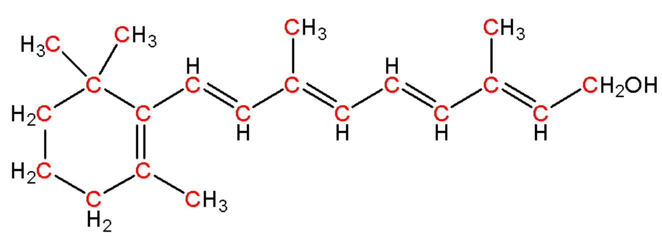
1. Based on functions

Major function	**Nutrients**
Produce energy	Carbohydrates, Fats
Build and repair body tissues	Proteins
Regulate biochemical reactions of the body	Vitamins, Mineral, Water

2. Based on chemical nature

i. Organic nutrients

The nutrients that contain carbon in their structural makeup are referred to as organic nutrients. They originate from living organisms. Examples-carbohydrates, lipids, proteins and vitamins.



Vitamin A

ii. Inorganic nutrients

Atom or molecule that does not contain carbon. Minerals e.g., Na (sodium), K (potassium), Ca (calcium), Mg (magnesium), Fe (iron) and H_2O (water) are the inorganic nutrients because they do not contain carbon and exist in simplest forms; so, they do not break down before absorption.

3. Based on importance

i. Essential nutrients

Those nutrients that cannot be synthesized by the body at all or can be synthesized insufficient quantities that cannot meet the body's requirement. Therefore, they must be supplied to our body through the diet. They are-

- 9 amino acids
- 2 fatty acids
- 13 vitamins
- 15 minerals

ii. Nonessential nutrient

Those nutrients that can be synthesized by the body in sufficient quantities when necessary are called nonessential nutrients. We may also get these nutrients from foods. Non-essential nutrients are as important as essential nutrients for normal body process. Simply unlike essential nutrients, they do not need to be present necessarily in the food. They are

- Certain amino acids
- Cholesterol
- Phospholipids etc

4. Based on the amount required daily

i. Macronutrients

Those nutrients that are needed in larger quantities every day are called **macronutrients.** They normally include carbohydrates, fats, proteins and water. Macronutrients (except water) are also called energy-providing nutrients. Carbohydrates, proteins, and fats are interchangeable as sources of energy. Water is the macronutrient needed in the largest amount-about 2-3 liters per day.

ii. Micronutrients

Those nutrients that are needed in smaller quantities every day are called **micronutrients** (e.g., minerals and vitamins). Unlike macronutrients, these are required in very minute amounts. Although, micronutrients are required in minute amount very day but their deficiency may lead to serious health consequences. In fact, most of nutrient related illnesses are due to the deficiency of micronutrients.

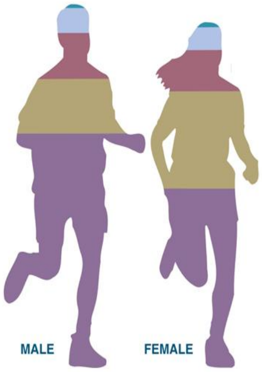
.

1.10 Nutrient (chemical) composition of human body

The approximate chemical compositions of adult human body are given in the following table.

Table 1.1: Chemical constituents of human body

Chemical constituent	% of Body weight
Water	60%
Proteins	17%
Fats	15%
Minerals	5%
Nucleic Acids	2%
Carbohydrates	only 1%



Infants and children have more water in their body as compare to adult. The second major nutrient (chemical compound) that makes up our body is protein. There are tens of thousands of different types of proteins in our body; most of them are enzymes. The third major nutrient after protein is lipids (fats). All 60 trillion cells of our body are made from lipids. Women have more lipids in their body as compare to men counterparts. We eat more carbohydrates containing foods than others. Surprisingly, our body contains very little carbohydrates, as carbohydrates turn to lipids/fats.

1.11 Food calories

The amount of energy in the form of heat required to raise 1°C temperature of 1 g of water is called one calorie. As calorie is relatively small unit, so to express energy content of foods **kilocalorie (kcal)** is often used. One kilocalorie (Kcal) is equal to 1000 calories (C). Thus, when we say that a food contains 400 calories, we are actually referring to kilocalories.

In our body, energy (calorie) is produced from the break down (catabolism) of carbohydrates, proteins, and fats. The energy content of carbohydrates, proteins and fats is summarized in the following table 1.2.

Table 1.2: Energy content of different macronutrients.

Nutrient	Energy content
Carbohydrate	4 kcal/g
Protein	4 kcal/g
Fat	9 kcal/g

When catabolic reactions occur, energy is released. About 40% of this energy is used for performing biological work. The remaining 60% is converted to heat; some of which is used to maintain normal body temperature and excess is lost to the environment.

1.12 Calculation of energy (Calories) in food

For example, suppose a chicken burger contains 50 g of carbohydrates, 25 g of fats and 15 g of proteins. Calculate the total number of kcal of the chicken burger.

Calculation:

Nutrient	Amount in burger	Energy content	Energy from burger
Carbohydrates	50 g	4 kcal/g	50g×4 kcal/g = 200 kcal
Fats	25 g	9 kcal/g	25g×9 kcal/g = 225 kcal
Proteins	15 g	4 kcal/g	15g×4 kcal/g = 60 kcal
Total energy from the chicken burger:			485 kcal
% of carbohydrates in the burger			200×100/485=41.2%
% of fats in the burger			225×100/485=46.4%
% of proteins in the burger			60×100/485=12.3%

Evaluation at the end of the lesson

Short answer questions:

1. Define foods.
2. Classify foods
3. Describe different types of foods.
4. What is nutrient dense and nutrient empty food?
5. Define nutrition and nutrient.
6. What is micro and macronutrient?
7. What is essential and nonessential nutrient?
8. Define organic and inorganic nutrients.
9. What is calorie? How can you calculate calorie of foods?

Lesson 2: Digestible Carbohydrates

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define carbohydrates and glycemic index;
- Classify carbohydrates and glycemic index foods;
- Calculate total glycemic index of foods;
- Describe the functions and deficiency diseases of digestible carbohydrates;
- Describe the consequences of lactose intolerances.

2.1 Introduction

Carbohydrate containing foods dominate daily diets across the world. The major portion of the calories of world population irrespective of rich and poor generally comes from carbohydrates. This has been true for centuries. Nonetheless, diets high in carbohydrates have been blamed for obesity, diabetes and hypertension. The health effect (good/bad) of carbohydrates depends on the type and source of the carbohydrate we eat.

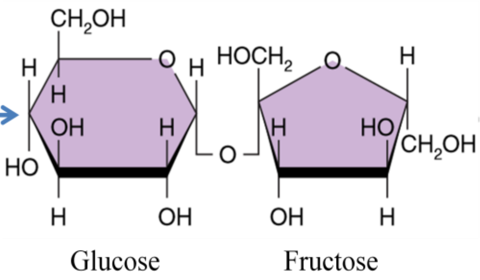
2.2 Definition of carbohydrates

Carbohydrates are a group of carbon, hydrogen, and oxygen containing organic compounds such as sugars, starches and fibers found mainly in fruits, grains, vegetables and milk products. The word "Carbo" means carbon and "Hydrate" means water. Generally, the ratio of hydrogen to oxygen atoms in carbohydrates is usually 2:1, the same as in water, for example, sugar ($C_{12}H_{22}O_{11}$). The term carbohydrate is synonymous with the Greek word "saccharide," which means sugar. Carbs are mainly found in plant foods. Most carbohydrates end in "ose".

Sucrose

$C_{12}H_{22}O_{11}$

(H:O=2:1)



2.3 Classification of carbohydrates

Carbohydrates can be classified in the following ways

a. Depending on the number of structural units

1. Monosaccharide: The basic structural unit of a carbohydrate is a single sugar unit called a monosaccharide (*mono,* meaning "one," and *saccharide,* meaning "sugar").

2. Disaccharides: When two monosaccharides are linked together, they form a disaccharide (di, meaning "two," and *saccharide*, meaning "sugar"). Mono-and disaccharides are sweet in taste and found in mainly plant sources.

3. Polysaccharides (complex sugar): Polysaccharides are just the polymer of monosaccharide units (poly means more than two). Technically, any carbohydrates with three or more monosaccharide units are considered as complex sugar or complex carbohydrates or polysaccharides which are nutritionally important.

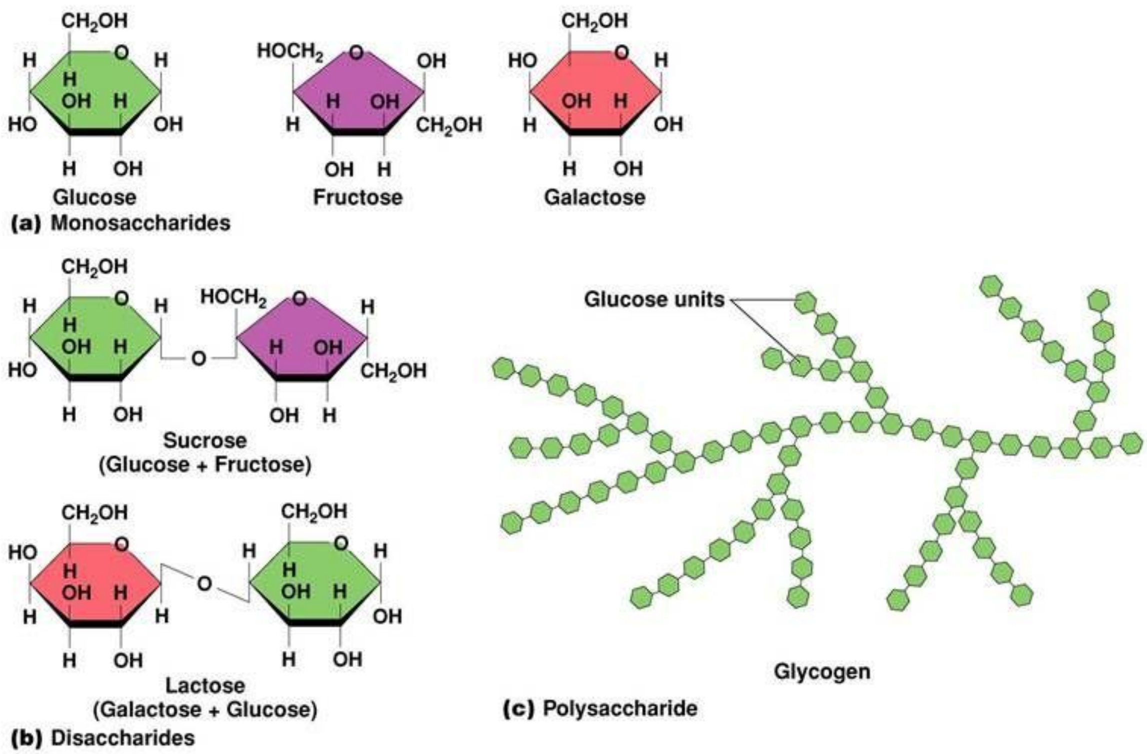


Figure 2.1: Different types of sugar.

b. Depending on the releasing characteristics

1. Fast-Releasing Carbohydrates

Fast-releasing carbohydrates are also known more simply as "sugars", absorb quickly in the blood stream after consumption. Fast releasing carbohydrates are grouped as either monosaccharides or disaccharides.

2. Slow-releasing carbohydrates

Polysaccharides are called slow-releasing carbohydrates as they digest slowly and release monosaccharide unit. They are long chains of monosaccharides that may be branched or unbranched. There are two main groups of polysaccharides: starches (amylose and amylopectin) and glycogen, and fibers (indigestible). In humans, the storage molecule of carbohydrates is called glycogen and in plants it is known as starches. Fiber cannot be broken down in the human body and passes through the digestive tract undigested.

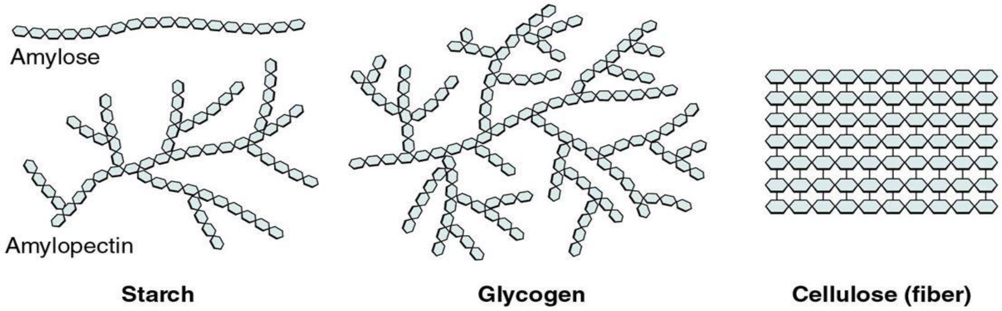


Figure 2.1 Structure of polysaccharides

2.4 General characteristics of carbohydrates

- Simple sugars are white, crystalline and sweet in taste
- Polysaccharides are white amorphous solids.
- Monosaccharides are soluble in cold and hot water but polysaccharides are partially soluble in hot water.
- All carbohydrates are compounds composed of (at least) C, H, and O.
- Carbohydrates are the most abundant compounds found in nature.
- The general formula for a carbohydrate is $(CH_2O)_n$ (Not all have this empirical formula).
- Produced by photosynthesis in plants from CO_2 and H_2O and energy.
- Are oxidized in living cells (respiration) to produce CO_2, H_2O, and energy.

Table 2.1: Sources of different classes of carbs are given in the following table:

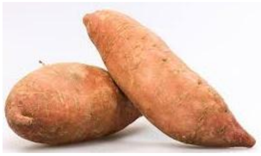
Sugar type	Chemical class	Class member	Sources
Simple sugar	Monosaccharide	Glucose (not occur single)	Corn syrup, processed foods
		Fructose (Fruit sugar)	Sweet fruits, honey
		Galactose (not occur single)	Milk, fermented starch products
		Ribose, Deoxyribose	DNA(deoxyribose)andRNA (ribose)
	Disaccharides	Sucrose (table/cane sugar) (Glucose+Fructose)	Sugar beets, sugar cane, molasses
		Lactose (milk sugar) (Glucose+Galactose)	Milk
		Maltose (malt sugar/corn sugar) (Glucose+Glucose)	Sweetener
Complex sugar	Starch (plant)	Amylose	Grains, legumes, and tubers
		Amylopectin	
	Glycogen (animal starch)	Polymer of glucose	Liver and muscle meats
	Dietary fiber (Plant)	Solube fiber	Citrus fruits, berries, oat, beans
		Insoluble fiber	Grains, fruits, vegetables, legumes

Table 2.2: Parcentage of carbs content in some important foods.


Rice (28%)


Wheat (24%)


Sugarcane (100ml)21%


Sweet potato (20%)


Potato (17%)


Ripen mango (17%)


Corn (19%)


Grape (18%)

2.5 Relative sweetness of different substances

Relative sweetness is defined as the ratio of concentrations of substances matching in sweetness with sugar (sucrose). Sucrose is the reference standard to which all other sweeteners are compared. Humans can recognize sweetness of about 1-2 % sucrose solution. Volunteers are often trained to quantitate sweetness on a 15 cm line scale, for convenience, using 2-15% sucrose solutions as references. Other sweeteners are then tasted at a series of dilutions to determine the concentration that is as sweet as a given percent sucrose reference. For example, if a 1% solution of sweetener X is as sweet as a 10% sucrose solution, then sweetener X is said to be 10 times as potent as sucrose.

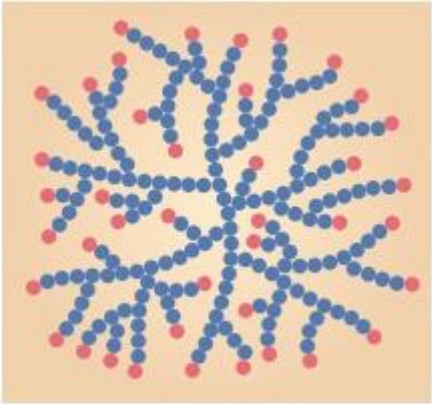
All the sugars are not same sweet; some are more sweeter than others (Table 2.2). The greater the relative sweetness the lesser amount is needed to taste sweet. Artificial sweeteners add essentially no calorie to our diet due to either a small amount is needed to produce sweet taste or pass through the body without being metabolized.

Some people use artificial sweeteners either for limiting sugar consumption for medical reasons, or for avoiding calories in fear of weight gain. As artificial sweeteners are not metabolized so they do not take part in dental cavities. Excessive consume of artificial sweetners may cause cancer.

Sources	Name of the substances	Relative sweetness
Natural sweeteners	Sucrose	1 (reference)
	Glucose	0.74
	Fructose	1.73
	Galactose	0.32
	Maltose	0.32
	Lactose	0.16
Artificial sweeteners (noncaloric)	Advantame	20,000
	Sucralose	600
	Saccharin	300
	Aspartame	200
	Cyclamate	30

2.6 Carbohydrate storage

Humans and animals store absorbed glucose from starches in the form of the very large molecule, glycogen. It is predominantly found in liver and muscle tissue in animals. A 70 kg adult person can store 350 g glycogen in skeletal muscle, 100 g in liver and 10 g as plasma glucose. Glycogen has many branches that allow it to break down quickly (the red dots indicate terminal glucose residues that are released from glycogen at one time) when energy is needed by cells in the body.



Glycogen

2.7 Glycemic index

2.7.1 Definition and introduction

The glycemic index is defined as a ratio of the incremental area under the blood glucose response curve (AUC) of a 50 g available carbohydrate portion of a test food to the same amount of available carbohydrate from a reference food (usually glucose/white bread) consumed by the same individual over a 2-h period, expressed as a percentage. The GI system allocates each food a score between 0 and 100. The higher the number, the greater the speed at which sugar enters into the bloodstream.

A food with carbohydrates that break down quickly during digestion and release glucose rapidly into the bloodstream tend to have a high GI and raise blood sugar levels higher and is suitable for energy recovery after exercise or for a person experiencing hypoglycemia; foods with carbohydrates that break down more slowly, releasing glucose more gradually into the bloodstream, tend to have a low GI.

After a meal containing carbohydrate, the plasma glucose rises, reaching a peak in about 15-45 min. depending on the rate of digestion and absorption. The plasma glucose returns to the fasting concentration within two to three hours. Plasma insulin concentration mirrors that of glucose, stimulating both glucose oxidation and glycogen storage.

In general, carbohydrate-containing foods rich in rapidly digestible starches (amylopectin) produce a high whereas foods rich in slowly digestible starches (amylose), fructose or contain substantial amounts of either insoluble fibre or fat produce a low glycaemic response. The term glycemic response is used to describe the rise and fall of blood glucose level and the duration over which it occurs.

2.7.2 Glycemic index (GI) determination protocol of foods

The steps of determining the glycemic index (GI) of foods are given below-

1. Healthy, overnight fasting volunteers are typically given a test food that provides 50 g of available carbohydrates and a control food (pure glucose/white bread) that provides the same amount of carbohydrate, on different days.
2. Blood samples for the determination of glucose concentrations are taken prior to eating, and at regular intervals (0, 15, 30, 45, 60, 75, 90, 120 min) for over period of 2 hrs after eating. The changes in blood glucose concentration over time are plotted as a curve.
3. The GI is calculated as the incremental area under the glucose curve (AUC) after the test food is eaten, divided by the corresponding AUC after the control food (pure glucose) is eaten. The value is multiplied by 100 to represent a percentage of the control food.

$$\text{Glycemic Index (GI)} = \frac{\text{Blood glucose AUC for test food}}{\text{Blood glucose AUC for reference food}} \times 100$$

4. In practice, the average GI value of a particular food is calculated based on the data collected from 10 healthy volunteers.

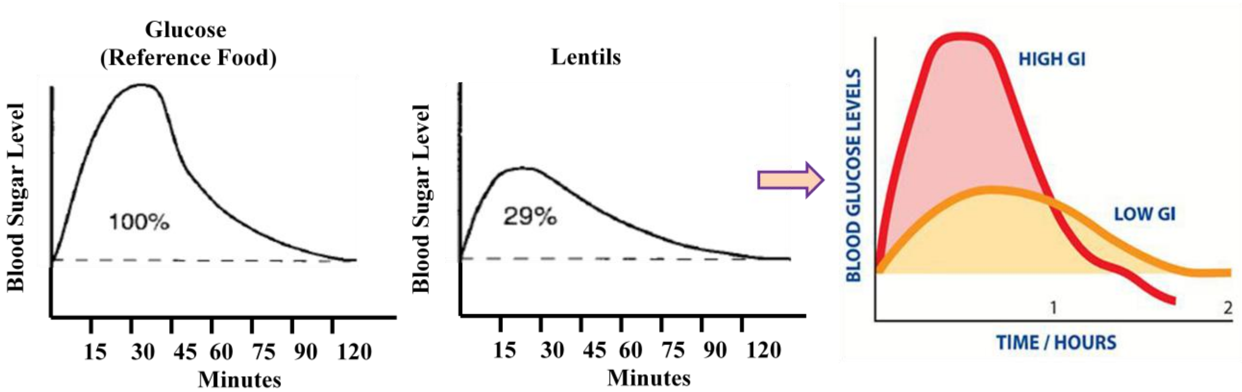


Figure: Blood glucose AUC for glucose and lentil

2.7.3 Classification of glycemic index

The glycemic index classification of foods can be used as a tool to assess potential rise of blood glucose levels after eating different carbohydrate-containing foods. GI of foods is critical for planning diet where glycemic (sugar) control is of importance such as losing weight and preventing obesity related chronic diseases such as such as diabetes and cardiovascular diseases.

Generally, GI of foods is determined separately. But most meals and snacks contain two or more foods. If we eat a food with a high GI, then it is better to combine it with a low-GI food to keep lower the overall GI of the meal or snack.

GI classification	GI range	Effect	Recommended consumption
Low	<55	Slow ↑ in blood sugar levels	Ideal for consumption
Medium	55-69	Moderate ↑ in blood sugar levels	Moderate amount
High	≥70	Rapid ↑ in blood sugar levels	Small amount

Table: *Glycemic index of different foods.

