FUNDAMENTALS OF FOOD AND NUTRITION

M.Sc., FOODS AND NUTRITIONAL SCIENCE,
First Year, Paper - I

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FOREWORD

Acharya Nagarjuna University, since its establishment in 1976, has been moving ahead in the path of academic excellence, offering a variety of courses and research contributions. The University achieved recognition as one of the eminent universities in the country by gaining A grade from the NAAC 2016. At present Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels to students of 447 affiliated colleges spread over the two districts of Guntur and Prakasam.

The University had started the Centre for Distance Education in 2003-04 with the aim to bring Higher education within the reach of all. The Centre has been extending services to those who cannot join in colleges, cannot afford the exorbitant fees as regular students, and to housewives desirous of pursuing higher studies to study B.A., B.Com, and B.Sc., Courses at the Degree level and M.A., M.Com., M.Sc, M.B.A. and LL.M. courses at the PG level.

For better understanding by students, self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been prepared with care and expertise. However constructive ideas and scholarly suggestions are welcome from students and teachers. Such ideas will be incorporated for the greater efficacy of the distance mode of education. For clarification of doubts and feedback, Weekly classes and contact classes are arranged at UG and PG levels respectively.

I wish the students who pursue higher education through Centre for Distance Education will not only be personally benefited by improving their qualifications but also strive for nation's growth by being a member in Knowledge society I hope that in the years to come, the Centre for Distance Education will grow in strength by introducing new courses, catering to the needs of people. I congratulate all the Directors, Academic coordinators, Editors, Lesson - Writers, and Academic Counsellors and Non-teaching staff of the Centre who have been extending their services in these endeavours.

Professor Rajasekhar P.
Vice-Chancellor (FAC)
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M.Sc., FOODS AND NUTRITIONAL SCIENCE (Course Code-139)

Paper- I: FUNDAMENTALS OF FOOD AND NUTRITION

SYLLABUS

UNIT I:

- Introduction to Terminologies: Food, Nutrition, Nutrient, Empty Calories, Health, Malnutrition, Edible portion of food, Balanced Diet.
- Basis for computing nutrient requirements: latest concepts in dietary recommendations, RDA- ICMR and WHO: their uses and limitations.

UNIT II:

- Carbohydrates: Definition, Composition, Classification, Food Sources (good and poor sources), Functions in human body, Recommended Daily Allowance in India (RDA), Importance of fibre.
- Fats And Oils: Definition, Composition, Saturated and Unsaturated fatty acids, Cholesterol (a brief note), Food sources of: (Fat, Oil, Saturated fatty acid, Unsaturated fatty acid, cholesterol), requirements and biological functions.
- Protein: Definition, Composition, Essential and Non-essential amino acids, Protein Quality (only Concept), Concept of Supplementary value of Protein, Food Source (good and poor source), Effect of deficiency, Functions.

UNIT III:

- Vitamins: Definition, Classification
- Fat Soluble Vitamins (A,D,E,K) – Functions, Food Sources, RDA, Name of the deficiency disease and symptoms.
- Water Soluble Vitamins (B complex and C): Functions, Sources, RDA, Deficiency diseases and its symptoms.

UNIT IV:

- Macro minerals: Calcium, Phosphorous, Sodium, Potassium, chloride - sources, biological functions, factors affecting availability.
- Micro minerals and their importance: - Cobalt, Copper, Zinc, Iron, Molybdenum, Selenium, Chromium, Iodine and fluorine in human nutrition – assessment of requirements of micro and macro minerals.

UNIT V:

- Nutrition and programmes by government for different nutrient deficiency diseases.

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UNIT–I

CHAPTER 1 INTRODUCTION TO TERMINOLOGIES

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OBJECTIVES

After going through this chapter, you should be able to:

- describe nutrition
- explain the food
- understand functions of nutrients
- define health.

STRUCTURE

1.1 INTRODUCTION

All living organisms need food, which is used as a source of energy, and materials for growth, maintenance and other activities of the body. Animals including humans have heterotrophic mode of nutrition, *i.e.*, they get their food requirements from other organisms, plants or other animals or both. Human food contains carbohydrates, fat, proteins, minerals, vitamins and water. Each food complement has a specific role, and all components must be present in proper proportions in each meal. Such a meal forms the "balanced diet." Lack of one or more food components can cause nutritional abnormalities.

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1.2 FOOD

Food is a substance which when taken, digested, and incorporated into the body tissues, provides materials for energy, tissue repair, growth, reproduction, regulation of life processes and resistance to diseases without harming the organism. The study of food stuffs, their nutritional value and requirements to keep fit and healthy is called *dietetics*.

Functions of Food

The food performs following functions in our body.

1. It provides energy to do work and to maintain body temperature.
2. It provides materials for the growth of the body.
3. It provides materials for the repair of worn out cells and tissues in the body.
4. It provides materials for the synthesis of cellular products like enzymes, hormones, antibodies, haemoglobin etc.
5. It helps in regulation of body processes to maintain life.

Types of Nutrients

Nutrients may be organic or inorganic in nature. The organic constituents of nutrients are carbohydrates, lipids, proteins and vitamins. The inorganic constituents of nutrients are minerals and water. Carbohydrates, lipids and proteins form the major part of the food and are termed as *macronutrients* or *food proper.* These serve the energy sources for the production of heat and perform different organic functions and hence are also termed as *proximate principles of food.* They are digested (hydrolyzed) in the alimentary canal to sugars, fatty acids glycerol and amino acids. These materials, after absorption, are supplied by blood to the tissues. Here, they are used for two main purposes. (*i*) for obtaining energy by oxidation, and (*ii*) for synthesizing carbohydrates, lipids, proteins and other organic compounds characteristic of human beings.

Water, minerals and vitamins have small molecules and are absorbed without any change. These are called *micronutrients.* Although, they do not provide energy, yet their deficiencies cause specific diseases and abnormalities in man, hence, they are also called *protective principles of food* or *food accessories.* Water forms a large part of our food and plays a multiple roles in the body. Mineral and vitamins form a very small part of the food, but play a vital role. They function as *regulatory substances.* All the six nutrients mentioned above are essential for normal healthy life and are needed in specific amounts in the diet. A deficiency of any of these materials results in abnormal functioning of the body.

In addition to these materials, a proper diet should also contain *roughage.* Roughage is a desirable but non-nutrient indigestible component of food which is formed of fibrous plant matter and connective tissues of animal matter. It does not yield energy, and also has no structural and functional role in the body. This food component is, however, desirable because it helps in maintaining the optimum efficiency of digestive tract.

Nutritional Classification of Foods

Different foods are grouped on the basis of nutrients contained in them and their functions in the body (Fig.1.1).

Based on functions, foods can be categorised into three broad groups of foods:

1. Energy giving foods
2. Body building foods
3. Protective or regulatory foods.

1. Energy giving foods. Energy is of primary importance to our body. We need energy to do work and also to make certain substances inside the body. There are certain foods which provide energy to our body. Such foods are rich in carbohydrates and fats *e.g.*, cereals, sugar, fats, oils, roots, tubers etc.

2. Body building foods. Several nutrients combine to build the body and to keep it in good condition. Body also needs the repair of damaged tissues. Certain foods provide materials for making new cells and repairing of the damaged tissues. Such foods are rich in proteins. *e.g.*, milk, egg, meat, fish, pulses, nuts and oilseeds etc.

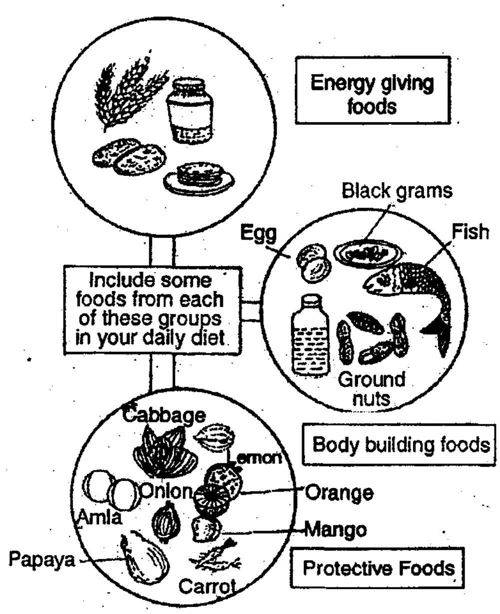

Fig. 1.1. *Three basic food groups.*

3. Protective or regulatory foods. Certain food constituents (nutrients) regulate the functions of the body and protect it against infection. These constituents are vitamins and minerals. They are though needed in small amounts yet are essential for health and well being. Absence of vitamins and minerals in the diet causes **'deficiency diseases'.** The foods rich in vitamins and minerals are whole cereals, green leafy vegetables, fruits, milk, fish etc. Three food groups and their sources are given in Table 1.1.

Table 1.1. Three Food Groups and their Sources

Food Group (According to Functions)	*Major Nutrients*	*Foods Containing the Nutrients*
1. Energy Giving	Carbohydrates and Fats	1. Cereals like rice and wheat 2. Starches like potato, sweet potato 3. Fat–Ghee and oil 4. Sugar
2. Body Building	Proteins	1. Milk 2. Meat—Mutton, chicken, fish, Egg white. 3. Pulses like dals, gram, soya bean, peas.
3. Protective	Minerals, Vitamins	1. Vegetables specially green leafy vegetables like spinach, cabbage, and 2. Dietary Fibre such as brinjal, beans and fruits.

Other Food Groups

The U.S. Department of Agriculture has suggested different food group plans in different years. These food group plan are— (*i*) The 7-food group plan, (*ii*) The 4-food group plan and (*iii*) The 11-food group plan.

1. The 7-Food Group Plan

This food group plan was given in the year 1943 by the U.S. Department of Agriculture. The 7-groups of the food and their nutrient contributions are given in Table 1.2.

Table 1.2. The Basic 7-Food Groups with their Nutrient Contributions

S.No.	*Food Groups*	*Main Nutrient Contributions*
1.	Bread, flour and cereal (whole grain, enriched or restored)	Carbohydrates and cellulose, Thiamine, Niacin, Riboflavin, Iron.
2.	Meat, poultry, fish and eggs	Proteins, Phosphorus, Iron and B-vitamins.
3.	Milk and milk products	Proteins, Calcium, Phosphorus and B-vitamins.

4.	Butter or fortified margarine	Fat and vitamin-A.
5.	Potatoes, other vegetables and fruits	Cellulose, vitamins and minerals in general.
6.	Green and yellow vegetables	Carotene (Provitamin A), Ascorbic acid and Iron.
7.	Oranges, grape fruit, tomatoes or raw cabbage or salad greens.	Ascorbic acid.

2. *The 4-Food Group Plan*

This food group plan was recommended in the year 1956 by the U.S. Department of Agriculture. The 4-food groups and their nutrient contributions are given in Table 1.3

Table 1.3. The 4-Food Group Plan and their Nutrient Contributions.

(Adopted from Essentials of an Adequate Diet U.S. Department of Agriculture, Agriculture Information Bulletin 160, 1956).

S.No.	*Food Groups*	*Main Nutrient Contributions*
1.	**Bread-cereal group** whole grain enriched, restored.	Carbohydrates and Cellulose, Thiamine, Niacin, Riboflavin, Iron.
2.	**Meat group** Beef, veal, Pork, Lamb, Poultry, Fish, Eggs.	Protein, Phosphorus, Iron and B-vitamins.
3.	**Milk group** Milk, cheese, ice cream (cheese and ice cream can replace part of the milk).	Proteins, Calcium, Phosphorus and vitamins.
4.	**Vegetable-fruit group**	Vitamins, Minerals and Cellulose.

3. *The 11-Food Group Plan*

This food group plan was given in the year 1964 by the U.S. Department of Agriculture. The 11-food groups and their nutrient contributions are given in Table 1.4.

Table 1.4. The 11-Food Group Plan and their Nutrient Contributions.

(U.S. Department of Agriculture 1964).

S.No.	*Food Groups*	*Main Nutrient Contributions*
1.	(*i*) Milk and Cheese	Proteins, Calcium, Phosphorus and vitamins.
	(*ii*) Ice cream	Fat and Carbohydrates.
2.	Meat, poultry and fish	Proteins, Phosphorus, iron and B-vitamins
3.	Eggs	Proteins, Fat, Vitamins, Iron and Phosphorus .
4.	Dry beans, peas and nuts	Proteins and B-vitamins

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5.	Flour, Cereals and baked products (Whole grain, enriched, restored)	Carbohydrate, Cellulose, Thiamine, niacin, riboflavin and iron
6.	Fats and oils	Essential fatty acids and vitamin E.
7.	Sugar, syrup and preserves	Carbohydrates
8.	Potatoes	Carbohydrates and ascorbic acid.
9.	Dark green and deep-yellow vegetables	Provitamin A (carotene), ascorbic acid and iron
10.	Citrus fruits and tomatoes	Ascorbic acid and potassium.
11.	Other vegetables and fruits	Cellulose and ascorbic acid.

Functions of Nutrients

The daily meals of human beings include wheat, rice, dal, vegetables, fruits, milk, eggs, fish, meat, sugar, butter, oil etc. These different foods contain different types of nutrients. Each nutrient has its own function, but the various nutrients must act together for effective action. The various nutrients found in foods include carbohydrates, proteins, fats, minerals, vitamins and water. Fibre is also an essential component of our diet. The functions of various nutrients are given below.

1. Carbohydrates. Starch present in cereals and sugar in sugar cane and fruits are examples of carbohydrates in food. The chief function of carbohydrates is to provide energy needed by our body. The carbohydrates which are not used immediately for this purpose are stored as glycogen or converted into fat and stored. The stored glycogen or fat are mobilised for energy supply when needed.

2. Proteins. The common food items which contain protein are milk, pulses, beans, cereals, fish, egg and lean meat. Casein in milk, albumin in egg, globulins in legumes and gluten in wheat are some examples of proteins occurring in common foods. The main function of protein is the building of new tissues and repair of the worn out tissues. Food proteins are also responsible for the synthesis of protective substances such as enzymes, hormones and antibodies. Protein, when taken in excess of the body's need, is converted to carbohydrates and fats and is stored in the body.

3. Fats. The food items containing fats include oil seeds, nuts, butter ghee and meat. The common examples of fats in food are oils in oil seeds, butter in milk and lard in meat. Fats are concentrated sources of energy. They are carriers of fat soluble vitamins and a source of essential fatty acids. If diet is rich in fat, the latter are stored as fat reserves in the body.

4. Minerals. The various minerals (*e.g.*, sodium, potassium, calcium, phosphorus, iron, iodine and others) are found in various foods in combination with organic and inorganic compounds. They are necessary for body building such as formation of teeth and bones and structural parts of soft tissues. They also play vital role in a number of physiological activities like muscle contraction, clotting of blood, conduction of nerve impulse etc.

5. Vitamins. Different types of vitamins are found in various foods. These are needed for growth and normal functioning of the body processes.

6. Water. Our body gets water from a number of food items like fruits, vegetables, milk, tea, coffee etc. However, most of the water needed by our body comes from plain drinking water. Water is essential for most of the biochemical reactions occurring in the body. It is also essential for the utilization of food materials in the body and elimination of wastes. It maintain the body's temperature and regulates a number of body processes.

Empty Calories

There are some eatables, which provide calories only and do not provide nutrients, such calories are called **empty calories.** The eatables that provide empty calories are often referred as junk foods. The food items such as candy, peppermints, ice creams, chocolates, soft drinks etc. provide only empty calories, leading to a number of health problems. These foods reduce or dull the appetite, without meeting the body's need. The food items providing the empty energy are quite popular among the children and adolescents. The consumption of junk foods among youngs should be discouraged for their healthy growth.

1.3 NUTRITION

All living organisms need raw materials to build up most of their own body molecules, and they require energy to perform the metabolic reactions that sustain life. The materials which provide the two primary requirements of life, *i.e.*, raw materials and energy, are called *nutrients.* A substance which is taken to supply the necessary nutrients to the body is termed *food* or *diet.* The sum total of the processes by which the living organisms obtain food and utilize it for use in various biological activities, such as growth, maintenance and for meeting their energy needs is called *nutrition.* A person who specializes in the processes and problems of nutrition is known as a *nutritionist* or *dietitian.*

1.4 HEALTH

According to World Health Organization (WHO) health is defined as '*a state of complete physical, mental and social well being and not merely the absence of disease or infirmity*'. Health is the basic to life and it is not possible to expect optimum results in any sphere of life without good health. A factory owner cannot expect the optimum output if he does not employ healthy workers. A farmer cannot get optimum crop in his fields, if he is not healthy. Health is, thus, directly related to our personal life and professional efficiency. Health is an essential characteristic, without which, we even cannot enjoy our leisure and lead a happy family and social life in the society.

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Conditions Essential for Good Health

Good health is a disease free condition as well as a state of complete, mental and social well being. A healthy human being generally has the following features:

- a clear skin and bright, clear eyes.
- body neither too fat nor too thin.
- fresh breath and good appetite.
- sound sleep and regular activity of bladder and bowels.
- coordinated body movements.

The conditions that are to be fulfilled for good health include:

1. Nutrition,
2. Proper habits,
3. Exercise and relaxation.

1. Nutrition

The process of procurement of substances (nutrients) necessary for growth, development, maintenance and activities of a living organism is called nutrition. Nutrition is really a process in which food is ingested and digested, its nutrients are absorbed and finally distributed to all parts of the body, where they are utilised in all the metabolic activities. Thus, nutrition provides materials required for the survival and maintenance of proper health.

We take food from various plant and animal sources. We need to take food to meet out our daily energy need. We consume energy not only during work but also while sleeping. The energy requirement depends on individual's age and special need. Growing children, pregnant women and nourishing mothers need more energy.

2. Proper Habits

The proper dietary habits *i.e.*, consumption of balanced diet and at a fixed time is another important aspect for good health. Personal and domestic hygiene are also very essential for good health. Following aspects should be kept in mind for healthy dietary habits.

(*i*) The food should be fresh and it should always be kept away from dust, flies, insects and microbes to avoid any infection and spoilage.

(*ii*) The utensils used for cooking and eating should be kept clean.

STUDENT ACTIVITY

1. Why do we need food?

2. Explain the conditions essential for good health.

(*iii*) Face and hands should be washed with soap before eating and handling the food.

(*iv*) Food should always be cooked with good (happy) feelings and cheerful mood.

(*v*) The addictive habits such as smoking, chewing tobacco, drinking alcohol, taking addictive drugs should be avoided. Such habits have damaging effects on our body and mind.

3. Exercise and Relaxation

Regular physical exercise in necessary to keep our body fit. It keeps the muscles and joints flexible, improves blood circulation and gives a good appetite. It also helps to have sound sleep. Physical exercises very with age, physical condition and nature of work of the individual. Physical exercises are more essential for the sedentary workers (*i.e.*, those working mostly in sitting position). Morning walk in fresh air is a good exercise for the middle aged and aged persons.

Regular sleep and relaxation are other aspects of good health. The duration of sleep varies with age and nature of work. Adequate rest is required by all parts of the body. A six to eight hours of sound sleep after a hard day's work gets the body going for hard work the next day. Infants, however, sleep for long hours as it is necessary for their growth. For children an average of eight hours of sound sleep is sufficient. For adults, six hours of sleep is enough. The old saying *'early to bed and early to rise makes a man healthy, wealthy and wise'* is a basic principle of good health. Late rising and late night sleep leaves a person tired during working hours.

Relaxation is also necessary after a work. Relaxation may be defined as an activity or recreation which provides a relief or diversion from work or effort. Relaxation improves the capacity to work. There are various ways of relaxation. Yoga and meditation relax the body and mind. Listening music and reading magazine are also a kind of relaxation. When the body feels fatigued, lying down or sitting with hands, feet relaxed and eyes closed, for a few minutes refreshes the body.

Balanced Diet

The kinds of food on which a person or a group live constitute a diet. A diet consists of many food items made from cereals, fruits, vegetables, meat, fish, eggs and milk etc. *'The diet which contains all the nutrients in the correct amount is called balanced diet'.* A balanced diet should also contain sufficient amounts of water and roughage material. Thus, the constituents of a balanced diet are: carbohydrates, fats, proteins, minerals (salts), vitamins, water and roughage. No single food can provide all the essential nutrients in adequate amounts. Therefore, a balanced diet consists of a number of food items taken together, provide all the nutrients, water and roughage to the body.

A balanced diet has the following qualities:

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1. Meets the nutrient requirement of the body.
2. Consists of different types of food items.
3. Provides adequate amount of energy.

Balanced diet varies with age, occupation and state of health. The food groups can broadly be classified into **food exchange system,** for planning of balanced diet. In this exchange system foods of specific serving size (quantity) are decided and standardized in terms of energy (k.cal), protein, fat and carbohydrate. A list of food exchange system (quantity) is given in Table 1.5. The balanced diets formulated by **Indian Council of Medical Research (ICMR)** for different age, occupation and state of health are given in Table 1.6 and 1.7.

Table 1.5. The Food Exchange System

Exchange List	*Serving size/or Raw Weight in (g)*	*Carbo-hydrate (g)*	*Protein (g)*	*Fat (g)*	*Energy (k. cal)*
Vegetables					
Green Leaf	1/2 Cup	6	Nil	•	30–40
Other	1/2 Cup	6–10	Nil	Nil	50–60
Fruit	Varies	10	Nil	Nil	40
Cereal	25	19–21	2–3	•	85
Legumes and Pulses	25	15	6	•	85
Milk	1/2 Cup	6	3.5	4.0	65
Meat	75	Nil	7.5	6.0	85
Fat	10	Nil	Nil	10.0	90
Sugar	10	10	Nil	Nil	40

Table 1.6. Balanced Diet as Recommended by ICMR
(The quantities are given in grams)

	Adult Man			*Adult Women*			*Children*		*Boys*	*Girls*
Food Item	*Seden-tary*	*Moder-ate work*	*Heavy work*	*Seden-tary*	*Moder-ate work*	*Heavy work*	*1–3*	*4–6*	*10–12*	*10–12*
Cereals	460	520	670	410	440	575	175	270	420	380
Pulses	40	50	60	40	45	50	35	35	45	45
Leafy vegetables	40	40	40	100	100	50	40	50	50	50
Other vegetables	60	70	80	40	40	100	20	30	50	50
Roots and Tubers	50	60	80	50	50	60	10	20	30	30
Milk	150	200	250	100	150	200	300	250	250	250
Oil and Fat	40	45	65	20	25	40	15	25	40	35
Sugar or Jaggery	30	3555	20	20	40	30	40	45	45	50

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Table 1.7. Suggested Substitution for Non-Vegetarian

Food Item which can be Deleted from Non-Vegetarian Diets	*Substitution that can be Suggested for Deleted Item or Items*
1. 50% of pulses (20–30 *g*)	1. One egg or 30 *g* of meat or fish 2. Additional 5 *g* of fat or oil
2. 100% of pulses (40–60 *g*)	1. Two egg or 50 *g* of meat or fish. One egg or 30 *g* meat. 2. 10 *g* of fat or oil.

Planning of Balanced Diets

A balanced diet must include various nutritional materials *i.e.*, proteins, carbohydrates, fats, minerals, vitamins, roughage and water in sufficient amount and proper proportion. Our food should contain various nutrients in such proportions as can satisfy all the needs of our body. The components of a balanced diet will differ according to age, sex, physical activity, economic status and the physiological state, *viz.*, pregnancy, lactation, etc. While planning of the balanced diet, economic status should be kept in mind. Balanced diets for the people of different economic groups are follows:

1. **High cost balanced diets.** Such diets will include liberal amounts of costly foods such as milk, eggs, meat, fish and fruits and moderate quantities of cereals, pulses and fats.

2. **Moderate cost balanced diets.** These diets will include amounts of milk, eggs, meat, fish, fruits and fats and liberal amounts of cereals, pulses, nuts and green leafy vegetables.

3. **Low cost balanced diets.** These diets will include small amounts of milk, eggs, meat, fish and fats and liberal amounts of cereals, pulses, nuts and leafy green vegetables.

Energy Value of Foods

The energy requirements of an individual and the energy content of food is expressed in terms of a measure of heat energy, because heat is the ultimate form of all energies. This is often referred to as *calorie* (cal) or *joule* (J). It is the amount of heat energy required to raise the temperature of 1 *g* of water to 1°C. Since this value is a tiny amount of energy, physiologists commonly use ***kilo calorie*** (k. cal) as a unit of measure (1 *k* cal = 1,000 cal) or ***kilojoule*** (k. J). One kilo calorie is the amount of energy required to raise the temperature of 1 kg of water to, nutritionists, traditionally refer to *k* cal as the *calorie* or *Joule* (always capitalised). The amount of heat liberated from complete combustion of 1 g food in the bomb colorimeter (a closed metal chamber filled with oxygen) is its ***gross calorific*** or ***gross energy value.*** The actual amount of energy liberated in the human body due to combustion of 1 g of food in the ***physiological***

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value of food. The gross calorific and physiological values of macronutrients are given in Table 1.8.

Table 1.8. Calorific and Physiological Value of Food.

Macronutrients	*Gross energy value (kcal/g)*	*Loss of food energy in digestion %*	*Energy available after digestion (k.cal/g)*	*Loss of food energy in metabolism (k.cal/g)*	*Physiological energy value of food (k.cal/g)*
1. Carbohydrates	4.1	2	40	nil	4.0
2. Proteins	5.65	8	5.2	1.2	4.0
3. Fats	9.45	5	9.0	nil	9.0

The energy values of foods given in the food composition table (Table 1.8) are calculated from their contents of carbohydrates, fats and proteins using the physiological energy values of 4 k.cal per gram of carbohydrates or proteins and 9 k.cal per gram of fat.

Energy Requirements

Energy requirements of an individual is expressed as total calories to be obtained from the food everyday. It is supplied by carbohydrates, proteins and lipids of the flood. Energy requirement includes the requirement for growth, maintenance, vital activities (heartbeat, respiration, urine formation etc.), temperature regulation, reproduction and muscular activities. Total calorie requirement, therefore, depends on the age, sex and level of muscular work. It is higher per kg of body weight in a growing child and in an adult, lower in old people, higher in an adult man than in an adult woman and higher during pregnancy and lactation. Calorie requirement rises with the level of muscular work. The energy requirement for adult men for various types of physical activity are given in Table 1.9.

Table 1.9. Mean Calorie Requirements for Various Types of Activities for Adult Man.

Type of Work	*(Kcal/hr) Range*	*Mean Calorie Requirements*
1. Very heavy work	600 – 750	675
2. Heavy work	450 – 590	525
3. Moderate work	300 – 440	375
4. Light work	150 – 290	225
5. Very light work	100 – 140	120
6. Standing	—	85
7. Sitting at rest	—	75
8. Basal metabolism*	—	65
9. Sleep	—	60

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*Energy metabolism of an individual at complete physical and mental rest in post absorptive state (*i.e.*, 12 hours after the intake of last meal) at a normal body temperature.

The energy requirements during work can be calculated by adding together the energy required for (*i*) basal metabolism (*ii*) additional energy required for work and (*iii*) specific dynamic action of food.

The requirements are influenced by (*i*) age, (*ii*) body size and weight, (*iii*) type of physical activity, (*iv*) climate, (*v*) sex and (*vi*) physiological state (pregnancy and lactation).

The recommended energy allowances of Nutrition Expert Group of ICMR, 1968 are given in table 1.10.