High GI (≥70)		**Low GI (≤ 55)**		Chickpeas	33
Foods	**GI**	**Foods**	**GI**	Soy milk	32
Maltose	105	Popcorn	55	Butter beans	31
Glucose	100	French fries	54	Pizza	30
Potato, white, baked	98	Ripe banana	52	Lentils	28
Oatmeal	87	Mango	51	Bareley	28
Cornflakes	82	Skim milk	50	Peach fresh	28
Pumpkin	75	Chocolate	49	Kidney beans	27
White rice, boiled	72	Carrots	49	Milk whole (av)	27
Watermelon	72	Sweet corn	48	Grapefruit	25
White bread	70	Sweet potatoes	48	Plum	24
Medium GI (56-69)		Peas (green)	48	Cherries	23
Foods	**GI**	Baked beans	48	Peanuts	21
Brown rice, boiled	68	Lactose	46	Ladies finger	20
Whole wheat bread	68	Grapes	43	Fructose	19
Soft drink, carbonated	68	Orange	43	Soya beans	18
Pineapple	66	Sugarcane juice	43	Broccoli	15
Sucrose	65	Green banana	42	Cucumber	15
Beetroot	64	Spaghetti	42	Lettuce	15
Raisins	64	Apple juice	41	Spinach	15
Dates	63	Haricot beans	38	Tomatoes	15
Multi-grain bread	62	Apple	40		
Ice cream	61	Pear	36		
Honey	58	Chocolate flavour	34		
Kiwifruit	58	Chocolate milk	35		
Potato chips	57	Fruit yougurt	35		
Orange juice	57	Chickpeas	33		
Papaya	56	Yoghurt flavour, low fat	33		
*Many healthy foods with low GI values are not in the database.					

Keep in mind, GI is only a rating of a food's carbohydrate content. Choosing low-carbs diets only based on GI and GL values may lead to over-consume fats and total calories. In other words just because the food has low GI one should not eat more of it, because it may not be healthy in terms high caloric and fat content.

2.7.4 Health Benefits of a low GI diet

- Consuming high GI foods will suddenly raise your blood sugar than normal level. Your body releases extra insulin to bring down your blood sugar level. If your body is asked to release extra insulin on a regular basis, it may lead to insulin resistance and ultimately type 2 diabetes. Low GI foods regulate blood sugar level more efficiently by increasing insulin sensitivity and thereby reducing the risk of type 2 diabetes.
- Everyone can benefit by eating a balanced diet of protein and fat, and foods that are lower GI index. Foods with a lower GI typically are high in fiber and nutrients and sustain your energy better throughout the day.
- Increase HDL cholesterol and reduces LDL cholesterol.
- Reduce cholesterol and other fats level and thereby reducing the risk cardiovascular diseases.
- Reduce risk of some cancers.
- Consuming low GI foods keeps us satiated longer because these foods are more slowly broken down for glucose utilization. Feeling satiety for longer demands less consumption of calories and thereby decreases weight.

2.7.5 Factors affecting GI

1. Processing such as grinding, cooking and boiling speed up digestion and absorption of carbohydrates and thereby elevate GI values. For example, the apple pie has a high GI compared to the fruit.
2. The addition of other foods that contain fiber, protein, fat and organic acids (vinegar) or their salts will generally reduce GI of the meal because they slow the digestive and absorption processes of carbohydrates. Chocolate has a lower GI than jelly beans.
3. Type of starch-some varieties of grain are digested and absorbed into the bloodstream more quickly. For example, short sticky rice has a higher GI than long basmati rice
4. Ripeness-the more ripe the fruit, the more sugar it contains-and the higher it's GI. For example, a very ripe banana has a higher GI than a slightly green one.
5. Refrigerating: when pasta, potatoes and rice are cooked, cooled and served in cold, they have more resistant starch and a lower glycemic index.
6. Foods with a higher fat content have a lower GI because fat tends to slow down the digestion of the foods. This shows that low GI foods are not necessarily healthy choices.
7. Glycemic response varies from person to person and also varies from one time of day to another.

2.8 Glycemic load (GL)

The glycemic load (GL) of food is a number that estimates how much blood glucose level of a person may raise by a given serving of a food after eating it. GL takes into account both glycemic index as well as amount of available carbohydrates in a given serving of a food. GL is calculated by the following formula-

$$GL = \frac{GI}{100} \times \text{Amount of available carbohydrates per serving of a food}$$

GL is calculated on a scale of zero to 60. A low GL is the better indicator that a food won't have much impact on blood glucose levels.

2.8.1 Calculation of GL of individual food

Problem 1: A white, medium size baked potato contains about 33 g available carbohydrates and GI is about 98. What will be expected GL from this baked after eating it?

Solution:

GL=GI/100×Available carbohydrate = 98/100× 33 ≈ **32 g**

Problem 2: A medium size apple contains about 15 g available carbohydrates and GI is about 40. What will be expected GL from this apple after eating it?

GL=GI/100×Available carbohydrate = 40/100× 15 = **6 g**

From these examples, we can see that potato will raise a blood sugar level five times more than that of the apple. When the amount of carbohydrate in a portion differs the best way to predict blood sugar effects will be via the GL.

A food with low GI may contribute huge GL to blood if it eats too much. On the contrary, a food with high GI may contribute low GL to blood if it eats a typical serving. For example, watermelon has a GI of 72, which is relatively high. However, a typical serving (1 cup diced) only has 10 g of carbohydrate (as watermelon contains 92% water) and GL =10 g×72/100≈7 g that will barely affect blood sugar. This is not common, as most foods with a high GI will have a correspondingly high GL.

GL values and their classification are given in the following table.

	Classification	GL
For a typical serving of a food	Low	≤10 g
	Moderate	11–19 g
	High	≥20 g
Individual meal (Total three meals/day)	Low	≤26 g
	Moderate	>26–≤40 g
	High	>40 g
Whole day	Low	< 80 g
	Moderate	80–120 g
	High	>120 g

For a 2000 kcal diet, the average daily glycemic load should not exceed 100. This means that meal should have a glycemic load equal to or less than 33.

2.8.2 Calculation of glycemic load of a mixed meal or diet

GL load of a mixed meal is the sum of the GLs for all foods consumed in that meal. Estimation of glycemic load of a mixed meal is particular important to know how much that meal may contribute the sugar load in your blood. For example, you have eaten a lunch with 3/2 cup white cooked rice, 1 cup cooked lentil soup (concentrated), 1 cup fried cauliflower florets, 1 medium size (60 g) cooked rui fish piece and 1 medium size apple, how much will be your total glycemic load?

Calculation of total glycemic load from your lunch are given in the following table-

S/N	Food	Portion size	Total carbs	Fiber	Available carbs	GI	GL	Classification
1	White cooked rice	3/2 cup	24 g	0 g	24 g	72	72×24/100=17g	Moderate
2	Cooked lentil soup (concentrated)	1 cup (40 g)	8 g	3 g	5 g	28	28×5/100=1 g	Low
3	Fried cauliflower florets	1 cup (85 g)	10 g	2 g	8 g	10	10×8/100=0.8g	Low
4	Medium size apple	1 (168 g)	23 g	4 g	19 g	40	40×19/100=8 g	Low
5	Cooked rui fish	1 piece	0	0	0	0	0	Low
							Total GL=27g	High

The recommended amount of available carbohydrate per meal is 45 to 60 g. Calculation of GL of a meal/diet based on published GI values of individual food and portion size may be inappropriate because factors such as food variety, ripeness, processing, and cooking are known to modify GL values. The estimation of meal GLs using published values of individual foods may be overestimated by 22 to 50% compared to direct measures of meal GLs.

2.8.3 Differences between GI and GL

Glycemic index	Glycemic load
1. GI is the ranking of carbohydrates containing foods based on how rapidly it is digested and released glucose (sugar) into the blood stream.	1. GL is used to predict immediate blood glucose response following consumption of a given serving of food.
2. It does not address the amount of available carbohydrates in a typical serving.	2. It addresses the amount of available carbohydrates in a typical serving.
3. Measures carbohydrates quality of food	3. Measures carbohydrates quality and quantity of food

Table 2.1: GI and GL values of some foods (GI of glucose=100).

Foods	GI	Typical Serving Size	Carbohydrate* per Serving (g)	GL per Serving**
White wheat flour bread	72	1 slice (30 g)	14	10
Brown, boiled rice	50	200 g (1 cup)	42	20
Coca Cola	54	1 cup (250 ml)	26	14
Whole barley flour bread	70	1 slice (30 g)	20	14
Whole wheat flour bread	68	1 slice (30 g)	11	7
Cornflakes	74	1 cup (30 g)	25	19
White boiled rice	72	1 cup (200) g	16	12
Basmati, white, boiled rice	58	¾ cup (150 g)	38	22
Cooked masoor dal soup (conc.)	28	1 cup (40 g)	5	2
Diced papaya, raw	56	1 cup (145 g)	12	7
Pineapple, raw	66	1 cup chunks (160 g)	18	12
Raisins	64	¼ cup (40 g)	30	19
Watermelon, raw	72	1 cup diced (140 g)	10	7
Apple, raw	40	1 medium size (100 g)	15	6
Orange, raw	42	1 medium size (130 g)	11	5
Orange juice	46	250 ml	26	12
Banana	55	1 medium (120 g)	20	11
Mango	56	120 g	14	8
Grapefruit	25	½ large (120 g)	12	3
Cooked chickpeas	10	1 cup (160) g	30	3
Soya beans, dried, boiled	15	150 g	6	1
Hamburger	68	95 g	25	17
Cashew nuts	25	50 g	12	3
Peanuts, crushed	8	50 g	4	0
Maggi noodles	48	180 g	23	11
Rice noodles	60	180	39	23
Popcorn	56	20 g	20	6
Potato crisps, plain, salted	51	50 g	24	12

Honey	74	1 tbsp (25 g)	21	16
Pumpkin peeled and boiled	66	80 g	18	12
Sweet corn	62	80 g	18	11
Carrots, raw, diced	35	1 medium (80 g)	6	2
Potato, white, baked	98	150 g	27	26
French fries	54	150 g	29	16
Boiled, mashed potato	71	150 g	20	14
Boiled, sweet potato	44	150 g	18	11
Peeled, baked, sweet potato	94	150	45	42
White bread	70	1 slice (30 g)	14	10
*Amount of available carbohydrates in a food serving that excludes indigestible carbohydrates, i.e., dietary fiber.**Numbers are rounded for simplicity's sake.				

2.8.4 Lowering dietary glycemic load

Some strategies for lowering dietary GL include:

- Increasing the consumption of whole grains, nuts (hazelnuts, almonds, walnuts, Brazil nuts etc), legumes (beans, lentils), seeds (chia, flaxseeds, hemp, sesame, pumpkin, sunflower) fruits (guavas, apples, apricots, pears etc), non-starchy (vegetables (asparagus, beans, broccoli, cabbage cauliflower, carrots, radishes, tomato etc).
- Decreasing the consumption of starchy, moderate- and high-GI foods like potatoes, white rice, and white bread
- Decreasing the consumption of sugary foods like cookies, cakes, candy, and soft drinks.
- Eating high GI foods with low GI foods at the same time has the effect of 'averaging' the GI. For example, eating cornflakes (a higher GI food) with milk (a lower GI food) will reduce the overall effect of the cornflakes on blood glucose levels.
- All foods can fit but choose healthy foods more frequently than less healthy choices.
- Choice foods that are less processed.

2.9 Functions of digestible carbohydrates

- ☞ Provide energy as a primary source to the body.
- ☞ Provide energy to red blood cells, brain tissues and other nervous tissues.
- ☞ Helps in efficient metabolism of lipids and proteins.

2.10 Deficiency diseases of digestible carbohydrates

Deficiency of digestible carbohydrates-

- ☞ May lead to tired, irritable, and shaky.
- ☞ Forces the body to break down stored fat to produce energy. Emergency production of energy leads to incomplete fat oxidization in the cells and substances called ketones are formed. Ketones area acids that accumulate in the blood and urine, upsetting the acid-base balance. Such a condition is called ketoacidosis. Ketoacidosis leads to the formation of ketoacids

which decreases the pH of brain cells and other parts of the body. Decrease in pH leads to denature of proteins which can lead to coma and even death.

- Also forces body to produce its own glucose from protein through a process called gluconeogenesis. It involves breaking down the proteins in blood and tissues into amino acids, then converting them to glucose. Using proteins for energy hampers to make new cells, repair tissue damage, support the immune system, or perform any of their other functions.

2.11 Lactose intolerance

Lactose is actually made of glucose and galactose joined together and present in milk produced by any animal. When we drink milk or eat any dairy product containing lactose, first it is digested into glucose and galactose by hydrolysis reaction in presence of enzyme, lactase in our digestive system before absorption.

Some people by genetic reasons may have deficiency of the enzyme, lactase or some people as they get older, their digestive system loses the ability to make this enzyme. So, when they drink milk, they cannot digest lactose into glucose and galactose; this is called lactose intolerance. Lactose is accumulated in the gut of lactose intolerance people and subsequently bacterial fermentation lead to the production of H_2 & CO_2 gases and low molecular weight acids like acetic acid, propionic acid & butyric acids. These acids are osmotically active which may lead to abdominal cramps, flatulence and diarrhea. Those who are suffering from lactose intolerance should either drink milk with lactase enzyme or lactase free or avoid drinking milk.

Evaluation at the end of the lesson:

Short Answer Questions:

1. Define carbohydrates.
2. Classify carbohydrates.
3. Write down the sources of different carbohydrates.
4. Discuss the functions of carbohydrates.
5. Describe the functions and deficiency diseases of digestible carbohydrates.
6. Why lactose intolerance occurs?

Lesson 3: Dietary fibers (Non-digestible carbohydrates)

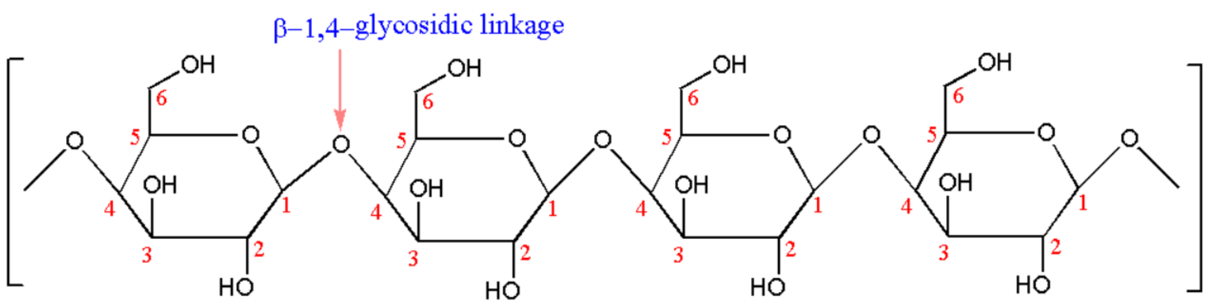
Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define dietary fibers;
- Classify dietary fibers;
- Describe health benefits and deficiency diseases of dietary fibers.

3.1 Dietary fibers

Dietary fiber (complex carbohydrates/polysaccharide), also called roughage, is the non-digestible parts of plants that form the support structures of leaves, stems, and seeds. They are polysaccharides (except lignins), highly branched, cross-linked and have β-1,4-glycosidic linkage among glucose units. Dietary fibers are considered as the plant's "skeleton''. They are non-digestible because human do not have enzyme to break down β-1,4-glycosidic linkage into absorbable form glucose. So, dietary fibers do not contribute energy to our diet as they pass through digestive tract without being absorbed.



Cellulose

3.2 Classification of dietary fibers

Dietary fibers can be classified based on physical properties-

1. **Soluble fibers:** They are soluble in water and become viscous, forming gel when wetted by water adding bulk to stools which serves to slow the rate at which stool passes through the small intestine. Examples of soluble fibers: pectins, gums and mucilages.

2. **Insouble fibers:** This type of fibers are not soluble in water; they are usually nonviscous, increases stool bulk and promotes to pass stool quickly through the intestine. Examples of insoluble fibers: cellulose, hemicelluloses and lignins

Table 3.1: Sources of dietary fibers

Dietary fibers	Members	Sources
Water insoluble/ less fermentable	Cellulose	Component of plant cell walls abundant in whole grains, legumes, the skin of fruits and vegetables
	Hemicelluloses	Often associated with cellulose
	Lignins (Noncarbohydrate)	Found in woody parts (seeds of fruits, bran, husk of grains), carrots and pears
Water soluble/viscous More fermentable	Gums	Seeds
	Pectins	Pears, apples, guavas, plums, gooseberries, and oranges and other citrus fruits contain large amounts of pectin,
	Mucilages	Psyllium husk (isabgul), seaweeds, oats, barley, legumes, eggplants

There is another type of fiber called functional fiber which is either extracted from plants or manufactured in laboratory. Functional fiber is added to food or supplied as supplement to prevent constipation or lowering blood glucose levels/cholesterol after meals. But they lack of nutrients and necessary phytochemicals that come with the fiber found in whole foods. For example, polydextrose psyllium β-glucans, cellulose, guar gum, inulin, resistant maltodextrin.

Most foods of plant origin contain mixtures of soluble and insoluble fibers. List of some high dietary fibers containing foods are given below (Table 3.2).

Table 3.2: Dietary fiber content of different foods (g/100 g edible portion)


Raspberries (6.5 g)


Lentils (7.9%)


Chickpeas (7.6%)


Kidney Beans (6.4%)


Oats (10.6%)


Popcorn (14.5%)


Almonds (12.5%)


Chia seeds (34.4%)


Whole wheat (13%)


Ladies finger (4.2%)


Broccoli (2.6%)


Green peas (6%)

Table 3.3: Typical serving size and fiber content of some foods

Fruits	**Serving size**	**Total fiber (grams)***
Raspberries	1 cup	8.0
Pear	1 medium	5.5
Apple, with skin	1 medium	4.5
Banana	1 medium	3.0
Orange	1 medium	3.0
Strawberries	1 cup	3.0

Vegetables	Serving size	Total fiber (grams)*
Green peas, boiled	1 cup	9.0
Broccoli, boiled	1 cup chopped	5.0
Turnip greens, boiled	1 cup	5.0
Brussels sprouts, boiled	1 cup	4.0
Potato, with skin, baked	1 medium	4.0
Sweet corn, boiled	1 cup	3.5
Cauliflower, raw	1 cup chopped	2.0
Carrot, raw	1 medium	1.5
Tomato, raw sliced	1 cup (180 g)	2.5
Raw, chopped cabbage	1 cup (89g)	2.5
Raw okra/ladies finger	1 cup (100 g)	3.5

Grains	Serving size	Total fiber (grams)*
Spaghetti, whole-wheat, cooked	1 cup	6.0
Barley, pearled, cooked	1 cup	6.0
Bran flakes	3/4 cup	5.5
Quinoa, cooked	1 cup	5.0
Oat bran muffin	1 medium	5.0
Oatmeal, instant, cooked	1 cup	5.0
Popcorn, air-popped	3 cups	3.5
Brown rice, cooked	1 cup	3.5
Bread, whole-wheat	1 slice	2.0
Bread, rye	1 slice	2.0

Legumes, nuts and seeds	Serving size	Total fiber (grams)*
Split peas, boiled	1 cup	16.0
Lentils, boiled	1 cup	15.5
Black beans, boiled	1 cup	15.0

Baked beans, canned	1 cup	10.0
Chia seeds	28 g	10.0
Almonds	28 (23 nuts)	3.5
Pistachios	28 (49 nuts)	3.0
Sunflower kernels	28 g	3.0

*Rounded to nearest 0.5 gram.

3.3 Fate of dietary fibers

Soluble and insoluble fibers behave somewhat differently in the gastrointestinal tract. Soluble fiber absorbs water and form viscous solutions that slow the rate at which nutrients are absorbed from the small intestine. Because neither soluble nor insoluble fiber can be digested in the small intestine and so they travel into the large intestine. Bacteria in the colon digest some soluble fiber to produce gas and fatty acids (propionic acid & butyric acids); fatty acids can be absorbed into the body and used as an energy source. Some soluble fiber-and most insoluble fiber-is excreted in the feces.

3.4 Health benefits of dietary fibers

A diet high in fiber has numerous health benefits related with gastrointestinal tract and chronic diseases; some of which are given below-

1. Prevents hemorrhoids and constipation

Consuming high fiber containing diet produces soft and large volume stool which reduces pressure for defecation. This reduces the incidence of constipation (dry and hard stool which difficult to pass) and prevents hemorrhoids (swellings of the veins in the rectal or anal area).
Adds bulk to the stool, which is easier to pass, hence decreases the chance of constipation.

2. Prevention of diarrhea

Soluble fiber can absorb excess fluid in the bowel. In case of loose watery stools, soluble dietary fiber can solidify loose stool because it absorbs water and adds bulk to stool.

3. Increase muscle strength of colon

Dietary fibers increase the amount and volume of stool. The presence of larger and softer stool in the colon stimulates **peristalsis** (rhythmic muscle contraction) that pushes the stool onwards and makes it easier to eliminate. The continuous pushing action of colon (gut) muscles makes it stronger.

4. Reduce the risk of heart disease

Soluble fibers due to its gel forming capacities increase the viscosity of the content of the small intestine. Absorption of fats (cholesterol, fatty acids and lecithin) comes from either foods or bile secretion is either blocked or slowed absorption into the bloodstream due to increase viscosity of the gastrointestinal content by soluble fibers and promotes fecal excretion and thereby reduces the risk of heart disease. Study shows that every additional 10 grams of fiber in the diet reduced the incidence of heart disease by 17%.

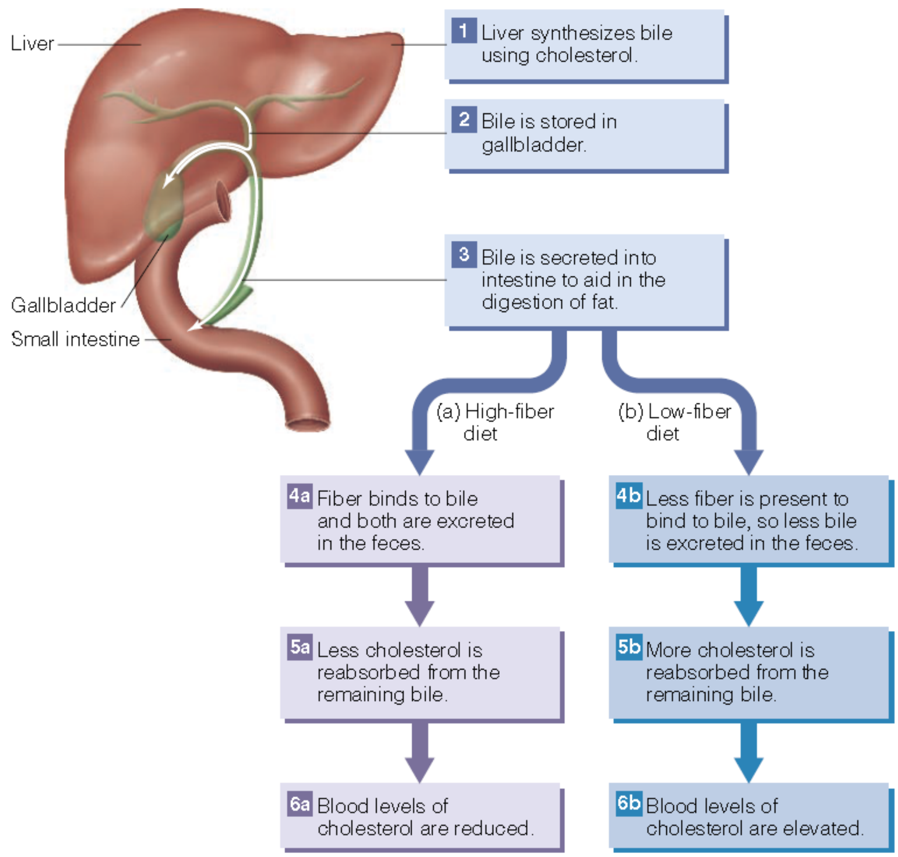


Figure 3.1: Mechanism of reduction of blood cholesterol by dietary fibers.

5. Prevent and manage diabetes

High-fiber diet slows the absorption of glucose from carbohydrate-containing meal by increasing viscosity of gastric and intestinal contents. Therefore, blood glucose levels will rise more slowly and less amount of insulin needed to keep glucose level in the normal range. This beneficial effect manages blood glucose level in individuals with diabetes and over the long term may reduce the risk of developing type 2 diabetes.

6. Enhance weight loss

Fibers slows gastric emptying rate which keeps you full for a longer time. This helps to prevent overeating. High fiber diet is low in calories and fats. Fibers also inhibit fats absorption. These combined effects of fibers enhance weight loss.

7. Prevent colon cancer

Fiber dilutes the intestinal contents and speeds up evacuation. These effects decrease exposure time of the potentially cancer-causing substances present in the intestinal contents to the lining cells of the colon. This role of fiber may reduce the incidence of colon cancer. The bulk and water of the feces may dilute the carcinogens to a nontoxic level.

8. Favour growth of beneficial bacteria

Favour the selection of beneficial gut bacteria such as *Bifidobacteria*, *Lactobacilli* and *Streptococci.* These bacteria detoxify harmful bacteria and synthesize beneficial compounds (e.g., vitamins) for us.

3.5 Deficiency diseases of dietary fibers

- Increase constipation and hemorrhoids.
- Increase risk of type 2 diabetes.
- Increase risk of heart disease due to increase cholesterol level.
- Increase body weight.
- Lack of fibrous foods increases the hardness of the stool. To eliminate the hard stool, large intestine needs to generate a great deal of pressure which weakens intestinal walls. The weakened intestinal wall then develops small outpouchings and form pockets (diverticula) (Figure 3.2) in which fecal material becomes trapped, infected and inflamed.

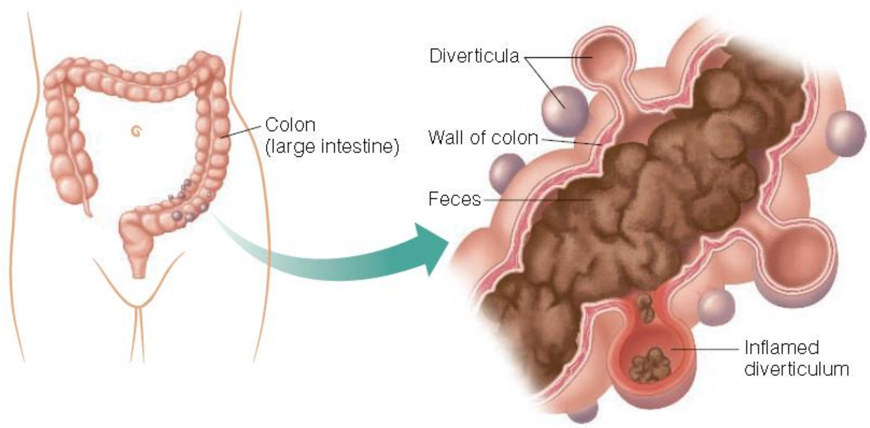


Figure 3.2: Diverticulosis occurs when bulging pockets form in the wall of the colon.

3.6 Problems with High-Fiber Diets

Consuming high fiber diet without drinking enough fluid/water can cause constipation (the stool becomes hard and difficult to eliminate). A sudden increase in fiber intake with plenty of fluid can cause abdominal discomfort, gas, and diarrhea due to the bacterial breakdown of fiber.

Too much fiber may decrease absorption of micronutrients (vitamins and minerals- zinc, calcium, magnesium, and iron) either by binding to them or by simply speeding the passage through the intestinal tract and before being absorbed which may lead to deficiencies. Children need high amount of nutrients but their stomach is small. Children consuming very high fiber containing foods may feel full before consuming enough food to meet their energy and nutrient needs.

3.7 Recommended amount of fiber intake

Dietary reference intakes (DRIs) recommend a daily intake of 25 grams for young adult women and 38 grams for young adult men. This recommendation refers to total fiber, which includes dietary fiber and functional fiber.

Life stage	Age	Males (g/day)	Females (g/day)
Infants	0-6 months	Not determined	Not determined
Infants	7-12 months	Not determined	Not determined
Children	1-3 yrs	19	19
Children	4-8 yrs	25	25
Children	9-13 yrs	31	26
Adolescents	14-18 yrs	38	26
Adults	19-50 yrs	38	25
Adults	51 yrs and older	30	21
Pregnancy	All ages		28
Breast feeding	All ages		29

Evaluation at the end of the lesson:

Short Answer Questions:

1. Define dietary fibers;
2. Classify dietary fibers;
3. Write down the sources of dietary fibers
4. Describe health benefits and deficiency diseases of dietary fibers.

Lesson 4: Lipids

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define lipids;
- Classify lipids;
- Describe the importance of essential fatty acids.
- Describe health benefits and deficiency diseases of lipids.

4.1 Lipids

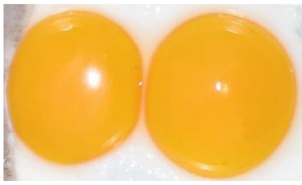
Lipids (Greek meaning fats) are a diverse group of organic compounds that are mainly insoluble in water and soluble in organic solvents such as hexane, chloroform, benzene, etc. Like carbohydrates, fats are composed of carbon, hydrogen but with a substantially lower proportion of oxygen.

4.2 Sources of Lipids

Common sources of lipids are fried foods, vegetable oil, butter, whole milk, cheese, cream cheese, nuts, egg, ghee, margarine, meats, and fish. Some of the healthy sources of lipids are given below


Avocado


Salmon


Egg yolk


Olives


Chia seeds


Nuts


Sunflower seeds


Peanut butter

4.3 Types of lipids

There are different types of lipids such as

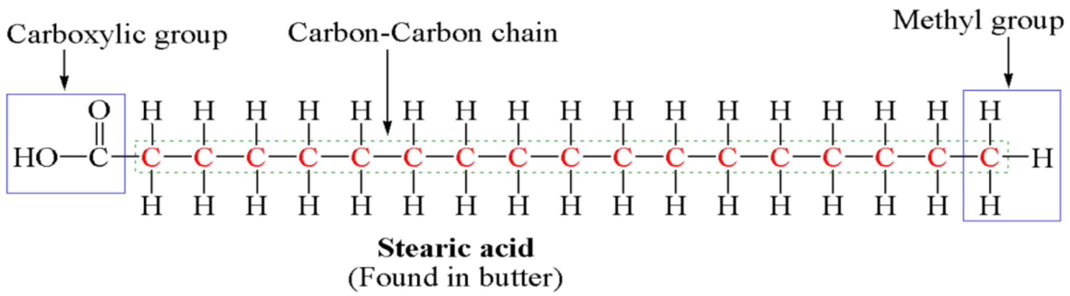
1. Fatty acids
2. Hydrogenated fats

3. Triglycerides
4. Phospholipids
5. Cholesterol and other sterols
6. Lipoproteins

Among them, fatty acids and triglycerides are nutritionally important as sources of energy and essential fatty acids; Triglycerides make up more than 95% of lipids in the diet.

1. Fatty acids

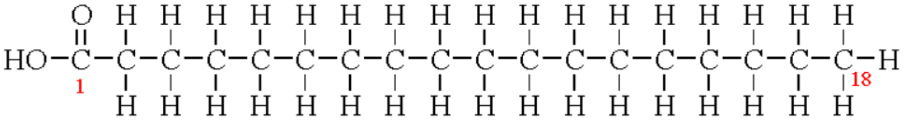
Fatty acids (FAs) are the simplest form of lipids. They are made of carbon chains with a methyl group at one end (CH_3) and a carboxyl group at the other end (COOH). Fatty acids in foods can differ from one another in two important ways-carbon chain lengths (4-24) and degree of saturation. Short-chain fatty acids (SCFA) are fatty acids with up to 5 carbon atoms, medium-chain fatty acids (MCFA) have 6 to 12, long-chain fatty acids (LCFA) 13 to 21, and very long chain fatty acids (VLCFA) are fatty acids with more than 22 carbon atoms. The majority of naturally occurring fatty acids, both in the diet and in the body, contain 16-18 carbon atoms.



Structure of fatty acid

Depending on the degree of unsaturation, fatty acids can be classified as

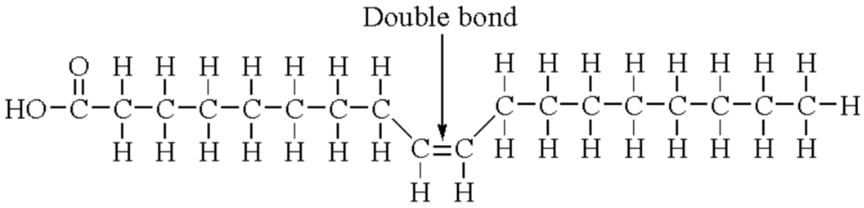
i. Saturated fatty acids (SFAs): SFAs are those where each of its carbon atoms is filled (saturated) to capacity with hydrogen atoms. All carbon atoms in such a fatty acid chain are bonded with single bonds. They are generally solid at room temperature. Saturated fats are found primarily in animal foods such as meat, milk, and cheese; also found in palm oil, palm kernel oil, and coconut oil (also called tropical oils because they are from plants that commonly grow in tropical climates).



Stearic acid (saturated) (Found in butter)

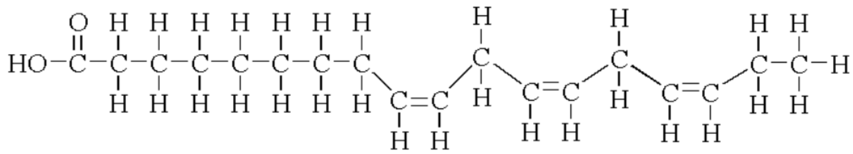
ii. Unsaturated fatty acids (USFAs): The unsaturated fatty acid has a kink (bend) at the site of the double bond (C=C). They are generally liquid at room temperature. Unsaturated fatty acids can be further divided into

a. Monounsaturated FAs: Those fatty acids having only one double bond between carbon atoms in the hydrocarbon chain are called monounsaturated (mono means one) FAs. Oils that are high in monounsaturated fatty acids include olive (75 percent of its fat is monounsaturated), peanut, and canola oils.



Oleic acid

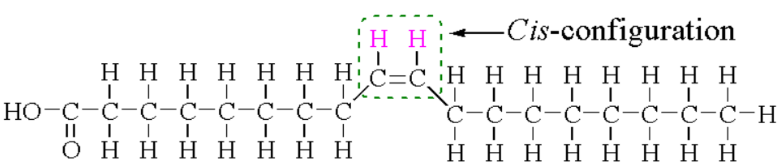
b. Polyunsaturated FAs: Those fatty acids having more than one double bond between carbon atoms in the hydrocarbon chain are called polyunsaturated FAs (poly means more than one). Good sources of polyunsaturated fatty acids include corn, soybean, and safflower oils.



α-linolenic acid

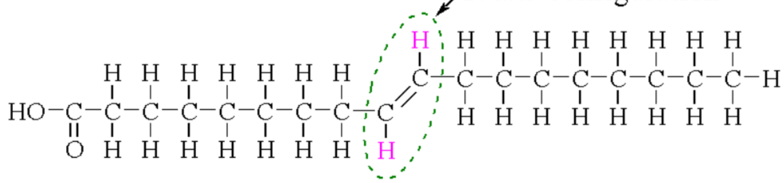
c. *Cis* and *Trans*-fatty acids

***Cis*-fatty acids**: In *cis*-fatty acids, the hydrogen atoms are on the same sides of the double bond of an unsaturated fatty acid. Most unsaturated fatty acids in natural foods (especially plant foods) have the *cis* configuration. Cis fatty acids have typical kink (bend) in the molecule.



***Cis*-oleic acid**

***Trans* fatty acid:** In *trans*-fatty acids the hydrogen atoms are on opposite sides of the double bond of an unsaturated fatty acid. *Trans* fatty acids have structure more closely resemble saturated fatty acids. *Trans* fatty acids are found in small amounts in milk and meat (3-10% of total fats) obtained from ruminant animals and in larger amounts in partially hydrogenated unsaturated fatty acids in oil (up to 60%; e.g., margarine) and repeatedly heated frying oil (e.g., oil reused in fast food and thereby in snack food, biscuits, chanachur, chips etc). Daily consumption about 5 g *trans* fats increase the risk of heart diseases, type 2 diabetes and cancer in adults by 23 %.



Trans-oleic acid

d. Essential and nonessential fatty acids: The body is capable of synthesizing most of the necessary fatty acids from absorbed nutrients. These fatty acids are known as **nonessential fatty acids.** However, only two fatty acids, α-linolenic (ω-3) and linoleic (ω-6) cannot be synthesized because the body cannot add a double bond in carbon-carbon of a fatty acid prior to the 9^{th} carbon from the methyl carbon (ω-end) and hence called **essential fatty acids,** (Table 4.2 and Figure 4.2). In other words, body cannot create double bonds at ω-3 and ω-6 positions. As EFAs cannot be synthesized by the body, so they must be obtained through diet or supplements.

The LC-PUFA (C-20) of the omega-3 and omega-6 fatty acid families is considered as conditionally essential fatty acids if the endogenous production from the parent fatty acids is inefficient to meet nutritional requirements. This may happen in certain disease conditions or developmental stage. The most important conditionally EFAs are EPA, DHA and ARA.

Table 4.1: Sources of essential fatty acids, ω-3 and ω-6

	ω-3 fatty acids	**ω-6 fatty acids**
Short chain form from plants		
Name	α-linolenic acid	Linoleic acid
Main sources	Green leafy vegetables, legumes, fatty fish, nuts, seeds, whole grain, and vegetable oil (such as soybean, canola, wheat germ, walnuts and flaxseed)	All nuts, seeds and vegetable oils (corn, sunflower, safflower, soybean)
Long-chain form from animals		
Names	EPA (eicosapentaenoic acid), DHA (docosahexaenoic acid)	Arachidonic acid (ARA)
Main sources	Oily fishes (salmon, tuna, sardines), red meat, egg yolk, human milk or can be synthesized from α-linolenic acid	Fish, meat and egg yolk or can be synthesized from linoleic acid

ω-3 Essential Fatty Acid:

α-linolenic acid (ALA, C18:3, ω-3)

Conditionally ω-3 Essential Fatty Acids :

Eicosapentaenoic acid (EPA, C20:5, ω-3)

Docosahexaenoic acid (DHA, C22:6, ω-3)

ω-6 Essential Fatty Acid:

Linoleic acid (LA, C18:2, ω-6)

Conditionally ω-6 Essential Fatty Acid:

Arachidonic acid (ARA, C20:4, ω-6)

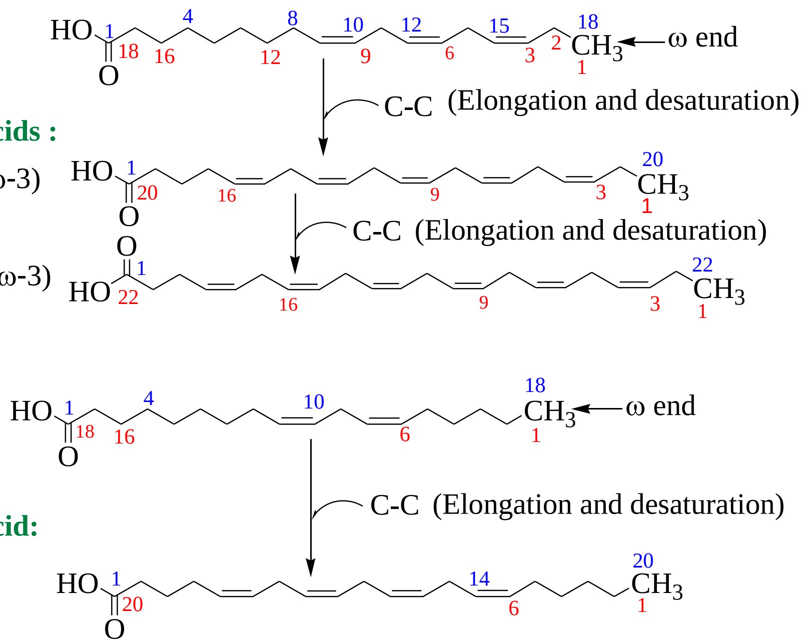


Figure 4.1: Chemical structures of essential and conditionally essential fatty acids.

Table 4.1: Fatty acid content in different dietary fat sources per 100 g.

Dietary fat	Saturated fats	MUFAs	ω-6 FAs	ω-3 FAs	ω-6:ω-3
Chia seed oil	10	7	19	64	1:3
Flaxseed oil	9	18	16	57	1:4
Canola oil	7	61	21	11	2:1
Sunflower oil	12	16	57	1	57:1
Corn oil	13	29	57	1	57:1
Olive oil	15	75	9	1	9:1
Soybean oil	15	23	54	8	7:1
Coconut oil	92	6	2	-	2:0
Palm oil	51	39	10	-	10:0
Butter	68	28	3	1	3:1
Safflower oil	8	77	14	1	14:1
Peanut oil	19	48	33	-	33:0
Cotton seed oil	27	19	54	-	54:0
Sesame oil	15	42	42	<1	42:0
Avocado	13	76	10	<1	10:0.5
Mustard oil	12	60	15	6	2.5:1
Rice bran oil	25	38	35	2	17.5:2
Groundnut oil	20	48	32	-	32:0

2. Hydrogenated fats

Hydrogenation (hardening) is the process of adding H-atom to the double of unsaturated fatty acids in vegetable oils. This process turns unsaturated vegetable oils into saturated fats. The hydrogenation process tends to flip some of the carbon-carbon double bonds into the "*trans*" form. Hydrogenated fats are solid at room temperature which may contain up to 45 % *trans* and are less likely to spoil. Margarine is made in this way from corn which may contain 15% *trans* fats. Trans fats have numerous negative health effect (see above *trans* fatty acids).

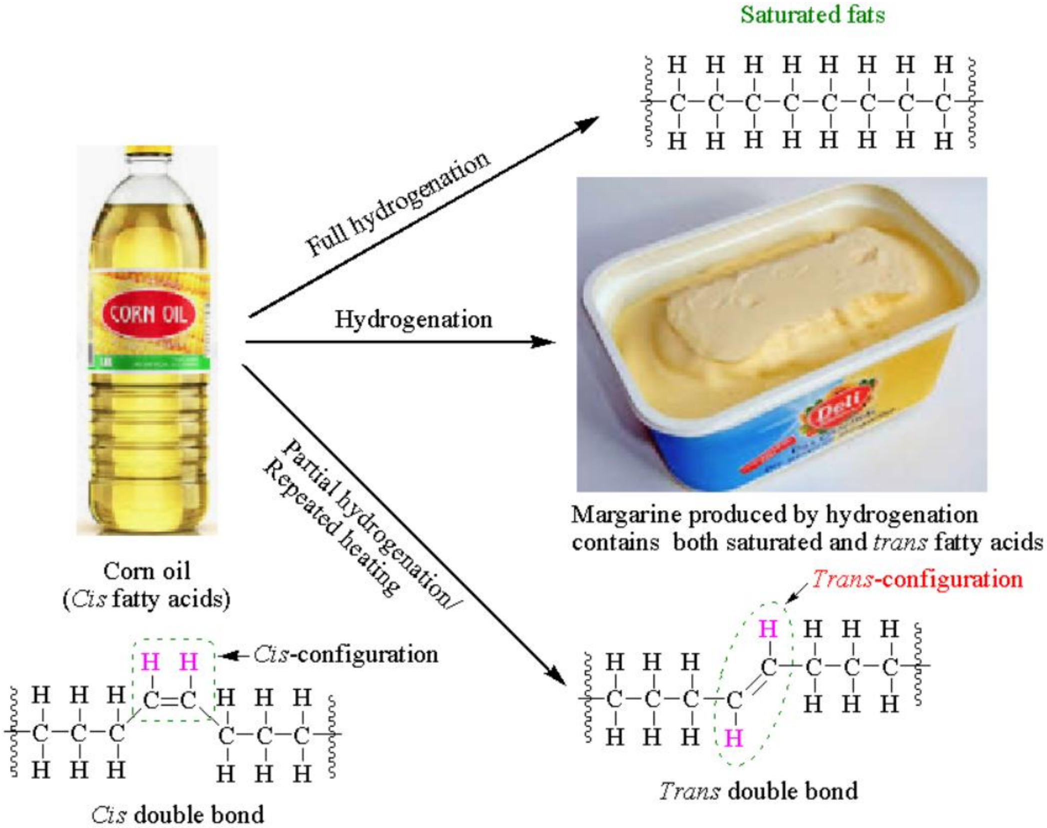
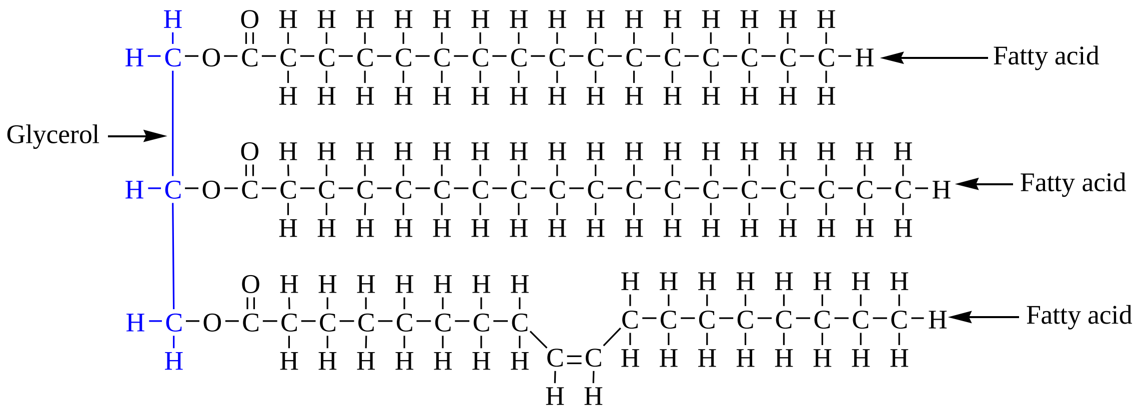


Figure 4.1: Conversion of *cis* FA to saturated and *trans* fatty acids.