Table 1.10. Recommended Calorie Allowances for Indians

Group	*Activity*	*k. cal*
1. Man (55 kg)	Heavy work	3,900
	Moderate work	2,800
	Sedentary work	2,400
2. Woman (45 kg)	Heavy work	3,000
	Moderate work	2,200
	Sedentary work	1,900
	Latter half of pregnancy	+300
	Lactation	+700
3. Infants: Under 1 Year	0–6 months	120/kg
	7–12 months	100/kg
4. Children	1–3 years	1,200
	4–6 years	1,500
	7–9 years	1,800
	10–12 years	2,100
	13–15 years (Boys)	2,500
	13–15 years (Girls)	2,300
	16–19 years (Boys)	3,000
	16–19 years (Girls)	2,200

Under Nutrition and Malnutrition

Malnutrition is a state of bad nutrition. Malnutrition can be defined as the physical condition of a person resulting either from a faulty or inadequate diet (*i.e.*, a diet that does not supply normal quantity of all nutrients) or from a physical inability to absorb or metabolise nutrients, owing to disease.

The are four types of malnutrition:

1. **Under nutrition.** Under nutrition is poor nourishment of the body due to inadequate quantity of food intake resulting in low nutrient consumption. (*'The intake of insufficient amount of food over an extended period of time is called under nutrition'*). In extreme cases; when, no food is consumed for days, it is called **starvation.**

2. Over nutrition. (*'The consumption of excessive quantity of food, over an extended period of time is called over nutrition'*). Over nutrition often lead to **obesity** (motapa), **atheroma** (deposition of cholesterol on arterial walls) and **diabetes** (madhumeh).

3. Imbalanced diet. It is a diet in which certain nutrients are in large proportion, while others are negligible. The intake of an imbalanced diet over an extended period of time leads to certain abnormalities. For example, the children fed on diet containing more carbohydrates than protein, lead to a disease called **kwashiorkor.**

4. Special deficiency. This form of malnutrition is caused due to relative or absolute lack of a specific nutrient in the diet. It leads to specific deficiency diseases. These deficiency diseases can be broadly divided into three group.

(*i*) **Protein calorie malnutrition.** Lack of proteins or carbohydrates or both in the diet of children leads to marasmus.

(*ii*) **Vitamins deficiency diseases.** Deficiency of vitamin A causes night blindness and that of vitamin C causes scurvy.

(*iii*) **Mineral deficiency diseases.** Deficiency of iron causes anaemia, goitre is caused due to iodine deficiency.

1.5 SUMMARY

- All living organisms need food. Food is a substance, which when taken, digested and incorporated into the body tissues, provides materials for energy, repair, growth, reproduction, regulation of life processes and resistance to diseases. The sum total of processes by which the living organisms obtain food and utilize it for use in various biological activities is called nutrition. The materials which provide raw materials and energy are called nutrients. Carbohydrates, lipids and proteins form the major part of the food and are termed macronutrients. Water, minerals and vitamins have small molecules and are called micronutrients. In addition to these materials a proper diet should also contain roughage.
- The carbohydrates and fats provide energy to our body and are called energy giving foods; Protein rich foods are called body building foods; while vitamins and minerals are called protective or regulatory foods.
- Health is the basic to life. It is a state of complete physical, mental and social well being and not merely absence of disease or infirmity. Proper nutrition, good habits, exercise and relaxation are essential conditions for good health. The kind of food on which a person live constitute a diet. The diet which contains all the nutrients in the correct amount is called balanced diet.

- The energy requirements of an individual and the energy content of food is expressed in terms of a measure of heat energy, because heat is the ultimate form of all energies. The energy requirement of an individual includes the requirement for growth maintenance, vital activities, temperature regulation, reproduction and muscular activities.

1.6 GLOSSARY

- **Nutrients:** The materials which provide primary requirements of life are called nutrients.
- **Diet:** A substance which is taken to supply the necessary nutrients to the body is termed as diet.
- **Nutrition:** The sum total of the processes by which the living organisms obtain food and utilize it for use in various biological activities is called nutrition.
- **Nutritionist or Dietitian:** A person who specializes in the processes and problems of nutrition is known as a nutritionist or dietitian.
- **Food:** Food is a substance which when taken, digested, and incorporated into the body tissues, provides materials for energy, repair, growth, reproduction, regulation of life process and resistance to diseases without harming the organism.
- **Dietetics:** The study of food stuffs, their nutritional value and requirements to keep fit and healthy is called dietetics.
- **Health:** A state of complete physical, mental and social well being and not merely the absence of disease or infirmity.
- **Balanced Diet:** The diet which contains all the nutrients in the correct amount is called balanced diet.
- **Under Nutrition:** The intake of insufficient amount of food over an extended period of time is called under nutrition.
- **Over Nutrition:** The consumption of excessive quantity of food, over an extended period of time is called over nutrition.

1.7 REVIEW QUESTIONS

I. Very Short Answer Type Questions:

1. What is a food?
2. What is nutrition?
3. Define health as per World Health Organisation.
4. What is a balanced diet?
5. Explain the following terms.

   (*i*) Malnutrition (*ii*) Under nutrition.

II. Short Answer Type Questions:

1. What is health? What is its importance in the life of an individual?
2. Describe different types of foods on the basis of functions.
3. Explain what is meant by energy value of foods.

III. Long Answer Type Questions:

1. Given an account of different types of food group plans as recommended by U.S. Department of Agriculture.
2. What is a balanced diet? How can a balanced diet be planned for the persons of different income groups?
3. Give an account of energy value of food and energy requirements of human beings.

1.8 FURTHER READINGS

- *Introduction to Nutrition:* Fleck, Henrietta; McMillan, New York, 1981.
- *Nutrition and Dietetics:* Shubhangi Joshi; Tata McGraw Hill; New Delhi, India, 1992.
- *Human Nutrition—Principles and Applications in India;* McDivitt Maxine E. and Sumati R. Mudambi; Prentice Hall, New Delhi, 1973.
- *Essentials of Food and Nutrition:* M. Swaminathan, Ganesh, Madras, India, 1985.
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CHAPTER 2 BASIS FOR COMPUTING NUTRIENT REQUIREMENTS

OBJECTIVES

After going through this chapter, you should be able to:

- know about general principles of deriving RDAs
- define basis of RDAs
- define Indian RDA reference man and woman
- explain the recommended dietary allowances for Indians
- describe the importance and limitations of recommended dietary allowances (RDAs).

STRUCTURE

2.1 INTRODUCTION

To maintain good health and physical efficiency, the diet should provide adequate amounts of all nutrients. For designing balanced diets, it is essential to know the daily requirements of different nutrients. The allowances for different nutrients have been recommended by various National and International Committees.

Some of these committees are mentioned below:

(*i*) Nutrition Expert Committee, I.C.M.R., India (1968),

(*ii*) Food and Nutrition Board, National Research Council, U.S.A (1974),

(*iii*) Panel on Recommended Allowances of Nutrients, Department of Health and Social Services, U.K. (1969), and

(*iv*) Human Nutritional Requirements, FAO/WHO (1974).

The daily requirement of different nutrients set up by the above committees is called *Recommended Dietary Allowances (RDAs).* The word 'recommended' is used to emphasise that these values need to be revised periodically on the basis of newer research data. The advisory committee of the *Indian Council of Medical Research* (ICMR) is responsible for the setting up, review and revision of RDAs.

2.2 NEED OF SETTING UP OF RDAs

Proper nutrition and dietary habits leads to sound health and good mental development. Deficiency of nutrients in the diet leads to serious health hazards.

During the second world war (1939–45), the military recruiting officers faced great difficulty in selection of young men, for military because a large number of them were underweight. As a result, efforts were made by the governments of different countries to deal with this situation. This led to the setting up of Recommended Dietary Allowances (RDA) in many countries. India was among the pioneer countries to set up RDAs. In India RDA was set up in the year 1944, that included dietary intake of energy, protein, calcium, iron, vitamin A, thiamine, ascorbic acid and vitamin D. On the basis of new researches and findings about the needs of dietary allowances, these recommendations are revised as per requirements.

In making RDA recommendations the ICMR committee was guided by the expert group of FAO and WHO and also the findings of studies carried out in India on nutrient requirements.

2.3 REVISIONS OF RDAs

On the basis of new findings RDA recommendations have been revised four times and fifth revision is expected in the near future. The revisions made to the basic recommendations of RDA are as follows:

- In 1958, the recommendations for energy were revised.

- In 1968, additional recommendations were made for four B-vitamin, namely riboflavin, nicotinic acid, folic acid and vitamin B_{12}.
- In the 1978 revision, the requirement for one more B-vitamin, pyridoxine (B_6), and the unit of energy, *joule,* adopted by International Union of Science (IUS) and International Union of Nutritional Science (IUNS) were included.
- The last revision was made in 1988, which included the following recommendations.
  - (*i*) the revision of body weight standards for Indians.
  - (*ii*) complete revision of energy requirements.
  - (*iii*) definition of quantum and type of fat intakes.
  - (*iv*) modifications of RDAs of vitamin A and D.
  - (*v*) inclusion of several nutrients and dietary factors not considered earlier such as fibre, electrolytes (sodium, potassium), magnesium, phosphorus, vitamin E and K, and
  - (*vi*) provisional recommendation on trace elements.

2.4 GENERAL PRINCIPLES FOR DERIVING RDA

To arrive at the nutritional requirements of an individual or the RDA for a population a number of general principles are used. The important principles are as follows.

(*i*) **Dietary Intakes.** The approach of dietary intakes has been used to arrive at the energy needs of an individual. The energy intakes are used as the basis for the RDA specially for the growing children.

(*ii*) **Growth.** The requirement of different nutrients for satisfactory growth is taken into account for RDAs. For instance, the intake of breast milk is essential for infants.

(*iii*) **Nutrient Balance.** The intake of nutrient and their retention in the body are taken into account for RDA recommendations.

(*iv*) **Obligatory Loss of Nutrients.** The minimal loss of the nutrient or its metabolic product through normal routes of elimination (*i.e.*, sweat, urine and faeces) is called obligatory loss of nutrients. This information is used to determine the amount of nutrient to be consumed daily through the diet to replace the obligatory loss. In infants and children, growth requirements are also added to the above maintenance requirements.

(*v*) **Functional Needs.** The nutrient requirements for various functions are assessed separately and added up to assess the total daily requirements.

(*vi*) **Nutrient Turnover.** The information obtained from the study of turnover of certain nutrients, in healthy persons, using isotopically labelled nutrients, has been used to determine their requirements. Vitamin A, vitamin C, iron and vitamin B_{12} requirement have been measured in this manner.

(*vii*) **Depletion and Repletion Studies.** The status of water soluble vitamins is measured by recording the levels of vitamins or its coenzyme in serum or blood cells (*i.e.*, erythrocytes, leucocytes). The requirements of ascorbic acid (vitamin C), thiamin, riboflavin niacin, and pyridoxine have been established using this approach. In this approach, the subjects (the persons under study) are first fed a diet very low in the nutrient being studied until the biochemical parameters reach a low level. After that feeding graded doses of the nutrient is studied. The level at which response increases rapidly indicates the level of requirement of the nutrient.

2.5 BASIS OF RDAs

The RDA is derived on the basis of following main points.

(*i*) the nutrient requirements determined by one or more approaches described above.

(*ii*) the nutrient requirements for different physiological groups.

(*iii*) the bio-availability of different nutrients from the diet.

(*iv*) computation of RDA after considering individual's variability.

(*v*) the age, body weights and heights. Desirable heights and weights of both children and adults are considered in recommending nutrient intakes as RDA.

The bio-availability of certain nutrients such as protein, iron, calcium, β-carotene and vitamin B_{12}, from the diet is a critical factor. The quality of protein (*e.g.*, proteins rich in essential amino acids) is also important. In case of minerals, the total intake and their absorption from foods is a critical factor. The absorption is affected by a number of factors such as the presence of absorption promoters, absorption inhibitors and nature of the medium. For example, the diet habitually consumed in India, are usually high in absorption inhibitors and low in promoters, hence absorption of iron is only 2 to 5 per cent. Certain vitamins are present in foods as provitamins which are converted into respective vitamin in the body. Such factors are also considered for RDAs.

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2.6 REFERENCE BODY WEIGHTS

The nutrient requirements vary with age and weight of an individual. In children, the body weights and heights of children reflect their state of health and growth rate. Desirable heights and weights of both children and adults are considered in recommending nutrient intakes as the RDA is intended for a healthy and well nourished population.

The body weights of Indian children and adolescents were used to compute their nutritional needs as per 1978 revision. Since 1944, a reference body weight of 55 kg for adult men and 45 kg for adult women were used for deciding the nutrient requirements. However, these weights do not match with the well nourished population and current heights of 163 cm for adult men and 151 cm for adult women. Therefore, the ICMR committee recommended that the reference weights for Indian men and women used for RDA be increased to 60 kg and 50 kg respectively. The reference body weights of Indians of different age groups are given in Table 2.1.

Table 2.1. Reference Body Weights of Indians of Different Age Groups.

Individuals	*Age (years)*	*Weight in kg*	
		Male	*Female*
1. Infants	0–0.5	5.4	5.4
	0.5–10	8.6	8.6
2. Children	1–3	12.6	11.8
	4–6	19.2	18.7
	7–9	27.0	26.7
	10–12	35.5	37.9
3. Adolescents	13–15	47.9	46.7
	16–18	57.3	49.9
4. Adults	20–50	60.0	50.6

2.7 REFERENCE MAN AND WOMAN

The nutrient needs vary with age and body weight. Therefore, man and woman with specific age and body weight has been designated as reference man and woman. In the Indian RDA reference man and woman has been defined as under.

1. **Reference Man.** The reference man is 20–39 years of age and 60 kg weight. He is healthy, free from disease and fit for work. He is employed in moderately active work for 8 hours, spends 8 hours in bed, 4 to 6 hours in leisure activities, sitting and moving about and 2 hours in active reaction walking or house hold duties.

Table 2.2. Recommended Dietary Allowances for Indians

Group	Particulars	Body Wt kg	Net energy kcal/d	Protein g/d	Fat g/d	Calcium mg/d	Iron mg/d	Vit.A Retinol	β-carotene µg/d	Thiamin mg/d	Riboflavin mg/d	Nicotinic acid mg/d	Pyridoxin mg/d	Ascorbic acid mg/d	Folic acid µg/d	Vit.B_{12} µg/d
Man	Sedentary Work		2425						1.2	1.4	16					
	Moderate Work	60	2875	60	20	400	28	600	2400	1.4	1.6	18	2.0	40	100	1
	Heavy Work		3800							1.6	1.9	21				
Woman	Sedentary Work		1875							0.9	1.1	12			100	1
	Moderate Work	50	2225	50	20	400	30	600	2400	1.1	1.3	14	2.0	40		1
	Heavy Work		2925							1.2	1.5	1.6				
	Pregnant woman	50	+300	+15	30	1000	38	600	2400	+0.2	+0.2	+2	2.5	40	400	1
	Lactation															
	0-6 months		+550	+25	45	1000	30	950	3800	+0.3	+0.3	+4	2.5	80	150	1.5
Infants	0-6 months	5.4	118/kg	2.05/kg		500				55 µg/kg	65µg/kg	710µg/kg	0.1	25	25	0.2
	6-12 months	8.6	98/kg	1.65/kg				350	1200	50µg/kg	60µg/kg	650µg/kg	0.4			
Children	1-3 years	12.2	1240	22	25	400	12	400	1600	0.6	0.7	8	0.9	40	30	0.2-1.0
	4-6 years	19.0	1690	30			18	400		0.9	1.0	11			40	
	7-9 years	26.9	1950	41			26	600	2400	1.0	1.2	13	1.6			60
Boys	10-12 years	35.4	2190	54	22	600	34			1.1	1.3	15				
Girls	10-12 years	31.5	1970	57			19	600	2400	1.0	1.2	13	1.6	40	70	0.2-10
Boys	13-15 years	47-8	2450	70	22	600	41			1.2	1.5	16				
Girls	13-15 years	46.7	2060	65			28	600	2400	1.0	1.2	14	2.0	40	100	0.2-1.0
Boys	16-18 years	57.1	2640	78	22	500	50			1.3	1.6	17				
Girls	16-18 years	49.9	2060	63			30	600	2400	1.0	1.2	14	2.0	40	100	0.2-1.0

NOTES

STUDENT ACTIVITY

1. What is meant by reference man and woman?

2. Why are recommended dietary allowances set up?

2. **Reference Woman.** The reference woman is 20–39 years of age and 50 kg weight. She is healthy and free from disease. She may be engaged for 8 hours in moderately active work in light industry or in general household work. Apart from 8 hours in bed, she spends 4–6 hours in light leisure activities and 2 hours in active house hold work, reaction or walking.

2.8 RECOMMENDED DIETARY ALLOWANCES FOR INDIANS

For designing balanced diets, it is essential to know the daily requirement of different nutrients. The recommended dietary allowances for nutrients for different age groups of Indian people are given in Table 2.2.

The Table contains RDAs for

(*i*) Energy and protein,

(*ii*) Minerals-calcium and iron,

(*iii*) Water soluble vitamins C and six of the vitamin B group,

(*iv*) Fat soluble vitamin. A, E and K, and

(*v*) Other nutrients.

It is quite evident form the table that:

- Only two nutrients *i.e.*, energy and proteins are needed in large amounts. The RDA for energy is about 40 kcal/kg body weight for a sedentary man and 37 kcal/kg body weight for a sedentary woman. Moderately active man's RDA is 48 kcal/kg body weight and woman's 40 kcal/kg body weight. The RDA of a man woman engaged in heavy activity is 63 kcal and 58 kcal/kg body weight respectively.
- The RDA does not vary with activity and it is 1 g/kg body weight for both man and woman.
- The RDA for minerals is much less, calcium is 400 mg/day for both man and woman, while iron is only 28 to 30 mg/day. (1 mg = one thousandth part of a gram). The requirement of iron for an adult woman is more than a man, to make up the periodic loss of iron during menstruation.
- Five water soluble vitamins (thiamin, riboflavin, niacin, pyridoxine and ascorbic acid) are needed in very small amounts and their RDAs are expressed in microgramme or mg. The remaining two B vitamins (folic acid and vitamin B_{12}) are needed only in traces, hence their RDA are expressed in microgramme or mg (1 mg = one millionth part of a gramme). The amount of

B-vitamins needed is related to the total energy needs. Therefore, these vitamins are required in slightly higher amount for an adult man than an adult woman.

- The requirement of fat soluble vitamin A, its percussor, β-carotene and vitamin D is also very minute and is expressed in microgrammes or mcg. The amount of vitamin-D is expressed in International Units (IU) and IU = 0.025 mcg.

The nutrient needs vary with age, activity and physiological status such as pregnancy and lactation, (Fig. 2.1) Generally, the physical activity depends on individual's occupation.

Age – 7-8 months	10 years	25 years	Pregnant	Moderate Activity
Calories – 785	1970	1875	2275	2225
Protein – 11g	57 g	50 g	65 g	50 g
Body Weight – 8 kg	31 kg	50 kg	60 kg	50 kg

Fig. 2.1 ***Energy and protein needs vary with age and occupation.***

2.9 IMPORTANCE OF RECOMMENDED DIETARY ALLOWANCES (RDAs)

The RDAs for nutrients are of great importance. The important practical uses of RDAs are given below.

1. Enable government to assess food needs of the population.
2. Provide basis for food distribution quota.
3. Guide agricultural planning policy.
4. Help in making policy of food export and import.
5. Help in planing of nutritionally adequate diet for inmates of large catering establishments such as hostels, canteens, hospitals, hotels etc.
6. Help in evaluating the food consumption surveys of population groups.

2.10 LIMITATIONS OF RECOMMENDED DIETARY ALLOWANCES (RDAs)

In spite of great importance, RDAs have following limitations:

1. RDAs cannot be used as standards to determine nutrient adequacy of an individual's intake.
2. RDAs are estimates of nutrient intakes which a population group require to consume to meet the physiological needs.
3. Individuals, whose intake of nutrients is below RDA, are not necessarily at risk of deficiency, since many individuals in population may have requirements well below RDA.
4. It is implied that intake of nutrient at RDA will involve very little risk of inadequacy.

2.11 SUMMARY

- Good health and physical efficiency can be maintained by the intake of adequate amounts of all nutrients. The allowances for different nutrients have been recommended by various National and International Committees. The daily requirement of different nutrients set up by these committees is called Recommended Dietary Allowances (RDAs).
- In making RDA recommendations, the ICMR committee was guided by the expert group of FAO and WHO. On the basis of new findings RDA recommendations are also revised. To arrive at the nutritional requirements, criteria like dietary intake, growth nutrient balance, obligatory loss of nutrients, functional needs, nutrient turnover, and depletion and repletion studies are taken into account. The nutrient requirements vary with age and weight of an individual. The RDAs help in assessing food needs and agricultural planning policies.

2.12 GLOSSARY

- **ICMR:** The advisory committee which is responsible for the setting up, review and revision of RADs.
- **Dietary Intakes:** The approach of dietary intakes has been used to arrive at the energy needs of an individual.
- **Nutrient Balance:** The intake of nutrient and their retention in the body are taken into account for RDA recommendations.
- **Functional Needs:** The nutrient requirements for various functions are assessed separately and added upto access the total daily requirements.

NOTES

2.13 REVIEW QUESTIONS

I. Very Short Answer Type Questions:

1. Expand the following
   (*i*) RDAs (*ii*) ICMR
2. What are Recommended Dietary Allowances?
3. When was RDA set up in India?

II. Short Answer Type Questions:

1. What are the uses of recommended dietary allowances?
2. What are the limitations of recommended dietary allowances?

III. Long Answer Type Questions:

1. What are the guiding principles to derive RDAs?
2. What are main features of recommended dietary allowances?

2.14 FURTHER READINGS

- *Introduction to Nutrition:* Fleck, Henrietta, McMillan, New York, 1981.
- *Nutrition and Dietetics:* Shubhangi Joshi; Tata McGraw Hill, New Delhi, India 1992.
- *Human Nutrition—Principles and Applications in India:* McDivitt Maxine E. and Sumati R. Mudambi; Prentice Hall, New Delhi, 1973.
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- *Handbook of Food and Nutrition.* M. Swaminathan; The Bangalore Printing & Pub. Co. Ltd. Bangalore; 2007.

UNIT–II

CHAPTER 3 CARBOHYDRATES

NOTES

OBJECTIVES

After going through this chapter, you should be able to:

- define carbohydrates and their compositions
- know about sugar substitutes
- describe the functions of carbohydrates
- explain the sources of carbohydrates in the diet and utilization of carbohydrates in the body
- know about regulation of blood sugar
- define carbohydrate calorie requirements
- explain dietary fibre.

STRUCTURE

3.1 INTRODUCTION

Carbohydrates are the main source of energy in our body. World's large population use cereals (wheat, rice and other grains) as the main source of carbohydrates. Thus, cereals are the staple food of large population of the world. In the Indian dietary about 65 to 80 per cent energy is provided by carbohydrates.

Carbohydrates are synthesised by green plants from CO_2 and water in presence of light through photosynthesis. They produce energy on oxidation in the body. Glucose is the simplest carbohydrate, which is an instant source of energy. Starch is the main carbohydrate found in our food items like cereals, potato, sweet potato etc. Cooked starch gets easily and completely digested into glucose.

3.2 DEFINITION

The term 'carbohydrates' is derived from French from *hydrate de carbone* meaning 'hydrate of carbon' or $C_n(H_2O)_n$. Accordingly, carbohydrates may be defined as 'organic substances having carbon, hydrogen and oxygen' where hydrogen and oxygen occur in the ratio of 2:1 as found in water (H_2O).

3.3 COMPOSITION

Chemically, carbohydrates are polyhydroxy aldehydes or ketones, *i.e.*, they contain many hydroxyl or alcoholic (–OH) groups besides carbonyl or carbon oxygen (–C = 0) group. In an **aldehyde**, the carbonyl group is present at the end of carbon chain, whereas, it is in the middle of the carbon chain in a **ketone.** Carbohydrates having aldehyde group are called **aldolases** (*e.g.*, glyceraldehyde, xylose, glucose, ribose, galactose etc.), while those with ketone group are known as **ketoses** (*e.g.*, dihydroxy acetone, erythrulose, ribulose, xylulose, fructose, pseudoheptulose, etc.). The suffix '*ose*' denotes a carbohydrate. Carbohydrates are produced by green plants during photosynthesis. About 80 per cent of the dry weight of the plant is made up of carbohydrates.

3.4 CLASSIFICATION

Carbohydrates are also called **saccharides** (G.K. *Sakcher* - sugar) or compound containing sugar. Sugars are simple carbohydrates and are commonly sweet in taste. They are soluble in water and have low molecular weight. Carbohydrates are broadly classified into: monosaccharides, oligosaccharides and polysaccharides.

1. **Monosaccharides:** They are simple carbohydrate monomers, which cannot be hydrolysed further into smaller units. They have a general formula $C_nH_{2n}O_n$. Monosaccharides usually have 3 to 7 carbon atoms per molecule.

   (*a*) Monosaccharides have following two important chemical properties: The aldehyde or ketone group of a monosaccharide can join an alcoholic group of another organic compound. The bond thus formed is called **glycosidic bond** (C–O–C). The process involves loss of water and is called condensation. Glycosidic bonds are

NOTES

also formed during the condensation of monosaccharides to form compound carbohydrates *i.e.*, oligosaccharides and polysaccharides.

(*b*) The sugars with a free **aldehyde** or ketone group reduce Cu^{2+} ions to Cu^{+} state. Therefore, they are known as **reducing sugars.**

Monosaccharides are classified according to their carbon atoms as under:

(*i*) **Biose ($C_2H_4O_2$)** have two carbon atoms per molecule. Glycolic aldehyde is the only member of this group. It is a crystalline substance and is easily soluble in water. It is sweet in taste.

(*ii*) **Trioses ($C_3H_6O_3$)** have three carbon atoms per molecule *e.g.*, glyceraldehyde and dihydroxyacetone. They occur in plant and animal tissues in small amounts and are derived from the breakdown of glucose.

(*iii*) **Tetroses ($C_4H_8O_4$)** have four carbon atoms per molecules, *e.g.*, erythrose, threose.

(*iv*) **Pentoses ($C_5H_{10}O_5$)** have five carbon atoms per molecule, *e.g.*, ribose deoxyribose, ribulose, xylose, arabinose. Deoxyribose contains one oxygen atom less than ribose. It has a formula $C_5H_{10}O_4$.

- **Ribose** is present in adenylic acid and Ribonucleic Acid (RNA) occurring in plant and animal tissues.
- **Deoxyribose** is a constituent of Deoxyribonucleic Acid (DNA), which is the hereditary material in the living organisms.
- **Xylose** does not occur in free form. Xylan (a polysaccharide) present in wood gum and straws is formed by joining of a large number of xylose molecules.
- **Arabinose** also does not occur in free form. Araban (a polysaccharide) present in cherry gum or gum arabic is formed by joining a large number of xylose molecules.

(*v*) **Hexoses ($C_6H_{12}O_6$)** have six carbon atoms per molecule *e.g.*, glucose, fructose, galactose, mannose and sorbose.