3. Triglycerides (Triacylglycerol)

The most plentiful lipids in our body and diet are triglycerides. A triglyceride is a molecule consisting of three (tri) fatty acids attached to a three-carbon glycerol backbone. When only one fatty acid combines with glycerol then it is called monoglyceride and when two is called diglycerides. Their fatty acid composition determines their taste, texture, physical characteristics, and health effects.



Structure of triglyceride

Triglycerides are two types-

i. Fats: When triglycerides containing a high proportion of saturated fatty acids are referred to as fats. Saturated fats are found primarily in animal foods such as meat, milk, and cheese; also found in palm oil, palm kernel oil, and coconut oil (also called tropical oils because they are from plants that commonly grow in tropical climates).

ii. Oils: When triglycerides containing a high proportion of unsaturated fatty acids are referred as oils. Oils are liquid at room temperature. Dietary sources of unsaturated fatty acids are olive oil, canola oil, peanut oil, etc.

4. Phospholipids (PLs)

Phospholipids consist of a glycerol backbone with fatty acids attached at the first two carbons and a nitrogenous base that contains a phosphate group attached at the third carbon. This unique structure makes phospholipids water soluble due to **amphiphilic** in nature; fatty-acid sides are hydrophobic (dislike water) and the phosphate group is hydrophilic (likes water).

Cell membranes consist of two layers of phospholipid molecules called a lipid bilayer. Phospholipids help to transport substances into and out of the cell. It acts as emulsifiers which break oils into small droplets so they can mix with water; also help to digest dietary fats. They are abundant, for example, in egg yolks, peanuts, soybeans and meat.

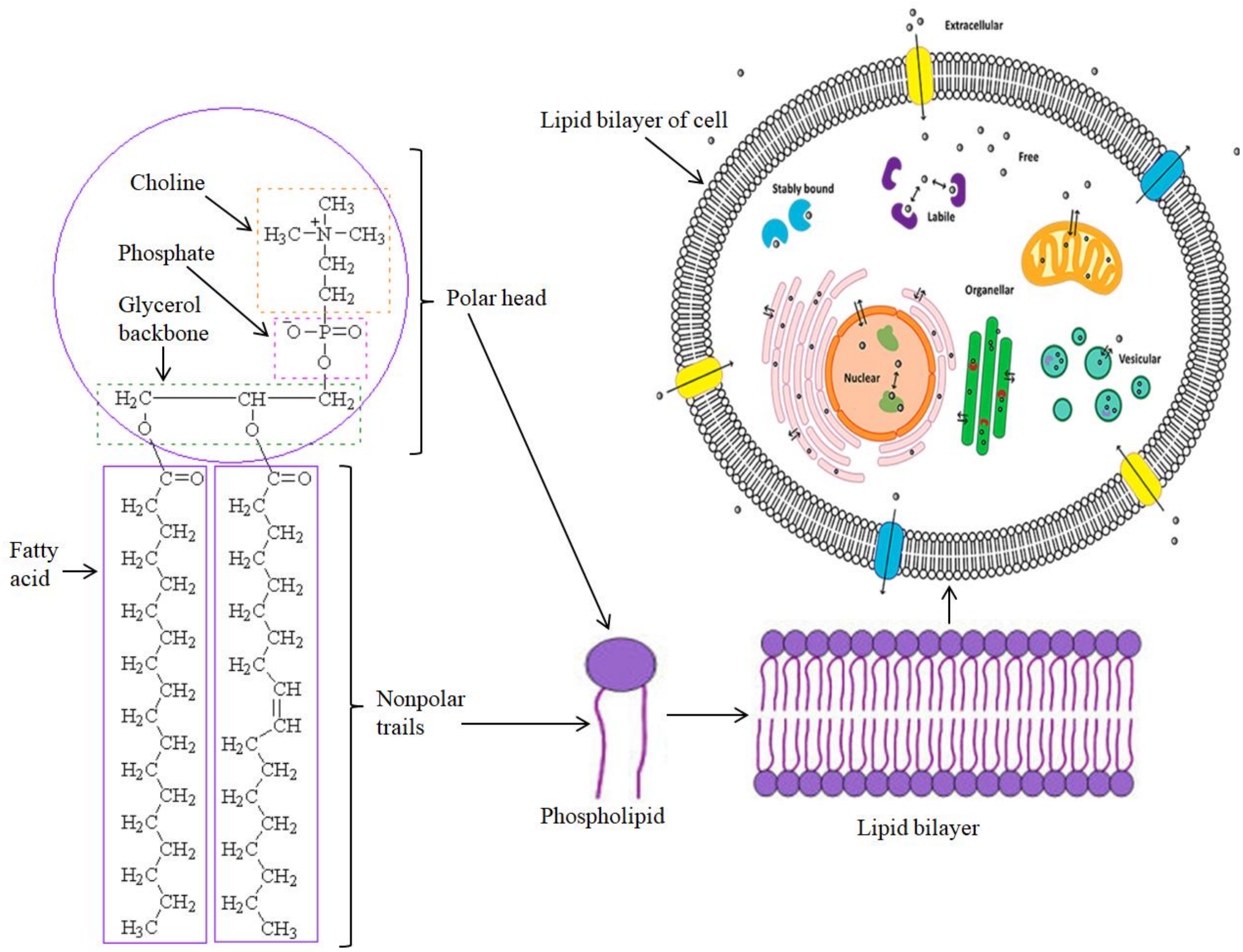
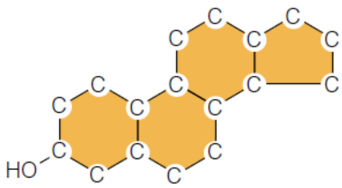


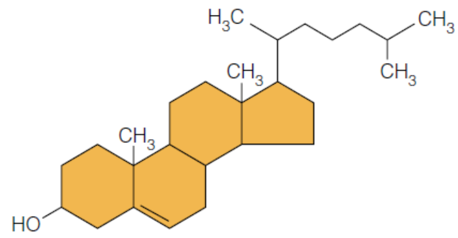
Figure 4.2: Phospholipid bilyer

5. Cholesterol and other sterols

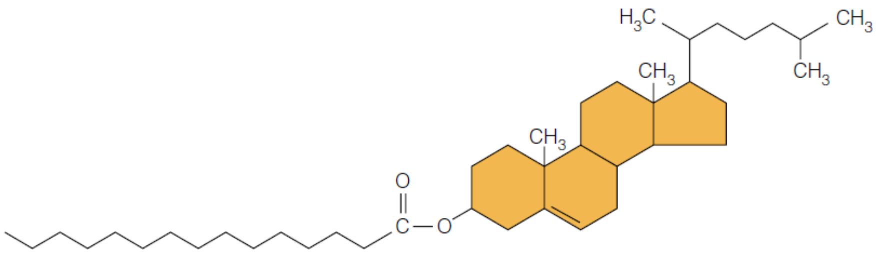
Cholesterol is probably the best-known sterol. It contains multiple-ring structure which is quite different from that of triglycerides or phospholipids. In food, cholesterol is found primarily as cholesterol esters, in which a fatty acid is attached to the cholesterol ring structure. Cholesterol is a common constituent (part) of one’s daily diet because it is found so abundantly in egg yolk, fatty meats, shrimp, butter, cream, cheese, whole milk, and organ meats (liver, kidneys and brains) Plant foods do not contain cholesterol. The body manufactures 800 to 1,000 mg of cholesterol a day in the liver



(a) Sterol ring structure



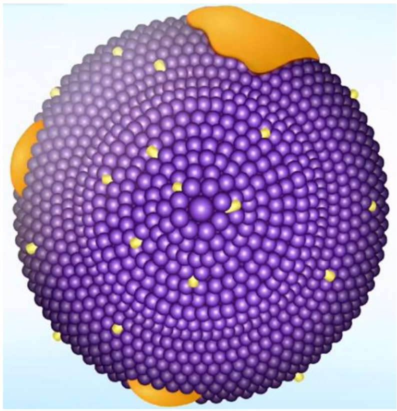
(b) Cholesterol



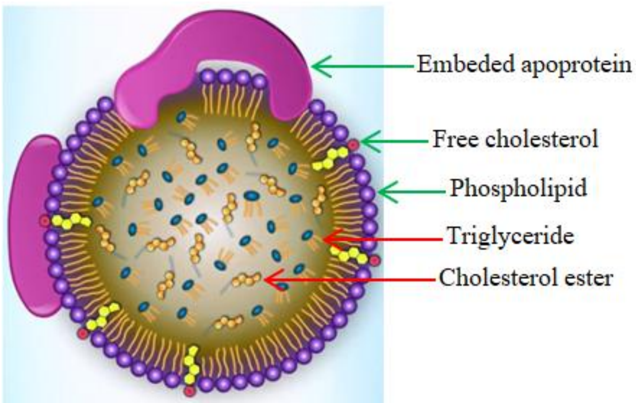
(c) Cholesterol ester

6. Lipoproteins

Lipids are transported in the blood by lipoproteins made up of a hydrophobic lipid core that consists of cholesterol ester and triglycerides. This hydrophobic core is surrounded by a single surface layer of amphipathic phospholipid and cholesterol molecules. These are oriented so that their polar groups face outward to the aqueous medium. There are supporting proteins on the surface of the lipoproteins called apoproteins. Because lipoproteins are soluble in blood, they are commonly called blood lipids.



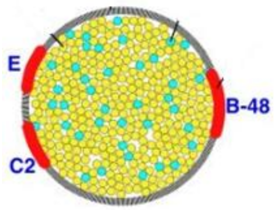
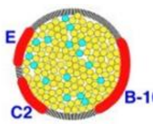
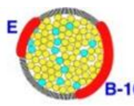
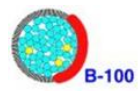
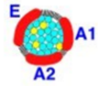
Lipoprotein structure



Cross sectional view of lipoprotein

Classification of lipoproteins

Depending on the density, lipoproteins are classified in the following ways; lower the density higher the fat content and larger in size, and conversely higher the density smaller in size and lower in fat content.

Types →	i. CM	ii. VLDL	iii. IDL	v. LDL	v. HDL
% composition in dry basis ↓					
Triglyceride	86	52	38	10	5-10
Cholesterol ester	3	14	30	38	14-21
Free cholesterol	2	7	8	8	3-7
Phospholipid	8	18	23	22	19-29
Protein	2	2	11	21	33-57
Density(g/ml)	<0.95	0.95-1.006	1.006-1.019	1.019-1.063	1.063-1.21
Diameter nm)	75-1200	30-80	15-35	18-25	7-20
Source	Intestine	Liver	Plasma	Liver/plasma	Liver/intestine

As the lipid content increases, density decreases and size increases, that is why chylomicrons are least dense but biggest in size, while HDL are rich in proteins, hence most dense but smallest in size.

Functions of different lipoproteins are briefly given below-

CMs: Dietary fats are absorbed as free fatty acids, glycerol and cholesterol in enterocytes of the intestine after digestion where they reassembled to form CMs. It contains more triglycerides than cholesterol. CMs enter into the systemic circulation through lymphatic vessels and reach to the peripheral tissues especially adipose, skeletal and cardiac where TGs of CMs are hydrolyzed by lipoprotein lipase (LPL) to free fatty acids (FFAs) and glycerol that cross the plasma membrane into the cells. Once inside the cells, FFA and glycerol are reassembled into triglycerides and stored or be used by the cells for energy.

CMRs: After removal of TGs, CMs become to CMRs that transport cholesterol to the liver cell for recycle.

VLDL: VLDLs are made primarily by the liver cells that contain more TGs than cholesterol which transport TGs to the peripheral tissues via blood as CMs.

VLDLR/IDL: Removal of triglycerides from VLDL results in the production of VLDL/IDL (TGs=Cholesterol); 50% of which enters into the liver cells by way of endoocytosis and is broken down. The other 50% IDL is acted upon by the hepatic lipase which removes TGs to become

LDL: LDL contains mostly cholesterol. LDL transports cholesterol to most body cells by receptor mediated endocytosis to be used. Excess cholesterol is added to the free cholesterol pool located inside the cell. When cholesterol level is high in the blood, body cells may receive excess amounts of cholesterol. High levels of LDLs in the blood are associated with an increased risk for heart disease and, therefore, are thought of as **"Bad"** cholesterol.

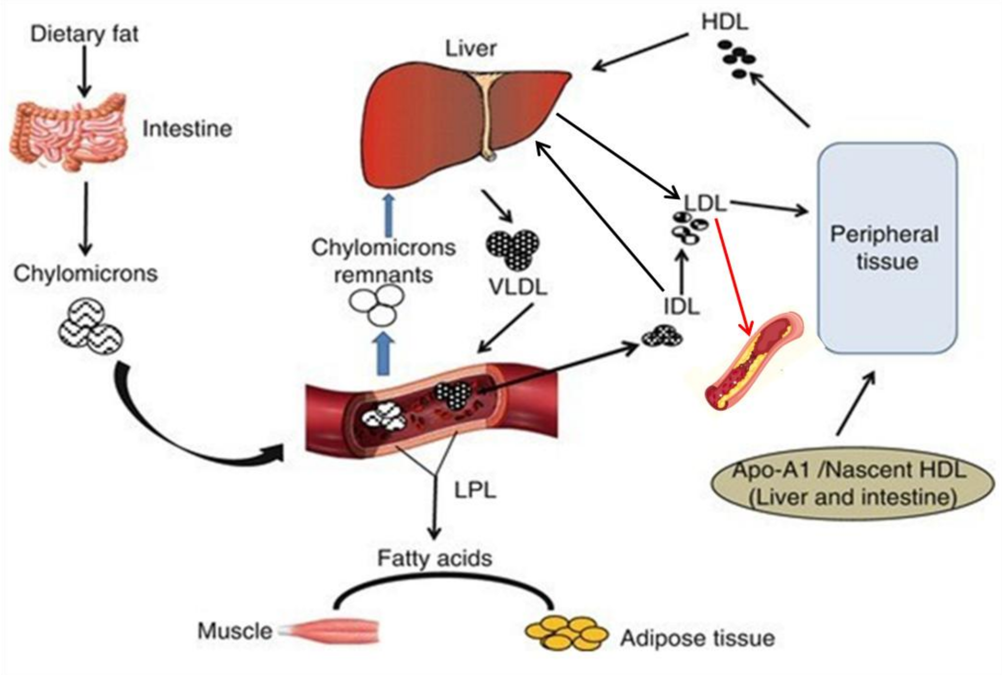


Figure 4.3: A brief overview of lipoproteins metabolisms.

HDL: Luckily, the body has a way to remove excess cholesterol from body cell; a protein called apoA1 is floating around in the plasma produced by the liver and small intestines. On body cells, there is a receptor called abca1. ApoA1 binds with abca1 receptor. This binding allows apoA1 to remove some cholesterol from the free pool inside the cells. ApoA1 also picks up some PLs from cell membranes and then becomes what is called nascent HDL.

LCAT (Lecithin Cholesterol Acyltransferase) an enzyme produced by the liver and located in the plasma. LCAT acts on free cholesterol in the nascent HDL and converts to it into a esterified cholesterol called cholesterol ester. The esterified cholesterols fall in the center of the nascent HDL to form a mature larger spherical HDL. Then HDL is uptaken by the liver cells and removes cholesterol from HDL. The liver uses cholesterol to produce bile; then bile is secreted to the intestine (where it helps break down fats) and part of this bile is excreted in feces. Hence HDL is called **"Good"** cholesterol as it scavenges excess cholesterol from the cells, tissues, arterial plagues and blood vessels and delivers these back to the liver.

The effects of different lipids on the blood level of LDL and HDL are summarized in the following tables-

Table 4.2: Effects of lipids on blood LDL and HDL level

Types of Fat	Effect on 'bad' LDL	Effect on 'good' HDL
Saturated	↑↑↑	**Neutral**
Trans	↑↑↑	↓↓
Monounsaturated	↓	**Neutral**
Polyunsaturated	↓↓	↑↑

4.4 Functions of Lipids

1. Fatty acids

- In general, fatty acids are used to synthesize triglycerides and phospholipids or catabolized to energy
- EEAs help to prevent DNA damage, fight infection, and are essential for fetal growth and development (brain and visual centers).
- ARA derived from omega-6 fatty acids are known to increase blood pressure, blood clotting, immune response, and inflammation.
- EPA and DHA derived from omega-3 fatty reduce blood pressure, inflammation, blood clotting, plasma triglycerides and cholesterol, and thereby reduce an individual's risk of heart disease.
- Monounsaturated fats help to regulate blood cholesterol levels, thereby reducing the risk for heart disease and stroke.
- PUFAs are also primary components of the tissues of the brain and spinal cord, where they facilitate the transmission of information from one cell to another and also reduce LDL level.

2. Triglycerides/fats

- Triglycerides consumed in the diet can be used as an immediate source of energy or be stored in the adipose tissue for future use.
- Provide energy at rest, during exercise, or in fasting.
- Helps in absorption and transport of fat-soluble vitamins (A, D, E, and K)
- Triglycerides are stored in adipose tissue which pads the body and protects the organs (kidney, heart, liver) from mechanical pressure.
- A layer of fat under the skin acts as insulator to help retaining body heat.
- Adds texture and flavor to foods.
- Contribute to satiety that causes feeling of fullness due to slow rate of digestion and to be energy rich.
- The fat around the joints acts as a lubricant and allows us to move these smoothly.

3. Phospholipids

- Constitute cell membranes and help in transporting fat soluble components in and out of cells.

4. Cholesterol

- Helps in making plasma membranes;
- Helps in making myelin sheath around neurons;
- Helps in synthesis of steroid hormones (cortisol, aldosterone, estrogen, testosterone);
- Helps in synthesis of vitamin D;
- Acts as precursor of bile salts.

4.5 Deficiency diseases of lipids

- Dry, scaly skin, poor growth and health with susceptibility to infections.
- Dermatitis and decreased capacity to reproduce.
- Impaired transport of lipids.

4.6 Lipids and Heart Disease

Regularly consuming diets high in saturated fat, cholesterol and *trans* fat may increase the risk of developing heart disease. Excess of these fats are deposited inside on artery walls as plaque by the LDL which is called **atherosclerosis**. Plague reduces the space for blood flow through arteries and thereby high pressure is needed to flow blood through it. Plague may rupture due to increase pressure and blood clotting is occurred in ruptured area. The blood clots block the blood to pass through the arteries; the cells die due to lack of oxygen which receives blood from such arteries. If an artery in the heart is blocked, heart muscle cells die, resulting in a heart attack, or **myocardial infarction**. If the blood flow to the brain becomes blocked, brain cells die and a stroke results.

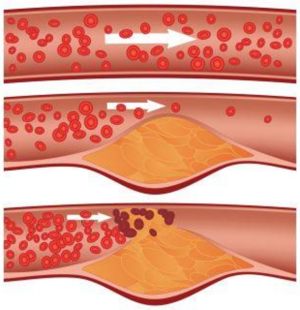


Figure 4.4: Top artery is healthy. Middle & bottom arteries show plaque formation, rupturing, clotting & blood flow occlusion.

4.7 Increasing and decreasing risk factors of heart diseases

Increasing and decreasing risk factors of heart diseases are summarized in the following table-

Factors increasing heart disease risk	**Factors decreasing heart disease risk**
1. With increasing age; 2. Diabetes, high blood pressure, obesity, high blood lipid levels; 3. Cigarette smoking, stress, sedentary lifestyle; 4. High saturated fat, cholesterol and *trans* fat intake.	1. Regular exercise (40 min. to 1 hr); 2. High intakes of monounsaturated fatty acids; 3. High intakes of polyunsaturated fatty acids with a healthy ratio of omega-6 and omega-3 fatty acids (5:1); 4. High-fiber intake 5. High intake of whole grains, fruits, and vegetables

4.8 Lipid profile

Regular testing of blood lipids over age twenty helps to take precaution to avert any life-threatening effects. According to the WHO, the following desired values are used to measure an overall lipid profile:

Lipids	Desirable	Borderline	Risk
Total cholesterol (mg/100 mL)	< 200	200 – 239	≥ 240
LDL-cholesterol (mg/100 mL)	< 130	130 – 159	>160
HDL-cholesterol (mg/100 mL)	>60	35 – 59	< 35
Triglycerides (mg/100 mL)	< 200	200 – 400	>400

4.9 Dietary Reference Intake (DRI) for Total Fat

To get optimal health benefits, the different types of lipid should consume in a balance way. Especially, ω-3 and ω-6 fatty acids should consume in balance way due to each others' opposite action. More consumption of ω-6 compare to ω-3 fatty acids may elevate the risk of allergies, arthritis, asthma, coronary heart disease, diabetes, cancer, autoimmune diseases and so on. DRIs of lipid are given below-

Fat category	Dietary Reference intakes	
Total fat	20-35% of total energy	
Saturated fat	≤10%	
Trans fat	< 1%	
Monounsaturated fats	15%	
Polyunsaturated fats	8 %	
ω-6 fatty acid	5-10%	Recommended by WHO
ω-3 fatty acid	0.6-1.2%	

Evaluation at the end of the lesson:

Short Answer Questions:

1. Define lipids;
2. Classify lipids;
3. Describe the importance of essential fatty acids.
4. Describe the lipid transport mechanism by lipoproteins.
5. Describe the functions of lipids.
6. Why excess fats cause atherosclerosis?
7. Describe the increasing and decreasing risk factors of heart diseases?
8. Describe deficiency diseases of lipids.

Lesson 5: Proteins-Sources, Functions and Deficiency Diseases

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define amino acids and proteins;
- Classify essential and nonessential amino acids;
- Explain mutual supplementation for complete protein source;
- Discuss functions and deficiency diseases of proteins.

Protein constitutes about 20 percent of the human body and is present in every single cell. Proteins are considered as the workhorses of life as they do a vast array of functions. An adequate supply of proteins in the daily diet is essential for normal growth and development and for the maintenance of health.

5.1 Amino acids

5.1.1 Definition of amino acids

Amino acids are the building blocks of proteins consist of a central carbon atom connected to a side chain, a hydrogen, a nitrogen containing *amino* group, a carboxylic acid group-hence the name "amino acid." There are 20 different amino acids; they all have different side chains.

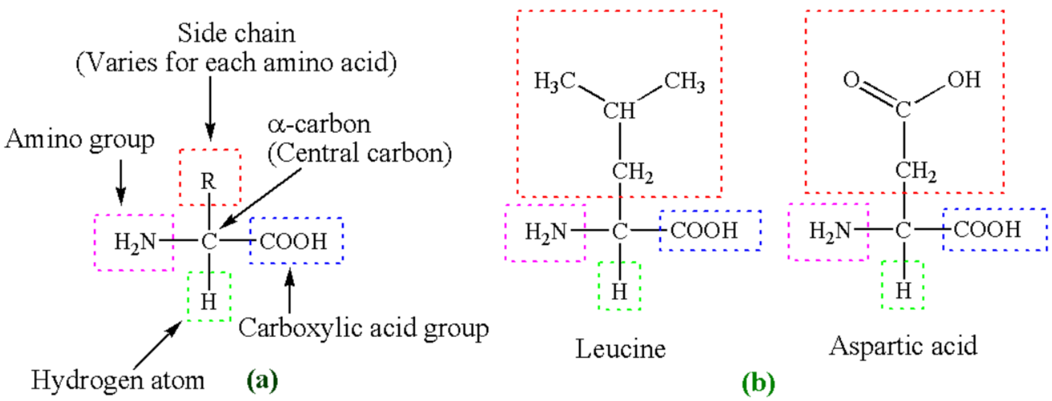


Figure 5.1. Basic structure of amino acids (a) and representative amino acids (b)

Classification of amino acids

Based on the nutritional aspects, amino acids are classified in the following ways-

1. Essential amino acids

Essential amino acids are those that the body cannot produce either at all or sufficient quantities to meet the physiological needs. Thus, essential amino acids must be consumed from food. Without sufficient essential amino acids, our bodies cannot make the proteins and other nitrogen-containing compounds that we need. Of the 20 amino acids, nine are classified as essential.

For example, synthesis of hemoglobin protein essential amino acid, histidine, is necessary. No amino acid can be substituted for histidine in synthesis of hemoglobin protein. If we do not consume enough histidine containing food, the production of hemoglobin is hampered and loses its ability to transport oxygen to cells.

2. Nonessential amino acids

Those amino acids that the body can synthesize sufficient amount from essential amino acids are called nonessential amino acids. They are just as important as essential amino acids, but we do not need to consume necessarily them through diet. Of the 20 amino acids, eleven are classified as nonessential.

3. Conditionally essential amino acid

Under certain conditions (during infancy, growth and in diseased states), a nonessential amino acid can become an essential amino acid. These types of amino acids are called conditionally essential amino acids. For example, the amino acid tyrosine can be synthesized in the body from the essential amino acid phenylalanine. However, if phenylalanine is deficient, tyrosine must be consumed in the diet.

Table 5.1: List of essential and nonessential amino acids

Essential amino acids		**Nonessential amino acids**	
Name	**3 letter code**	**Name**	**3 letter code**
Histidine	His	Alanine	Ala
Isoleucine	Ile	*Arginine	Arg
Leucine	Leu	Asparagine	Asn
Lysine	Lys	Aspartic acid	Asp
Methionine	Met	*Cysteine	Cys
Phenylalanine	Phe	Glutamic acid	Glu
Threonine	Thr	*Glutamine	Gln
Tryptophan	Trp	Glycine	Gly
Valine	Val	Proline	Pro
		Serine	Ser
		*Tyrosine	Tyr
***Conditionally essential amino acids**			

5.2 Proteins

Simply, proteins are macromolecules composed of amino acids. Amino acids are commonly called protein's building blocks joined by peptide bonds. Besides carbon, hydrogen and oxygen atoms like carbohydrates and lipids, proteins also contain additional element nitrogen and in some cases sulphur atoms. Unlike carbohydrates and lipids, proteins are made according to instructions provided by our genetic material, DNA.

Our body can synthesize proteins (50,000-100,000 unique proteins from combinations of just 20 amino acids) by selecting the needed amino acids from the "pool" of all amino acids available in the bloodstream at any given time. The situation is just like the endless number and variety of words that can be made with only 26 letters.

Muscles, ligaments, organs, tendons, tissues, glands, nails, hair-almost every part of our body are made from proteins. All enzymes of our body are protein in nature. Protein is appropriately named as the word "protein" is derived from Greek word "proteios" which means "outmost importance''.

5.2.1 Sources of proteins


Lean meat


Poultry


Fish

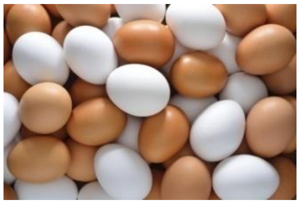

Milk


Cheese


Tofu


Seeds and nuts


Legumes


Eggs

5.2.2 Classification of proteins

Proteins can be classified in the following ways-

1. Based on peptide bonds

When two amino acids join together, the amine group of one binds to the acid group of another in a unique type of chemical bond called a peptide bond. In the process, a molecule of water is released as a by-product.

i. **Dipeptide:** A molecule containing two amino acids joined by a peptide bond.

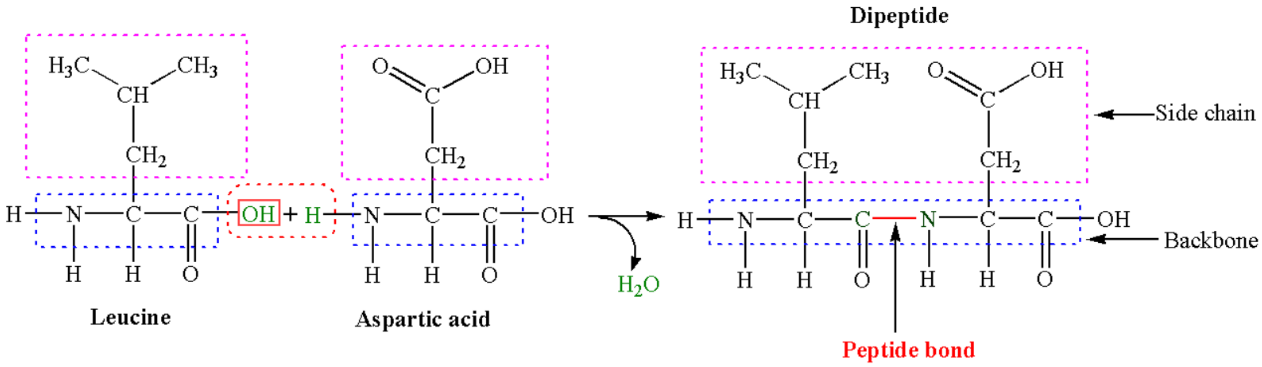


Figure 5.2 Amino acid bonding. Two amino acids join together to form a dipeptide. By combining multiple amino acids, proteins are made.

ii. Tripeptide: A molecule containing three amino acids joined by peptide bonds.
iii. Oligopeptide: In oligopeptide, 4-9 amino acids are joined together by peptide bonds.
iv. Polypeptide: In polypeptide, 10 or more amino acids are bonded together.

2. According to the composition

i. **Simple proteins:** composed only of amino acids, e.g. albumin, globulins, insulin etc.
ii. **Complex (conjugated) proteins:** proteins that have a non-protein part, for example

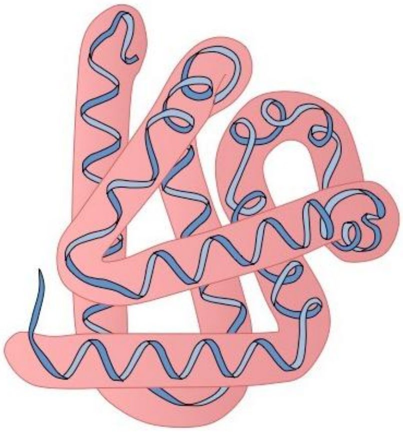
a. **Lipoproteins:** Conjugated with lipids, e.g., LDL, HDL
b. **Glycoprotein**: Conjugated with sugar (carbohydrate), e.g.
   - Some hormones such as erythropoeitin, LH, FSH
   - present in cell membrane structure
   - blood groups that are present on the surface of RBCs (A, B, O)
c. **Nucleoproteins:** Basic proteins histones conjugated with nucleic acid (DNA or RNA).e.g. chromosomes, ribosomes
d. **Metalloproteins:** Conjugated with metals (Fe, Cu, Zn etc), e.g.,
   - Fe containing proteins, e.g., hemoglobin, myoglobin, ferritin, transferring
   - Cu containing proteins, e.g., ceruloplasmin
   - Mg containing proteins, e.g., kinases and phosphatases.
e. **Phosphoproteins:** Conjugated with phosphate group, e.g., casein, ovo-vitellin

3. According to the shape of the proteins

a. **Fibrous proteins:** Structural proteins usually play a protective or supportive role, e.g. collagen, keratin and elastin.

b. **Globular proteins:** polypeptide chains tightly folded into compact spherical or globular shape, e.g., albumin, globulins, enzymes.


Fibrous protein


Globular protein

4. According to the functions

Classification	Functions	Example
a. Catalytic proteins		
▪ Enzymes	Catalyze chemical reactions	Lactate dehydrogenase (LDH), amylase, pyruvate dehydrogenase
b. Noncatalytic proteins ▪ Carrier proteins	Carry molecules or ions through the bloodstream	Hemoglobin, albumin
▪ Receptor proteins	Bind hormones and neurotrans-mitters to cell membranes	The insulin receptor
▪ Membrane transport proteins	Carry molecules across cell membranes	Na^+/K^+-ATPase, which transports K^+ ions into cells and pumps Na^+ ions out of cells
▪ Structural proteins	Form extracellular structures such as hair and nails	Collagen, keratin
▪ Contractile proteins	Extend or contract muscles cells or subcellular parts	Actin, myosin, tubulin
▪ Storage proteins	Store nutrients	Casein, ferritin

5. Based on protein quality/nutritional aspects

Based quality, proteins can be classified as

i. Complete proteins or High quality proteins

Proteins which contain all nine of the essential amino acids in sufficient quantities required by the body to promote growth and health are called complete or high-quality proteins. Animal foods such as milk, cheese, egg white, fish, poultry and meat are complete protein sources.

ii. Incomplete proteins or Low quality proteins

Proteins that do not contain all of the essential amino acids in sufficient quantities to support growth and health are called incomplete (or low-quality) protein. Consequently, incomplete proteins need helping from other proteins to build tissue.

Proteins found in plant foods (e.g., corn, grains, nuts, sunflower seeds, sesame seeds and legumes such as soybeans, navy beans, pinto beans, split peas, chickpeas, and peanuts) are incomplete proteins. Gelatin is the only incomplete protein found in the animal sources.

Figure 5.3. Complete protein sources

Figure 5.4. Incomplete protein sources

5.3 Differing proteins from each other

Our body have thousands of different proteins. They differ from each other in four different ways-

a. Number of amino acids in the polypeptide chain
   Some proteins might be 50 or 60 amino acids long and other proteins might be 500 or 600 amino acids long.
b. Types of amino acids in the polypeptide chain;
   Some proteins may contain all 20 types of amino acids and others may contain 10 out of 20 amino acids.
c. Ordering of amino acids in the polypeptide chain;
   Two different proteins may contain same number and types of amino acids but they differ from each other in ordering of these amino acids in the polypeptide chains.
d. Coiling of the polypeptide chain.
   Proteins differ in their three dimensional structures how they are coiled. Every single protein has different molecular conformation/shape.

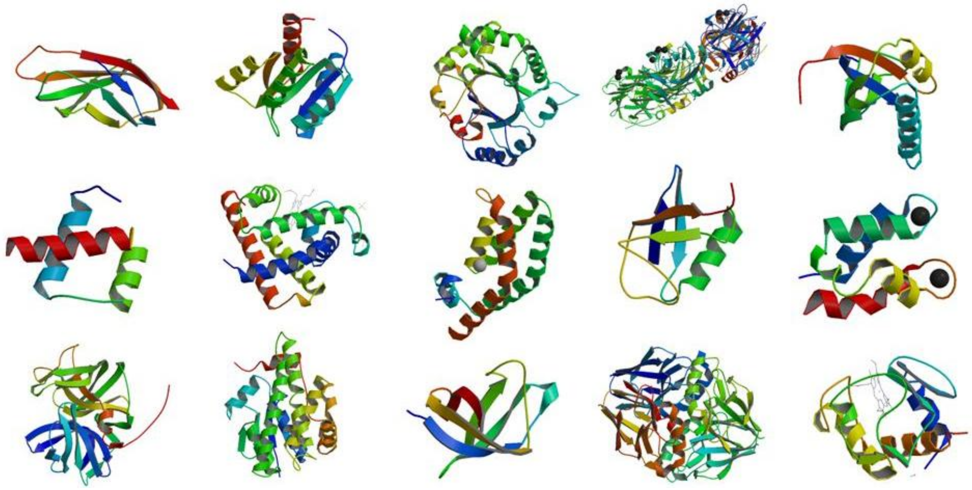


Figure 5.5. **Different shape of proteins**

5.4 Principle of mutual supplementation for complete protein source

If a diet is inadequate in any essential amino acid, protein synthesis cannot proceed beyond the rate at which that amino acid (AA) is available. This amino acid is called a limiting amino acid (LAA).

Mutual supplementation is the process of combining two or more incomplete protein sources to make a complete protein, and the foods involved are called complementary foods. Suppose food A has limiting essential amino acids Met and Leu but rich in Lys and Thr, and another food B has the opposite strength and weakness that means has limiting amino acids Lys and Thr and but rich in Met and Leu. Another way of making complementary food is that food, for example, food A besides containing sufficient other essential amino acids it has limiting amino acid Met and other the contrary food B has sufficient Met in addition to other essential amino acids. If we combine food A with food, we can make complete protein source. This concept has been summarized in the following table.

Table 5.2. Tricks of complementary food combination

Food	No. of EEA			Total EAAs	Target AA sequence in protein	Limiting AA	No. of target protein from food	Protein Value
	Met	Leu	Phe				Met–Leu–Phe	
1	10	10	10	30		None	10	10
2	2	18	10	30	Met–Leu–Phe	Met	2	2
3	18	2	10	30		Leu	2	2
(2+3) ÷2	10	10	10	30		None	10	10

Examples of complementary food combination:

Consider a meal of beans and rice. Beans are low in the amino acids methionine and cysteine but have adequate amounts of isoleucine and lysine. Rice is low in isoleucine and lysine but contains sufficient methionine and cysteine. By combining beans and rice, a complete protein source is created.

Food 1	LAA	RAA	Food 2	LAA	RAA	ECFC (Food 1+2)	
Legumes	Met & Cys	Ile & Lys	Grains	Ile & Lys	Met & Cys	Rice+ Lentil	
			Nuts & seeds	Ile & Lys	Met & Cys	Rice+ hazelnut	
Vegetables	Lys, Met & Cys		Grains		Met & Cys	Rice+spinach +chickpea	
			Legumes		Lys	Tofu+broccoli +almond	
			Nuts & seeds		Met & Cys		

LAA: Limiting, RAA: Rich in amino acids, ECFC: Example of complementary food combination

When we eat one potentially complementary protein, its amino acids join those in the amino acid pool. Body uses these free amino acids for synthesizing complete proteins. However, it is wise to eat complementary-protein foods during the same day, as partially synthesized proteins cannot be stored for later time to be complete. Mutual supplementation is important for vegetarian who do not consume animal foods and poor people who are unable to buy animal foods.

5.5 Maintaining acid-base balance

The body's metabolic processes result in the constant formation of acids and bases. These substances are transported in the blood to be excreted through the kidneys and the lungs. The human body maintains **pH**, or the acid–base balance of the blood very tightly. The body goes into a state called **acidosis** when the blood becomes too acidic. **Alkalosis** results if the blood becomes too basic. Acidosis and alkalosis can cause coma and death by denaturing body proteins.

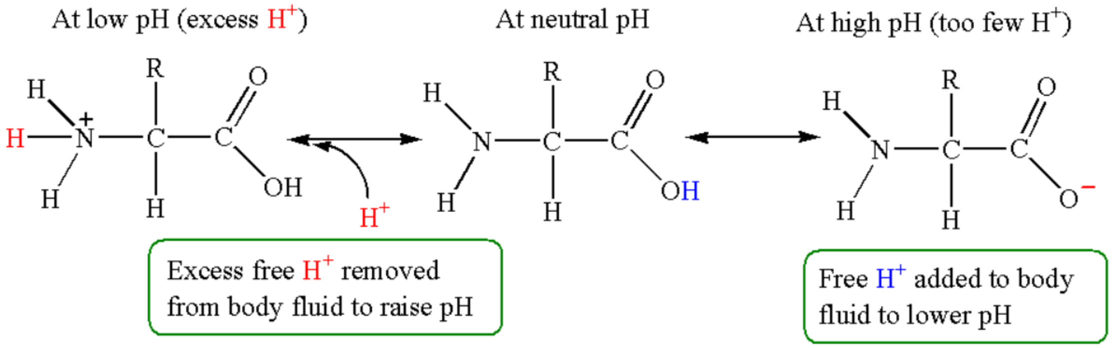


Figure 5.3. Buffering action of proteins

Proteins are excellent **buffers,** meaning they can maintain proper acid–base balance. Acids contain hydrogen ions, which are positively charged. The side chains of proteins have negative charges that attract the hydrogen ions and neutralize their detrimental effects on the body. Proteins can release the hydrogen ions when the blood becomes too basic. In this way, proteins maintain acid-base balance and blood pH.

5.6 Functions of Proteins

Proteins do numerous functions in our body. Note that proteins function most effectively when we consume adequate amounts of the other energy nutrients, carbohydrates and fat. When there is no enough energy available, the body uses proteins as an energy source, limiting their availability for the functions.

1. The primary function of proteins is to build and repair body tissues.
2. Most of the hormones and all enzymes are proteins in nature. Hormones and enzymes are essential for the regulation of metabolism and digestion.
3. Antibodies are proteins that defend against invading microbes and allergens.
4. Proteins help in maintaining fluid and electrolyte balances in the body and thus prevent edema (abnormal retention of body fluids).
5. Help in muscle contraction and relaxation.
6. Proteins act as a buffer in maintain proper acid-base balance.
7. Proteins assist in transporting and storage of nutrients
8. Provide energy when carbohydrate and fat intake are inadequate.

5.7 Daily protein requirements

The DRIs recommend 0.8 grams of protein per kilogram of body weight per day for everyone 19 years of age or older. Protein requirements are higher for children, teens, pregnant and lactating women due to their growing demands. Extreme stresses on the body, such as infections, fevers, burns, and surgery, increase protein losses and therefore, increase dietary needs.

Age (yrs)	Recommendation (g/kg/day)
0–0.5	1.52
0.5–1	1.50
1–3	1.10
4–13	0.95
14–18	0.85
19 and older	0.80

5.8 Deficiency of proteins

- Hamper tissue building and repair;
- Loss appetite, and weight;
- Delay in wounds healing;

- Fatigue, muscle weakness;
- Acidosis or alkalosis
- Thin hair, weak nails and decrease libido
- A general deficiency of calories (proteins, carbs and fats) known as marasmus characterized by severe muscle wasting, arms and legs become very thin;
- Kwashiorkor due to sudden or recent lack of protein-containing food (such as during a famine) characterized by edema, painful skin lesions, and changes in the pigmentation of skin and hair. The mortality rate for kwashiorkor patients is high.

Marasmus

Kwashiorkor

5.8 Problems associated with excess intake of proteins

If a person consumes more protein than his/her body's needs, the extra amino acids will be broken down and transformed into fat. Another concern associated with consumption of high-protein from animal foods, which are high in saturated fat and cholesterol. Therefore, consuming high-protein may increase the risk of heart disease.

Long-term consumption of high-protein diets may cause colon cancer and increase calcium excretion which depletes the calcium of bones and may contribute to osteoporosis. Excess proteins put extra burden on the liver to convert amino acids to urea and the kidneys to excrete excess urea than they are prepared to handle.

Evaluation at the end of the lesson:

Short Questions:

1. Define proteins.
2. What are essential and nonessential amino acids?
3. What is limiting amino acids?
4. What are the functions and deficiency diseases of proteins?
5. Discuss about the importance of complementary food combinations.

Lesson 6: Water

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define water;
- Discuss about distribution of fluid (water) in our body;
- Explain fluid and electrolyte balance;
- Discuss the functions of water;
- Discuss the consequences of deficiency diseases or excess of water.

Water is a neutral molecule (chemical formula H_2O) and has a pH of 7.0, meaning it is neither acidic nor basic. Maintaining the right level of water in our body is crucial for proper functioning of the body. 50 to 60% of the body weight of normal adults is composed of water.

Humans can live about 30 to 45 days without food but only 10 to 14 days without water. Thirst/dry mouth indicates low water level in our body, or blood electrolyte concentrations too high and sends signals to the brain stimulating the feeling to drink. Water lost during either exercise or heavy work is not replaced can be a life-threatening situation.

6.1 Distribution of fluid (water) in our body

Body water is divided into two basic compartments: intracellular and extracellular. The intracellular fluid (ICF) compartment is the system that includes all fluid within cells enclosed by their plasma membranes and accounts for about 64% of total body fluid. Extracellular fluid (ECF) surrounds all cells in the body.