- **Glucose** also called **blood sugar, grape sugar** or **dextrose** is the most widely spread and most important hexose in the living systems. It is a common respiratory substrate. It contains free aldehyde group, hence can reduce Fehling's solution and Benedict's solution and is called reducing sugar. Glucose occurs in free state (upto 2–6 per cent) in many fruits. The blood of a normal healthy human contains about 80–100 mg of glucose per 100 ml of blood. A person suffering from diabetes mellitus, may contain 180–300 mg of glucose per 100 ml of blood.
- **Fructose (Levulose)** also called **fruit sugar** because of its common occurrence in fruits (exception grapes). Nectar and honey also contain fructose. It is the sweetest of all naturally occurring sugars.
- **Galactose** does not occur in free state. It is a constituent of lactose (a disaccharide) present in milk.

2. **Oligosaccharides:** They are compound carbohydrates formed by condensation of 2–9 monosaccharide molecules. The monosaccharide units, when linked up are called **residues**. The oligosaccharides are classified according to the number of their monosaccharide units or monomers. They are **disaccharides** (*e.g.*, sucrose, lactose, maltose, **trisaccharides** (*e.g.*, raffinose), **tetrasaccharides** (*e.g.*, stachyose), and so on.

Disaccharides are the smallest and commonest oligosaccharides in the cells. They are formed by condensation of two monosaccharide molecules by the elimination of one molecule of water. Biologically important disaccharides are sucrose, lactose, maltose and thrihalose.

- **Sucrose** is the common **cane** or **table sugar** obtained from sugarcane and sugar beet. It is the storage product of photosynthesis in these plants. Sucrose is formed by the condensation of one molecule each of glucose and fructose with the removal of one molecule of water. Sucrose is readily hydrolysed to glucose and fructose by dilute mineral acids or by the enzyme *sucrose* present in the intestinal juice.

  $$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\textit{Dil Hcl/Sucrose}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

  Sucrose is non-reducing sugar. However, if it is hydrolysed to produce glucose and fructose, then the hydrolysed solution gives Benedict's test (*i.e.*, reduces Benedict's solution).

- **Lactose** or **milk sugar** is formed naturally in the milk of all mammals but has not so far been found in plant foods. Cow's and buffalo milks contains about 4 per cent, while human milk contains about 7 per cent of lactose. Lactose is formed inside mammary glands by condensation of two hexose molecules, glucose and galactose. Lactose is hydrolysed to glucose and galactose by the enzyme *lactase* present in the intestinal juice.

  $$\text{Lactase} + H_2O \xrightarrow{\textit{Lactase}} \text{Glucose} + \text{Galactose}$$

  Souring of milk occurs due to conversion of lactose into lactic acid by bacteria.

- **Maltose** or **malt sugar** is formed in the germinating stachy grains (*i.e.*, cereals such as barley, jowar, ragi *etc.*) due to hydrolysis of starch by the enzyme *amylase* (*diastase*)

  $$\text{Starch} \xrightarrow{\textit{Amylase}} \text{Maltose}$$

  Maltose is formed by the condensation of two molecules of glucose by the elimination of one molecule of water. It is hydrolysed to glucose by the enzyme *maltase* present in the intestinal juice.

  $$\text{Maltose} + H_2O \xrightarrow{\textit{Maltase}} \text{Glucose} + \text{Glucose}$$

- **Trihalose** is formed in some fungi and haemolymph of some insects.

Sweetening Index: Different sugars have different sweetening index. The relative sweetness of some sugars and saccharin (a white crystalline compound $C_7H_5O_3NS$, used as a non-caloric sweetening agent) is given in Table 3.1.

Table 3.1. Sweetening Index of Some Sugar and Some Other Compounds

Sugars and Other Compounds	*Relative Sweetness (Sucrose, 100)*
1. Lactose	16
2. Galactose	32
3. Maltose	32
4. Glucose	74
5. Sucrose	100
6. Invert sugar (2:1 *glucose and fructose*)	130
7. Fructose	174
8. Saccharin ($C_7H_5O_3NS$)	45,000
9. Monellin (*a protein*)	2,00,000

Among sugars, fructose has the highest sweetening index of 174. However, a protein, monellin has the highest sweetening index of 2,00,000.

3. Polysaccharides: They are complex carbohydrates, which are formed by polymerisation of large number of monosaccharide monomers. The latter are joined by glycosidic bonds with a loss of water, each time a monosaccharide molecule is added.

$$\underset{\text{Monosaccharide}}{n\,(C_6H_{12}O_6)} \longrightarrow \underset{\text{Polysaccharide}}{(C_6H_{12}O_6)_n} + nH_2O$$

Here '*n*' stands for the unknown number of monosaccharide molecules. Polysaccharide are linear branched or unbranched molecular chain. Unlike sugars, they are not sweet. Many plant foods possess diffferent types of polysaccharides in varying amounts. The important polysaccharides present in plant foods are described below.

(*i*) Starch: Starch is the reserve food in most plants. It is also called *amylum*. The important sources of starch are cereals and millets (65 to 85 per cent), roots and tubers (19 to 35 per cent). Starch is formed as end product of photosynthesis. Starch molecules accumulate to form tiny granules called *starch grains*. Starch grains may be rounded, oval, polygonal or rod shaped in outline. Each grain consists of several layers or shells arranged in concentric or eccentric manner around a common point called *hilum* (Fig 3.1). **Starch grains** may occur singly **or in groups.** The two types are known as simple and compound starch grains.

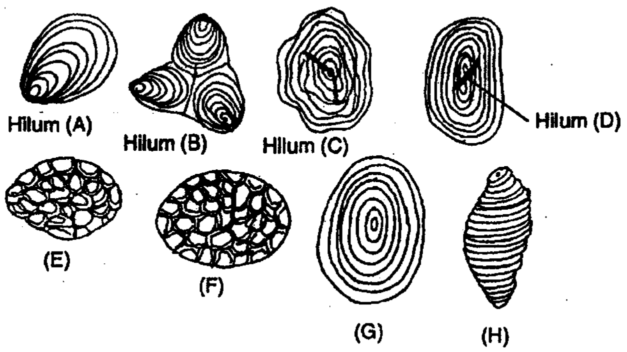

Fig. 3.1. *Types of starch grains. (A) simple starch grain of potato. (B) compound starch grain of Potato. (C) a simple starch grain of Maize. (D) a simple starch grain of Pea. (E) a compound starch grain of Rice. (F) a compound starch grain of Oat. (G) a simple starch grain of Wheat. (H) a simple starch grain of Banana.*

Starch consists of two components: **amylose** and **Amylopectin** (both glucose polymers). In general, 20 to 30% of starch consists of amylose and rest as amylopectin. Amylose molecule is an unbranched but spirally coiled chain of about 200 to 2000 glucose units. Amylopectin molecule is a much branched chain of about 2000 to 2,00,000 glucose units. In both amylose and amylopectin, the successive glucose units are joined by 1–4α glycosidic bonds, while the branches in amylopectin are formed by 1–6α glycosidic bonds (Fig. 3.2). Amylose is more soluble in water than amylopectin. Starch can hold iodine (I_2) molecules in the helical portion, hence give blue colour, when stained with iodine solution.

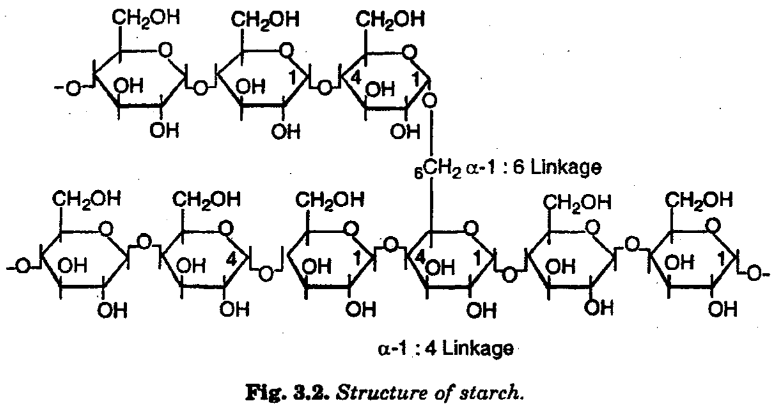

Fig. 3.2. *Structure of starch.*

Properties of Starch: Starch is a white tasteless powder, insoluble in cold water. It forms a paste when boiled with water. Cereal starches differ from root and tuber starches in their physical properties. A starch paste (containing 5 per cent starch) made out of cereal starches sets to a thick jelly on cooling, while a 5 per cent starch paste made with tuber or root starches remains as a thick fluid and does not set to a thick jelly. This is due to the differences in the chemical nature of amylose and amylopectin present in them.

Starch yields glucose when hydrolysed with dilute mineral acids. Glucose is prepared by hydrolysis of starch.

$$\text{Starch} \xrightarrow{\textit{Dil. Acid}} \text{Glucose}$$

Starch is hydrolysed into maltose by the enzymes, *salivary amylase* (*ptylin*) present in saliva and *pancreatic amylase* present in pancreatic juice.

$$\text{Starch} \xrightarrow{\textit{Amylase}} \text{Maltose}$$

(*ii*) **Glycogen:** Glycogen is a main reserve food in animals, bacteria and fungi. It is also known as **animal starch.** Chemically, glycogen is similar to starch. Its molecule consists of a long much branched chain of about 30,000 glycose residues and a molecular weight of about 4.8 million. The successive glucose units are joined by 1–4 α glycosidic bonds and branches are formed by 1–6 α glycosidic bonds. Glycogen is usually formed and stored in muscle cells and liver cells. These cells prepare it from glucose drawn from the blood stream. Liver of an adult human may store upto 0.91 kg of glycogen. In shape, glycogen granules appear ellipsoid and flattened, and lie freely inside the cells. Glycogen can also hold iodine (I_2) molecules in the helical portion and gives red colour with iodine solution.

(*iii*) **Inulin:** Inulin is a fructan storage polysaccharide in fleshy roots of *Dahlia* and related plants. It consists of fructose residues. Inulin is not metabolised in human body and readily filtered through the kidney. It is therefore, used as intravenous injection to determine the kidney function. It is also used in breads for diabetics.

(*iv*) **Dextrins:** Dextrins are polysaccharides formed by the partial hydrolysis of starch by acids or amylase. They are composed of large number of glucose molecules. They are soluble in cold water.

(*v*) **Cellulose (cellulin):** Cellulose is the main structural component of cell walls of plants. It is a fibrous polysaccharide made up of glucose. A cellulose molecule consists of an unbranched and linear chain of 6000 or more glucose residues. The successive glucose residues are joined togehter by 1–4β–glycosidic linkage. Consequently alternate glucose molecules lie at 180° to each other (Fig. 3.3). Cellulose molecules do not occur singly. A number of chains are arranged in close antiparallel manner and are held together by hydrogen bonds. About 20,000 cellulose chains or molecules are packed together to form a *microfibril*, visible under the electron microscope. Cellulose cannot hold iodine (I_2) molecules hence give no colour with iodine solution.

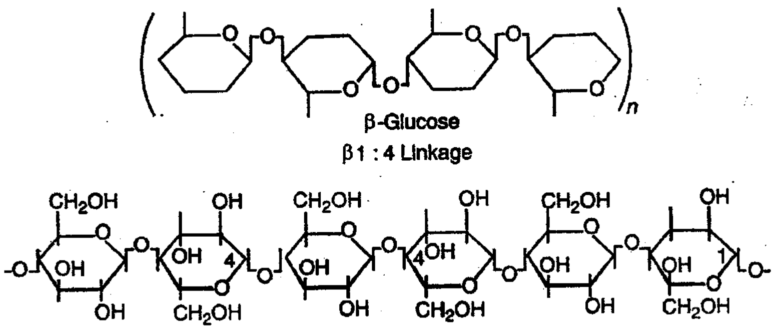

Fig. 3.3. *Structure of cellulose.*

Cellulose form the bulk of human food. However, it cannot be digested by the human beings, because they lack the enzyme *cellulase*, required to digest cellulose. In human food cellulose acts as roughage, necessary for the proper functioning of the digestive system.

Carboxymethyl cellulose is used as emulsifier and smoothening agent in ice-creams, cosmetics and medicines. Cellulose is hydrolysed to soluble sugars with the help of microbes. The sugars are then allowed to undergo fermentation for obtaining ethanol, butanol, acetone, methane and other useful chemicals.

(*vi*) **Pectin:** Pectin is a heteropolysaccharide composed of sugars arabinose and galactose, the sugar acid galacturonic acid and methanol. It is present in the matrix of cell wall and middle lamella, pectin is soluble in water and can undergo sol $\rightleftharpoons$ gel interchange. It is commercially used as jellying agent in food industries. It is also used in medicine for the treatment of diarrhoea.

(*vii*) **Hemicellulose:** Hemicellulose is a mixture of polysaccharides xylans, galactans, arabagalactans and glucomannans. Hemicellulose is found in the cell wall where it helps in binding pectic compounds and cellulose microfibrils. It is present in all vegetables, bran of cereals and hulls of legumes.

(*viii*) **Galactans:** Galactans are polysaccharides composed of galactose molecules. They occur in large amounts in sea weeds. The well known polygalactan is agar agar. Agar-agar is used in preparation of media for culturing bacteria. It is also used in medicine for relieveing constipation in children.

(*ix*) **Fructosans:** Fructosans are polysaccharides formed by polymerisation of a large number of fructose molecules. Fructosans are present in onions and Jerusalem artichoke.

(*x*) **Pentasans:** Pentasans are polysaccharides formed by polymerisation of a large number of pentoses. They occur in grasses and straw.

3.5 SUGAR SUBSTITUTES

NOTES

The people, who wish to reduce their calorie intake, are advised to take calorie free sugar substitutes or artificial sweeteners. Two of the commonly available sugar substitutes are saccharin and aspartame.

1. **Saccharin:** Chemically, saccharin is α-sulphobenzimide. It is 300 to 500 times sweeter than sucrose and passes through the body unchanged. It is used as a sugar substitute without any adverse effects. It is used in beverages and desserts. The only drawback is it leaves a bitter after taste, if used in large amount.
2. **Aspartame:** It is a dipeptide of two amino acids, aspartic acid and phenylalanine. *Nutrasweet* and *Equal* are the trade names of aspartame. The aspartame is thermolabile (sensitive to heat) hence cannot be used as a sweetner in cooked or baked foods. Persons suffering with phenylketonuria are advised not to use aspartame as a substitute of sugar.

3.6 FUNCTIONS OF CARBOHYDRATES

Carbohydrates have a variety of functions in the body.

1. The main function of carbohydrates in the body is to supply energy. Carbohydrates are the source of readily available energy, which is required for physical activities as well as for the working of the cells. Each gramme of carbohydrate as starch or sugar provide 4 kcal energy in the body.
2. Starch, which serves the main source of carbohydrates in the average diets has a blend taste and is non-irritant and hence it can be consumed in large amounts to provide major part of the energy requirement of the body.
3. Glycogen (a polysaccharide) stored in the muscles and liver act as reserve food (reserve fuel) which help in maintaining a constant level of glucose in the blood. About 300 gm. of glycogen is present in the liver and muscle cells at a given time.
4. Carbohydrates are involved in the synthesis of non-essential amino acids by combining with nitrogen.
5. Carbohydrates and their derivatives serve as precursors of a number of biomolecules. For instance, ribose and deoxyribose are components of nucleic acids and nucleotides.
6. Lactose (the milk sugar) provide galactose required for brain development. It also help in absorption of calcium and phosphorus, and hence growth and maintenance of bones.
7. Lactose is fermented into lactic acid by the action of *Lactobacilli* (bacteria) present in the gastrointestinal tract. These bacteria

NOTES

synthesise vitamin B_{12} and also prevent the growth of number of disease causing and putrefactive bacteria.

8. Carbohydrates are involved in fat metabolism and thus prevent acidosis.
9. Carbohydrates help in maintaining of water balance in the body a low carbohydrate diet causes loss of water and electrolytes (especially sodium and potassium) from the tissues in the urine and can lead to involuntary dehydration.
10. Some carbohydrates provide characteristic flavour and taste to the diet.
11. Cellulose constitutes the bulk of human food. It acts as roughage, necessary for the proper functioning of the digestive system. It helps in smooth movement of food waste and easy elimination of stool.

3.7 SOURCES OF CARBOHYDRATES IN THE DIET

Almost all types of vegetarian food items contain carbohydrates in one form or the other. The important food items that act as sources of carbohydrates in our diets include cereals, millets, pulses, roots, tubers, sugar and jaggery. Milk and sugar are important sources of carbohydrates in the diet of infants.

Green plants synthesize carbohydrates from CO_2 and water in presence of sunlight through the process of photosynthesis. The carbohydrates synthesized during photosynthesis are stored in plants in the form of starch as a reserve food in seeds (*e.g.*, cereals and legumes), roots and tubers. These food items are the primary energy sources in the human dietary.

Cereals and tubers (potato), which are the staple food in the Indian dietary, contribute major source of energy and proteins, and also some minerals and vitamins. Pulses and legumes serve as source of proteins, iron and vitamin B complex, vegetables and fruits provide dietary fibres, minerals and vitamins. Milk is the main source of a very important sugar, lactose in the diet. Fruit juices and the juices obtained from other plant parts (*e.g.*, sugarcane and beet root) are excellent source of quick energy. The carbohydrate content of important foods is given in Table 3.2.

Table 3.2. Carbohydrate Content of Some Foods

Food Items	*Carbohydrate g/100g*
Cereals and millets (rice, jowar, etc.)	63–79
Pulses (Bengal gram, red gram, etc.)	56–60
Nuts and oilseeds	10–25
Roots and tubers (potato, tapioca, sweet potato. etc.)	22–39

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Arrow root flour	85–87
Cane sugar	99
Sago	87–89
Honey	79–80
Jaggery	94–95
Milk (fluid)	4–5
Dried fruits (Raisin, dates, etc.)	67–77
Fresh fruits	10–25

3.8 UTILISATION OF CARBOHYDRATES IN THE BODY

Starch (the main carbohydrate present in the diet) is partly hydrolysed by *salivary amylase* (*ptyalin*) of saliva in the mouth to maltose, isomaltose and dextrin. About 30 per cent of the starch present in the food is hydrolysed in the oral cavity, because of the shorter time the food is retained here.

Starch $\xrightarrow{\textit{Salivary amylase}}$ Maltose + Isomaltose + α. Dextrins. Further digestion of carbohydrates occurs in the intestine by the enzymes present in the intestinal juice. The intestinal juice contains a number of carbohydrate digesting enzymes such as *maltase, isomaltase, sucrase* (*invertase*), *lactase* and *α-dextrinase*. These enzymes hydrolyse complex carbohydrates into monosaccharides (such as glucose and fructose)

$$\text{Maltose} \xrightarrow{\textit{Maltase}} 2\ \text{Glucose}$$

$$\text{Isomaltose} \xrightarrow{\textit{Isomaltase}} 2\ \text{Glucose}$$

$$\text{Sucrose} \xrightarrow{\textit{Sucrase}} \text{Glucose} + \text{Fructose}$$

$$\text{Lactose} \xrightarrow{\textit{Lactase}} \text{Glucose} + \text{Galactose}$$

$$\alpha\text{-Dextrins} \xrightarrow{\alpha-\text{Dextrinase}} \text{Glucose}$$

The glucose formed by the digestion of the starch and sugar is absorbed in the intestinal and carried to the liver through blood. The absorbed glucose maintain the glucose level in the blood. Excess glucose is stored as glycogen in the muscle and liver. The stored glycogen is converted into glucose, when the blood glucose level drops by the action of hormone glucagon secreted by pancreas. Excess of glycogen is converted into fat.

3.9 REGULATION OF BLOOD SUGAR

In a healthy person, the glucose homeostasis in blood is maintained jointly by the two hormones, insulin and glucagon produced by pancreas.

Glucagon stimulates breakdown of stored glycogen into glucose (glycogenolysis) in the liver, and thus increases the glucose level in the blood. The secretion of glucagon is controlled by feedback in accordance with the level of glucose in the blood. Excess of glucose in the blood suppresses the secretion of glucagon, whereas fall of glucose stimulates its production.

Insulin enhances cellular uptake and utilisation of glucose. It also stimulates conversion of glucose into glycogen (glycogenesis) in the target cells. The secretion of insulin is regulated by feedback from the blood glucose concentration. When the blood glucose level drops the secretion of insulin is suppressed. When the blood glucose level increases, the secretion of insulin is stimulated. Thus, the two hormones (insulin and glucagon) are 'antagonistic' to one another and jointly maintain the level of glucose in the blood.

Blood plasma contains 0.1 per cent glucose as blood sugar. Usually blood glucose level is about 80–100 mg per 100 ml of blood 12 hours after a normal meal. But its concentration rises soon after a carbohydrate rich diet. In a normal person, the fasting glucose is 70–110 mg/dl (decilitre). The glucose level after breakfast or post prependial (PP) is 110–140 mg/dl. If it is higher it causes *diabetes mellitus* (*hyperglycemia*), and its low-level causes *hypoglycemia* (*i.e.*, less amount of glucose in the blood).

3.10 CARBOHYDRATE CALORIE REQUIREMENTS

The body has a specific need for carbohydrates as a source of energy for the brain and other tissue cells, for the synthesis of lactose of milk (in lactating women), galactose and other sugars present in cerebrosides, mucopolysaccharides, etc. Carbohydrates are also required for the synthesis of non-essential amino acids. The percentage of calories derived from carbohydrates present in diets varies in the people of different countries. It is 60–70 per cent in developing countries, while it is 40–50 per cent in Europe and 30–40 per cent in USA. In a balanced diet, the carbohydrate calories should be at least 40 per cent. The level of carbohydrate calories in the diet depend on the availability of fat in the diet. The optimum level of carbohydrate calories according to persons physiological needs is given in Table 3.3.

Table 3.3. Optimal Level of Carbohydrate Calorie Need

Age Group	*Optimal level of carbohydrate calories (per cent of total calories)*
1. Adults	50–70
2. Pregnant and Nursing mothers	40–60
3. Children (above 5 years) and Adolescents	50–70
4. Pre school children (1–5 years)	40–60
5. Infants (1–12 months)	40–50

STUDENT ACTIVITY

1. Write the properties of starch.

2. How are carbohydrates utilized in the body?

Recommended Dietary Allowances

In general a minimum of 100 g carbohydrates are needed in the diet for a normal person. However, most of the diets contain carbohydrates more than this amount. If the carbohydrate are consumed more than the body's need, the excess of carbohydrates are converted into fat and are stored as reserve. Since, carbohydrates are the cheapest source of food energy. They supply upto 80 per cent of the calories in low cost diets in India. The amount of calories supplied by carbohydrates may be less in high cost diets having sufficient proteins and fats. For instance, if proteins of the diet supply 10 per cent calories, fats 20 per cent, then carbohydrates must supply the remaining 70 per cent calories.

Clinical Problems Related to Carbohydrate Intake

1. Obesity. Excess intake of food may cause a great deal of harm to the body. The excess nutrients are stored as increased body mass. Such a situation is called **over nutrition**. The excess intake of high calorie nutrients such as sugar, honey, sweets, candy, soft drinks etc. sweets contain a lot of fat in addition to sugar. Fats are concentrated source of calories. When the calorie input (in the form of food) exceeds the calorie output, the extra calories are changed into fat. This fat accumulates in tissues, leading to over weight and awkward body. Obese people are more prone to diabetes, osteoarthritis hypertension and heart ailments. Obese women are more prone to infertility. Regular exercise and low calorie diet are recommended to such persons.

2. Dental Caries. Frequent intake of sweets, candies, soft drinks etc., is hazardous to teeth. When sugar remain in contact with teeth, it tends to lead tooth decay. If it is not checked, it may lead to dental caries. Chewy sweets often remain in contact with teeth for long time unless the mouth is not rinse thoroughly after eating the sweet or candy. Therefore, children must be taught to rinse their mouth thoroughly after taking a sweet or candy to prevent tooth decay.

3.11 DIETARY FIBRE

The structural parts of plants, which are not digested by enzymes in the human digestive tract and do not contribute any nutrients to the body are known as **dietary fibres**. Cellulose, hemicellulose and pectin present in the coverings of seeds, fruits, vegetables and other edible parts of the plants which are undigestable are referred to as **fibres**. Pectins present in many fruits have the ability to absorb water and form gels, hence pectins are used in the preparations of jams and jellies.

Dietary fibres can be broadly classified into two categories:

(*i*) **Water Insoluble Fibres**. These are the structural parts of plant cell walls which are not dissolved in water *e.g.*, cellulose, hemicellulose and lignin. Water insoluble fibres are found in whole wheat, wheat bran, seeds, nuts and vegetables.

(*ii*) **Water Soluble Fibres.** These are viscous plant fibres which can be dissolved in water *e.g.*, pectins, gums and mucilages. Water soluble fibres are found in fruits, oat, barley, legumes and beans.

Food Sources of Fibres

All most all plant foods contain fibres whole cereal grains and their flour, fruit such as apples eaten with their skin, bananas, pineapple, vegetables such as cabbage, spinach, amaranthus, legumes and beans are good sources of fibres (Fig. 3.3). The fibre quantity present in different food items is given in Table 3.4.

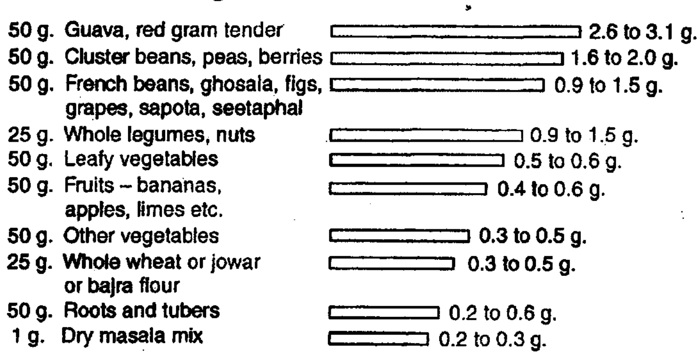

Fig. 3.3 *Fibre content to foods.*

Table 3.4. Fibre Content of Foods

Food	*Fibre g/100g EP*[1]
Cereals, whole	1.2–1.9
Cereals, refined	0.2–0.7
Pulses, whole	3.7–5.3
Pulses, split	0.7–1.5
Nuts and oilseeds, vegetables	1.3–6.6
Leafy and other	0.5–3.2
Roots and tubers	0.4–1.8
Fruits	0.5–2.7

1. EP-Edible portion.

Fibre Requirements

So far the amount of fibres needed for the human body has not been recommended. However, some expert feel that five to six grams of fibre per day is sufficient for an adult human. An average mixed diet consisting of a raw vegetable, fresh fruit with skins, cooked food and vegetables usually provide sufficient fibre. Chapatis made from whole wheat flour are good source of fibre. The fibre content in the diet can be increased by increasing the amount of whole cereal grains or whole wheat bread in the diet.

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Functions of Fibres

Although, the fibre constituents of the food (*e.g.*, cellulose, hemicellulose, lignin etc.) do not provide any nutrient to the body, a these are indigestable. However, these indigestable materials serve a number of useful purposes in our body.

1. Fibres constitute bulk of the human food, which act, as roughage necessary for the proper functioning of the digestive system.
2. They stimulate peristaltic (rhythmic) movements of gastro intestinal tract by adding bulk to the intestinal contents.
3. The insoluble fibres needs chewing and thus improve masticating of food.
4. Dietary fibres absorb water and swell up. This increases surface area of food mass for enzymatic activity, thus improve digestion.
5. Dietary fibres increase food bulk and cause feeling of fullness. Thus, help obese person to reduce total calorie intake and lose weight.
6. Fibres reduce transit time and bind with bile pigments and cholesterol and help carry these out of the body.
7. The sponge like swollen mass of fibres ensure smooth elimination of faeces.
8. Fibres make the stools soft and thus dilute the potential carcinogens if any in the food.
9. Fibres cause rapid transit of stools and thus reduce the risk of colon cancer.

Problems Related to Dietary Fibres

Lack of fibres in the diet may result in number of disorders of digestive tract. Shortage or lack of fibres in the diet make it difficult to eliminate the food waste from the body. Consistent shortage of fibres in the diet may lead to constipation and other disturbances of the colon. This condition can be rectified by an increase in fibre intake in the form of leafy vegetables, fruits with skin and salad in the diet.

Fibres are best taken from natural foods and not as fibre supplements. Food sources not only provide fibres but also vitamins and minerals, whereas fibre supplements do not provide any nutrients. An excess intake of fibre may result in intestinal obstruction, if it is not accompanied by a liberal intake of water. If fibre intake is increased suddenly, intestinal cramps, diarrhoea and excessive intestinal gas formation may take place. Therefore, the fibre content in the meal should be increased gradually over a period of several weeks.

3.12 SUMMARY

- Carbohydrates are the main source of energy in our body. They are synthesised in green plants. Chemically, carbohydrates are polyhydroxy aldehyde or ketones. Carbohydrates are broadly classified into monosaccharides, oligosaccharides and polysaccharides. The important carbohydrates present in foods includes glucose, fructose (monosaccharides), sucrose, lactose, maltose (disaccharides), starch, cellulose (polysaccharides). Carbohydrates perform a variety of functions in the body including, source of energy and precursors of a number of biomolecules.

- In a vegetarian diet cereals, millets, pulses, tubers, sugar and jaggery are the main sources of carbohydrates. The carbohydrates of the food are digested in the mouth and intestine to form hexose sugars like glucose and fructose. The hexose sugars are absorbed in the intestine. People of different age groups require different quantities of carbohydrates. In general, a minimum 100 g carbohydrates are needed in the diet for a normal person. Excess intake of high caloried nutrient intake may cause obesity.
- The dietary fibres are also essential in a balanced diet. The structural parts of plants, which are not digested by enzymes in the human digestive tract and do not contribute any nutrients to the body are called dietary fibres. Fibres constitute bulk of the food and act as roughage necessary for the proper functioning of the digestive system and easy elimination of faeces from the body.

3.13 GLOSSARY

- **Starch:** It is the reserve food in most plants. Starch is formed as end product of photosynthesis.
- **Glycogen:** It is a main reserve food in animals, bacteria and fungi. it is also known as animal starch.
- **Inulin:** It is a fructan storage polysaccharide in fleshy roots of Dahlia and related plants.
- **Dextrins:** Dextrins are polysaccharides formed by the partial hydrolysis of starch by acids or amylase.
- **Cellulose:** It is the main structural component of cell walls of plants. It is a fibrous polysaccharide made up of glucose.
- **Hemicellulose:** It is a mixture of polysaccharides xylans, galactans, arabagalactans and glucomannans.
- **Pentasans:** Pentasans are polysaccharides formed by polymerisation of a large number of pentoses.
- **Dietary Fibre:** The structural parts of plants, which are not digested by enzymes in the human digestive tract and do not contribute any nutrients to the body are known as dietary fibres.

NOTES

3.14 REVIEW QUESTIONS

I. Very Short Answer Type Questions:

1. What are carbohydrates?
2. What are saccharides?
3. Why are monosaccharides called reducing sugars?
4. Give the chemical name of the following:
   (*i*) Cane sugar (*ii*) Fruit sugar (*iii*) Malt sugar
   (*iv*) Milk sugar (*v*) Grape sugar.
5. What are polysaccharides?
6. How is obesity caused?

II. Short Answer Type Questions:

1. What are the main sources of starch in our diet?
2. Give an account of the importance of starch in our body.
3. Why are cereals used as staple food in India?
4. Why is fibre important in our diet?
5. What are two important properties of monosaccharides?
6. What are sugar substitutes? What is their use?
7. What is meant by recommended dietary allowance of carbohydrates?
8. What are the functions of dietary fibres in our body?
9. Explain the problems related to dietary fibres.
10. Mention the food sources of fibres.
11. Why is frequent intake of sweets and candies is hazardous to the health?

III. Long Answer Type Questions:

1. Give an account of function of carbohydrates in the body.
2. Explain the importance of carbohydrates in the body.
3. Explain the role of starch and cellulose in our diets.

3.15 FURTHER READINGS

- *Outlines of Biochemistry:* E.E. Conn, P.K. Stumpf, R.H. Doi; Wiley India, Pvt Ltd; 2007.
- *Biochemistry:* Pawar, Chatwal: Himalayas Pub. House; New Delhi; 1988.
- *Biochemistry:* U. Satyanarayan, U. Chakrapani; Books and Allied (P) Ltd. Kolkata; 2008.
- *Essentials of Food and Nutrition:* M. Swaminathan; Ganesh Madras, India 1985.

CHAPTER 4 FATS AND OILS

OBJECTIVES

After going through this chapter, you should be able to:

- explain classification of fats and sources of fats
- describe the cholesterol
- know about digestion and absorption of fat
- describe the functions of dietary fat
- know about fat intake in India
- explain the (RADs) and disorders due to excess dietary intake of fats.

STRUCTURE

4.1 INTRODUCTION

The terms 'lipids' is applied to a group of naturally occurring substances characterised by their insolubility in water, greasy feel and solubility in some organic solvents. They are widely distributed both in plant and animal kingdoms. Lipids are an essential part of our body, accounting for about one sixth of our body weight. Fats are the best known members of chemical substances called lipids. They constitute an important part of our diet and supply 10–30 per cent of the total energy needs. In our body fat is found deposited beneath the skin and around the internal organs to minimise loss of body heat and also act as cushions to absorb mechanical impacts. Food fats include solid fats, oils and related compounds such as cholesterol and fat soluble vitamins. The intake of fat rich diet may lead to over weight and obesity.

4.2 COMPOSITION

Lipids (G.K. *lipos*-fat) are esters of fatty acid with alcohols and related substances. They include substances like cooking oil, butter, ghee, natural rubber, cholesterol, eucalyptus oil, menthol and Lipids exhibit a variety of structures but have certain common characteristics. They are all made of carbon, hydrogen and sometimes oxygen. The number of oxygen atoms in a lipid molecule is always small as compared to the number of carbon atoms. Sometimes small amounts of phosphorus, nitrogen and sulphur are also present. Lipids are non-polar and, therefore, insoluble in water. They get dissolved in a number of non-polar organic solvents like ether, chloroform, benzene and acetone. Generally, lipids do not polymerise to form macromolecules. However, they may combine with carbohydrates and proteins. Lipids are often classified into fat, cutin, suberin, waxes, phospholipids, glycolipids, and sterols. The basic components of all lipids are fatty acids.

4.3 CLASSIFICATION

Lipids are classified on the basis of their chemical structures into following categories.

I. Simple lipids *e.g.,* fatty acids, fats and oils
II. Compound lipids *e.g.,* phospholipids, glycolipids, lipoproteins
III. Derived lipids *e.g.,* vitamins, A, D, E and K, and sterols.

I. Simple Lipids

Simple lipids are esters of fatty acids and alcohol. Fatty acids, neutral fats, and oils are the common examples of simple lipids.

Fatty Acids

Fatty acids are organic acids with a hydrocarbon chain ending in a carboxylic group (–COOH). Some fatty acids also posses hydroxyl group. The hydrocarbon chains of fatty acid may possess straight or ring structure. Most fatty acids have an even number of carbon atoms between 14 and 22, mostly 16 or 18.

Fatty acids are grouped into two broad categories : saturated and unsaturated fatty acids.

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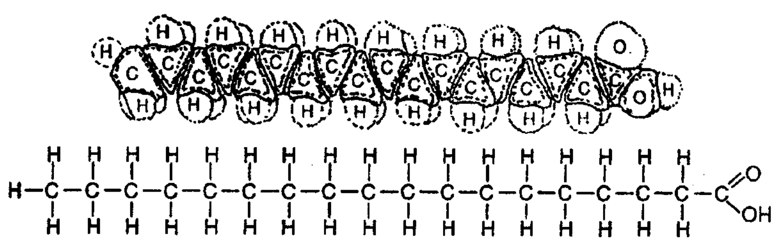
1. Saturated Fatty Acids

The saturated fatty acids do not have double bonds in their carbon chains. They cannot take up any more hydrogen, hence saturated. They are straight chain molecules. They have a general formula $CH_3(CH_2)_nCOOH$. *e.g.*,

$CH_3(CH_2)_{14}COOH$	$CH_3(CH_2)_{16}COOH$
Palmitic acid	Stearic acid

A fatty acid molecule has a polar end with a free hydroxyl group and a non-polar end with a hydrocarbon chain. It is represented as

$R{-}C\genfrac{}{}{0pt}{}{/\!\!/O}{\backslash OH}$ where R denotes the hydrocarbon chain (Fig. 4.1)



Stearic acid, $CH_3(CH_2)_{16}COOH$

Fig. 4.1. *Structure of stearic acid (a saturated fatty acid).*

2. Unsaturated Fatty Acids

Unsaturated fatty acids have one or more double bonds in their carbon chains. They can take up additional hydrogen, hence unsaturated. The unsaturated fatty acids have a general formula $C_nH_{2n}{-}2xO_2$, *e.g.*, Oleic acid ($C_{18}H_{34}O_2$), linoleic acid ($C_{18}H_{32}O_2$), linolenic acid ($C_{18}H_{30}O_2$) and arachidonic acid ($C_{20}H_{32}O_2$). The 18 carbon unsaturated fatty acids–oleic, linoleic, linolenic acids and 20 carbon arachidonic acid have 1, 2, 3 and 4 double bonds respectively. They have a bend or kink at each double bond. The kinks make the fatty acid chain more disordered and hence more fluid at ordinary temperature (Fig. 4.2).

$$CH_3(CH_2)_7CH = CH(CH_2)_7COOH$$

Oleic acid

$$CH_3(CH_2)_4CH = CHCH_2CH = CH(CH_2)_7COOH$$

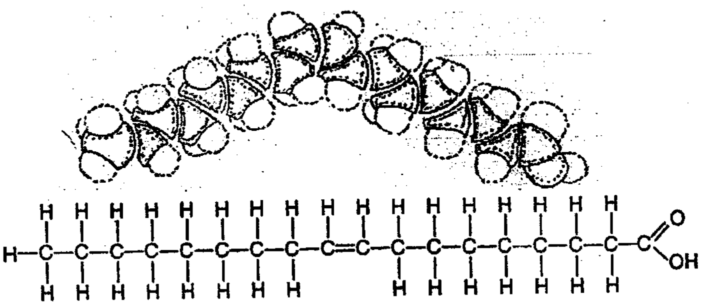
Linoleic acid

$$CH_3CH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_7COOH$$

Linolenic acid

$$CH_3(CH_2)_4CH = CHCH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_3COOH$$

Arachidonic acid



Oleic acid, $CH_3(CH_2)_7CH = CH(CH_2)_7COOH$

Fig. 4.2. *Structure of oleic acid (an unsaturated fatty acid). Note the kink produced by the double bond.*

Most plant lipids have unsaturated fatty acids, while most animal lipids have saturated fatty acids. Aquatic animals of colder water, however, possess unsaturated fatty acids.

Fatty acids with less carbon atoms are readily miscible with water, *e.g.*, acetic acid and propionic acid, but the solubility decreases as the number of carbon atoms increases in the hydrocarbon chain. Saturated fatty acids with less than 10 carbon atoms are liquid at room temperature, and those having more are solids. Melting point also increases with increasing number of carbon atoms (Table 4.1).

Table 4.1. Some Naturally Occurring Fatty Acids with their Melting Points

Saturated Fatty Acids			
Common Name	*Empirical Formula*	*Chemical Structure*	*Melting Point (°C)*
Acetic acid	$C_2H_4O_2$	CH_3COOH	16°
Propionic acid	$C_3H_6O_2$	CH_3CH_2COOH	–22°
n-Butyric acid	$C_4H_8O_2$	$CH_3(CH_2)_2COOH$	–7.9°
Caproic acid	$C_6H_{12}O_2$	$CH_3(CH_2)_4COOH$	–3.4°
Lauric acid	$C_{12}H_{24}O_2$	$CH_3(CH_2)_{10}COOH$	44°
Myristic acid	$C_{14}H_{28}O_2$	$CH_3(CH_2)_{12}COOH$	54°
Palmitic acid	$C_{16}H_{32}O_2$	$CH_3(CH_2)_{14}COOH$	63°
Stearic acid	$C_{18}H_{36}O_2$	$CH_3(CH_2)_{16}COOH$	70°
Arachidie acid	$C_{20}H_{40}O_2$	$CH_3(CH_2)_{18}COOH$	75°
Unsaturated fatty acids			
Palmitoleic acid	$C_{16}H_{30}O_2$	$CH_3(CH_2)_5CH = CH(CH_2)_7COOH$	11°
Oleic acid	$C_{18}H_{34}O_3$	$CH_3(CH_2)_7CH = CH(CH_2)_7COOH$	13°
Elaidic acid (trans–9 octadecenoic acid)	$C_{18}H_{34}O_2$	$CH_3(CH_2)_7CH = CH(CH_2)_7COOH$	–
Linoleic acid	$C_{18}H_{32}O_2$	$CH_3(CH_2)_4CH = CHCH_2CH = (CH_2)_7 COOH$	–5°

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Linolenic acid	$C_{18}H_{30}O_2$	$CH_3CH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_7COOH$	–10°
Arachidonic acid	$C_{20}H_{32}O_2$	$CH_3(CH_2)_4CH = CHCH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_3COOH$	–50°

The unsaturated fatty acids having only one double bond in their molecules are called **monounsaturated fatty acids** (MUFA), Oleic acid, found in olive oil, is a monounsaturated fatty acid.

The unsaturated fatty acids having two or more double bonds in their molecules are called **polyunsaturated fatty acids** (PUFA), corn oil contains polyunsaturated fatty acids.

The methyl end of the fatty acid molecule is termed as **Omega** end. If the first double bond in the fatty acid at in the third carbon atom from the methyl end, it is called **Omega-3** fatty acid (*e.g.*, linolenic acid) if it is at the sixth carbon from the methyl end, it is termed as **Omega-6** fatty acid (*e.g.*, linoleic acid) and when it is at the ninth carbon, it is called **Omega-9** fatty acid (*e.g.*, oleic acid).

About 20 fatty acids are found in foods and body tissues. The chain length of a fatty acid is decided by the number of carbon atoms in their molecules. Thus, short chain fatty acids contain 4 to 6 carbon atoms, medium chains have 8 to 12 carbon atoms, long chain fatty acids have 14 to 18 carbon atoms and extra long chain fatty acids have more than 20 carbon atoms in their molecules. Milk fat, vinegar and coconut oil contain short chain fatty acids, whereas, long chain fatty acids are found in most vegetable oils and animal fats. Fish oils contain the extra long chain fatty acids (Table 4.2)

Table 4.2. Carbon Chains of Some Fatty Acids in Different Foods

Name	*No. of C atoms*	*Chain Length*	*Type*	*Food Source*
Acetic	2	Short	Saturated	Vinegar
Butyric	4	Short	Saturated	Butter
Caproic	6	Short	Saturated	Butter
Caprylic	8	Short	Saturated	Coconut
Myristic	14	Long	Saturated	Nutmeg and Mace
Palmitic	16	Long	Saturated	Palm oil and lard
Stearic	18	Long	Saturated	Beef tallow
Oleic	18	Long	Monounsatd.	Olive oil
Linoleic	18	Long	Polyunsatd.	Groundnut, sesame, corn oil, sunflower
Clupanadonic	22	Extra-long	Polyunsatd.	Fish Oils

Essential Fatty Acids (EFAs)

Most plants and many animals can synthesis all types of fatty acids. However, some animals including man cannot synthesize three amino acids, linoleic acid, linolenic acid and arachidonic acids. These are called **essential fatty acids** (EFAs). Most edible oils like those of sunflower, groundnut, mustard, cotton seed etc., contain essential fatty acids. Essential fatty acids must be present in the human diet. Their deficiency may cause **phrenoderma or follicular hyper keratosis.**

Essential fatty acids are characterised by the following features.

(*i*) These are not synthesised in the human body.

(*ii*) These become available only through diet.

(*iii*) These are required for a number of functions in the body.

Most vegetable oils (except coconut oil) are good source of linoleic acid. Soyabean and rape seed oils, green leafy vegetables, cabbage and lettuce are good sources of omega-3 fatty acids. Among fish foods, which contain omega-3 fatty acids include fishes like tuna, sardines and salmon.

Roles of EFAs

1. EFAs are essential for growth in the young and maintenance of normal healthy skin.
2. They are precursors of some derived lipids such as prostaglandins, which regulate vascular functions.
3. The EFAs such as omega-3 fatty acids, Decosa Hexenoic Acid (DHA) and Eicosa Pentenoic Acid (EPA), have important role in the development of eyes and brain in foetus. These EFAs also provide protection against rheumatoid arthritis and cardiovascular diseases.
4. The prostaglandins have a variety of effects such as vasodilation, vasoconstriction, inflammatory and allergic reaction. They also play a significant role on blood clotting and stimulation of intestinal and bronchial muscles.

Deficiency of EFAs. Deficiency of EFAs results in a flomly skin, development of itchy sores on scalp, diarrhoea and retarded growth. Such symptom may develop in low birth weight infants and in the adults fed with fat free diets for a long duration. EFA deficiency may also result in the change in fatty acid composition of many tissues including biological membranes and mitochondria.

Refined and Hydrogenated Oils

The process of refining and hydrogenation oils are described below:

1. Refined Oils. The refined oils are vegetable oils, made free from odour and colour. The refining of vegetable oils involves following steps.

(*i*) Alkali refining to remove free fatty acids.

(*ii*) Bleaching with Fuller's earth or activated carbons to remove colouring matter, and

(*iii*) Deodourisation with super heated stream.

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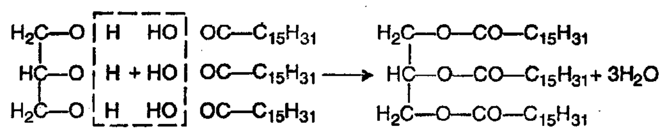
2. Hydrogenated Oils. The hydrogenated oils are used as substitute for ghee. The refined oils obtained as described above is hydrogenated under optimum temperature and pressure in the presence of nickel catalyst. In this process, hydrogen is added to the unsaturated linkages. It decreases the unsaturated fatty acid contents of the oils and the latter are converted to solid fats. The vanaspathi sold in India consists mostly of hydrogenated refined groundnut oil to which sesame oil (5 percent) is added. Vanaspathi is usually fortified with vitamin A.

3. Fats and Oils. Neutral or true fats are esters of fatty acid and glycerol (glycerine). Each molecule of glycerol can react with three molecules of fatty acids. Three molecules of water are eliminated in this process. Depending on the number of fatty acids, attached to the glycerol molecule, the esters are called **mono-, di-or tri-glycerides** or **acylglycerols.**

Triglycerides are the most common fats in cells. Mono- and diglycerides occur as intermediates in certain biosynthetic reactions. The three fatty acids are similar only in few fats (*e.g.,* tripalmitin, tristearin). They are called **pure fats.** Most fats have dissimilar or two of the three fatty acids are similar. They are called **mixed fats,** (*e.g.,* butter). Fats are named after the names of fatty acids, *e.g.,* dipalmito-stearin, palmito-oleio-stearin etc.



Glycerol (1 Molecule) — Palmitic acid (3 Molecules) — Tripalmitin (A pure fat)

Most neutral fats are mixtures of different triglycerides. Depending on the physical nature, fats are differentiated into **oils and hard fats.**

Oils

Oils are generally liquid at room temperature. They are rich in unsaturated fatty acids and short chain fatty acids, consequently have low melting points *e.g.,* groundnut oil, rape seed oil, mustard oil, sesame seed oil (til oil), sunflower oil, safflower oil etc. Unsaturated fatty acid can combine with oxygen and other chemicals. Therefore, exposed oils have a tendency to solidify. Hence, they are called **drying oils.**

Hard Fats

Hard fats are solid at room temperature. They contain long chain saturated fatty acids and have high melting point *e.g.,* animal fat. Butter is soft because it contains good quality of short chain fatty acids.

Many vegetable oils are claimed to be "rich in polyunsaturates". This means that the fatty acids present in these oils have more than one double bond. Such oils are recommended by physicians for persons

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who suffer from high blood cholesterol or cardiovascular diseases. It is because polyunsaturated fatty acids lower the blood cholesterol. Edible oils having polyunsaturated fatty acids can be converted into hard fats through the process of **hydrogenation.** In hydrogenation unsaturated fatty acids are changed to saturated and the oil becomes a solid fat. Vegetable ghee (vanaspati) and margarine are obtained from oils through hydrogenation.

During commercial process of hydrogenation, hydrogen is added to some (not all) of the double bonds of the unsaturated fatty acids to increase the firmness and the melting point of the product. However, this processing also changes the isomers (shape, configuration) of some of the remaining unsaturated fatty acids. Most unsaturated bonds in nature are in *'cis'* form (folded pattern), but after hydrogenation, many double bonds acquire linear pattern to become *'trans'* form. Though, these fatty acids are still unsaturated, but they behave like saturated fatty acids.

Iodine Value of Fats and Oils

Different types of fats and oils have different amounts of unsaturated fatty acids, which can be measured by estimating the iodine value of the fat or oil. Iodine value is defined as 'the number of grams of iodine absorbed by 100 g of fat or oil'. Two atoms of iodine are added to each unsaturated linkage.

The content of some fatty acids in some fats and oils are given in Table 4.3.

Table 4.3. Linoleic and Linolenic Acid Content of Edible Oils

S.No.	Oil	Linoleic g/100g	Linolenic g/100g	Total EFA g/100g
1.	Safflower (*Kardi*)	74.0	0.5	74.5
2.	Soybean	52.0	5.0	57.0
3.	Sunflower	52.0	trace	52.0
4.	Maize (corn)	50.0	2.0	52.0
5.	Cottonseed	50.3	0.4	50.7
6.	Sesame (*til*)	40.0	0.5	40.5
7.	Rice bran	33.0	1.6	34.6
8.	Groundnut	28.0	0.3	28.3
9.	Rape/mustard	13.0	9.0	22.0
10.	Palmolein	12.0	0.3	12.3
11.	Olive			
12.	Vanaspati	3.4	–	3.4
13.	Coconut	2.2	–	2.2
14.	Ghee	1.6	0.5	2.1

Rancidity in Fats

Fats undergo oxidation along with hydrolysis, when exposed to air. Oxidation takes place at double bonds of the fatty acid, yielding short chain acids, aldehyde, resins, etc. This impart unpleasant odour and taste to the fat. It is termed as **rancidity.** The rancid fat is unsuitable for human consumption, because besides having an unpleasant smell and taste, it oxidizes essential dietary constituents. The rancidity can be prevened by using small amount antioxidants to the fat. The commonly used antioxidants in commercial fats are nordihydroguiretic acid and tertiary butyl para-cresol. Tocopherol is a natural antioxidant found in vegetable oils.

II. Compound Lipids

The important compound lipids present in animal and human tissues are given below:

1. Phospholipids: Phospholipids are triglyceride lipids in which one fatty acid is replaced by a phosphate group. Some phospholipids also have a nitrogenous compound attached to the phosphate group. Phospholipids are **amphipathic** molecules *i.e.*, carry both hydrophilic (water attracting) polar and hydrophobic (water repellant) non-polar groups. Hence, in an aqueous medium, they form a double layered membrane or **lipid bilayer.** Such lipid bilayers are the basic components of cell membrane. Two important phospholipids found in human tissues are lecithin and cephalin.

(*a*) **Lecithins.** Consists of glycerol, phosphoric acid, choline and fatty acids. The fatty acids commonly found in lecithin are palmitic, stearic, oleic, linolenic and arachidonic acids. Lecithins are important constituents of lipoproteins, particularly chylomicrons. They have important role in fat metabolism in liver.

(*b*) **Cephalins.** Structurally, they resemble with lecithins, but have ethanolamine, colamine or serine in place of choline.

2. Glycolipids: Glycolipids contain a variety of sugars, but are devoid of a phosphate group. *Cerebrosides* are common glycolipids found in human tissues. Cerebrosides contain hexoses (galactose and glucose), fatty acid and amino alcohol, but no phosphoric acid or glycerol.

III. Derived Lipids

These are lipid like substances such as steroid and other derivatives of lipids.

1. Steroids or Sterols: Steroids are wax like lipids of high molecular weight. The basic structure of steriods is derived from a fusion of three cyclohexane rings and one cyclopentane ring. It is commonly called *perhydrocyclopentanophenanthrene* (*terane*) ring system. Steriods are classified as:

(*i*) Animal steroids. *e.g.*, cholesterol

(*ii*) Plant steroids. *e.g.*, phytosterol, and

(*iii*) Mycosterols. *e.g.*, ergosterol

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4.4 CHOLESTEROL

Cholesterol occurs in relatively high concentrations in nervous tissues, sebum and in bile. The blood of normal human beings contains 150–250 mg/100 mL of blood. When cholesterol level rises in blood, it tends to get deposited in the walls of arteries (called *arteriosclerosis*), leading to high blood pressure and other cardiovascular disorders. Cholesterol has following useful roles in animals.

(*a*) It is a precursor of steroid hormones like progesterone, estradiol (female sex hormones), testosterone (male sex hormone), aldosterone, cortisol (adrenal cortex hormone), ecdysone (moulting hormone).

(*b*) It produces bile salts that emulsify fat during digestion.

(*c*) It forms vitamin D (calciferol) on exposure to ultraviolet rays.

(*d*) Cholesterol is an essential component of animal cell membrane and the cell membrane of mycoplasmas.

4.5 SOURCES

Human dietary fats and lipids are obtained from both plants and animals. The vegetable oils used in food preparations are extracted from oil seeds and nuts, whereas, butter and ghee are animal fats extracted from milk. The vegetable oils include groundnut oil, palm oil, cotton seed oil, mustard oil, rape seed oil, sesame seed oil (til oil), sunflower oil, safflower oil, etc. (Fig. 4.3). Oils are generally liquid at room temperature. They are rich in unsaturated fatty acids and short chain fatty acids, consequently have low melting point. Vegetable oils are hydrogenated to form almost solid fat called vegetable ghee or **vanaspati.** Vegetable ghee is usually fortified with vitamins A and D, as it is used as a substitute of ghee.