Extracellular fluid has two primary constituents: the fluid component of the blood (called plasma) and the interstitial fluid (IF) that surrounds all cells not in the blood. The body has other water-based ECF. These include the cerebrospinal fluid that bathes the brain and spinal cord, lymph, the synovial fluid in joints, the pleural fluid in the pleural cavities, the pericardial fluid in the cardiac sac, the peritoneal fluid in the peritoneal cavity, the aqueous humor of the eye, in GI cavity and glandular secretions.

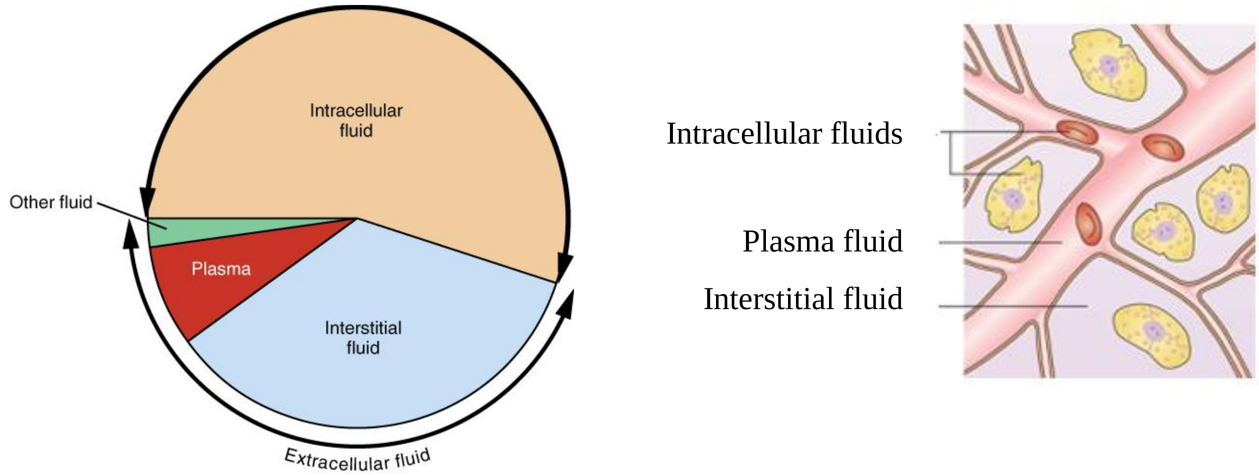


Figure 6.1. Body compartments and percentage of their water content.

6.2 Fluid and Electrolyte Balance

Water in our body is not pure but rather a mixture of cells, proteins, glucose, lipoproteins, electrolytes, and other dissolved substances. **Electrolytes** are minerals that have either positive (also called cations) (e.g., Ca^{2+}, Na^{+}) or negative charge (also called anions) (e.g., Cl^{-}). K^{+} and Na^{+} are the principal electrolyte in intracellular fluid (ICF) and extracellular fluid (ECF), respectively.

Sensible (through urine) and insensible (through feces, perspiration and respiration) water lost must be replaced in terms of both volume and electrolyte content. Body maintains the fluid and solutes (dissolved substances) balance in different compartments through homeostatic mechanism.

Water can move freely across cell membranes by osmosis from an area of low to an area of high solutes concentration. The purpose of movement of water across the cell membranes is to maintain the same **osmolality** (the total number of dissolved particles) inside and outside of the cells.

For example, if the concentration of sodium in ECF is reduced, water flows from the ECF into the cells, causing cellular edema. This triggers the kidneys to reabsorb sodium. When the missing sodium is replaced in the ECF, the excess water from the cells moves back to the ECF, and the edema is disappeared. Cells indirectly control water movement across the cells by controlling movement of electrolytes and other solutes

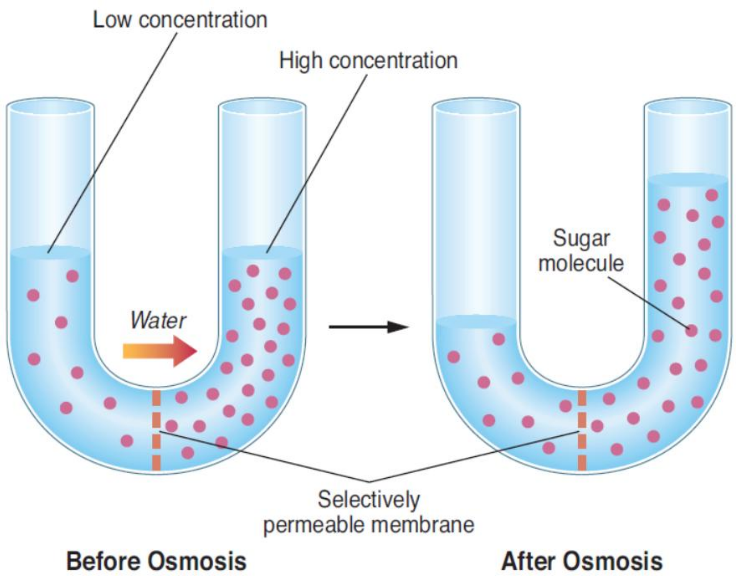


Figure 6.2. In osmosis, water passes through the selectively permeable cell membrane from an area of low-solute concentration to an area of high-solute concentration.

A role of thumb, 1 mL water is needed for every calorie consumed from food. For example, if person consumes 1,800 kcal through food, he/she needs to drink 7.5 glasses of fluid. Fever, diarrhea, unusual perspiration, and hyperthyroidism increase water requirement.

6.3 Tonicity, Osmosis and Size of the cells

The ability of an extracellular fluid/solution to make water move into or out of a cell by osmosis is known as its **tonicity**. A fluid's tonicity is related to its **osmolarity**. When solutions of different osmolarities are separated by a membrane only permeable to water, but not to solute, water will move from the lower osmolarity side to the higher osmolarity side.

Three terms (isotonic, hypotonic and hypertonic) are used to compare the osmolarity of a cell to the osmolarity of the extracellular fluid around it.

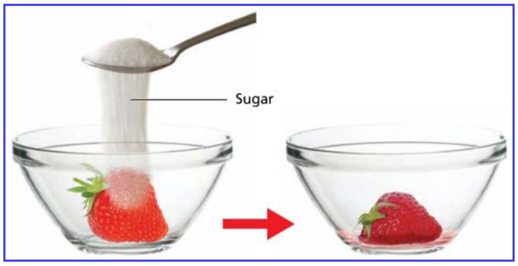
6.3.1 Isotonic solution

An extracellular solution is said to be isotonic (*iso* means the same) when it has the same osmolarity as inside of the cell. When a cell is placed in isotonic solution, there will be no net movement of water into or out of the cell.

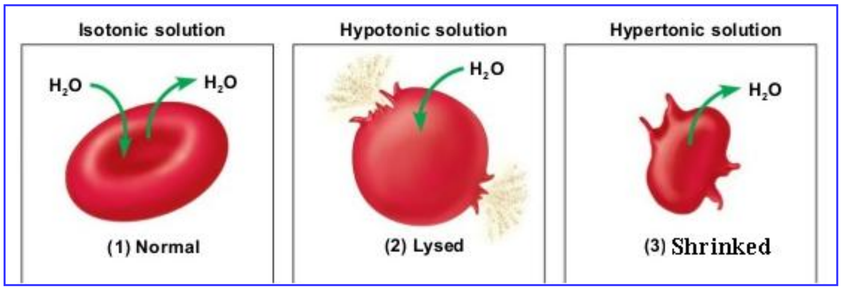
6.3.2 Hypotonic solution

If the extracellular fluid has lower osmolarity than the fluid inside the cell, it's said to be hypotonic (*hypo* means less than) to the cell. When a cell is placed in hypotonic solution, there will be net movement of water into the cell. In such a case, the cells keep their water volume constant by pumping electrolytes outside the cells in an effort to balance the concentrations of dissolved particles on either side of the membranes. The cells without wall will swell up and may burst (lyse). Lysis of cells is a reversible process.

6.3.3 Hypertonic solution



If the extracellular fluid has a higher osmolarity than the cell's cytoplasm, it's said to be hypertonic (hyper means greater than) to the cell. If a cell is placed in a hypertonic solution, water moves from inside the cell to the outside and the cell will shrink. Cells keep their water volume constant by pumping electrolytes inside the cells in an effort to balance the concentrations of dissolved particles on either side of the membranes. For example, when sugar is sprinkled on the surface of the strawberries, water will move out of the strawberries to dilute the sugar. The strawberries will be shrinked. It is a reversible process.



6.4 Functions of water

Of all the nutrients, water is considered as the most critical for our body as its absence produces lethal effect within a few days. Water performs the following four basic functions:

1. Transports Substances

Water is called the "universal solvent" because more substances are dissolved in it than any other solvent. The water molecule has different electrical charges-one end is positive and another end is negative. This property allows water to surround other charged molecules and disperse them.

Water serves as a transport medium to deliver substances to cells and remove wastes. For example, blood (which contains 90% water) transports oxygen, nutrients, hormones, drugs, and other substances to cells and removes metabolic waste products such as CO_2, urea, ketones etc from the cells and transports to the lungs or kidneys for excretion.

2. Serves as a medium for chemical reactions

Water acts as a medium for all biochemical reactions in the body. Among the roles it plays is as a medium in which all of the body's metabolic reactions occur. Water also participates directly in a number of chemical reactions, many of which are involved in energy production. The addition of water to a large molecule can break it into two smaller ones.

3. Regulates body temperature

Water plays an important role in fixing body temperature at around set point 98.6°F (37°C). The water in blood helps to regulate body temperature at around set point by increasing or decreasing the amount of heat lost at the body surface. Body can operate properly in narrow range of temperature around set point. Too low or too high of a temperature causes enzymes to stop functioning and metabolism is halted which can be life threatening.

When body temperature starts to raise, the blood vessels in the skin dilate (meaning the opening becomes wider), which increases blood flow to the skin and allows more heat to be released into the environment. The most obvious way that water helps to regulate body temperature is through the evaporation of sweat. When body temperature increases, the brain triggers the sweat glands in the skin to produce sweat, which is mostly water. As the sweat evaporates from the skin, heat is lost, cooling the body.

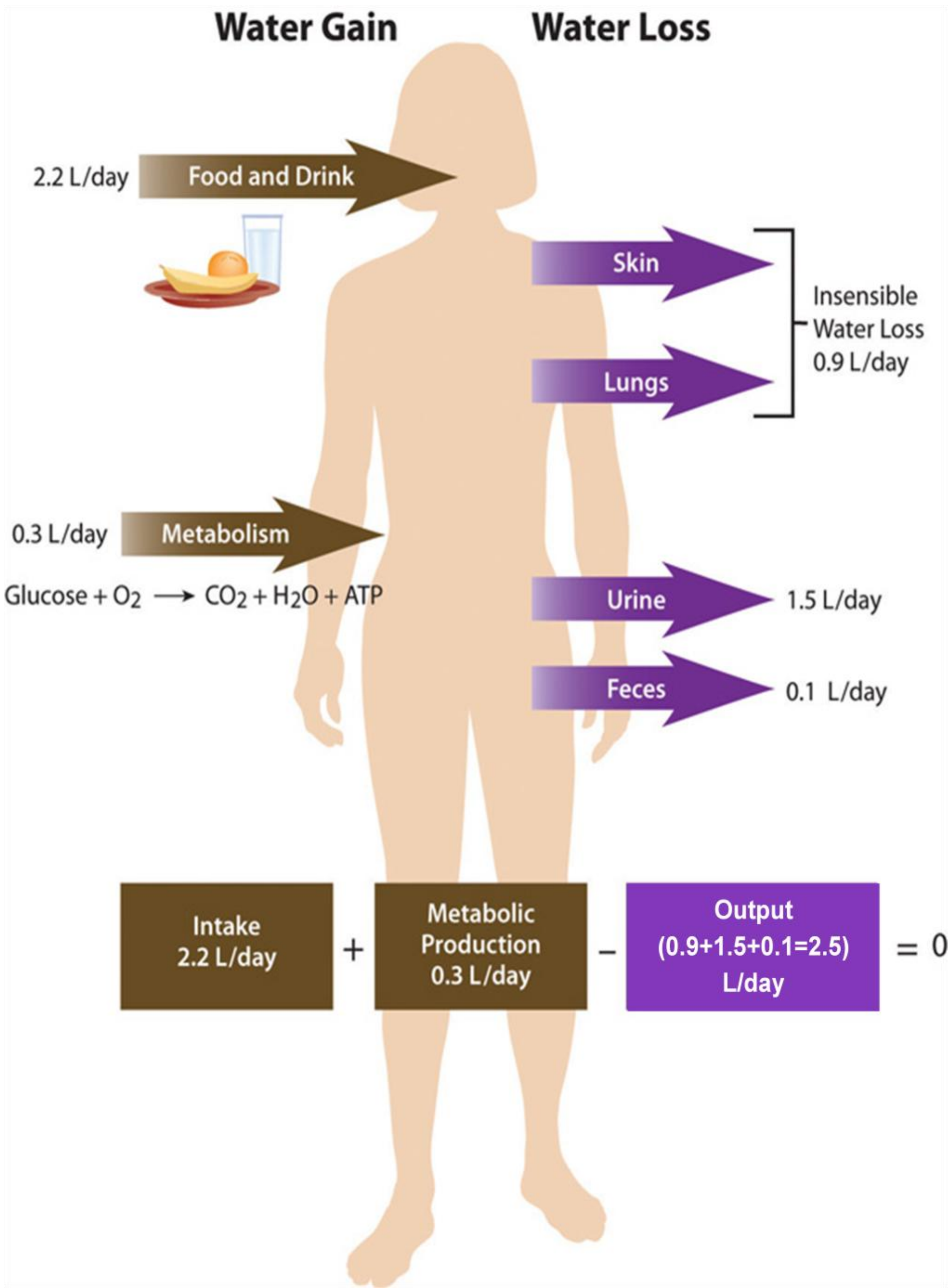
4. Acts as lubricant/shock absorber

Water protects the body by acting as a cushion. For example, fluids inside the eyeballs and spinal cord cushion against shock; the fluid between joints cushions, lubricates and eases the movement of articulated bones.

6.5 Regulation of daily water balance

Daily water input

Total water output per day is about 2.5 L. This must be balanced through water input. Our body tissues can produce around 300 mL of water per day through metabolic processes. The remaining water output must be balanced by drinking fluids and eating solid foods. The average fluid consumption approximately per day is 1.5 L through beverages and 700 mL through solid foods.



6.6 Daily water output

Body loses water in two ways: insensible way and sensible way. In insensible way, body loses 400 mL through exhalation and 500 mL through skin. In **sensible way, body loses about 1.5 L** through urine and roughly 100 mL through feces. Kidneys can increase or decrease urine output depending on the situation; in short kidneys regulate urine output.

6.7 Recommended water intake daily

The recommendation for total water intake is about 2.7 L (11 cups; 1 cup is equivalent to 250 mL) per day for women and 3.7 L (15 cups) per day for men. It is important to note that recommended water intake includes water from all sources such as drinking pure water, milk, juice and other beverages. Water and other beverages account for about 80% of adult fluid intake. The other 20% comes from water in foods.

The demand for water intake is increased in certain incidences which increase water loss such as drinking caffeine containing beverages (e.g., coffee, tea) (caffeine is a diuretic that increases water loss in the urine), sweating in exercise, in dry environment (water is evaporated quickly from the skin and lungs), low-calorie diets (extra urine is produced in order to excrete ketone bodies produced by fat breakdown), high-protein and high-salt diets (extra urine is produced in order to eliminate the urea from protein breakdown and the extra salt, respectively), high-fiber diets (fiber increases water lost in the feces). Water loss can be estimated by weighing before and after exercise. To restore fluid balance, 2 to 3 cups of fluid should be consumed for every ½ kg of weight lost.

Water needs are also higher for pregnant women to allow for the increase in maternal blood volume, the production of amniotic fluid, and the needs of the fetus. During lactation, fluid needs are increased because the fluid secreted in milk, about 3 cups per day, must be restored by the mother’s fluid intake.

6.8 Water content of different foods

90–99	Nonfat milk, strawberries, blueberries, watermelon, lettuce, cabbage, celery, spinach, squash, pumpkin, watermelon, bottle gourd, tomato, broccoli, cucumber, carrots
80–89	Fruit juice, yogurt, apples, grapes, oranges, carrots, broccoli, pears, pineapple, milk, pears
70–79	Bananas, potato, chicken
60–69	Pasta, legumes, salmon, meat
50–59	Ground beef, hot dogs, steak, feta cheese
40–49	Pizza
30–39	Cheddar cheese, bread
20–29	Pepperoni, cake, biscuits, honey
10–19	Butter, margarine, raisins, wheat flour, rice
1–9	Walnuts, dry-roasted peanuts, crackers, cereals, pretzels, peanut butter
0	Oils, sugars

6.9 Consequences of deficiency or excess

Excess water: Water Intoxication/Hyponatremia

Water intoxication can occur due to either too much water or too little sodium (called hyponatremia) in the body. This can occur due to improper administration of intravenous fluids, or drinking too much plain water during excessive sweating. For example, hyponatremia can occur in an athlete if he/she drinks plain water to replenish water and sodium lost in sweating. Water intoxication may cause edema. Water intoxication is extremely rare, primarily because healthy kidneys are capable of excreting up to one liter of excess water per hour.

Water deficiency: Dehydration

Dehydration (inadequate water in the body) can occur due to inadequate intake or abnormal loss such as severe diarrhea, vomiting, hemorrhage, burns, diabetes mellitus, excessive perspiration, excessive urination, or the use of certain medications such as diuretics. Symptoms of dehydration include low blood pressure, thirst, dry skin, fever, and mental disorientation.

A loss of 10% of body water can cause serious problems. Blood volume and nutrient absorption are reduced, and kidney function is upset. A loss of 20% of body water can cause circulatory failure and death. Infants are at high risk of dehydration during vomiting and diarrhea. Electrolytes are always lost with water; so intravenous (IV) fluids may be required to replace water loss. The thirst sensation often lags behind the body's need for water, especially in the elderly, children, athletes, and the ill.

Evaluation at the end of the lesson:

Short Questions:

1. Define water.
2. Discuss about distribution of fluid (water) in our body.
3. Explain fluid and electrolyte balance.
4. Discuss the functions of water.
5. Discuss the consequences of deficiency diseases or excess of water.

Lesson 7: Fat soluble vitamins

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define vitamin;
- Classify vitamin;
- Describe sources, functions and deficiency diseases of fat soluble vitamins.

7.1 Vitamins

Vitamins regulate a wide range of biochemical reactions within the body. Most vitamins with known functions are coenzymes (helpers of enzyme). The name vitamin implies their importance. *Vita* in Latin means life.

Vitamins are a group of essential organic micronutrients that are needed for normal cell function, growth, and development, found in minute amounts in natural foodstuffs or sometimes produced synthetically: deficiencies of vitamins produce specific disorders.

Many people think that vitamins are sources of energy for our bodies. But the truth is that vitamins do not provide energy. Unlike carbohydrates, lipids, or proteins, vitamins do not provide energy or serve as the body's building materials.

Of the thirteen vitamins recognized as essential, humans can synthesize only small amounts of vitamins D and K, so we must consume virtually all of the vitamins in our diets. Almost everyone who eats a varied and healthful diet can readily meet their vitamin needs from foods alone. The specific amounts and types of vitamins in foods vary.

7.2 Classification of vitamins

Vitamins are classified depending on their solubility-

1. Fat soluble vitamins
2. Water soluble vitamins (Discussed in details in next lesson)

1) Fat soluble vitamins: Those which are soluble in fats but not in water are called fat soluble vitamins, such as-
   i) Vitamin A or Retinol
   ii) Vitamin D or Calciferol
   iii) Vitamin E or Tocopherol
   iv) Vitamin K or Phylloquinone

They are found in the fatty portions of foods (butterfat, cod liver oil, corn oil, and so on) and are absorbed along with dietary fat. Fat-containing meats, dairy products, nuts, seeds, vegetable oils, and avocados are all sources of one or more fat-soluble vitamins.

In general, the fat-soluble vitamins are readily stored in the body's adipose tissue; thus, we don't need to consume them every single day. Of the four fat-soluble vitamins, vitamins A and D are the most toxic; **megadosing** with ten or more times the recommended intake of either can result in irreversible organ damage and even death.

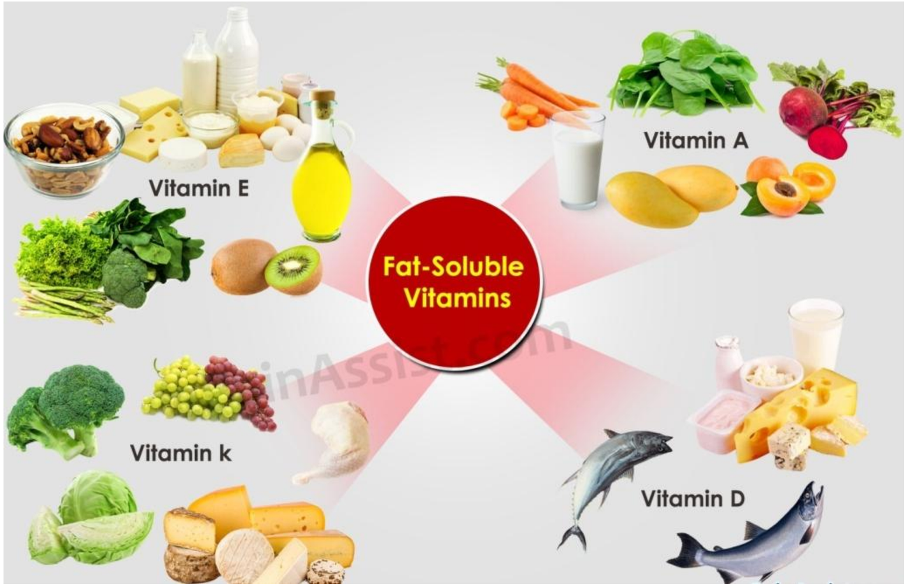


Figure 7.1. Sources of fat soluble vitamins

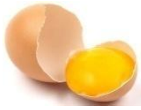
Sources, functions and deficiency diseases of fat soluble vitamins are given below-

7.3 Vitamin A

Vitamin A consists of two basic dietary forms: preformed vitamin A, also called **retinol,** which is the active form of vitamin A; and ***β*-carotene** (yellow-orange pigments) (also called provitamin A/precursor of vitamin A) the inactive form of vitamin A which can be converted into vitamin A in our body and are found in plants. Body can convert 10% of plant origin provitamin A to vitamin A.