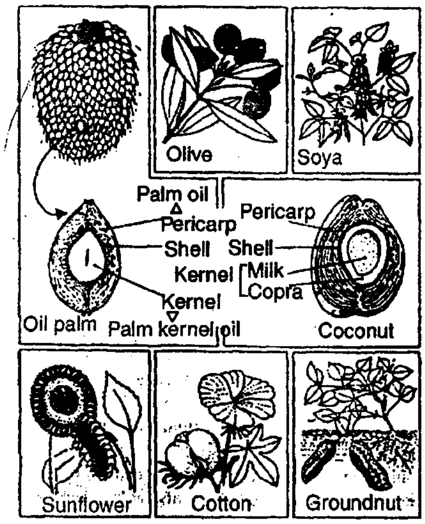

Fig 4.3. *Some important sources of vegetable oils.*

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The animal foods such as milk, egg, meat and liver are the sources of hidden fat in the diet. Nuts, oil seeds, milk, eggs and meat supply not only fats but are also the sources of protein, mineral and vitamin of B complex group. Ghee, butter, eggs and liver are good sources of vitamin A.

The amount of fat present in different foods and the amount energy provided by these foods is given in Table 4.4.

Table 4.4. Fat Content and Energy Value of Different Food Items

Food	*g / 100g*	*Calories / 100g*
Visible Fats		
Oil, vegetables	100.0	900
Vanaspati	100.0	900
Ghee, cow's	99.5	895
Butter	81.0	729
Invisible Fats		
Oilseeds & nuts	37.0–64.5	537–681
Mutton, muscle	13.3	194
Eggs, hen	13.3	173
Liver, sheep	7.5	150
Milk, cow	4.1	67

4.6 DIGESTION AND ABSORPTION OF FAT

Fats and oils of the ingested food is digested in the small intestine. In small intestine, fats and oils are broken down into small droplets by the action of bile. This process is called *emulsification*. The emulsified fats are hydrolysed into a mixture of diglycerides, monoglycerides and fatty acids by the action of pancreatic and intestinal *lipases*. Further, di and monoglycerides are hydrolysed into fatty acids and glycerol. However, normally the digestion of fats remains incomplete in the intestine. Hydrolysis of fats is a slow process and a few hours available for the action of lipase in the intestine are not enough for the completion of fat hydrolysis.

$$\underset{\text{(Fat)}}{\text{Triglyceride}} \xrightarrow{Lipase} \text{Fatty acid + Diglyceride}$$

$$\text{Diglyceride} \xrightarrow{Lipase} \text{Fatty acid + Monoglyceride}$$

$$\text{Monoglyceride} \xrightarrow{Lipase} \text{Fatty acid + Glycerol}$$

The product of fat digestion, *i.e.*, fatty acids and glycerol are absorbed in the small intestine. Since, fatty acids and glycerol being insoluble in water, cannot be absorbed into the blood as such. They are first incorporated into small droplets called **micelles,** which move into the intestinal mucosa. They are reformed into very small protein coated fat globules called the *chylomicrons,* which are transported into the lymph vessels

STUDENT ACTIVITY

1. What are the roles of cholesterol in the body?

2. How does the rise in blood cholesterol is harmful to the body?

(lacteals) in the villi of the intestine. These lymph vessles ultimately release the absorbed substances into the blood stream.

4.7 RECOMMENDED DIETARY ALLOWANCES (RDAs) FOR FATS

NOTES

The requirement of fat is based mainly on two factors:

(*i*) The energy needs, and (*ii*) the requirement of essential fatty acids. It has worked out to about 12 g of fat per day. A higher, level of intake of 20 g/day is desirable to provide energy density and palatability for normal adults. It is desirable, that an upper limit of 20 g/day of fat intake for adults and 25 g/day for young children be followed, in view of the possible complications resulting from excessive intake of fat. However, to meet the requirement of essential fatty acids, the diet should contain at least 10 g of vegetable oil, which is a good source of linoleic acid.

4.8 FUNCTIONS OF DIETARY FAT

The dietary fats perform a number of functions in the body.

1. It is a concentrated source of energy, yielding more than twice the energy supplied by carbohydrates per unit weight (*i.e.*, 4.5 k cal/g for carbohydrate and 9.3 k cal/g for fats).
2. Fats are essential for the absorption of vitamins A, D, E and K, and especially carotenoids (provitamin A) present in foods of vegetable origin.
3. Some fats are the sources of some vitamins. For example, fish liver oil, butter and ghee contain vitamin A; many vegetable fats contain vitamin E, and red palm oil is a good source of carotene (Provitamin A).
4. The essential fatty acids (*viz.*, linoleic acid, linolenic acid and arachidonic acids) are essential for maintaining tissues in normal health, are obtained from the dietary fats.
5. Fats help to reduce the bulk of the diet as starchy foods absorb lot of water during cooking.
6. Fats improve the palatability of the diet and give satiety value, *i.e.*, a feeling of fullness in the stomach.
7. Fats are essential for the utilisation of galactose present in lactose.
8. Fats are deposited in the adipose tissues which serve as a reserve source of energy during starvation. Also the adipose tissue found beneath the skin and around the internal organs minimise loss of body heat and also act as cushions to absorb mechanical impacts.

9. Phospholipids, glycolipids and sterols serve as structural lipids. They are important components of cell membranes.
10. Cholesterol is used in the synthesis of steroid hormones, vitamin D and bile salts.

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4.9 FAT INTAKE IN INDIA

The diet surveys by **National Nutrition Monitoring Bureau (NNMB)** of India shows that the daily intake of visible fats vary from 3 to 20 g/day in rural areas and 20 to 42 g/day in the urban areas of the country. In addition, the intake of invisible fats may vary from 16 to 30 g/day, and in some population groups, it may be upto 50 g/day. Thus, the total fat intake may contribute 10 to 30 per cent of dietary energy. The nature of dietary fat also varies in different part of the country. It is mustard and rape seed oil in Punjab, Haryana, Rajasthan, U.P., Bihar and West Bengal, groundnut oil in West and some part of South India, coconut oil in Kerala, Karnataka, Tamil Nadu and Orissa and Safflower and Sunflower oil in North Karnataka and parts of Southern Maharashtra. Though, a minimum amount of fat in the diet is essential for proper functioning of the body. However, an excess is harmful. Therefore, the minimum level and the safe upper limit of fat intake have to be considered.

4.10 DISORDERS DUE TO EXCESS DIETARY INTAKE OF FATS

Although fat is essential for our health, but too much of it in the diet may lead to disorders such as hyper cholesterolemia and obesity.

1. **Hyper Cholesterolemia.** It is caused due to excess intake of saturated fats such as milk sweets, butter, ghee, hydrogenated vegetable oils, red meat and eggs, and a very sedentary life styles. It increases blood cholesterol level tremendously. Cholesterol is deposited on the lining of arteries and arterioles, which become narrow and stiff. This leads to high blood pressure which may cause some heart disorders. The inner surface of the arteries also becomes irregular and this may cause clot formation, or thrombosis. Clot formation, in a narrowed coronary artery may cause heart attack.
2. **Obesity.** It is caused by excessive intake of high calorie nutrients such as sugar and saturated fats. Fat accumulates in tissues, leading to over weight and **awkward** body. This may cause high blood pressure, diabetes and heart ailments. Regular exercise and intake of green vegetables are recommended to such persons.

4.11 LIPIDS IN BLOOD

A number of lipids occur in human blood. Normal human plasma in the post absorptive state contains about 500 mg lipids/100 mL of blood. Out of which about 120 mg are triglycerides, 160 mg phospholipids, 180 mg cholesterol and about 10–15 mg of free fatty acids.

4.12 SUMMARY

- Lipids are characterised by their insolubility in water and solubility in some organic solvents. They include substances like cooking oils, butter, ghee and vitamins A, E and K. Human dietary fats are obtained from both plants and animals. Lipids are usually classified into simple, compound and derived lipids. Simple lipids include fatty acids, fats and oils.
- Fatty acids are organic acids with a hydrocarbon chain ending in a carboxylic group. Saturated fatty acids do not have double bonds in their carbon chains. Unsaturated fatty acids have one or more double bonds in their carbon chains. Most plants and many animals can synthesise all types of fatty acids. However, three fatty acids cannot be synthesized by the human body. These are called essential fatty acids (EFAs). Deficiency of EFAs results in a flamly skin, development of itchy sores on scalp, diarrhoea and retarded growth.
- Neutral fats are esters of fatty acids and glycerol. They are solid at room temperature and contain long chain saturated fatty acids. Oils are generally liquid at room temperature, and are rich in unsaturated fatty acids. Edible oils can be converted into neutral fats through hydrogenation. Vegetable ghee and margarine are obtained from oils through hydrogenation.
- Phospholipids and glycolipids are important compound lipids found in cell membrane and human tissues. Steroids such as cholesterol are derived lipids. Cholesterol has a number of useful roles in the body. However, a high blood cholesterol level leading to high blood pressure and other cardiovascular disorders.
- Fats are digested and absorbed in the small intestine. The dietary fats perform a variety of functions in the body, besides meeting energy needs and requirements of essential fatty acids. Excess of fats in the diet may lead to disorders such as hypercholesterolemia and obesity.

4.13 GLOSSARY

- **Lipids:** Lipids are fatty acid esters of alcohols and related substances. They include substances like cooking oil, butter, ghee, natural rubber, cholesterol, carotene of carrot, lycopene of tomato, eucalyptus oil, menthol and vitamins A, E and K.
- **Fatty Acids:** Fatty acids are organic acids with a hydrocarbon chain ending in a carboxylic. Some fatty acids also posses hydroxyl group.
- **Refined Oils:** The refined oils are vegetable oils, made free from odour and colour.
- **Hydrogenation:** Hydrogenation unsaturated fatty acids are changed to saturated and the oil becomes a solid fat.
- **Phospholipids:** Phospholipies are triglyceride lipids in which one fatty acid is replaced by a phosphate group.
- **Glycolipids:** Glycolipids contain a variety of sugars, but are devoid of a phosphate group.
- **Cerebrosides:** Cerebrosides are common glycolipids found in human tissues.
- **Steroids:** Steroids are wax like lipids of high molecular weight.

4.14 REVIEW QUESTIONS

I. Very Short Answer Type Questions:

1. What are lipids?
2. What are Fatty acids?
3. What are essential fatty acids?
4. Name the essential fatty acids.
5. Name the disorder caused by the deficiency of essential fatty acids.

II. Short Answer Type Questions:

1. What are the main sources of human dietary fats and lipids?
2. Differentiate between
   (*i*) Saturated fatty acids and unsaturated fatty acids
   (*ii*) Fats and oils.
3. What are essential fatty acids and what are their roles?
4. Write a brief note on:
   (*i*) Refined oils (*ii*) Hydrogenated oils
   (*iii*) Iodine value of oils
5. What are the basis of RDAs for fat?

III. Long Answer Type Questions:

1. Give an account of functions of dietary fats in the body.
2. Explain the various disorders caused by the excess intake of fats.
3. Discuss the functions of essential fatty acids and the effects of their deficiency.

NOTES

4.15 FURTHER READINGS

- *Outlines of Biochemistry:* E.E Conn, P.K. Stumpf; R.H. Doni, Wiley India, Pvt. Ltd: 2007.
- *Biochemistry:* Pawar, Chatwal: Himalayas Pub. House New Delhi: 1958.
- *Biochemistry:* U. Satya Narayan, V. Chakrapani; Books and Allied (P) Ltd: Kolkata; 2008.
- *Essential of Food and Nutrition:* M. Swaminathan; Ganesh Madras, India: 1985.
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CHAPTER 5 PROTEINS

NOTES

OBJECTIVES

After going through this chapter, you should be able to:

- know about chemical composition of proteins
- define structure of proteins
- explain important properties of proteins
- describe the classification of proteins and functions of proteins
- know about chemical score and protein requirements.

STRUCTURE

5.1 INTRODUCTION

Proteins (Gk. *proteios* = something of primary importance) are among the most important macromolecules of organisms. The term 'protein' was coined by **Gerardus Johannes Mulder** (1802–1880) and is derived from the Greek word *proteios* meaning 'of the first rank'. Proteins consitute about 12 per cent of the cell content and are next to water. There are thousands of different types of proteins in the body, each having a unique structure and function. For this reason, *"the word protein implies not one but a large group of complex organic compounds made up of small units called amino acid"*. They play important roles in physiological processes, hence are essential for the life.

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5.2 CHEMICAL COMPOSITION OF PROTEINS

Chemically, a protein is made up of carbon, hydrogen, oxygen, nitrogen and sulphur. Some proteins additionally contain phosphorus, iron and other elements. Proteins are highly organised linear polymers of amino acids. A protein may be a heteropolymer or homopolymer. A homopolymer has only one type of monomer repeating '*n*' number of times. The linear polymers of amino acids are called polypeptides. A protein may contain one or more polypeptides. The protein having a single polypeptide chain is called **monomeric protein.** While the protein having two or more polypeptide chains is termed as **oligomeric protein.** In a polypeptide molecule, many amino acids remain serially linked by peptide bond (—CO—NH—) formed between amino and carboxylic groups of successive amino acids. The order in which amino acids occur is specific for particular protein. The various permutations and combinations of the 20 amino acids allow the synthesis of a large number of proteins. For instance, in a polypeptide of only 100 amino acid residues, there can be 20^{100} possible arrangements or types of polypeptides. This accounts for thousands of specific proteins found in each of the living species. Closely related species have many similar proteins, while unrelated species have fewer common proteins.

5.3 STRUCTURE OF PROTEINS

Proteins are macromoleculars formed from a large number of amino acid. Amino acids condense to form peptides. In condensation process, the carboxylic group of one amino acid joins with the amino group of another amino acid with a loss of water molecule. The bond thus formed (–CO–NH–) is called **amide** or **peptide bond.** Successive amino acids may be linked by peptide bonds to form a linear chain of many amino acids (Fig. 5.1). A chain of two amino acid is called **dipeptide** and that of three in termed as **tripeptide.** These are a few amino acids in **oligopeptide** and many in a **polypeptide.** Like an amino acid a peptide has amino group at one end and carboxylic group at another end.

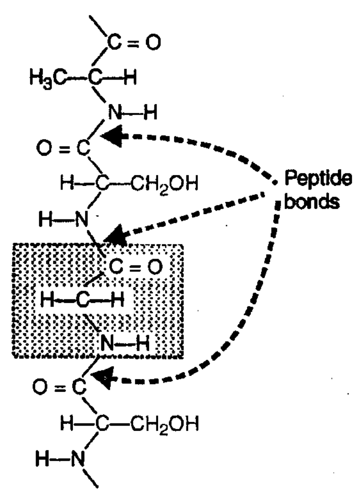

Fig. 5.1. *A part of a polypeptide showing peptide bonds linking amino acids. One amino acid is shown in stippled box.*

The sequence of amino acids in polypeptide chain gives the protein its **primary structure.** The primary structure albeit very important, does not a protein functional. To be functional the protein must have a particular 3-dimensional structure (conformation). A functional protein contains one or more polypeptide chains. The sequence of amino acids in the chain determines where the chain will bend or fold, and where the various lengths will be attacted to each other. Through hydrogen bonds peptide chains assume a **secondary structure.** When a chain is arranged like a coil, it is called an **α-helix.** When two or more chains are joined together by intermolecular hydrogen bonds, the structure is called **pleated sheet** (Fig. 5.2). Helical structure is found in keratin of hair and pleated structure in silk fibres.

In a large protein such as haemoglobin or an enzyme, further fold and coils are needed to attain the functional conformation. This is termed **the tertiary structure** (Fig. 5.3). The coils and folds of the protein molecule are so arranged as to hide non-polar amino acid side chains inside and expose the polar side chains. The 3-dimensional conformation of a protein brings distant amino acid side chains closer. The active sites of proteins such as enzymes are thus formed. The conformation of proteins is easily changed by pH, temperature and chemical substances and hence the function of proteins is labile and subject to regulation.

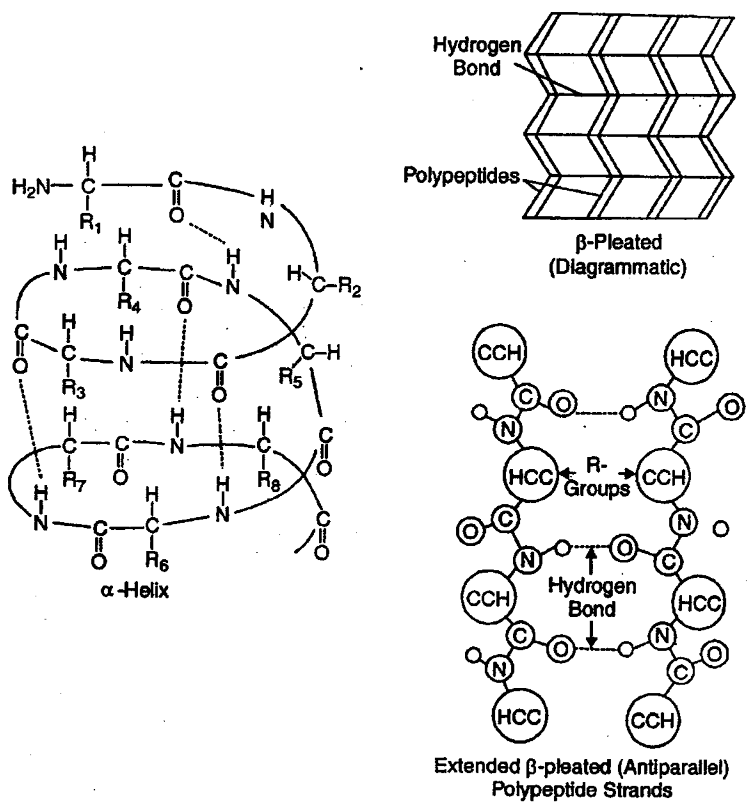

Fig. 5.2. *Secondary structure of proteins.*

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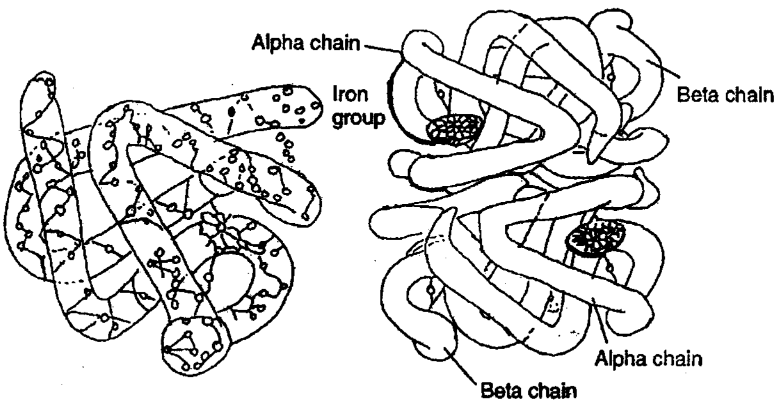

A. Protein myoglobin B. Protein haemoglobin = 4 polypeptides (2 alpha chains, 2 Beta chains)

Fig. 5.3. *Tertiary structure of proteins.*

5.4 PROPERTIES

Proteins have following important properties:

1. **Macromolecules.** Proteins are large sized molecules with minimum molecular weight of 4500 for adrenocorticotropin to the maximum of 46,00,000 for pyruvate dehydrogenase.
2. **Specificity.** Each species has certain specific proteins not found in others. Closely related species share several common proteins. Number of common proteins decreases with the increase in dissimilarity between species. This principle is used in bringing out evolutionary relationships amongst various groups of plants and animals.
3. **Colloids.** Being large sized many protein form colloidal solutions.
4. **Reactivity.** A protein may bind as well as react with a variety of chemicals due to the presence of several reactive groups on the side chains of its amino acids. In a protein, the reactive groups are formed due to specific surface configuration due to intrachain and interchain bonding and folding. This specificity provides functional diversity to proteins for performing different cellular activities. **Enzymes** are specific due to their proteinaceous nature. **Antibodies** are complex glycoproteins which attach to particular pathogens and their toxins for their immobilisation. Certain bacterial **toxins,** which affect specific tissues or organs are also proteins. Similarly, membrane based proteins have reactive sites for certain nutrients.
5. **Permeation.** Proteins cannot pass through cell membranes. They enter or leave the cells by endocytosis or exocytosis.

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Normally, each cell prepares its own proteins by polymerisation of amino acids.

6. **Denaturation and Renaturation.** High temperature, drastic change in pH or salts of heavy metals soap, detergents, alcohol and some disinfectants disrupt the bonds that maintain tertiary structure, leading to the loss of functional activity of proteins. This change is called **denaturation.** In some cases removal of denaturing agent causes re-establishment of the bonds required for the maintenance of tertiary structure. This phenomenon is called **renaturation.**
7. **Amphoteric Nature.** Due to the presence of both basic (amino group) and acidic (carboxyl group) groups, proteins are amphoteric in nature.

> In aqueous medium a protein possesses both cationic and aminoic groups on the same molecule. A chemical, like protein carrying both positive and negative charges is called amphoteric. The ionic state of the protein depends on the pH of the medium. At a specific pH, a protein may be electrically neutral because the number of positive charges is exactly balanced by the number of negative charges. This pH is known as **iso-electric point.** At physiological pH of 7.4, a protein rich in basic amino acids like lysine and arginine have more of negative charges and behave as **basic protein.** Histones associated with DNA is a basic protein. Similarly, a protein with acidic amino acids like aspartic acid and glutamic acid have more of positive charge and behave as a **acidic protein.** Most blood proteins are **acidic proteins.**

5.5 CLASSIFICATION OF PROTEINS

Proteins are classified on the basis of shape and constitution of their molecules.

I. On the Basis of Shape. Depending upon the shape, proteins are classified into two types: fibrous and globular.

1. **Fibrous proteins.** They are thread like structural proteins which may occur singly or in group. Fibrous protein generally possess secondary structure and are insoluble in water. Some of the fibrous protein are contractile. The common example of fibrous proteins are **collagen** of connective tissue, **actin** and **myosin** of muscles, **keratin** of scales, feathers, hair, claws, nails, horns and hoofs, silk of spider web.

   Fibrinogen is also a fibrous but soluble protein of blood plasma. It forms insoluble **fibrin** during clotting of blood.
2. **Globular proteins.** They are spherical non-contractile proteins which may be enzymatic or non-enzymatic. They have tertiary

or quaternary structure. Smaller globular proteins are usually soluble in water and are not coagulated by heat, *e.g.,* histones. Water solubility decreases but heat coagulability increases with the increase in size of globular proteins. Egg albumin, serum globulines and glutelines (wheat, rice) are examples of large globular proteins, which get coagulated by heat.

II. On the Basis of Constitution. On the basis of constitution, proteins are of three types: simple, conjugated and derived.

1. **Simple proteins.** These are formed of amino acids only. They include egg albumin, serum globulins, gluteins of wheat and rice, keratin of hair and nails, histones, protamines and several enzymes.
2. **Conjugated proteins.** These are formed by the binding of a simple protein with a non-protein called the **prosthetic group.** Depending upon the types of prosthetic group, conjugated proteins are of several types (Table 5.1).

Table 5.1. Different Types of Conjugated Proteins

Conjugated Proteins	*Prosthetic Group*	*Occurrence*
(*i*) **Nucleoproteins**		
(Nucleoprotein complexes)		
(*a*) Deoxyribonucleoproteins (DNPs)	DNA	Chromosomes
(*b*) Ribonucleoproteins (RNPs)	RNA	Ribosomes
(*ii*) **Metalloproteins**	Metal ions	Iron in ferritin
(Metal protein complexs)	(Fe, Cu, Mn, Zn)	
(*iii*) **Chromoproteins**	Metal ions	Iron in ferritin
(Pigment protein complex)	(Fe, Cu, Mn, Zn)	
(*a*) Haemoglobin	Fe	Erythrocytes (RBCs)
(*b*) Cytochromes	Fe	Electron carriers, Enzymes
(*c*) Flavoproteins	FMM, FAD	Enzymes
(*d*) Haemocyanin	Cu	Blood of some animals
(*e*) Rhodopsin	Vitamin A	Retina
(*f*) Chloroplastins	Chlorophylls	Thylakoids
(*g*) Biliproteins	Phycobillins	Phycobilisomes
(*iv*) **Phosphoproteins**	Phosphate	Casein of milk,
(Phosphate, protein complexes)		Vitellin of egg yolk
(*v*) **Lipoproteins**	Lipids	Cell membranes
(Lipid protein complexes)		
(*vi*) **Glycoproteins**	Carbohydrates	Plasma membrane
(Carbohydrate protein complexes)		
(*vii*) **Mucoproteins**	Mucoid carbohydrates	Mucin in saliva
(Mucilage protein complexes)		

NOTES

3. **Derived proteins.** These are formed through denaturation, coagulation or partial breakdown of natural proteins. They include metaprotein, proteoses, peptones, short peptides formed in protein digestion and fibrin.

5.6 FUNCTIONS OF PROTEINS

Proteins perform a number of functions in the organisms. The main functions of proteins are as follows:

1. **Structural Proteins.** Many proteins serve as building material of cells and tissues. They take part in the formation of colloidal complex of protoplast, cell membranes, organelles, extracellular matrices and fibres. Some proteins form supporting structures, *e.g,* elastin of ligaments, collagen of tendons, cartilages, bone and connective tissue.
2. **Protective Structures.** Fibrous protein keratin is the major constituent of external protective structures of animals like hair, feathers, horny layer of skin, nails, claws, hoofs etc. Cobweb of spider and protective covering in the cocoon stage of silk moth is made of white insoluble protein fibroin.
3. **Compatability Proteins.** The walls of pollen grain contain proteins for compatability, incompatability reaction with the stigma during pollination.
4. **Enzymes.** Many proteins function as enzymes to catalyse biochemical reactions that occur in the living world. Enzymes play a key role in the metabolism.
5. **Carrier Proteins (Transport Proteins).** Some proteins acts as carriers which bind and transport specific molecules across a membrane or in a body fluid. Haemoglobin of RBCs transports oxygen in the body. Myoglobin of muscles store oxygen. α-globulin of blood carries thyroxine and bilirubin, β-globulin transport vitamins A, D and K, cholesterol and ions in the blood. Serum albumin carries fatty acids and lipids in the blood. In plants P-proteins helps in the transport of organic compounds through phloem.
6. **Receptor Proteins.** A number of proteins present on the external surface of cell membrane acts as receptor molecules. These bind with specific informational molecules like hormones reaching the cell and mediate in their cellular effects.
7. **Hormones.** Some hormones are proteinaceous, *e.g.,* insulin (sugar metabolism regulating hormone) parathyroid (calcium and phosphate transport regulating hormones). Hormones play a key role in the regulation of metabolism.

8. **Contractile Proteins.** Myosin and actin make the muscle fibres contractile to bring about movements and locomotion. The contractile system is basically made up of protein actin but association with myosin is essential for contraction.
9. **Defence.** Some proteins act as antibodies (immunoglobulins) that participate in the defence mechanism of the body.
10. **Microtubules.** They are formed of protofilaments built up of two proteins, α and β tubulin. Microtubules are unbranched, hollow submicroscopic tubules which form the structural material of cilia, flagella, basal bodies, centrioles and spindle apparatus.
11. **P-Protein.** It is a special vibratile protein present in sieve tube elements. Which is supposed to actively participate in the transport of nutrients.
12. **Storage Proteins.** These occur in milk, eggs and seeds to nourish the young ones. They include casein of milk, albumin of egg white and glutelin in cereals. Iron storing protein commonly found in animal tissue is **ferritin.** The proteins having all the essential amino acids are called **first class proteins.**
13. **Proteins Buffers.** Proteins also help in maintaining a balance of acidity and alkalanity by combining with excess acids and bases. They, thus, acts as 'biological buffers'.
14. **Visual Pigments.** Rhodopsin and iodopsin are protein pigments. They are present in rods and cones of retina respectively. They take part in perception of image.
15. **Toxins.** Many toxins of microbes, plants and animals are proteins. Bacterial toxins, ricin of castor oil seeds and snake venom are proteins.
16. **Blood Clotting Proteins.** The proteins fibrinogen and thrombin help in blood clotting to check bleeding from injuries.
17. **Mucoproteins.** The mucoproteins are present in mucus produced by salivary glands and mucus glands of a alimentary canal. The mucus protects the lining of alimentary canal from friction and digestive juices.
18. **Sweetest Substance.** Monellin, a protein derived from an African berry is 2000 times sweeter than sucrose. It is non-toxic and non-caloric, hence may prove suitable for diabetic patients.
19. **Repressor.** Most of the repressors that regulate geneaction are protein in nature.
20. **Other Proteins.** Enkephalins are small peptides, which bind to specific receptor sites in the brain and influence the perception of pain and pressure. Human memory is believed to be stored in specific proteins called **memory proteins.**

5.7 SOURCES

NOTES

Humans get protein from both plant and animal foods. However, plants are the primary source of proteins, because they can synthesize proteins from inorganic molecules. Animals depend on plants to fulfill their protein requirements. The main sources of proteins in human diet include cereals, pulses, nuts, oil seeds, milk, eggs, fish, chicken and meat.

In the Indian dietary, cereals and their products are consumed in large quantities and are included in almost all the meals. Therefore, cereals constitute major source of protein in the Indian diets. Cereals and pulses, when cooked in water, supply only one third or less of the protein present in the raw foods, as these foods, absorb water at least two times of their weight. However, foods from animal sources such as milk, eggs, fish and meat do not gain water on cooking. Therefore, there is very little decrease in the amount of protein supplied by the foods of animal sources. A meal comprising of cereals and pulses supplies almost all the essential amino acids. Most vegetable and fruits supply proteins only in small amount. However, the proteins of vegetable and fruit sources enhance the quality of proteins in the diet.

The dietary composition varies in different regions of our country. In major part of the country diets include cereals, pulses, milk and milk products. In coastal regions of the country fish and meat constitute major source of protein.

Protein Sources in Indian Diets

A section of Indian population (10 to 15 per cent of the population) is vegetarian due to their religions belief. About 80 per cent people restricts their consumption of animal foods to one or two days a week. Thus, these people are vegetarian for 5 or 6 days a week. In Indian diets milk and milk products are accepted universally in the vegetarian diets. The people taking vegetarian diet and milk are called lacto-vegetarians.

The protein sources in the Indian vegetarian diet are cereals, pulses and legumes, milk and milk products, vegetable and fruits. Over six varieties of cereals and millets and sixteen types of pulses and legumes are used in Indian diet. Being a tropical country there are over 150 varieties of leafy and 250 varieties of other vegetables provide enough options to have a nutritionally rich combinations. In normal Indian diets, cereals are the staple food, and pulses, milk and vegetables are served with cereal preparations. This makes the quality of protein combination excellent in the Indian diets.

The principal sources of protein in the Indian dietary are given in Table 5.2.

NOTES

Table 5.2. Protein Contents (range) of Different Groups of Foods.

S.No.	Food groups	Protein content (g / 100 g)
1.	Cereals and millets	6–14
2.	Pulses (legumes), dry	18–24
3.	Oil seeds and nut (except coconut)	18–40
4.	Meat, fish and liver	18–20
5.	Eggs	12–14
6.	Milk (fresh)	3.5–4.0
7.	Milk (dried whole)	26–28
8.	Milk (dried skimmed)	33–38
9.	Vegetables fresh	
	(*i*) Leafy	1–4
	(*ii*) Roots and tubers	1–1.5
	(*iii*) Other vegetabls	1–7

Protein Quality (Nutritive Value of Proteins)

The quality of protein depends on the kinds and amounts of the essential amino acids present in the food protein. Essential amino acids are those amino acids which are not synthesised in human body from their precursors, and hence must be supplied by the dietary proteins. These include leucine, isoleucine, valine, tryptophan, phenyl alanine, lysine, methionine and threonine. Children also need two more amino acids–arginine and histidine in their diets as these may not be synthesised in sufficient amounts to meet the rapid growth of infants. These are called **semiessential amino acids.** The rest of the 20 protein forming amino acids are called **non-essential amino** acids. The word non-essential is misleading, as these amino acids are necessary in the body for tissue building, repair and other metabolic functions. These are so important that the body synthesises these amino acids itself. The only reason these are termed non-essential, as these need not to be provided by the diet. The nutritional classification of amino acids is given in Table 5.3.

Table 5.3. Nutritional Classification of Amino Acids

S.No.	Essential (Indispensable)	Semi-essential	Non-essential (Dispensable)
1.	Leucine	1. Arginine	1. Glycine
2.	Isoleucine	2. Histidine	2. Alanine
3.	Valine		3. Aspartic acid
4.	Tryptophan		4. Glutamic acid
5.	Phenylalanine		5. Cysteine
6.	Lysine		6. Cystine
7.	Methionine		7. Serine
8.	Threonine		8. Tyrosine
			9. Proline
			10. Hydroxyproline

Some food proteins lack one or more essential amino acids. For example, cereals are low in lysine, while majority of pulses are poor in methionine. But, when cereals and pulses are consumed together in a meal, complement each other and improve the quality of protein supplied to the body. On the other hand almost all animal proteins such as milk, eggs, chicken, fish and meat provide all essential amino acids.

The quality of protein depends on their essential amino acid composition. On the basis of essential amino acid composition proteins are broadly classified into three groups.

1. **Complete Proteins.** These proteins contain all essential amino acids *e.g.*, milk, egg, meat etc. These protein promote good growth.
2. **Partially Complete Proteins.** These proteins partially lacking in one or more essential amino acids. *e.g.*, plant proteins. These proteins promote moderate growth.
3. **Incomplete Proteins:** These proteins lack one or more essential amino acids. *e.g.*, gelatin (zein). Such proteins do not promote growth.

5.8 EVALUATION OF PROTEIN QUALITY

These are several methods to determine the quality of proteins in the diet. These include the evaluation of Digestibility Coefficient (DC), biological Value (BV), Net Protein Utilization (NPU), Net Available Protein (NAP) and Protein Efficiency Ratio (PER). These value for proteins can be calculated as under .

1. Nitrogen Balance Method. In this method, the Digestibility Coefficient (DC) and Biological Value (BV) of the protein can be determined using rats or human subjects. The protein digested is expressed in terms of digestibility coefficient.

$$DC = \frac{\text{Protein intake } (g) - \text{Protein lost in digestion } (g)}{\text{Protein intake } (g)} \times 100$$

The biological value (BV) is the percentage of the absorbed nitrogen (N) retained by the body. The nitrogen content of the food eaten by an animal and the nitrogen content of the urine and faeces are determined. The biological value (BV) is calculated by using following formula.

$$BV = \frac{\text{N retained by the body [dietary N} - \text{(urinary N + faecal N)} \times 100}{\text{N absorbed (dietary N} - \text{faecal N)}}$$

The quality of protein is directly related to its BV. The BV increases with increase in the percentage of nitrogen absorbed being retained. The BV of whole wheat in 65, brown rice 73 and that of milk is 84. However, due to complementary effect of food mixtures, the BV of

STUDENT ACTIVITY

1. What factors decide the quality of proteins in a diet?

2. What are good proteins in the diet?

NOTES

mixed diets is higher than the arithmetical average of the component of food proteins.

2. Net Protein Utilisation (NPU). The net protein utilization takes into account the losses in digestion and metabolism. It is calculated by the following formula.

$$NPU = \frac{\text{Digestibility Coefficient} \times \text{Biological value}}{100}$$

3. Net Available Protein. This is calculated using the following formula

$$\text{Net Available Protein} = \frac{\text{Protein \%} \times \text{NPU}}{100}$$

4. Protein Efficiency Ratio (PER). Protein efficiency ratio is not based on intake and output of protein residues. But, it is based on the ability of proteins to promote the growth of albino rats. Therefore, it is less accurate than BV and NPU. But this method is easy to use. In this method, a known amount of test protein in an adequate diet is fed to young rats for four weeks under standardised conditions and the weight gain is determined. The PER is obtained by dividing the weight gain by grams of protein fed.

$$PER = \frac{\text{Gain in body weight } (g)}{\text{Protein intake } (g)}$$

5.9 CHEMICAL SCORE

Chemical score refers to the comparison of amino acid composition of the food protein with the amino acid of a reference protein (such as milk, egg, etc.) or FAO reference protein. The amino acid score is the concentration of the limiting amino acids per gram in the food/food mixture as a percentage of the same amino acids per gram of the reference protein. It is calculated as under

$$\text{Amino acid score} = \frac{mg \text{ of limiting amino acid}/g \text{ of test protein} \times 100}{mg \text{ of the same amino acid}/g \text{ of reference protein}}$$

The different parameters of protein quality and net available proteins of some foods are given in Table 5.4.

Table 5.4. Protein Content, DC, BV, NPU, PER and Net Available Protein Content of Some Foods

Name of Food	*Protein Content*	*DC (%)*	*BV (%)*	*NPU (%)*	*Net Available Protein (%)*	*PER*
Animal foods						
Egg, hen's	13.3	98	98	96	12.8	4.5
Milk, cow's	3.5	95	85	81	2.8	3.0

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Milk, buffalo's	4.3	94	85	81	3.5	3.0
Meat	19.8	96	82	79	15.6	2.9
Fish	21.5	96	80	77	16.6	2.9
Cereals						
Bajra or pearl millet	11.6	80	61	49	5.7	1.8
Jowar or sorghum	10.4	81	58	47	4.9	1.6
Maizc	11.1	85	50	43	4.8	1.4
Ragi	7.1	80	60	48	3.4	1.4
Rice, milled	7.0	93	70	65	4.6	2.2
Wheat, whole	11.8	85	60	51	6.0	1.7
Pulses						
Bengal gram dhal	22.5	84	62	52	11.7	1.7
Black gram dhal	24.0	82	54	45	10.8	1.6
Green gram dhal	24.0	85	58	49	11.8	1.6
Red gram dhal	22.3	83	56	46	10.3	1.6
Nuts and Oilseeds						
Groundunt	26.7	92	54	50	13.4	1.7
Cocount fresh	4.5	82	67	56	2.5	2.3
Soybean	40.0	86	64	55	22.0	2.0
Sesame	18.3	80	60	48	8.8	1.7

5.10 PROTEIN REQUIREMENTS

Proteins are essential for growth, maintenance and proper functioning of the body. The utilization of dietary proteins in the body is affected by a number of factors such as (*i*) calorie intake, (*ii*) digestibility coefficient of proteins and (*iii*) biological or nutritive value of the proteins. For maximum utilization of dietary proteins, the calorie intake should be adequate. In case of inadequate calorie intake, a part of the dietary protein is used up in meeting the energy requirements and the protein need will not be satisfied. A part of dietary proteins is lost in digestion and metabolism.

It is always better to derive proteins in the diet from different sources such as cereals, pulses, nuts, oil seeds, milk and flesh foods. Such diets provide all essential amino acids to the body. In general, milk and animal proteins have a higher nutritive value than vegetable proteins. Therefore, the diets of growing children and nursing mothers should, in particular, contain higher amounts of protein derived from milk or egg and flesh foods.

The protein requirement depends on age and physiological state of a person. As determined by nitrogen balance studies, the protein requirement is found to be between 0.5 to 0.6 g/kg of body weight, if the source of protein supplies the amino acids in the proportion needed by the body. Since, the amino acids of the food combination may not be so well proportioned, the recommended daily allowance for protein is set to 1.0 g/kg of body weight for adults. During infancy, pregnancy and lactation, there is an increased need of protein for growth. Persons suffering from burns or wasting diseases such as tuberculosis and rheumatic fever, also need additional quantity of protein for regeneration of wasted tissues. Similarly, if there is loss of blood due to excessive menstruation, haemorrhages, blood donation etc. More protein is needed in the diet. The recommended dietary intake of proteins are presented in Table 5.5.

Table 5.5. Recommended Dietary Intakes of Proteins.

(Recommended Dietary Intake for Indians, ICMR, 1990)

Particulars of the Individual	*Protein g/day*
Man (60 kg)	60
Woman (50 kg)	50
Woman, pregnant (latter half of pregnancy)	65
Woman, nursing mother (0–6 months of lactation)	75
Infants, 0–6 months	2.05 g/kg/day
Infants, 7–12 months	1.65 g/kg/day
Children, 1–3 years	22
Children, 4–6 years	30
Children, 7–9 years	41
Boys 10–12 years	54
Girls 10–12 years	57
Girls 13–15 years	70
Boys, 13–15 years	65
Boys, 16–18 years	78
Girls, 16–18 years	63

5.11 DISORDERS RELATED TO PROTEIN DEFICIENCY

Deficiency of protein in the diet cause a number of disorders. Protein deficiency during pregnancy may result in stress, vomiting, swelling of feet etc. Though, these symptoms are commonly accepted as a normal part of pregnancy, but it has adverse effect on the growth and development of foetus. In children, deficiency of protein in the diet results in stunted growth, retarded mental development and low weight.

Protein-Energy Malnutrition (PEM)

NOTES

Generally growing children suffer from **Protein Energy Malnutrition (PEM)** because they need more proteins for their growth and development. Protein energy malnutrition lead to two types of diseases *viz.* Kwashiorkor and Marasmus.

1. **Kwashiorkor.** Kwashiorkor is caused due to severe protein deficiency. It occurs in children in the age group of 1–3 years particularly belonging to poor families. The main cause of kwashiorkor include (*i*) early termination of breast feeding by the mother (*ii*) diet contains mainly fats and carbohydrates (*iii*) late introduction of supplementary protein food, and (*iv*) unplanned spacing of the children.

   Symptoms (*i*) Children stop growing (*ii*) Their bellies become swollen and hair colour fades (*iii*) Children may suffer with diarrhoea (*iv*) Children may mental retardation, anaemia, fatty liver oedema (swelling of body parts) and slendered legs (Fig. 5.4)

(A) (B)

Fig. 5.4. (A) *Child suffering from Kwashiorkor showing oedema of legs, hand and crazy pavement dermitosis.*

(B) *Same child after treatment with processed protein food.*

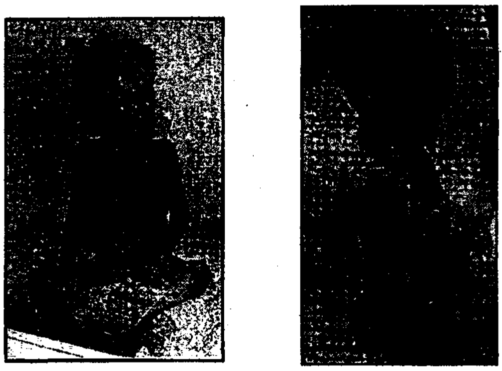
2. **Marasmus.** Marasmus is a type of PEM, which is caused due to prolonged protein deficiency and total deficiency of food calories. It occurs due to early replacement of mother's milk

NOTES

to the diet deficient in protein and calories and unplanned spacing between the children.

Symptoms. (*i*) Children suffering form this disease show mental retardation of irreversible nature (*ii*) The body becomes lean and weak (*iii*) The skin becomes thin, dry and wrinkled. (*iv*) Ribs becomes very prominent. (*v*) The child is not able to digest and absorb the food and suffers from diarrhoea. (*vi*) There is atropy of digestive glands and intestinal mucosa (Fig. 5.5)

However, children suffering from marasmus do not suffer from oedema.



(A) (B)

Fig. 5.5. (A) *child suffering from marasmus*
(B) *Same child after treatment with protein enriched cereal food.*

Treatment of PEM

The treatment of PEM involves (*i*) supply of an acceptable and readily digestible diet rich in proteins, calories and other dietary essentials in required amounts (initially liquid diet for a week), and (*ii*) treatment of any infection, if present. The diet usually consists of skimmed milk powder, sugar, cooked cereals and banana. Fat is introduced in the diet from the 2nd week of treatment. The daily calorie intake should be 140–150 k cal/kg of body weight and protein intake 3–5 g/kg body weight. Vitamin A deficiency is corrected by the administration of the required amounts of synthetic vitamin A.

5.12 SUMMARY

- Proteins are among the most important macromolecules of the organisms. They are highly organized linear polymers of amino acids. The sequence of amino acids in a polypeptide chain gives the protein its primary structure. The coiling of polypeptide chains provide a protein its secondary structure. Further folds and coils of the chain attain its functional conformation, and is termed as tertiary structure. Proteins are large molecules and undergo denaturation at high temperature, change in pH, presence of salts and some other chemicals.

- Proteins are classified on the basis of shape and constitution of their moleculas. Proteins perform a number of functions including, building of tissues, repair, regulation of metabolism and defence. The main sources of proteins in human diet include cereals, pulses, nuts, oil seeds, milk, egg, fish, chicken and meat. The quality of protein depends on the kinds and amounts of amino acids present in the food protein. The good food proteins contain all the essential amino acids. The protein quality is evaluated using different parameters. In general, milk and animal proteins have a higher nutritive value than vegetable proteins. The dietary proteins derived from different food sources, provide all the essential amino acids. The protein requirements depend on age and physiological state of a person. Deficiency of proteins in diet may cause serious disorders, such as protein energy malnutrition.

5.13 GLOSSARY

- **Proteins:** Proteins are highly organised linear polymers of amino acids. A protein may be a heteropolymer or homopolymer.
- **Antibodies:** Antibodies are complex glycoproteins which attach to particular pathogens and their toxins for their immobilisation.
- **Fibrinogen:** It is also a fibrous but soluble protein of blood plasma. It forms insoluble fibrin during clotting of blood.
- **Mucoproteins:** The mucoproteins are present in mucus produced by salivary glands and mucus glands of a alimentary canal.
- **Toxins:** Toxins of microbes, plants and animals are proteins.
- **Microtubules:** Microtubules are unbranched, hollow, submicroscopic tubules which form the structural material of cilia, flagella, basal bodies, centrioles and spindle apparatus.

5.14 REVIEW QUESTIONS

I. Very Short Answer Type Questions:

1. Who coined the term protein for the first time?
2. What are monomeric proteins?
3. What are oligomeric proteins?

4. What is a peptide bond?
5. Why are proteins called amphoteric in nature?
6. What are essential amino acids?
7. Name the semi-essential amino acids.
8. What is meant by PEM?

II. Short Answer Type Questions:

1. Give chemical composition of proteins.
2. What is meant by primary, secondary and tertiary structures of proteins?
3. Give an account of the properties of proteins.
4. Mention the protein sources in the Indian diet.
5. Why do animal proteins have higher nutritive value than the vegetable proteins?
6. What is PEM? What are the causes of PEM?
7. Explain the following:
   (*i*) Biological value of the protein.
   (*ii*) Protein efficiency ratio.
   (*iii*) Net protein utilization.
8. Write notes on.
   (*i*) Kwashiorkor
   (*ii*) Marasmus.
9. Give an account of the sources of proteins in the diet.

III. Long Answer Type Questions:

1. Give an account of the protein requirements of the body.
2. Describe the functions of proteins in the body.
3. Give a brief account of classification of proteins.

5.15 FURTHER READINGS

- *Outlines of Biochemistry:* E.E. Conn, P.K. Stumpf, R.H. Doni, Wiley India, Pvt. Ltd; 2007.
- *Biochemistry:* Pawar, Chatwal: Himalayas Pub. House, New Delhi; 1988.
- *Biochemistry:* U. Satyanarayan, V. Chakrapani; Books and Allied (P) Ltd: Kolkata; 2008.
- *Essentials of Food and Nutrition:* M. Swaminathan; Ganesh; Madras, India; 1985.

UNIT–III

CHAPTER 6 VITAMINS

NOTES

OBJECTIVES

After going through this chapter, you should be able to:

- define vitamins
- describe the classification of vitamins
- know about disorders of vitamin A
- describe important sources of vitamin A
- define vitamin D
- explain sources of vitamin D
- know about effects of deficiency of vitamin
- know about dietary sources of vitamin E and K.

STRUCTURE

6.1 INTRODUCTION

In 1911, **Dr. Casimir Funk** found that the food contain apart from ordinary nutrients, certain substances that are essential for normal functioning of the human body. He named these substances **Vitamins** (L. *vita* = life + *amine*-), as it was first though that they were all amino acids. Though this view is now known to be incorrect, the name "vitamins" is still used. It is better to call them "accessory food substances."

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6.2 DEFINITION

Vitamins are organic compounds regularly required in small amounts in the diet of living being in order to ensure healthy growth and reproduction. Vitamins are essential nutrients because the living being cannot synthesize such compounds.

Generally vitamins are synthesized by plants and are found in animals as a result of food intake or the activity of the microorganisms in the gut. A sufficiently varied and balanced diet will provide all vitamins in proper amounts. Vitamin D may be produced in the skin by irradiation (ultra violet) of sterols. Some vitamins may be stored in the body, chiefly liver. Others must be supplied constantly because they are extracted in the urine, if present in excess amount in the diet. The absence of a vitamin in the diet, or its poor absorption from the digestive tract, usually produces a disease with characteristic symptoms.

6.3 CLASSIFICATION OF VITAMINS

Vitamins are classified according to their solubility into two groups: Fat soluble vitamins and water soluble vitamins.

I. Fat Soluble Vitamins

1. Vitamin A,
2. Vitamin D,
3. Vitamin E, and
4. Vitamin K.

II. Water Soluble Vitamins

1. Vitamins-B complex
   - (*i*) Thiamine (vitamin B_1)
   - (*ii*) Riboflavin (vitamin B_2)
   - (*iii*) Nicotinamide (vitamin B_3)
   - (*iv*) Pantothenic acid (vitamin B_5)
   - (*v*) Pyridoxine (vitamin B_6)
   - (*vi*) Cyanocobalmin (vitamin B_{12})
   - (*vii*) Folic acid (vitamin M)
   - (*viii*) Biotin (vitamin H)
   - (*ix*) Choline
   - (*x*) P-Amino Benzoic acid, and
   - (*xi*) Inositol
2. Vitamin-C (Ascorbic Acid)
3. Vitamin-P (Bioflavonoids)

Fat Soluble Vitamins

Fat soluble vitamins can only be absorbed in the body in presence of fat. Therefore, some fat must be present in the diet for their absorption. Fat soluble vitamins can be stored in the body, hence their occasional intake of very high sources may help the body, to tide over periods of low intake. The requirement for fat soluble vitamins may be met by intake of a percursor or the vitamins itself. Not much of fat soluble vitamins are lost in normal cooking procedures.

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6.4 VITAMIN A

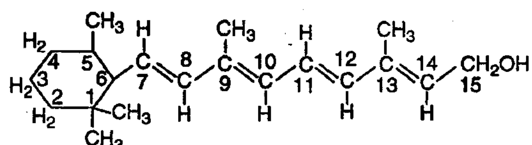
Vitamin A group includes **retinol, retinal** and **retinoic acid.** Their parent substance is β carotene which is called **provitamin.** Vitamin A is also known as anti-xerophthalmic vitamin and anti-infection vitamin.

Vitamin A was the first fat soluble vitamin to be discovered. In 1917 **Mc Collum** and **Davis** found that a fat soluble factor present in butter was essential for the growth of rats on synthetic diet. They called the factor as **fat soluble A.** Later, it was discovered that vitamin A occurs only in foods of animal origin. Vitamin A activity is also possessed by carotenoids found in plants. Hence, carotenoids are called provitamin A.

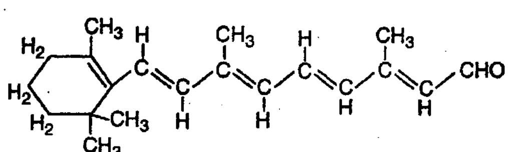
Structure of Vitamin A

Vitamin A, (Retinol) contains a β-ionone ring. The side chain contains one alcoholic group and 4 double bonds. Because of the presence of alcoholic group, it forms esters with acids. The presence of double bonds in the side chain, vitamin A is easily destroyed by oxidation. Vitamin A is stable to heat (100°C) for a short duration in absence of oxygen. It is slowly destroyed, when exposed to light.

Vitamin A_1 or **retinol** and its aldehyde derivative, **retinal,** have the following structures.

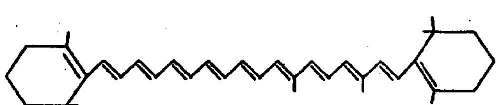


Retinol (Vitamin A_1)



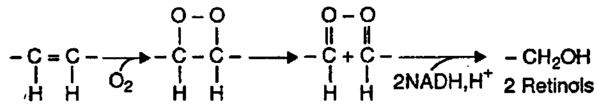
Retinal (Vitamin A_1 -aldehyde)

These compounds are formed from their parent substance β carotene, which is called provitamin.



β-carotene

An *enzyme oxygenase* located in the **intestinal** mucosa cleaves β. **carotene,** **yielding two molecules** of vitamin **A aldehyde or retinal.** The latter is then **reduced** to retinal by alcoholic **dehydrogenase.**



β-carotene 2 Retinals

Vitamin A_1 aldehyde (Retinal) occurs in the rods and cones in the retina of the eyes.

Vitamin A_2 occurs in the livers of fresh water fish. It differs from vitamin A_1 in having one more double bond in the β-ionone ring.

Physiological Functions of Vitamin A

1. Vitamin A is essential for vision in dim light. It is essential for visual pigment **rhodopsin** (visual purple) of rod sells and **iodopsin** (visual violet) of cone cells of the retina of eye. In light rhodopsin splits into **retinal** (=retinene) an aldehyde derivative of vitamin A and a protein **scotopsin** (opsin). This process of splitting is called **bleaching.** In the dark, rhodopsin is resynthesized from retinal and scotopsin, making rods functional. Iodopsin present in the cones is sensitive to bright light and colours, hence works in day light and artificial light.
2. Vitamin A is also required for the normal growth and development of lacrymal glands (tear glands).
3. It is also essential for the maintenance of epithelial cells of skin and mucous membrane. Healthy epithelial cells do not allow infection, that is why vitamin A is also called anti-infection vitamin.
4. It is essential for the formation of bones and teeth. Excess of vitamin A make the bones brittle which can fracture easily.
5. It is necesssay for reproductive health and reproduction.
6. Vitamin A has anti-cancer property.
7. Retinol in the lowest oxidation state probably serves as hormone.

Disorders of Vitamin A Deficiency

Deficiency of Vitamin A causes following disorders.

1. **Night Blindness (Nyctalopia).** It is characterised by the lack of vision in dim light. *i.e.*, the subjects cannot see objects in dim light. The subject find it difficult to read in dim light.
2. **Xerosis Conjunctival.** It is characterised by the keratinisation of the epithelial cells of conjunctiva. As a result, the conjunctiva

becomes dry, thickened, wrinkled and pigmented. The pigmentation gives the conjunctiva a smoky appearance.