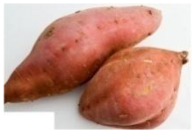
7.3.1 Major sources

Animal:

Liver | Butter | Whole milk | Egg yolk | Cod liver oil | Small fish

Plants (Precursors): Green and orange fruits and vegetables, such as



Carrots Sweet potatoes Broccoli Pumpkin Mango Fortified oil

7.3.2 Functions of vitamin A

1. Plays an important role in vision in dim light/low light conditions, bone growth and development, reproduction, and cell division;
2. Assists in maintaining the linings and coverings of tissues;
   Helps in regulating the immune system, which fights infections;
3. Helps in maintaining healthy skin;
4. Acts as an antioxidant.

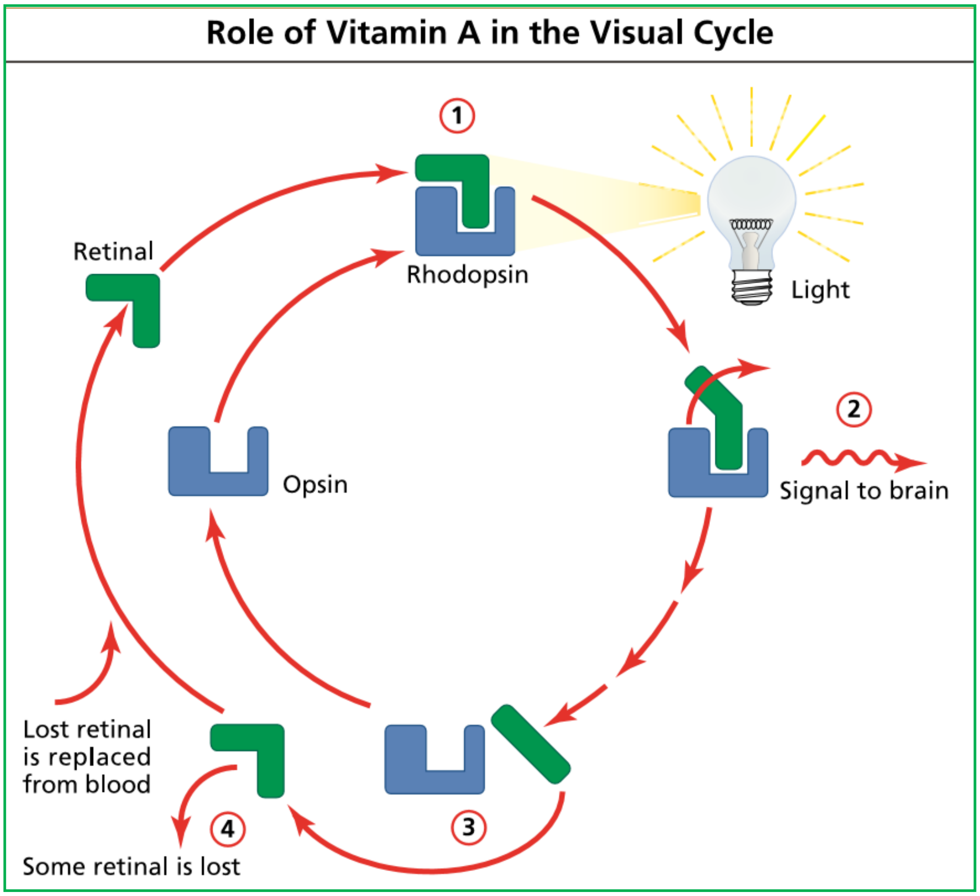


Figure 7.1. Vitamin A is an important part of the visual cycle. In the eye, retinal combines with opsin to form rhodopsin (1). When low light strikes rhodopsin, retinal changes shape, causing a

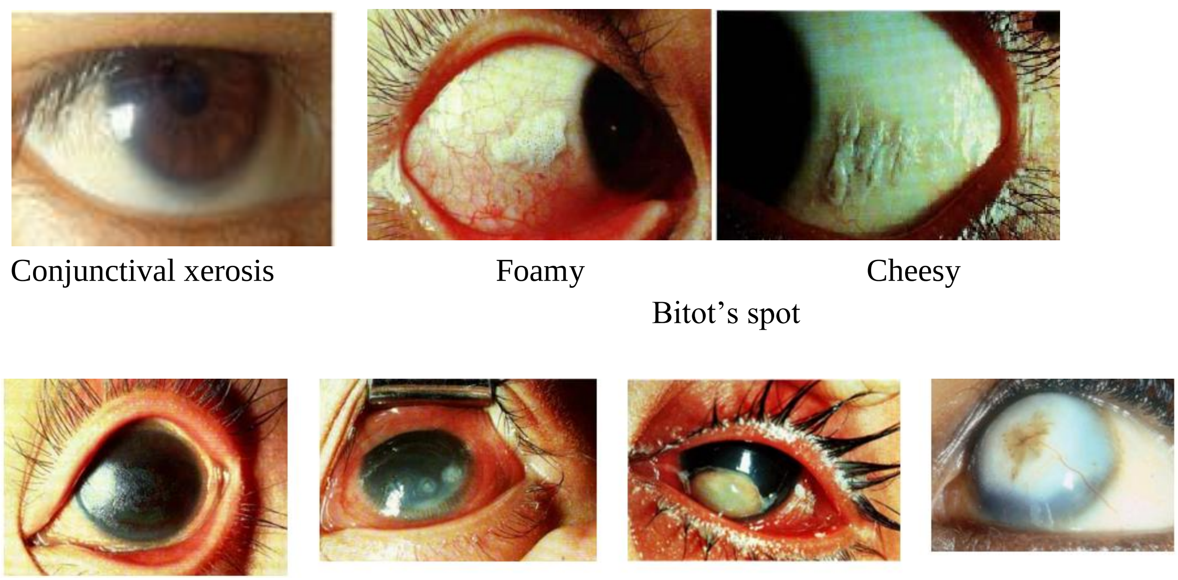
nerve signal to be sent to the brain (2) and retinal to separate from opsin (3). Some of this retinol is lost and must be replaced from retinoids in the blood (4).

7.3.3 Deficiency symptoms of vitamin A

1. Xerophthalmia (dye eye)

Vitamin A deficiency can lead to the dysfunction of the linings and coverings of the eye, causing dryness of the eyes, a condition called xerophthalmia. This condition can progress, causing ulceration of the cornea and eventually blindness. The successive ocular signs and symptoms that appear depending on the severity of vitamin A deficiency are given below-

a) Night blindness (inability to see in dim light/low light) (earliest clinical signs)
b) Conjunctival xerosis (dryness)
c) Bitot's spots (foamy/cheesy appearance on white area)
d) Corneal xerosis (cornea becomes dry and hazy)-Up to corneal xerosis stage, vision can be restored fully through supplementation of high-dose vitamin A capsule).
e) Corneal ulceration/keratomalacia
f) Corneal scaring (grey-white appearance of cornea)



Conjunctival xerosis | Foamy | Cheesy
Bitot's spot

Corneal xerosis | Corneal ulceration with infection | Keratomalacia (1/3 of cornea) | Corneal scaring

Figure 7.2. Ocular signs and symptoms of vitamin A deficiency [Source: WHO, 1995]

Other deficiency symptoms

1. Dry, rough skin; slow and faulty development of bones and teeth.
2. Increased incidence of ear, sinus, respiratory, urinary, and digestive system infections.

3. Stunted growth, delayed wound healing and follicular hyperkeratosis especially in the knees and elbows.

7.3.4 Risk groups of vitamin A deficiency

Those groups of people having high demand of vitamin A are at the highest risk of developing vitamin A deficiency such as children, adolescents and pregnant and lactating mother. Infants suffering from diarrhoeal diseases and infections are also at risk of vitamin A deficiency.

7.3.5 Toxicities

Hypervitaminosis A, or vitamin A toxicity, typically results from taking high-dose supplements over a long period of time. Fatigue; bone and joint pain; spontaneous abortion and birth defects of fetuses in pregnant women; dry skin, nausea, diarrhea and headache; liver damage; nervous system damage; blurred vision; hair loss; skin disorders, etc.

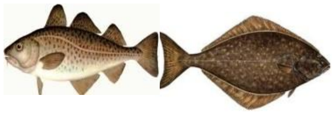
7.4 Vitamin D

Vitamin D is known as the sunshine vitamin. It is made in our skin from its precursor, cholesterol, when skin is exposed to sunlight. 90% of our daily vitamin D requirements can be met just exposing 20 minutes of our body (40%; face, arms, legs or back) to sunlight (ultraviolet B radiation) between 10 am to 3 pm two to three times every week. Vitamin D is only essential in the diet when exposure to sunlight is limited or when the body's ability to make it is reduced.

Vitamin D is heat-stable and not easily oxidized, so it is not harmed by storage, food processing, or cooking.

7.4.1 Major food sources:

The best food sources of vitamin D are-


Milk Fish liver oils Egg yolk Butter Fatty fish

7.4.2 Functions

1. The primary function of vitamin D is to help in absorption of calcium and phosphorus from the small intestine.
2. Vitamin D is also necessary for the normal calcification of bone.
3. Vitamin D is also now believed to play a role in preventing cells from transforming into cancer cells.

7.4.3 Deficiency diseases of vitamin D

Vitamin D helps in absorption of calcium from intestine as well as deposition of calcium and phosphorus in the bone. Deficiency of either vitamin D or calcium or both may lead to inadequate mineralization or demineralization of the skeleton resulting the following signs and symptoms/diseases-

1. General signs and symptoms

- Hypotonia (low muscle tone)
- Irritability, fits
- Profuse sweating while asleep,
- Delayed in walking, delayed dentition
- Leg pain
- Retarded growth
- Poor teeth and bone formation
- Tetany-insufficient calcium in the blood can cause a condition characterized by involuntary muscle movement
- Protruding abdomen (due to low abdominal and intestinal muscle tone and descending displacement of the liver and spleen)

2. Severe deficiency diseases/signs and symptoms

Severe deficiency of vitamin D may lead to the deformities of the skeleton which includes

a. Rickets

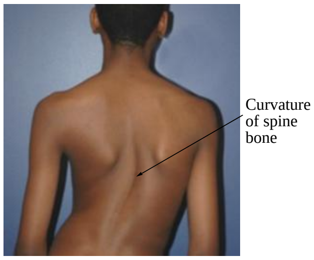
A deficiency of vitamin D in children causes the bone disease called nutritional rickets. Rickets is very common among children (6 months-2 years) in developing countries and is characterized by soft, weak, deformed bones that are exceptionally susceptible to fracture. The signs and symptoms of rickets include

In upper extremities

Larger head (frontal and parietal bossing), rachitic rosary/beading of the ribs (prominent knobs of bone at the costochondral junctions), pigeon chest deformity (chest bones grow outwardly and usually happen during adolescent growth spurt), scoliosis (sideways curvature of the spine) and so on.

Frontal bossing

Rachitic rosary



Pigeon chest deformity **Scoliosis**

In lower extremities

Bowed legs (varus), knocked knees (valrus), enlargement of wrist and ankle joints, windswept deformity (combination of valgus deformity of one leg with varus deformity of the other leg), bending of leg, etc.

Bowed legs **Knocked knees** **Enlargement of wrist joints**

Enlargement ankle joints **Windswept deformity** **Bending of leg**

b. In adults, vitamin D deficiency causes a similar disease called **osteomalacia** (*osteo* means bone and *malacia* means softening) which is characterized by low bone mineral density.

c. **Osteoporosis** (*osteo* means bone and *porosis* means porous) is condition where the bones become very porous (less dense), weak, and are more likely to fracture just like brittle glass or soft clay can easily break apart. Other factors contributing to osteoporosis include deficiency of vitamin D and sex hormones. Osteoporosis primarily affects middle-aged and elderly people, 80% of them are women.

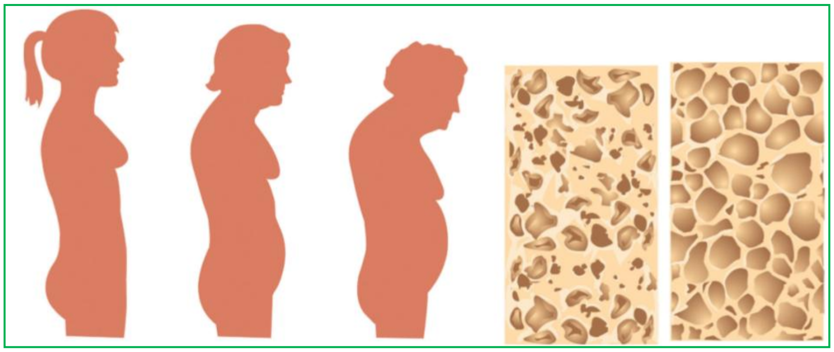


Figure 7.3. Osteoporosis is characterized by a gradual weakening of the bones, which leads to poor skeletal formation.

7.4.4 Risk groups of vitamin D deficiency:

- People living in cool countries where sunlight either absent in day time or too low level to synthesize vitamin D in the body (e.g., Eastern Europe) or people wearing heavy clothing so that sunlight cannot reach to the skin;
- Lack of exposure to the sunlight in combination with diets low in vitamin D and high in phytic acid (found in bread);
- People staying inside house;
- Elderly (due to skin pigmentation) and dark-skinned populations.

7.4.5 Toxicities of vitamin D: Hypervitaminosis D can cause calcification of soft tissues and kidney stones (hypercalcemia), hypertension.

7.5 Vitamin E

Vitamin E consists of two groups of chemical compounds. They are the tocopherols and the tocotrienols. There are four types of tocopherols: alpha, beta, delta, and gamma. The most biologically active of these is alpha-tocopherol.

7.5.1 Major sources

Vegetable oils

Wheat germ

Nuts

Green leafy vegetables

7.5.2 Functions

1. Acts as a powerful antioxidant to protects cell membranes, polyunsaturated fatty acids, and vitamin A from oxidation;
2. Protects white blood cells;
3. Enhances immune function;

4. Improves absorption of vitamin A;
5. Lower risk of heart disease and cancer.

7.5.3 Deficiency diseases of vitamin E

Vitamin E deficiency is rare because it is plentiful in the food supply and is stored in many of the body's tissues.

7.5.4 Risk population

People suffering from fat malabsorption (because vitamin E is absorbed with fat) are at risk of vitamin E deficiency.

7.6 Vitamin K

There are several forms of vitamin K, one synthesized by plants, one synthesized by animals (including humans) and a large range of types synthesized by bacteria in the small intestine of humans. Vitamin K deficiency is fairly uncommon in healthy adults, because bacteria in the intestines synthesize the vitamin.

Breast milk is a poor source of vitamin K and newborns have no bacteria in their gut to synthesize it. To ensure normal blood clotting, infants are typically given a vitamin K injection within six hours of birth.

7.6.1 Major sources:


Broccoli


Cabbage


Spinach


Kale


Cow's milk

7.6.2 Functions

1. Helps in blood clotting by acting as a coenzyme.
2. Helps in bone metabolism

7.6.3 Deficiency symptoms

- Increases clotting time and prone to hemorrhage;
- Bone mineral density is reduced, and the risk of fractures increases.

7.6.4 Risk population of vitamin K deficiency

Those people are at risk of vitamin K deficiency who are suffering from fat malabsorption, use antibiotic for long time (as antibiotics kill intestinal bacteria), consuming diet containing inadequate vitamin K, or using anticoagulants.

Table 7.1: Recommended dietary allowances of fat-soluble vitamins per day

Types	Age (years)	Vit. A (mg RE)	Vit. D (µg)	Vit. E (mgTE)	Vit. K (µg)
New born	0 to 0.5	375	7.5	3	5
	0.5 to 1	375	10	4	10
Children	1 to 3	400	400	6	15
	4 to 6	500	500	7	20
	7 to 10	700	700	7	30
Man	11 to 14	1000	5	10	45
	15 to 18	1000	5	10	65
	19 to 24	1000	5	10	70
	25 to 50	1000	5	10	80
	51+	1000	5	10	80
Woman	11 to 14	800	10	8	45
	15 to 18	800	10	8	55
	19 to 24	800	10	8	60
	25 to 50	800	10	8	65
	51+	800	5	10	65
Pregnant		800	10	10	65
Lactating Mother	1 to 6 months	1300	10	12	65
	2 to 6 months	1200	10	11	65

RE=Retinol equivalent, TR=Tocopherol, mg=milligram,µg=microgram [1g=1000 mg; 1 mg= 1000µg]

Evaluation at the end of the lesson:

Short Questions:

1. Define vitamin.
2. Classify vitamin.
3. Describe sources, functions and deficiency diseases of vitamin A.
4. Describe sources, functions and deficiency diseases of vitamin D.
5. Describe sources, functions and deficiency diseases of vitamins E and K.

Lesson 8: Water soluble vitamins

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define water-soluble vitamins;
- Describe sources, functions and deficiency diseases of water soluble vitamins.

8.1 Water-soluble vitamins

Water-soluble vitamins are those vitamins which are soluble in water. They are not stored in the body (as oppose to fat-soluble vitamins) except vitamin B_{12}; after absorption, excess vitamins are excreted in the urine. As they are not stored, so a continuous supply is needed daily through the foods, supplements or a combination of both.

Unlike fat-soluble vitamins, they can be destroyed by heat or by being exposed to the air. Boiling and poaching will cause a great loss of water-soluble vitamins, such as folate, vitamin B_1 and C; so steaming and microwave cooking as good methods to minimize the loss of vitamins.

Water soluble vitamins include

i. Vitamin C or Ascorbic acid

ii. Vitamin B complex-Vitamin B complex is composed of several compounds such as-

a) Vitamin B_1 or Thiamine
b) Vitamin B_2 or Riboflavin
c) Vitamin B_3 or Niacin
d) Vitamin B_5 or Pantothenic acid
e) Vitamin B_6 or Pyridoxine
f) Vitamin B_7 or Biotin
g) Vitamin B_9 or Folic acid or Folate
h) Vitamin B_{12} or Cyanocobalamin

Earlier vitamins B_4, B_8, B_{10} and B_{11} were included in group B vitamins. Later, these vitamins were found not to be essential in our diet and were subsequently removed from the list. Group B vitamins exhibit similar function in our body, that's why they are called vitamin B complex.

Sources, functions, deficiency diseases and risk group of deficiency of water soluble vitamins-

8.2 Vitamin C

8.2.1 Major sources:

No animal food contains vitamin C. Vitamin C is only found in plant foods and the best sources are-

Citrus fruits

Broccoli, Cabbage

Berries, Gapes

Tomatoes

Green papers

8.2.2 Functions

1. Acts as antioxidant.
2. Enhances iron absorption from nonheme sources (e.g., plant sources).
3. Enhances immune function.
4. Promotes wound healing.
5. Promotes the formation of new blood vessels.
6. Helps in excreting harmful chemical.

8.2.3 Deficiency diseases

1. Deficiency of vitamin C leads to scurvy which is characterized by gingivitis (soft, bleeding, and swollen gums, loose teeth); flesh that is easily bruised; hemorrhages under the skin; delaying wound healing; sore joints and muscles; and weight loss.
2. Retardation in growth.
3. Anemia, bone pain and fractures.

Scurvy

8.2.4 Hypervitaminosis

Excessive doses can cause kidney stones and break down red blood cells

8.2.5 Risk groups of vitamin C deficiency

Those populations do not eat fresh fruits and vegetables or those rely entirely on inadequate ration are at risk of vitamin C deficiency.

8.3 Vitamin B_1

8.3.1 Sources

Plant sources


Unpolished rice


Whole wheat


Oats

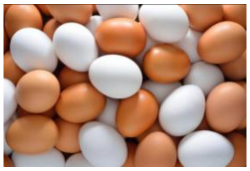

Corn


Rye


Barley

8.3.2 Animal sources


Liver


Eggs


Seeds


Nuts


Legumes

8.3.3 Functions

1. It is essential for the metabolism of carbohydrates and some amino acids.
2. It is also essential for nerve and muscle function.

8.3.4 Deficiency diseases

Deficiency symptoms include loss of appetite, fatigue, nervous irritability, and constipation. An extreme deficiency causes beriberi. There are three types of beriberi-

a. Dry Beriberi -Peripheral neuropathy

- Difficulty in walking.
- Burning sensation in the feet.
- Loss of feeling (sensation) in hands.
- Paralysis of the lower legs.
- Calf muscle tenderness.
- Tingling, ataxia

b. Wet Beriberi-Cardiopathy

- Edema (swelling) of lower legs, trunk and face
- Increase heart rate and enlargement of heart
- Congestive heart failure (cause of death)


Dry beriberi


Wet beriberi

c. Infantile beriberi-Sudden onset of shock which is preceded by a hoarse, week cry; poor feeding; and vomiting.

8.3.5 Risk groups of vitamin B_1 deficiency:

- Consuming diets rich in anti-thiamine factors, such as sulphites (added in food processing), thiaminase (found in raw fish and shellfish) and phytic acid (found in betel nuts).
- Consuming polished rice as a staple food which has not been parboiled.
- Breastfed babies whose mothers are in deficiency of vitamin B_1.

8.4. Vitamin B_2

8.4.1 Sources

Riboflavin is found in small amount in animal and plant foods. Some sources are-


Milk


Meat


Poultry


Fish


Green vegetables

8.4.2 Functions

1. Essential as co-enzymes for carbohydrates, proteins and fats metabolism
2. Necessary for tissue maintenance, especially the skin around the mouth and for healthy eyes.

8.4.3 Deficiency symptoms

A deficiency of riboflavin may lead to cheilosis, a condition characterized by

- sores on the lips
- cracks at the corners of the mouth
- glossitis (inflammation of the tongue),
- dermatitis, and
- eye strain in the form of itching, burning.


Sore lips


Glossitis


Dermatitis


Mouth corner cracks


Eye stain

8.5. Vitamin B_3 or Niacin

8.5.1 Sources

The best sources of niacin are meats, poultry, fish, peanuts and legumes. Milk and eggs provide good sources of its precursor, tryptophan (an amino acid). Vegetables and fruits contain little niacin.

8.5.2 Functions

- Helps in energy metabolism by acting as coenzymes.
- Inhibits production of cholesterol.
- Assists in triglyceride breakdown.