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3. **Xerosis Cornea.** It is the condition when dryness spreads to cornea, which gives a dull, hazy and lustreless appearance to the cornea.
4. **Keratomalacia.** This condition is caused, when xerosis of conjunctiva and cornea is left untreated. As a result, the corneal epithelium becomes opaque and ulcerated. It may lead to bacterial infection resulting in blindness (Figs. 6.1 and 6.2).
5. **Bitot's Spots.** This condition was described by **Bitot in 1863** in children having other signs of vitamin A deficiency. These are greyish or glistening white plaques formed of desquamated thickened conjunctival epithelium, which are usually triangular in shape and firmly adhering to the conjunctiva (Fig. 6.3).
6. **Follicular Hyperkeratosis (Phrynoderma).** It is characterised by hyperkeratinisation of epithelium lining of the hair follicle. The skin becomes rough and dry with papules of varying sizes (Fig. 6.4). Earlier, it was believed that this condition can be treated with vitamin A. Recent studies, however, indicate that the disorder can effectively be treated through administration of essential fatty acids and pyridoxin.

Treatment of vitamin A deficiency

The mild to moderate cases of vitamin A deficiency can be treated by the daily oral dose of 10,000 μg of fat soluble vitamin A for a period of 10 days. In severe cases, larger doses of 50,000 μg of fat soluble vitamin A have to be administered daily for a few weeks. The studies carried out at the National Institute of Nutrition, Hyderabad, have shown that a single massive dose of 100,000 μg of fat soluble vitamin A helps to prevent A deficiency in children for about 6 months.

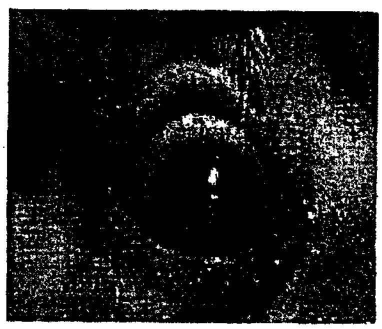

Fig. 6.1. *Keratomalacia. (with necrosis of cornea).*

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Fig. 6.2. *Both eyes blind due to vitamin A deficiency.*

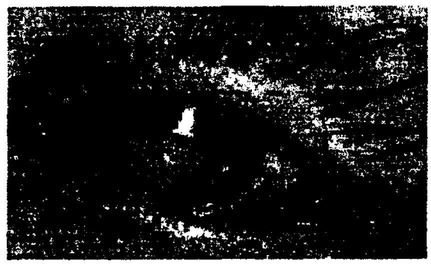

Fig. 6.3. *Bitot's Spot.*

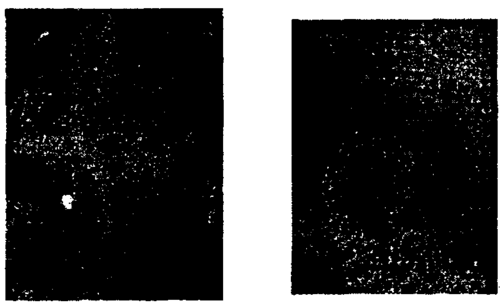

Fig. 6.4. *Phrynoderma : The extensor aspects of the extremities are involved. The horny summits of the keratinized follicles may be seen clearly in the magnified picture on the left.*

Hypervitaminosis A

It vitamin A is taken in excess, it causes loss of appetite, sparcity of hair, itching rash, painful swellings over long bones, headache, nausea (discomfort preceding vomiting), vomiting and drowsiness. The disorder disappears, when intake of vitamin A is stopped.

Dietary sources of vitamin A

Vitamin A is present in cod liver oil, shark liver oil, milk, butter and clarified butter (ghee). It is also synthesised in the body from plant pigments called carotenes. Carotenes occur in yellow vegetables and crops like maize, carrot and papaya, and in green leafy vegetables like spinach. Among various dietary sources of vitamin A, fish liver oils are the richest source, butter and egg are good sources, while milk is a fair source of vitamin A. The important dietary sources of vitamin A are given in Table 6.1.

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Table 6.1. Important Sources of Vitamin A

S. No.	*Source*	*Vitamin A content (μg / 100g)*
1.	*Rich sources:*	
	(*i*) Fish liver oils	6,660–1000,000
	(*ii*) Cod liver oil	10,000–100,000
	(*iii*) Cod liver oil (B.P)	18,000
	(*iv*) Shark liver oil	9,000–16,000
	(*v*) Shark liver oil (I.P)	6,660
	(*vi*) Liver (sheep, goat, ox or pig)	6,000–10,000
2.	*Good sources:*	
	(*i*) Butter	720–1200
	(*ii*) Ghee (clarified butter fat)	600–700
	(*iii*) Egg (hen), whole	300–400
	(*iv*) Egg, yolk	600–800
	(*v*) Milk powder, full cream	400–450
3.	*Fair sources:*	
	(*i*) Milk cow's or buffalo (whole)	50–60
	(*ii*) Fatty fish	30–40

The carotenes present in the vegetables are absorbed to the extent of 25–50 per cent depending on the quantity of fat in the diet and the extent to which the vegetables have been haemogenized. The conversion of carotenes to vitamin A occurs in the intestinal mucosa by the enzyme ***oxygenase***. According to the Nutrition Expert Group ICMR, 4 μg of β carotene is equivalent to 1 μg vitamin A. The important sources of carotenes are given in Table 6.2. Red palm oil and green leafy vegetables are rich sources of carotene.

Table 6.2. Important Sources of Carotene

Source	*Carotene Content (μg / 100g)*	*Vitamin A Equivalent* (μg)*
Red palm oil	25,000–33,000	6,250–8,250
Green leafy vegetables	1,300–8,000	325–2,000
Carrot	1,300–2,600	325–650
Pumpkin, yellow	600–720	150–180
Mango, ripe	1,500–3,000	375–750

*4 mg Carotene = 1 μg of vitamin A.

NOTES

Recommended Daily Allowances of Vitamin A

The daily requirement of vitamin A for an adult is 600 mcg of retinal or 2400 mcg of beta-carotene per day derived from foods of either animal or vegetable origin. The allowance for infants is 350 mcg of retinol or 1400 mcg of β carotene. The need increases gradually as the child grows to adolescence. During pregnancy, no increased allowance is recommended, but the allowance is increased to 950 mcg of retinal or 3800 mcg of beta carotene during lactation. The recommended dietary allowances of vitamin A for different age, sex grouping are given in Table 6.3.

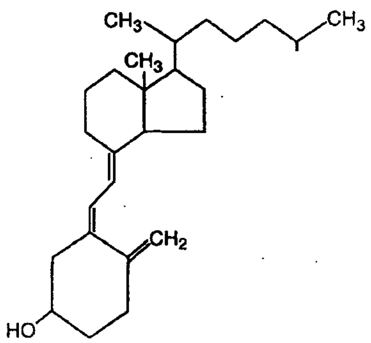
Table 6.3. Recommended Dietary Allowances of Vitamin A (Recommended Dietary Allowances for Indians ICMR 2000)

Age - Sex Groups	*Retinol (mcg-day)*	*B. carotene mcg/day*
Infants (6–12 months)	350	1400
1–6 years	400	1600
7–12 years	600	2400
13–18 years	600	2400
Adult Man and Woman	600	2400
Pregnant Woman	600	2400
Lactating woman	950	3800

6.5 VITAMIN D

Vitamin D represents a group of fat soluble vitamins, which are structurally related to sterols. It is also known as **anti-richitic vitamin** or **sunshine vitamin.** Vitamin D exists in two forms: **Vitamin D_2 (Ergocalciferol)** a synthetic derivative of plant sterol and **vitamin D_3 (cholecalciferol)** a derivative of cholesterol.

Mellanby in 1918 produced rickets experimentally in dogs and cured it by administrating cod liver oil to such animals **Mc Collum** (1922) showed that of vitamin D causes rickets. **Angus** (1931) isolated crystalline vitamin D_2 and **Windaus** (1936) isolated vitamin D_3.



Vitamin D_3 (Cholecalciferol)

Occurrence

Several compounds are known to be effective in preventing rickets; all are derived by irradiation of different forms of provitamin D. Thus, vitamin D_2 (calciferol) is produced commercially by the irradiation of the plant steroid, ergosterol. In animal tissues, 7 dehydocholesterol, which occurs naturally in the epidermal layers, can be converted by ultra violet irradiation to vitamin D_3. Vitamin D_3 can be synthesised in the body in adequate amounts by simple exposure to sunlight even for five minute per day. Vitamin D_3 in also present in fish oil.

Physiological Functions of Vitamin D

Vitamin D performs a number of important functions in the body. These include.

1. *Absorption of Calcium and Phosphorus:* Vitamin D promotes the absorption of calcium and phosphorus in the small intestine. It increases the permeability of the intestinal mucosal cells to calcium ion, apparently by changing the character of the plasma membrane to calcium permeation. Vitamin D behaves more like a hormone than as the cofactor of an enzyme. That is, its effect is in controlling the production of a specific calcium—binding protein rather than influencing directly the activity of a specific enzyme.
2. *Bone Calcification:* Vitamin D regulates the deposition and resorption of calcium and phosphorus in the bone tissues.
3. Vitamin D maintains the normal functioning of parathormone (hormone secreted by parathyroid gland).
4. Vitamin D has a specific function in.tubular reabsorption of calcium and phosphate in Kidney.
5. It affects the metabolism of citric acid, which is a normal constituent of many body tissues including bones.
6. It exerts an anti-rachitic effect. Because it regulates metabolism of calcium and phosphorous, it effects normal growth of the body and formation of teeth and bones.

Sources of Vitamin D

Irradiation of skin with sunlight is the main source of vitamin D. The mid-day sun is rich in UV rays and helps in synthsising this vitamin. Vitamin D is present only in foods of animal origin, which include egg yolk, milk, butter and fish liver oils. Fish liver oils such as halibut, cod, shark and saw fish liver oils are the richest source of vitamin D. Fish liver oils do not form part of the diet and have to be taken as a supplement **Vanaspati ghee** (produced through hydrogenation of vegetable oils) is generally fortified with 180 IU (International Units)

STUDENT ACTIVITY

1. What are recommended daily allowances of vitamin A?

2. What are the physiological functions of vitamin D?

of vitamin D per 100 g. As the per capità consumption of Vanaspati ghee is India is quite low so the impact of this fortification is limited. The vitamin D contents of some foods are given in Table 6.4.

NOTES

Table 6.4. Vitamin D Content of Certain Foods

Food	*Vitamin D*	
	µg / 100g	*I.U. / 100g*
1. *Fish Liver Oils*		
(*i*) Halibut liver oil	500–10,000	20,000–400,000
(*ii*) Cod liver oil	200–750	8,000–30,000
(*iii*) Cod liver oil B.P.	200	8,000
(*iv*) Shark liver oil	30–100	1,200–4,000
2. *Other Foods*		
(*i*) Fat, Fish (sardine, salmon, herring)	5–30	200–1,200
(*ii*) Egg, hen, whole	1.25–1.5	50–60
(*iii*) Egg, yolk	3–4	120–160
(*iv*) Butter	0.5–1.5	20–60
(*v*) Ghee (clarified butter fat)	0.5–1.5	20–60
(*vi*) Milkpowder, full fat	0.4–0.6	15–25
(*vii*) Milk fresh, whole	0.05–0.1	2–4

1 microgram of vitamin D = 40 I.U.

Absorption and Storage of Vitamin D

Fat and bile is essential for the absorption of vitamin D. It gets into general circulation *via* lymph and is stored in sufficient amounts in the liver.

Recommended Daily Allowances of Vitamin D

It is difficult to set requirements for Vitamin D due to its unique hormone like nature, its synthesis in the skin by exposure to sunlight and its limited food sources. As the extent of synthesis of this vitamin and dietary intake is not easy to determine, exact data on requirement of vitamin D is not available only a range of value is recommended. The daily requirements of vitamin D for infants, children, pregnant and nursing women have been estimated to be 10 µg (400 I.U.) and for older children and adults about 5 µg (200 I.U.). In tropical climates, half the above requirements will be adequate if the subjects are exposed to direct sunlight for few hours daily.

Hypervitaminosis D

Excess of vitamin D produces toxic symptoms. Extremely large doses of vitamin D cause hypercalcaemia, hyper phosphatemia, anorexia (loss of appetite), nausea, vomiting and diarrhoea. It also cause calcification of soft tissues such as arteries, kidneys and lungs.

Effects of Deficiency of Vitamin D

When vitamin D is not available in adequate quantities, the calcification of bones does not occur resulting in following deformities.

1. **Rickets.** This disorder is found in children getting inadequate quantity of vitamin D. It is characterised by softness and deformities of bones like bow legs, pigeon chest, enlarged joints and skull deformation (Fig. 6.5). The teeth may fail to develop normally due to poor calcification, and may have pits and cracks which render them to decay. In young girls, improper formation of the bones of the pelvis may result in difficult deliveries, later on their life.

Fig. 6.5. *A child suffering from rickets showing marked bony deformities.*

2. **Osteomalacia.** This disorder occurs in adults, not getting adequate quantity of vitamin D. This disorder is common in North India and Pakistan especially among women who have had many pregnancies and have nursed their children for long period. The bones may become weak that they fail to bear the body weight and bend (Fig. 6.6). The bones become liable to easy fracture.

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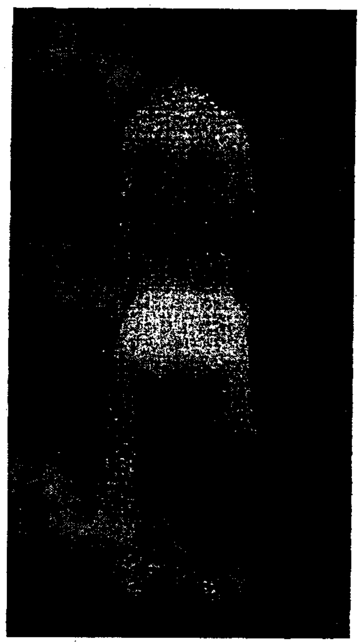

Fig. 6.6. *A case of advanced Osteomalacia showing marked deformities affecting the spine, pelvis and lower extremities.*

Treatment of Vitamin D Deficiency

The deficiency disorders of vitamin D can be prevented by supplementing the diet daily with 400 I.U.0 of vitamin D. The rickets and osteomalacia can be treated effectively by administrating 1000 to 5000 I.U. of vitamin D orally for about a month, followed by 800 I.U. of vitamin D daily for 6 months.

6.6 VITAMIN E

Vitamin E is also called **tocopherol** (Gk. *tokos* = child birth, *pherein* = to carry), **antifertility vitamin, fertility vitamin, vitamin of reproduction** and **beauty vitamin.** Vitamin E represents a group of eight compounds which are collectively called **tocopherols.** These are **alpha, beta, gamma, zeta$_1$, zeta$_2$, eta, delta** and **epsilon.** α tocopherol has the highest activity.

In 1920 **Mattill** and **Conklin** first reported the interaction of food factors with reproduction. In 1922 **Bishop** and **Evans** termed the food factor as factor 'X'. **Suse** (1922) suggested that the substance 'X' or the fertility vitamin be called vitamin E. Tocopherols are derivatives of 6-hydroxy chroman with a phytyl side chain. They are soluble in fats and fat solvents. They are destroyed by oxidation and heat.

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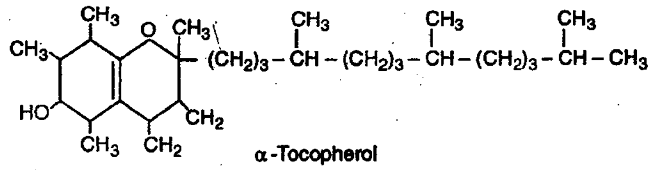
α-Tocopherol

Physiological Functions of Vitamin E

The important functions of vitamin E are as follows:

1. Tocopherols are excellent anti-oxidants and thus maintain normal bio-membrane structure. It inhibits oxidation of unsaturated fatty acids and vitamin A.
2. Vitamin E plays a specific role in **selenium metabolism.** Selenium is an essential component of the enzyme *glutathione peroxidase* that scavenges toxic hydroperoxy compounds in tissues.
3. It keeps skin healthy.
4. In also decreases fragility (weakness) of the erythrocytes (RBCs). Thus, its deficiency also causes anaemia in which RBCs are devoid of haemoglobin.
5. Vitamin E has anti-cancer property. It is used for curing tumour cancer.
6. It maintains normal functioning of reproductive organs, hence it is called fertility vitamin.
7. It maintains the muscles of the body, therefore, vitamin E should be a part of athlete's diet.
8. Vitamin E is used to prevent heart attacks and treat Alzheimer's disease in some patients.
9. A derivative of vitamin E (one of the tocopherols) is said to be necessary for the synthesis of coenzyme Q, which is a component in the electron transport chain.
10. It helps in development and cell formation. Thus, it is needed in the diet of pregnant and lactating women and for the new born infants particularly premature infants.
11. Vitamin E is required for proper use of vitamin A in the body.

Dietary Sources of Vitamin E

Tocopherols are known to occur in a variety of plant and animal foods. Wheat germ and whole cereal are good source of vitamin E. The most important natural sources of tocopherols are vegetable oils, of these wheat germ oil has the highest concentration. Corn oil, cotton seed oil and safflower oil contain considerable amounts of tocopherols. Although fish liver oils are rich in vitamin A and D, but they are poor sources of vitamin E. Lettuce (garden plant with crisp leaves used as salad) is a good source of this vitamin. Of animal tissues, liver is usually the highest in vitamin E. Tocopherols are also found in animal body fat stored in adipose tissue. Vitamin E content of some oils and fats are given in Table 6.5.

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Table 6.5. Vitamin E Contents of Some Oils and Fats

Oils and fats	*Vitamin E mg/100g*	
	α-tocopherol	*Total*
Butter	—	2.4
Coconut oil	3.6	8.3
Cottonseed oil	47.0	81.0
Mustard oil	8.6	32.0
Peanut oil (groundnut oil)	11.0	22.0
Rice bran oil	58.0	91.0
Safflowerseed oil	—	80.0
Soybean oil	15.9	118.0
Sunflowerseed oil	—	70.0
Wheat germ oil	142.8	255.0
Lard	—	2.7

Recommended Daily Allowances

A daily intake of 10 to 15 mg of vitamin E for children and 20 to 25 mg for adolescents and adults is recommended. For pregnant and lactating woman, this amount is slightly higher *i.e.*, 300 mg/day.

Absorption and Storage of Vitamin E

Like other fat soluble vitamins, vitamin E is absorbed along with fat in the small intestine. It is stored in the liver, muscles and body fat in the adipose tissue.

Effects of Deficiency of Vitamin E

The deficiency of vitamin E results in:

(*i*) Reproductive failure.

(*ii*) Degeneration of muscles (muscular dystrophy)-a degenerative diseases of skeletal muscles.

(*iii*) Increased haemolysis (breakdown of erythrocytes or RBCs) leading to macrocytic anaemia (RBCs become larger).

(*iv*) Slow growth and degeneration of renal tubules.

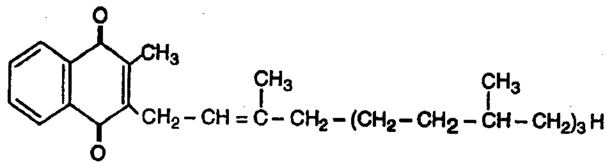
NOTES

6.7 VITAMIN K

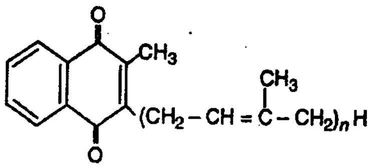
There are three derivatives of vitamin K : **phylloquinone** (K_1) **menaquinones** (K_2) and **menadione** (K_3). Phylloquinone is the major form of vitamin K. It is also called **anti-haemorrhagic vitamin** and **coagulation vitamin.**

The credit for discovery of this vitamin goes to **Dam,** a Danish Scientist who reported it in 1935 and named it as vitamin K, symbolising the Danish term "Koagulation Faktor". **Dam** and **Karror in 1939 isolated vitamin K in crystalline form. Dam** and **Doisy** got the 1943 Nobel Prize for chemical nature of vitamin K.

Vitamin K_1 was first isolated from alfalfa. It has the phytyl side chain consisting of four isoprene units, three of which are fully reduced. In the vitamin K_2 series, six to nine isoprene units occur in the side chain.



Vitamin K_1 (phylloquinone or phytyl - menaquinone)



Vitamin K_2 series

Physiological Functions of Vitamin K

(*i*) Vitamin K is essential for coagulation of blood. It is required for the synthesis of prothrombin (the precursor of thrombin) in the liver for normal clotting of blood. Thus, vitamin K helps in blood clotting, prevention of haemorrhage and excessive bleeding in wounds.

(*ii*) It also plays role in mitochondrial electron transport and oxidative phosphorylation.

Dietary Sources of Vitamin K

Vitamin K_1 occurs in plant foods, while vitamin K_2 occurs in microorganisms. The best source of vitamin K_1 are the green leafy vegetables such as alfalfa (a clover like plant used for fodder), spinach, cabbage, amaranthus etc., and vegetable oils carrot, tomato, cauliflower, wheat bran, wheat germ etc., are also a good source of vitamin E. It is synthesized by bacteria in the large intestine (colon). Infact vitamin K_1 is abundant in vegetable oils, leafy green vegetables and wheat bran. Vitamin K_2 is synthesized by the intestinal bacteria.

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The use of sulpha drugs and antibiotic drugs kills intestinal bacteria, which disturbs the normal synthesis of vitamin K in the intestine. Thus, patients treated with antibiotics for a long time after surgery are likely to suffer from vitamin K deficiency, which may delay the healing of wounds.

Absorption and Storage of Vitamin K

Vitamin K is absorbed in the small intestine along with fats. Bile play significant role in the absorption of vitamin K. The absorbed vitamin K is stored in liver cells in appeciable amounts.

Recommended Daily Allowances

The Indian RDA committee considered that no recommendation need to be made for vitamin K, since vitamin K deficiency is seen in India only occasionally in premature new born infants. It is suggested that a dose of 0.5–1.0 mg of vitamin K be administered intramuscularly to such infants.

Effects of Deficiency of Vitamin K

Vitamin K deficiency can occur in two ways (*i*) Inadequate intake of vitamin K, and (*ii*) Inadequate intestinal absorption.

(*i*) Inadequate intake of vitamin K by the mother's may cause the haemorrhagic disease of the new borns. The infants have a low prothrombin level. Such infants recover rapidly when vitamin K is administered through injection.

(*ii*) Inadequate intestinal absorption of vitamin K may results because of defective secretion of bile due to disfunctioning of liver, pyloric or intestinal obstructions or poor absorption due to diarrhoea or dysentery. It may result a decrease in the prothrombin content of the blood leading to faulty blood clotting. The tendency of bleeding (haemorrhage) is also observed in such subjects.

Hypervitaminosis K

Excess intake of vitamin K causes gastro intestinal disturbance and anaemia.

An important characteristic of fat soluble vitamins is that these vitamins can be stored in the body in sufficient amounts, mostly in the liver. Therefore, their deficiency do not appear for long times.

6.8 SUMMARY

NOTES

- Vitamins are organic compounds regularly required in small amounts in the diet of animal for healthy growth and reproduction. Generally vitamins are synthesized in plants and are found in animals as a result of food intake or by the activity of the microorganisms in the gut.
- Vitamins are of two types : fat soluble and water soluble. Fat soluble vitamins include vitamin A, D, E and K. Vitamin A is essential for vision, formation of bones and teeth and maintenance of epithelial cells of skin. Its deficiency causes night blindness and xerophthalmia. Vitamin D is essential for the absorption of calcium and phosphorus in the intestine. It regulates calcification in the bone tissues. Vitamin D is synthesized in the body in sunlight in addition to the food sources. Its deficiency causes rickets in children and oestomalacia in adults. Vitamin E maintains normal functioning of reproductive organs and keeps skin healthy. Its deficiency results in reproductive failure and degeneration of muscles. Vitamin K is essential for coagulation of blood. Its deficiency results delay in blood clotting.

6.9 GLOSSARY

- **Vitamins:** Vitamins are organic compounds regularly required in small amounts in the diet of a... in order to ensure healthy growth... cannot synthesize such compounds.
- **Fat Soluble Vitamins:** Fat soluble vitamins can only be absorbed in the body in presence of fat.
- **Vitamin A:** Vitamin A group includes retinol, retinal and retinoic acid. It is also known as anti-xerophthalmic vitamin and anti-infection vitamin.
- **Nyctalopia:** It is characterised by the lack of vision in dim light.
- **Phrynoderma:** It is characterised by hyperkeratinisation of epithelium lining of the hair follicle.
- **Vitamin D:** This represents a group of fat soluble vitamins, which are structurally related to sterols. It is also known as antirichitic vitamin or sunshine vitamin.
- **Vitamin E:** It is also called tocopheral, antifertility vitamin, fertility vitamin, vitamin of reproduction and beauty vitamin.
- **Vitamin K:** It is essential for coagulation of blood.

6.10 REVIEW QUESTIONS

NOTES

I. Very Short Answer Type Questions:

1. What are vitamins?
2. Who discovered vitamins?
3. Name the two major classes of vitamins.
4. What is hyper vitaminosis?

II. Short Answer Type Questions:

1. Explain the role played by
   (*i*) Vitamin A in vision
   (*ii*) Sunlight in synthesis of vitamin D
   (*iii*) Vitamin K in blood clotting
2. Explain the functions of vitamin A.
3. What are the disorders caused by vitamin A deficiency?
4. Write the dietary sources of :
   (*i*) Vitamin A (*ii*) Vitamin D (*iii*) Vitamin E
5. How is the deficiency of vitamin treated?
6. What are the disorders caused by the deficiency of vitamin D?
7. How is deficiency of vitamin D deficiency?
8. What are the physiological functions of vitamin E?
9. Write the dietary sources of
   (*i*) Vitamin E (*ii*) Vitamin K
10. Why should a overdoses of vitamin A and D be avoided?

III. Long Answer Type Questions:

1. Give an account of functions, deficiency disorder and dietary sources of vitamin A.
2. Describe the importance of vitamin D and vitamin K in human body.
3. Describe the functions, dietary sources and deficiency symptoms of vitamin E.

NOTES

6.11 FURTHER READINGS

- *Outlines of Biochemistry:* E.E. Conn, P.K. Stumpf; R.H. Doni, Wiley India, Pvt. Ltd; 2007.
- *Biochemistry:* Pawar, Chatwal: Himalayas Pub. House New Delhi; 1988.
- *Biochemistry:* U. Satyanarayan, V. Chakrapani; Books and Allied (P) Ltd; Kolkata; 2008.
- *Essential of Food and Nutrition:* M. Swaminathan; Ganesh, Madras, India; 1985.
- *Handbook of Food and Nutrition:* M. Swaminathan: The Bangalore Printing & Pub. Co. Ltd. Bangalore; 2007.

CHAPTER 7 WATER SOLUBLE VITAMINS

NOTES

Objectives

After going through this chapter, you should be able to:

- define Vitamin B complex, Vitamin C (Ascorbic Acid) and Vitamin P (Bioflavonoids)
- explain RDA of water soluble vitamins
- describe the dietary sources of various types of vitamins
- know about deficiency diseases of vitamins.

Structure

7.1 INTRODUCTION

Because of their water solubility, water soluble vitamins except vitamin B_{12} have no stable storage form and must be provided continuously in the diet. Vitamin B_{12} can be stored in the liver. All water soluble vitamins except vitamin C and vitamin P act as coenzymes or cofactors in enzymatic reactions, water soluble vitamins are absorbed quickly in the body and the amount not utilized is excreted through urine. Therefore, an adequate amount of these vitamins must be supplied in the daily diet. Some of the water soluble vitamins are partly lost in cooking procedures. This factor should be kept in mind, while meeting their requirements.