8.5.3 Deficiency diseases

Serious deficiency of niacin leads to pellagra (an Italian word meaning rough skin) commonly referred to as 4 Ds (dermatitis, diarrhea, dementia and death). Pellagra is also associated with deficiency of tryptophan and other B vitamins.

Dermatitis-

- Symmetrical distribution of skin lesions on the direct sunlight exposed parts. The lesions with erythema look like sunburn. There is a clear demarcation zone between the normal skin and pellagra dermatitis affected skin.

Diarrhea- Increased frequency and fluidity of the stools, often with blood and mucus.

Dementia (Neurological disorder) symptoms include

- Anxiety (fear and worry)
- Irritability (respond or reaction to stimulus)
- Poor memory, Insomnia (sleeplessness).
- Headaches
- Restlessness

Death-If not treated.

Fig. Symptoms of pellagra

8.5.4 Risk groups of niacin deficiency

- Those people eating maize as staple food without cooking with lime water or alkali.
- People solely rely on ration which contains inadequate niacin.

8.6. Vitamin B_5 or Pantothenic acid

8.6.1 Sources

Pantothenic acid is mainly found in animal foods such as meats, poultry, fish, and eggs. It is also found in whole-grain and legumes. In addition, it is thought to be synthesized by the body.

8.6.2 Functions

- Takes part in metabolism of carbohydrates, fats, and proteins.
- Helps synthesis of the neurotransmitter (acetylcholine) and steroid hormones.
- Improves human skin and hair

8.6.3 Deficiency symptoms

Vitamin B_5 deficiency is exceptionally rare. Signs and symptoms include fatigue, irritability, numbness, muscle pain, and cramps

8.7. Vitamin B_6 or Pyridoxine

8.7.1 Sources

Some of the pyridoxine dense foods are-


Poultry


Fish


Liver


Kidney


Potatoes


Whole oats


Whole wheat


Bananas


Spinach

8.7.2 Functions

- Helps in protein metabolism and absorption.
- Aids in releasing glucose from glycogen.
- Acts as a catalyst in converting tryptophan to niacin.
- Helps in synthesis of hemoglobin and neurotransmitters such as serotonin and dopamine.

8.7.3 Deficiency symptoms

- Muscle weakness, dermatitis, mouth sores, fatigue, and confusion;
- Anemia (RBCs size is normal or somewhat smaller but the hemoglobin content is lower).

8.8. Vitamin B_7 or Biotin

8.8.1. Sources: The best dietary sources of biotin are egg yolks, milk, poultry, fish, broccoli, spinach, and cauliflower.

8.8.2 Functions

- Helps in lipid metabolism.
- Helps in the synthesis of glucose and some nonessential amino acids.

8.8.3 Deficiency symptoms

Symptoms of biotin deficiency are similar to those of other B vitamins, but may also include hair loss when severe.

8.9. Vitamin B_9 or Folic acid/Folate

8.9.1 Sources


Green leafy veg.


Legumes


Sunflower seeds

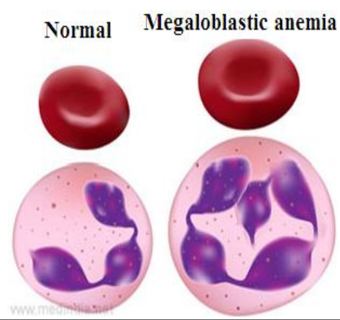

Citrus fruits


Liver

8.9.2 Functions

- Helps in synthesis of DNA and thus production of new cells, including red blood cells.
- Prevention of malformation of the neural tube (the tissue in a fetus, from which the brain and spinal cord develop)
- Synthesis of the amino acids
- Lower blood homocysteine levels by converting homocysteine to methionine.
- Regulate gene expression.

8.9.3 Deficiency diseases



- Causes megaloblastic anemia where immature and large RBCs circulate in the bloodstream.
- Deficiency during the early weeks of pregnancy causes neural tube defects which leads to anencephaly (the brain fails to develop normally) and spina bifida (abnormal development of the lower spinal cord).
- Increases homocysteine levels in blood which causes atherosclerosis and thereby increased risk of heart attack and stroke.
- May lead to silent gene expression; it may cause to develop cancer.

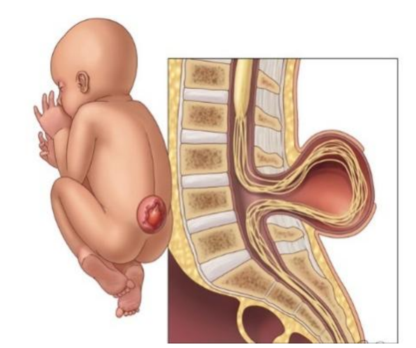


Fig. Spina bifida

8.9.3 Risk groups of folate/folic deficiency

Those having high demand but consume less folate containing foods such as infants, adolescents, pregnant and lactating mothers.

8.10. Vitamin B_{12} or Cyanocobalamin

8.10.1 Sources

The best food sources of B_{12} are animal foods, especially


Organ meats


Lean meat


Seafood


Eggs


Dairy products

8.10.2 Functions

☞ Assists with formation of blood.

☞ Required for healthy nervous system function.

☞ Involved as enzyme cofactor in metabolism of homocysteine.

8.10.3 Deficiency diseases

Megaloblastic anemia (an abnormally big of red blood cell) (megaloblast).

8.10.4 Risk groups of vitamin B_{12} deficiency

Vitamin B_{12} is only found in animal foods. Those who are strictly vegan may have chance to develop deficiency.

Table 8.1. Recommended dietary allowances of water-soluble vitamins per day.

Types	Age (years)	Vit. C (mg)	Vit. B_1 (mg)	Vit. B_2 (mg)	Niacin (mg)	Vit. B_6 (mg)	Folate (µg)	Vit. B_{12} (µg)
New born	0 to 0.5	30	0.3	0.4	5	0.3	25	0.3
	0.6 to 1	35	0.4	0.5	6	0.6	35	0.5
Children	1 to3	40	0.7	0.8	9	1	50	0.7
	4 to 6	45	0.9	1.1	12	1.1	75	1
	7 to10	45	1	1.2	13	1.4	100	1.4
Man	11 to 14	50	1.3	1.5	17	1.7	150	2
	15 to 18	60	1.5	1.8	20	2	200	2
	19 to 24	60	1.5	1.7	19	2	200	2
	25 to 50	60	1.5	1.7	19	2	200	2
	51+	60	1.2	1.4	15	2	150	2
Woman	11 to 14	50	1.1	1.3	15	1.4	180	2
	15 to 18	60	1.1	1.3	15	1.5	180	2
	19 to 24	60	1.1	1.3	15	1.6	180	2
	25 to 50	60	1.1	1.3	15	1.6	180	2

	51+	60	1	1.2	13	1.6	180	2
Pregnant		70	1.5	1.6	17	2.2	400	2
Lactating	1-6 mon.	95	1.6	1.8	20	2.1	280	2.6
Mother	7-12 mon.	90	1.6	1.7	20	2.1	260	2.6

Evaluation at the end of the lesson:

Short Questions:

1. Define vitamin.
2. Classify vitamin.
3. Describe sources, functions and deficiency diseases of vitamin C.
4. Describe sources, functions and deficiency diseases of vitamin B_1.
5. Describe sources, functions and deficiency diseases of vitamins B_2, B_3 and B_6.
6. Describe sources, functions and deficiency diseases of folic acid.
7. Describe sources, functions and deficiency diseases of vitamin B_{12}.

Lesson 9: Minerals

Learning outcomes

Upon completion of this lesson, the learners will be able to

- Define minerals;
- Classify minerals;
- Describe sources, functions and deficiency diseases of water soluble vitamins.

Minerals are inorganic elements (non-carbon containing) that occur naturally in the earth's crust. They are the simplest form of chemicals and are not digested or broken down prior to absorption. Body can only use ions of minerals (water soluble form) which are also called electrolytes because they carry electrical charges. Minerals cannot be synthesized in the laboratory or by any plant or animal, including humans. However, humans can obtain minerals from water or plant foods or animal foods those eating plants.

9.1. Classification of minerals

1. **Major minerals:** Major minerals are those that require at least 100 mg per day. Major minerals with known functions in the body include calcium (Ca), phosphorus (P), magnesium (Mg), sulfur (S), sodium (Na), potassium (K), and chloride (Cl). Special attention will be given in supplying calcium and phosphorus.
2. **Trace minerals:** Trace minerals are those that require less than 100 mg per day. Currently, eight trace minerals are recognized as essential for human health: iron (Fe), iodine (I), copper (Cu), selenium (Se), zinc (Zn), fluoride (F), manganese (Mn) and chromium (Cr). Some attention must be paid eating foods that provide enough iron and iodine.

Sources, functions, deficiency diseases and risk of deficiency of major minerals

9.2 Calcium (Ca)

9.2.1 Sources

Most abundant mineral in body is calcium appears in combination with phosphates. About 99% stored in bone and teeth.


Milk


Egg yolk


Shellfish


Leafy vegetables


Small fish

9.2.2 Functions

- Develop bones and teeth in combination with phosphorus.
- Helps in transmission of nerve impulses.
- Helps in blood clotting.
- Helps in normal heart action
- Maintain normal muscle activity.
- Helps in cell division, glycogen metabolism, release of neurotransmitters and hormones.

9.2.3 Deficiency diseases

Similar signs and symptoms are observed due to the deficiency of calcium as vitamin D deficiency.

9.2.4 Risk groups of calcium deficiency

- Those having high demand of calcium such as children, adolescents, pregnant and lactating mother.
- Decrease sex hormone production and skin pigmentation (skin pigmentation prevents sunlight penetration into the skin), middle-aged and elderly people are at risk of calcium deficiency.

9.3. Phosphorus (P)

9.3.1 Sources


Dairy products


Meat


Fish


Poultry


Nuts

9.3.2 Functions

- Helps in formation of bones and teeth.
- Maintains blood pH.
- Plays role in muscle contraction and nerve activity.
- Component of many enzymes.

- Involved in energy transfer (ATP).
- Component of DNA and RNA.

9.3.4 Deficiency diseases:

- Bone demineralization(loss of minerals),
- Fatigue, and anorexia, muscle weakness, dizziness

9.4. Sodium (Na)

9.4.1. Sources: Table salt, fast foods, processed foods, meats, eggs, milk, cheese, etc.

9.4.2 Functions

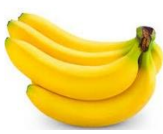
- Maintain fluid balance.
- Transmission of impulses across nerve and muscle fibers.
- Acid-base balance.
- Muscle contraction.

9.4.3 Deficiency or Excess

Excessive loss of sodium due to severe vomiting, diarrhea, or heavy sweating can upset the acid-base balance in the body. Alkalosis may develop due to excessive sodium loss which cause tetany. An excess of sodium cause edema which can cause hypertension and congestive heart failure.

9.5. Potassium (K)

9.5.1 Sources: Some important sources are-


Banana


Orange juice


Coconut water


Tomatoes


Water melon


Potatoes

9.5.2 Functions:

- Needs for generation and conduction of impulse in neurons and muscle fibers.
- Maintains fluid and electrolytes balance.
- Participates many biochemical reactions in the body.
- Regulates heart rate.

9.5.3 Deficiency or Excess

Deficiency (**hypokalemia**) can be caused by diarrhea, vomiting, diabetic acidosis, severe malnutrition, or excessive use of laxatives or **diuretics.** Nausea, anorexia, fatigue, muscle weakness, and heart abnormalities (tachycardia) are symptoms of its deficiency. **Hyperkalemia** can be caused by dehydration, renal failure, or excessive intake. Cardiac failure can result.

9.6. Chloride (Cl)

9.6.1 Sources: Sufficient amount is found table salt (sodium chloride) and sea foods.

9.6.2 Functions

- Maintains fluid and electrolytes balance.
- Maintains acid-base balance.
- Transmits nerve impulse.
- Forms gastric hydrochloric acid (HCl).

9.6.3 Deficiency

Normally deficiency is rare but may occur due to vomiting, diarrhea, or excessive use of diuretics; also can occur in patients who follow long term sodium-restricted diets.

9.7. Magnesium

9.7.1 Sources

Green leafy vegetables (Mg part of the green pigment, chlorophyll, which is vital for photosynthesis), whole grains, fish, meats, avocados, nuts, milk, legumes, etc.

9.7.2 Functions

- Required for normal functioning of muscle and nervous tissue.
- Helps in bone maintenance.
- Magnesium is required for functioning cellular energy molecule, ATP.
- Plays a role in the synthesis of DNA and RNA, carbohydrates, and lipids.
- Activate more than 300 enzymes and coenzymes.

9.7.3 Deficiency

Due to the wide availability, magnesium deficiency is rare on normal diets.

9.8. Sulfur

9.8.1 Sources

Amino acids cysteine and methionine containing protein foods such as fish, meat, milk, broccoli, etc.

9.8.2 Functions

- ☞ Component of amino acids cysteine and methionine;
- ☞ Part of vitamins biotin & thiamine as well as insulin hormone;
- ☞ Helps in detoxification of harmful chemicals in the liver.

9.8.3 Requirements or Deficiency

Neither the amount of sulfur required by the human body nor its deficiency is known.

9.9. Iron

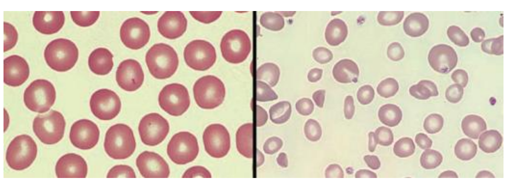
9.9.1 Sources: Meat, poultry, fish, whole-grains, vegetables, fruit and eggs

9.9.2 Functions

- ☞ Iron is present in hemoglobin of RBC which helps to carry oxygen to all parts of the body.
- ☞ Iron is also present in myoglobin (a muscle protein) which helps to supply and store oxygen in muscles.
- ☞ Plays an important role in immune function.
- ☞ Participates in energy production (component of coenzymes in electron transport).
- ☞ Helps in oxidative degradation of drugs and toxic chemicals.

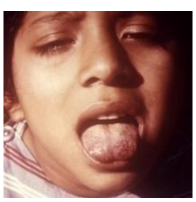
9.9.3 Deficiency diseases

WHO considers iron deficiency to be the number one nutritional disorder in the world. Deficiency of iron causes anemia (small and pale RBCs). Symptoms include fatigue, weakness, irritability, and shortness of breath. Clinical signs include pale skin and spoon-shaped fingernails.



RBCs: Healthy (*left*) and anemic (small and pale) (*right*)

Spoon-shaped fingernail



Pale face and tongue

9.9.4 Risk groups of iron deficiency

- Women of child-bearing age (because of blood loss through menstruation);
- Pregnant and breastfeeding women (because of increased iron requirements);
- Babies greater than six months who are exclusively breastfed;
- Babies less than six months in particular-who are fed on animal milk;
- Complementary foods that are often low in iron;
- People living in regions where malaria and intestinal parasitic infestation are prevalent are also at risk;
- Insufficient intake, malabsorption, lack of sufficient stomach acid, excessive blood loss, frequently donate blood, or take excessive antacids.

9.9.5 Toxicity: Nausea, vomiting, and diarrhea; dizziness, confusion; rapid heartbeat, organ damage, death.

9.10. Iodine

9.10.1 Sources: Sea foods, iodized salt, vegetables grown in iodine-rich soils.

9.10.2 Functions

Iodine is necessary for the synthesis of the thyroid hormones, thyroxine and triiodothyronine. Thyroid hormones are responsible for a number of important functions in the body such as-

- Regulates metabolic rate;
- Regulate body temperature;
- Necessary for protein synthesis;
- Intestinal absorption of glucose and galactose, as well as lipolysis;
- Promote nitrogen retention;
- Uptake of glucose by adipocytes;
- Growth and development in particular brain development;
- Prevent certain types of cancer.

Different sea foods containing iodine

9.10.3 Deficiency diseases

- Maternal deficiency- stillbirths, spontaneous abortions
- Infants born from iodine deficient mothers-endemic cretinism characterized by severe physical and mental retardation, low birth weight outcome.
- Goiter or enlargement of thyroid gland is the first symptoms of iodine deficiency.
- Intense feeling of fatigue, depression, slow down metabolism leads to weight gain.

Cretinism

- Reduce cognitive abilities like memory and overall thought process.
- Increase risk of infection as white blood cells cannot work against infection without iodine.

9.10.4 Risk groups of iodine deficiency

- People living in northern region (e.g., Kurigram, Dinajpur) of Bangladesh because soil of this region contains very low-level iodine and thereby crops.
- People consuming salt lack of iodine and not sea foods are also at risk of deficiency.
- Women of reproductive age, pregnant women, infants, adolescents.

Endemic goiter

WHO estimates iodine deficiency affects over two billion people worldwide and it is the number-one cause of preventable brain damage worldwide.

9.11. Zinc

9.11.1 Sources: Dietary sources of zinc are red meat (3-5 mg/100 g), whole grains and legumes (2-3 mg/100 g) and oysters (70 mg/100 g).

9.11.2 Functions

Zinc is necessary for

- ☞ maintain immune function;
- ☞ DNA synthesis, cell division, protein synthesis and digestion;
- ☞ cell growth and repair;
- ☞ normal sperm counts in males;
- ☞ cell repair and wound healing;
- ☞ decrease stool volume and frequency.

9.11.3 Deficiency diseases

- Growth retardation, dwarfism, delayed sexual maturation;
- Hypogonadism (subnormal development of male sex organs);
- Eye and skin lesions, hair loss, diarrhea;
- Increased incidence of illness and infection;
- Poor wound healing, anemia and acnelike rash;
- Decreased appetite and taste acuity.

9.12. Copper (Cu)

9.12.1 Sources: Organ meats, shellfish, legumes, nuts, cocoa, whole grains

9.12.2 Functions

- ☞ An essential component of several enzymes.
- ☞ Helps in the formation of hemoglobin
- ☞ Aids in the transport of iron to bone marrow (soft tissue in bone center) for the formation of red blood cells.
- ☞ Participates in energy production (component of coenzymes in electron transport).
- ☞ Plays important role in oxidation-reduction (redox) reactions and in scavenging free radicals.

9.12.3 Deficiency or Toxicities

Anemia, reduced levels of white blood cells, osteoporosis, in infants and growing children. Excess copper can be highly toxic-Nausea, vomiting, and diarrhea, liver damage.

9.13. Fluoride (F)

9.13.1. Sources: Fish, seafood, legumes, whole grains, drinking water

9.13.2. Functions: Development and maintenance of healthy teeth and bones.

9.13.3. Deficiency: Dental caries, low bone density

9.13.4. Toxicity: Fluorosis (hypomineralization of **tooth** enamel) of teeth and bones.

Evaluation at the end of the lesson:

Short Questions:

1. Define minerals.
2. Classify minerals.
3. Describe sources, functions and deficiency diseases of calcium.
4. Describe sources, functions and deficiency diseases of iron.
5. Describe sources, functions and deficiency diseases of iodine.
6. Describe sources, functions and deficiency diseases of folic acid.
7. Describe sources, functions and deficiency diseases of zinc.

[**Note:** It is an impossible task to consume optimum level of micronutrients through correctly balance food choices; rather the best approach is to eat a variety of healthful foods every day.]

Table 9.1. The amount of daily requirements of different major and trace minerals

Life stage	Ca (mg/d)	P (mg/d)	Na (g/d)	Cl (g/d)	K (g/d)	Mg (mg/d)	Fe (mg/d)	I (µg/d)	Zn (mg/d)	F (mg/d)	Cu (µg/d)
Infants											
0–6 mo	210*	100*	0.12*	0.18*	0.4*	30*	0.27*	110*	2*	0.01*	200*
7-12 mo	270*	275*	0.37*	0.57 *	0.7*	75*	**11**	130*	**3**	0.5*	220*
Children											
1–3 y	500*	**460**	1.0*	1.5*	3.0*	**80**	**7**	**90**	**3**	0.7*	**340**
4–8 y	800*	**500**	1.2*	1.9*	3.8*	**130**	**10**	**90**	**5**	1*	**440**
Male											
9–13 y	1300*	**1250**	1.5*	2.3	4.5* *	**240**	**8**	**120**	**8**	2*	**700**
14–18 y	1300*	**1250**	1.5*	2.3*	4.7*	**410**	**11**	**150**	**11**	3*	**890**
19–30 y	1000*	**700**	1.5*	2.3*	4.7*	**400**	**8**	**150**	**11**	4*	**900**
31–50 y	1000*	**700**	1.5*	2.3*	4.7*	**420**	**8**	**150**	**11**	4*	**900**
51–70 y	1200*	**700**	1.3*	2.0*	4.7*	**420**	**8**	**150**	**11**	4*	**900**
>70 y	1200*	**700**	1.2*	1.8*	4.7*	**420**	**8**	**150**	**11**	4*	**900**
Female											
9–13 y	1300*	**1250**	1.5*	2.3*	4.5*	**240**	**8**	**120**	**8**	2*	**700**
14–18 y	1300*	**1250**	1.5*	2.3*	4.7*	**360**	**15**	**150**	**9**	3*	**890**
19–30 y	1000*	**700**	1.5*	2.3*	4.7*	**310**	**18**	**150**	**8**	3*	**900**
31–50 y	1000*	**700**	1.5*	2.3*	4.7*	**320**	**18**	**150**	**8**	3*	**900**
51–70 y	1200*	**700**	1.3*	2.0*	4.7*	**320**	**8**	**150**	**8**	3*	**900**
>70 y	1200*	**700**	1.2*	1.8*	4.7*	**320**	**8**	**150**	**8**	3*	**900**
Pregnancy											
14–18 y	1300*	**1250**	1.5*	2.3*	4.7*	**400**	**27**	**220**	**12**	3*	**1000**
19–30 y	1000*	**700**	1.5*	2.3*	4.7*	**350**	**27**	**220**	**11**	3*	**1000**
31–50 y	1000*	**700**	1.5*	2.3*	4.7*	**360**	**27**	**220**	**11**	3*	**1000**
Lactation											
14–18 y	1300*	**1250**	1.5*	2.3*	5.1*	**360**	**10**	**290**	**13**	3*	**1300**
19–30 y	1000*	**700**	1.5*	2.3*	5.1*	**310**	**9**	**290**	**12**	3*	**1300**
31–50 y	1000*	**700**	1.5*	2.3*	5.1*	**320**	**9**	**290**	**12**	3*	**1300**

[Note: Recommended Dietary Allowances (RDAs) (**bold type)** and Adequate Intakes (AIs) followed by an asterisk (*).]