Water soluble vitamin include the following vitamins.

1. Vitamins B complex
   (a) Vitamin B_1 (Thiamin) (b) Vitamin B_2 (Riboflavin)

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(*c*) Vitamin B_3 (Niacin)
(*d*) Vitamin B_5(Pantothenic Acid)
(*e*) Vitamin B_6 (Pyridoxine)
(*f*) Biotin (Vitamin H)
(*g*) Folic Acid
(*h*) Vitamin B_{12} (Cyanocabalamin)
(*i*) Choline
(*j*) Para- Amino – Benzoic Acid
(*k*) Inositol

2. Vitamin – C (Ascorbic Acid)
3. Vitamin – P (Bioflavonoids)

7.2 VITAMIN B COMPLEX

A number of substances have been identified and grouped together under the heading vitamin–B complex. However, it is important to note that each of the B vitamin is a separate vitamin in name, structure and function.

Six members of this group, namely, thiamine, riboflavin, niacin, pyridoxine, folic acid and vitamin B_{12} are included in the RDA because definite requirements of these vitamins have been established (Table 7.1) through research. A diet which provides adequate amount of these six vitamins, also carried enough of the other members of this group.

Table 7.1. Daily Allowances of Vitamins for Indians (Recommended by the Nutrition Expert Group, I.C.M.R., 1968)

Group	*Particulars*	*Vitamin A*		*Thiamine (mg)*	*Riboflavin (mg)*	*Nicotinic acid (mg)*	*Vit.[1] B_6 (mg)*	*Vit.[1] E (mg)*	*Ascorbic acid (mg)*	*Folic acid (μg)*	*Vit. B_{12} (μg)*
		as Vit.A (μg)	*Carotene (μg)*								
Infants	Birth 6 months	400	—	0.3	0.5	6	0.3	5	30	25	0.2
Infants	7-12 months	300	1200	0.5	0.6	8	0.4				
Children	1-3 years	250	1000	0.6	0.7	8	0.6	10			
Children	4-6 years	300	1200	0.8	0.8	10	0.9	10			
Children	7-9 years	400	1600	0.9	1.0	12	1.2	15			
Children	10-12 years	600	2400	1.0	1.2	14	1.4	20	30-50	50-100	0.5-1.0
Adolescents	Boys 13-15 years	750	3000	1.3	1.4	17	1.8	25			
Adolescents	Girls 13-15 years	750	3000	1.1	1.2	14	1.6	25			
Adolescents	Boys 16-18 years	750	3000	1.5	1.7	21	2.0	25			
Adolescents	Girls 16-18 years	750	3000	1.1	1.2	14	2.0	25			
Men	Sedentary work	750	3000	1.2	1.3	16					
	Moderate work	750	3000	1.4	1.5	19	2.0	30	50	100	1
	Heavy work	750	3000	2.0	2.2	26					
Women	Sedentary work	750	3000	1.0	1.0	13					

	Moderate work	750 3000	1.1	1.2	15	2.0	25	50	100	1
	Heavy work	750 3000	1.5	1.7	20					
	Pregnancy (2nd half)	750 3000	+0.2	+0.2	+2	2.5	30	50	300	1.5
	Lactation (upto 1 year)	1150 4600	+0.4	+0.4	+5	2.5	30	80	150	1.5

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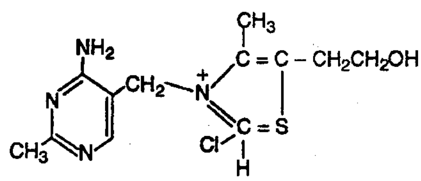
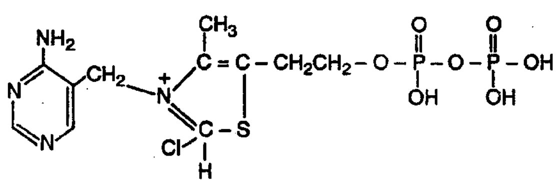
(*a*) Vitamin B_1 (Thiamin)

Vitamin B_1 is also known as *thiamin, aneurin, antineuratic, vitamin, antiberiberi, substance*. Thiamin (B_1) was discovered by ***Eijkman*** (1897). It was first isolated in 1926 from rice polishings by ***Jansen*** and ***Donath***. They isolated 100 mg of crystals from 100 kg of rice polishings. Subsequently, it was synthesized in 1936 by ***R.R. Williams*** and is now available in the market in the form of thiamin hydrochloride.

Thiamin consists of pyrimidine and thiazole rings linked by a methylene bridge. Because of the presence of sulphur in the molecule this vitamin was named thiamin. It exists mainly in various inter convertible phosphorylated forms, chiefly Thiamin Pyrophosphate (TPP). It is readily soluble in water and slightly soluble in alcohol. It is destroyed by heat in neutral or a alkaline solutions.



Thiamin (B_1)



Thiamin pyrophosphate (TPP)
(co-carboxylase)

Physiological Functions of Thiamin

(*i*) Vitamin B_1 is important for the formation of Thiamin pyrophosphate (TPP) which is the active coenzyme form of vitamin B_1. Thiamin pyrophosphate (TPP) serves as coenzyme in Kreb's cycle of respiratory pathway.

(*ii*) Vitamin B_1 is essential for carbohydrate and amino acid metabolism.

(iii) It plays important role in tissue respiration, tones the nervous system (the nervous system mainly depends upon carbohydrate metabolism for energy) and muscles.

(iv) It improves appetite and promotes growth.

Dietary Sources of Thiamin

Thiamin occurs in the outer coats of the seeds of many plants including the cereal grains. Unpolished rice and food made of whole cereal are good source of this vitamin. In animal tissues and yeast, it occurs primarily as coenzyme thiamin pyrophosphate or co-carboxylase. Vitamin B_1 is also synthesized by the bacteria in the colon.

Died yeast, rice polishings and wheat germ are rich sources; whole cereals, legumes, oil seeds and nuts are good sources, and milled cereals, vegetables, fruits, milk, meat and fish are fair sources of vitamin B_1. The vitamin is destroyed by cooking. The thiamin contents of some foods are given in Table 7.2.

Table 7.2. Thiamin Contents of Some Foods

Foodstuffs	*Thiamine (mg/100g)*
1. *Rich sources*	
(i) Dried yeast	3–6
(ii) Rice polishings (from raw paddy)	2–3
(iii) Wheat germ	1.5–2.5
2. *Good sources:*	
(i) Whole cereals (whole wheat, millets, oats, etc.)	0.4–0.6
(ii) Legumes (chickpea, pigeon pea, etc.)	0.45–0.6
(iii) Oilseeds and nuts (soybean, peanut, sesame seeds, cashewnut)	0.65–1.1
(iv) Liver	0.3–0.4
3. *Fair sources*	
Milled cereals	
(i) Raw milled rice, wheat flour and pearled barley	0.07–0.12
(ii) Vegetables	0.04–0.15
(iii) Fruits	0.02–0.06
(iv) Milk	0.05
(v) Meat and fish	0.11–0.18

Recommended Daily Allowance

As thiamin is directly involved in energy and carbohydrate metabolism, the thiamin requirement is expressed in terms of energy intake. Thus, the recommended thiamin allowance is 0.5 mg/1000 calories for all age groups.

NOTES

Effects of Deficiency of Thiamin

(*i*) Deficient intake of thiamin disturbs the digestive system resulting in loss of appetite (anorexia), poorly toned muscles and constipation. Loss of appetite may be accompanied by nausea and vomiting.

(*ii*) Deficiency of vitamin B_1causes *beri-beri* disease. The term 'beri-beri' is a Singhalese word meaning 'I can't I can't, which describes the disease, as the person is always too ill to do anything, beri-beri was discovered by *Eijkman* in1897. He observed that the disease, occurred mainly in people subsisting on a polished rice diet. Beri-beri disease is characterised by loss of appetite and weight and vigour, retarded growth, degeneration of nerves, muscle atrophy, even paralysis, weakened heartbeat and fatigue.

There are two forms of beri-beri found in adults: (*i*) *wet beri-beri* and (*ii*) *dry beri-beri*. Another form of beri-beri called 'infantile beri-beri' occurs in infants.

In addition to the general symptoms, 'wet beri-beri' is characterized by oedema of legs (Fig.7.1A), enlargement of heart and palpitation and breathlessness.

Dry beri-beri is characterised by tingling and numbness of the legs and hands, wasting of muscles and difficulty in walking (Fig.7.1B).

Infantile beri-beri is characterized by restlessness, sleeplessness, palpitation, breathlessness and enlargement of heart. The disease may prove fatal.

(A) (B)

Fig. 7.1 (A) *A case of wet beri-beri,* (B) *A case of dry beri-beri.*

During the second world war (1939–1945), many prisoners of war (POW) were disabled or killed by beri-beri in German and Japanese POW camps.

STUDENT ACTIVITY

1. What are the dietary sources of thiamin?

2. What disorders are caused due to deficiency of vitamin B_1?

Sometimes sea faring fishermen eat raw fish from their catch. They may suffer from paralysis due to vitamin B_1 deficiency, because muscles of raw fish contain an enzyme which destroys thiamin. However, cooked fish has no such enzyme because heat destroys that enzyme.

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Vitamin B_1 and Alcohol

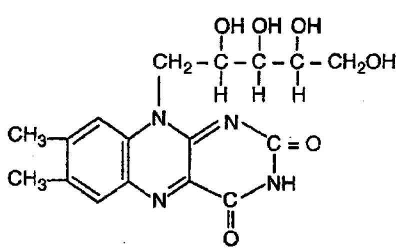
Alcohol interferes with the metabolism of B_1 in the liver. Alcohol intake along with a deficiency of vitamin B_1 can damage brain cells. Deficiency of vitamin B_1 in alcoholics causes **Wernick's and Korsakoff's syndromes.** Wernick's syndrome is characterised by mental disturbance, paralysis of eye movements and loss of power of muscular coordination. Korsakoff's syndrome is characterised by confusion and impairment of memory, specially for recent events. Therefore, regular alcoholics should take vitamin–B complex everyday.

(*b*) Vitamin B_2 (Riboflavin)

Riboflavin was isolated from several sources by different scientists and named according to source as *lactoflavin* (from milk), *ovoflavin* (from egg yolk), *hepatoflavin* (from liver) and *verdoflavin* (from grass). Vitamin B_2 is also called *vitamin G.*

Pure riboflavin was isolated from milk and other foods in 1933 by *Kuhn* and his co-workers. The vitamin is a yellow – green (L. flavus = yellow) fluorescent pigment containing the sugar 'ribose', hence the name riboflavin.

Riboflavin (vitamin B_2) consists of the sugar alcohol D-ribitol attached to 7, 8 dimethyl isoalloxazine. The vitamin occurs as a component of two flavin coenzymes, flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). The vitamin is slightly soluble in water. It is stable in acid medium, but it is destroyed slowly in alkaline medium at room temperature. When in solution, riboflavin is destroyed on exposure to sunlight. This is the reason, that the prolonged exposure of milk to direct sunlight decreases the riboflavin content of milk considerably.



Riboflavin

Physiological Functions of Riboflavin

(*i*) Riboflavin is a component of *flavin mononucleotide (FMN)* and *flavin adenine dinucleotide (FAD)*, which act as coenzyme in various hydrogen transfer reactions in metabolism.

(ii) The vitamin is essential for growth and health.
(iii) It maintains normal healthy skin and oral mucosa.
(iv) It is also associated with the physiology of vision.

NOTES

Dietary Sources of Riboflavin

Milk and some products of it such as yoghurt (curds), butter milk, milk powder and concentrated milk are rich sources of vitamin B_2. It is absent in butter and ghee, because the vitamin is water soluble and remains in the water extract during the removal of butter from milk or curd. Liver and kidney of animals and birds are also good sources of riboflavin. Pulses, green leafy vegetables, eggs and meat contain the vitamin in fair amount. Cereals, roots and fruits are poor sources of riboflavin. The riboflavin contents of some foods are given in Table 7.3.

Table 7.3. Riboflavin Content of Foods

Foodstuffs	*Riboflavin*
1. *Rich sources:*	
(i) Liver	3.0 – 4.0
(ii) Dried yeast	3.5 – 4.5
(iii) Egg powder	1.6 – 2.0
(iv) Skim milk powder	1.6 – 1.7
(v) Whole milk powder	1.3 – 1.4
2. *Good sources:*	
(i) Milk	0.15 – 0.20
(ii) Eggs	0.29 – 0.35
(iii) Meat	0.2 – 0.3
(iv) Fish	0.2 – 0.3
(v) Whole cereals	0.10 – 0.16
(vi) Legumes and dhals	0.21 – 0.32
(vii) Oilseeds and nuts	0.15 – 0.30
(viii) Green leafy vegetables	0.15 – 0.30
3. *Fair sources:*	
(i) Milled cereals and cereal	
(ii) Products (raw milled rice white flour)	0.03 – 0.08
(iii) Roots, tubers and other vegetables	0.03 – 0.12

Recommended Daily Allowance

Riboflavin requirement is related to total energy requirement. The general RDA standard is 0.60 mg of riboflavin/1000 k cal for all age groups. However, the requirement of riboflavin increases during pregnancy and lactation and also with increased activity and calorie intake.

Thus, the recommended allowance varies from 0.7 mg for an infant to 1.7 mg for an adolescent.

NOTES

Effects of Deficiency of Riboflavin

(*i*) Deficiency of riboflavin causes *cheilosis*, which is characterised by inflammation and cracking at the angles of mouth.

(*ii*) The deficiency of the vitamin also results in digestive disorders, burning sensation in the skin and eyes, depression, forgetfulness, scaly dermatitis at angles of nostrils and keratitis of cornea.

(*iii*) The adults fed on riboflavin deficient diet develop scrotal dermatitis/scrotal lesions.

Treatment of Riboflavin Deficiency

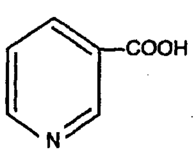
Riboflavin deficiency can be treated through oral administration of 5 mg of riboflavin per day to the children for one month and 10 mg per day to the adults for 1– 2 months.

(c) Vitamin B_3 (Niacin, Nicotinamide or Nicotinic Acid

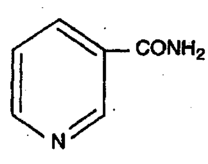
Niacin is also known *P.P. factor* (pellagra preventing factor of Goldberger) *Goldberger's P.P. factor*, *Antipellagra factor* and *vitamin PP.*

Goldberger (1912) identified pellagra as a disease caused by deficiency of a dietary factor. **Funk** was the first to isolate this vitamin from rice polishing in 1914. In 1937 *Elvehjem* and coworker discovered that nicotinic acid was effective in curing *canine black tongue* disease in dogs. *Smith* and others found that nicotinic acid cured pellagra in humans. Thus, a known substance nicotinic acid was identified as a vitamin. *Cowgill* suggested that the term *'niacin'* be used for nicotinic acid to avoid association with the nicotine of tobacco.

Nicotinic acid contains a pyridine nucleus. Another form of vitamin is the amide nicotinamide or niacinamide. The nicotinic acid is sparingly soluble in water, while nicotinamide is highly soluble in water. Both are stable to heat and not destroyed by autoclaving at 120°C for 20 minutes.



Nicotinic acid



Nicotinamide

It is important to note that plants and most animals can synthesize nicotinic acid (niacin) from the essential amino acid *tryptophan*. This requires pyridoxal phosphate (active coenzyme form of vitamin B_6–

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pyridoxine). This vitamin is also synthesized by colon bacteria. Tobacco contains an alkaloid, *nicotine*, which can be used as a raw material for preparation of nicotinic acid or niacin.

Physiological Functions of Niacin

(*i*) Niacin forms two coenzymes. *Nicotinamide Adenine Dinucleotide (NAD)* and *Nicotinamide Adenine Dinucleotide Phosphate (NADP)* which play important role in the metabolism of carbohydrates, fats and proteins.

(*ii*) It is also essential for the normal functioning of the gastrointestinal tract and the nervous system.

Dietary Sources of Niacin

Both plant and animal foods contain niacin. Died yeast, liver and groundnuts are excellent sources of niacin. Whole cereals, legumes, meat and fish are good sources, while milled cereals, root and tubers, other vegetables, milk and eggs are fair sources of niacin. The niacin contents of some foods are given in **Table 7.4**

Table 7.4. Niacin Content of Foodstuffs

Foodstuffs	*Niacin (mg/100g)*
1. *Rich sources:*	
(*i*) Dried yeast	25–35
(*ii*) Liver	16–20
(*iii*) Rice polishings (from raw rice)	16–18
(*iv*) Peanut (groundnut)	14–15
(*v*) Peanut flour	19–20
2. *Good sources:*	
(*i*) Whole cereals	3–5
(*ii*) Legumes	2–3
(*iii*) Meat	6–7
(*iv*) Fish	3–4
3. *Fair sources:*	
(*i*) Milled cereals	0.5–1.2
(*ii*) Maize	0.6–1.2
(*iii*) Roots and tubers	0.5–1.0
(*iv*) Other vegetables	0.2–0.6
(*v*) Milk	0.2
(*vi*) Egg	0.2

Recommended Daily Allowance

Since, niacin is involved in the utilisation of carbohydrates, the requirement of niacin is related to the total calories in the diet. The recommended amount is 6.6 mg of niacin per 1000 calories. The total niacin equivalent required daily on the basis of calorie equivalent could range from 8 mg to 26 mg depending on the age and occupation of the individual.

The niacin requirement is affected by all the factors, which affect energy needs. Since tryptophan (an amino acid) present in dietary protein is converted in the human and animal body. Thus, the total niacin requirement is stated in terms of 'niacin equivalents' about 60 mg of tryptophan can give rise to 1 mg of niacin. Niacin equivalents are calculated as follows.

$$\text{Niacin equivalents mg} = \text{niacin content in mg} + \frac{\text{Tryptophan content in mg}}{60}$$

The niacin equivalents of some foods are given in Table 7.5.

Table 7.5. Niacin Equivalents in Foods (In 100 g Edible Portion)

Foods	*Niacin (mg)*	*Tryptophan (mg)*	*Niacin equivalent (mg)*
1. *Cereals:*			
(*i*) Rice (raw, milled)	1.9	87	3.3
(*ii*) Rice (parboiled)	3.8	71	5.0
(*iii*) Wheat (Whole, flour)	4.3	133	6.5
(*iv*) Bajra	2.3	204	5.7
(*v*) Jowar (sorghum)	3.1	116	5.0
2. *Pulses:*			
(*i*) Arhar (tur dal)	2.9	143	5.3
(*ii*) Black gram	2.0	269	6.5
(*iii*) Green gram (whole)	2.1	230	5.9
(*iv*) Lentil	2.6	241	6.6
(*v*) Bengal gram (whole)	2.9	137	5.2
(*vi*) Groundnuts	19.9	243	23.9
3. *Vegetables:*			
(*i*) Amaranthus	0.4	45	1.1
(*ii*) Potato	1.2	26	1.6
4. *Animal foods:*			
(*i*) Milk	0.1	62	1.1
(*ii*) Egg	0.1	192	3.3
(*iii*) Pomfrets	2.6	196	5.8

Effects of Deficiency of Niacin

(*i*) Niacin deficiency causes a disease *pellagra* (Italian *pelle* = Skin, *agra* = rough; *pellagra* = rough skin), Pellagra is especially

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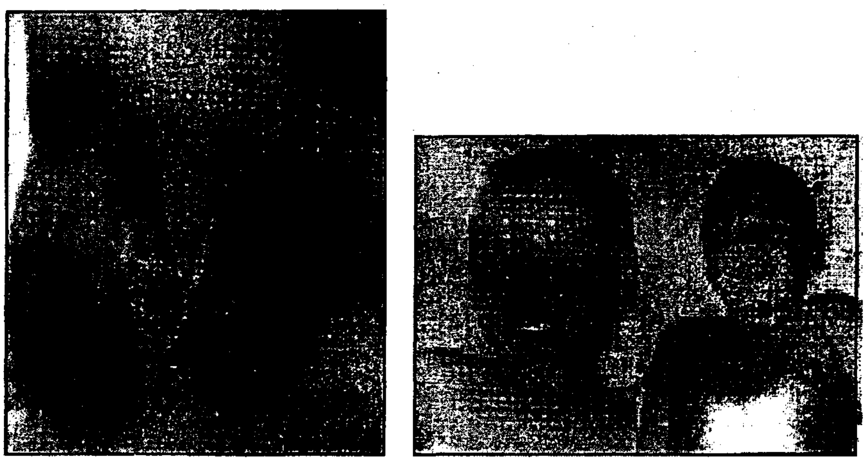
frequent among people eating food with low tryptophan (an essential amino acid) content.

Pellagra is characterised by three Ds namely *dermatitis* (inflammation of skin, which becomes scaly and papillated), diarrhoea (watery stool) and dementia (mental deterioration which may lead to madness). Muscle atrophy and severe inflammation of mucous membrance of alimentary canal may occur (Fig. 7.2).

It has been observed that pellagra exists in endemic form in some parts of India, when Jowar (kaffir corn) and maize is the staple food. These crops have high content of leucine which interferes in the conversion of tryptophan to niacin and also the conversion of niacin to coenzymes in the tissues.

(*ii*) A canine disease (disease of dog) called *'Black Tongue'* is caused by deficiency of niacin.



(A) (B)

Fig. 7.2: *Pellagra* (A) *Pellagra dermatitis in forearms* (B) *Pellagra dermatitis on face and neck.*

Treatment of Pellagra

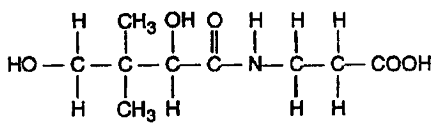
Pellagra can be treated by administrating a dose of 50 mg of nicotinamide intramuscularly twice a day for a week followed by an oral dose of 100 mg of nicotinamide twice a day for about 2 to 3 weeks.

(*d*) Vitamin B_5 (Pantothenic Acid)

Pantothenic acid is one of the vitamins of B group which can prevent or cure a specific type of dermatitis (chick pellagra) in chicks. It is also known *chick antidermatitis factor. Willams* and co-workers (1938) isolated it in pure form as its calcium salt.

Pantothenic acid exists both in free and in combination with B-mercapto – ethylamine, adenine, ribose and phosphoric acid. The latter form is

Pantothenic acid exists both in free and in combination with B-mercapto – ethylamine, adenine, ribose and phosphoric acid. The latter form is known as coenzyme. Pantothenic acid is highly soluble in water. It is stable to autoclaving at 120°C for 30 minute in neutral pollution but is destroyed in acid or alkaline medium.



Pantothenic acid

Physiological Functions of Pantothenic Acid

(*i*) Pantothenic acid is an important component of coenzyme A (COA), which is involved in the metabolism of carbohydrates and fats.

(*ii*) It is required for the normal functioning of the adrenal glands.

(*iii*) It is associated with healthy skin and hair.

Dietary Sources of Pantothenic Acid

Pantothenic acid is widely distributed and found in various food stuffs (hence its name). It is present in *cereals, yeast, milk, groundnut, tomatoes, liver, kidneys meat,* egg yolk etc. Tea also contain significant amount of pantothenic acid. It is also synthesized by bacteria in the colon. Pantothenic acid contents of common foods are given in Table 7.6.

Table 7.6. Pantothenic Acid Content of Foods

Foodstuffs	*Pantothenic acid (mg / 100g)*
1. *Rich sources:*	
(*i*) Dried yeast	10–11
(*ii*) Liver (ox, sheep and goat)	7–8
(*iii*) Rice polishings	3–4
(*iv*) Wheat germ	2–3
2. *Good sources:*	
(*i*) Whole cereals	0.6–1.5
(*ii*) Legumes	0.6–2.2
(*iii*) Nuts and oilseeds	0.6–2.1
(*iv*) Egg	1.5–1.6
(*v*) Meat	0.3–0.4
(*vi*) Milk	0.3–0.4
(*vii*) Fish	0.5–0.6

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3. *Fair sources:*	
(*i*) Milled cereals	0.5–0.7
(*ii*) Vegetables	0.2–1.0
(*iii*) Fruits	0.1–0.3

Recommended Daily Allowance

The recommended daily allowance of pantothenic acid varies for different age groups. It is 1.5 to 2.5 mg/day for infants, 5 to 8 mg/day for the children, 8 to 10 mg/day for adolescents, 10 mg/day for adults and 10 to 15 mg/day for pregnant and lactating women.

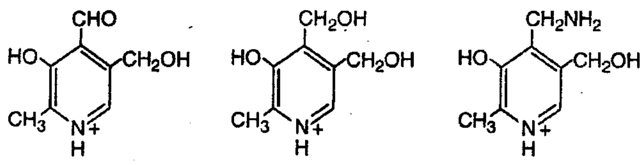
Effects of Deficiency of Pantothenic Acid

Because pantothenic acid is found in almost all food stuffs, its deficiency is rare in humans. Pantothenic acid produced experimentally in humans showed dermatitis, retarded growth, failure of reproduction, alapecia (loss of hair), greying of hair, degenerative changes in the nervous system, gastro intestinal disorders and fatty liver. A condition called *burning feet syndrome* observed in prisoners of war during World War II in Japan and Burma was due to deficiency of pantothenic acid in their diet. *Gopalan* (1946) found that burning feed syndrome observed in Indian subjects responded to the treatment with ca-pento thenate (20-40mg) administered intramuscularly.

(*e*) Vitamin B_6 (Pyridoxine)

Three compounds belong to the group of vitamins known as B_6. They are *pyridoxal, pyridoxine* and *pyridoxamine*. This vitamin is also known *Rat antidermititis factor, Antiachrodynia factor* and *Adervin*. The term vitamin B_6 was given by *Gyorgyi* in 1934 to pyridoxine.

The three forms vitamin B_6 contain pyridine nucleus and has the same vitamin activity. Pyridine is readily soluble in water. It is destroyed slowly, when its neutral or alkaline solution is exposed to light. Its partial destruction occurs when its neutral or alkaline solution is autoclaved at 120^0 for 30 minutes.



Pyridoxal | Pyridoxine or Pyridoxol | Pyridoxamine

Physiological Functions of Pyridoxine

(*i*) It is a coenzyme for amino acid and fatty acid metabolism. All three (pyridoxine, pyridoxal and pyridoxamine) appear to be

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equally active as precursors for the coenzyme *pyridoxal phosphate.* Pyridoxal phosphate is a versatile coenzyme that participates in the catalysis of several important reactions of amino acid metabolism known as *transmination* (transfer of amino group from one amino acid to another), *decarboxylation* (removal of carbon dioxide) and *racemization* (formation of an equilibrium mixture of DL alanine from either D or L alanine).

(*ii*) It is essential for maintaining the nervous system in normal condition.

(*iii*) Vitamin B_6 is found useful in the treatment of nausea and vomiting during pregnancy (morning sickness), radiation sickness and muscular dystrophy.

Dietary Sources of Vitamin B_6

Vitamin B_6 occurs in foods in all the three forms (pyridoxine, pyridoxal and pyridoxamine). The main sources of vitamin B_6 are whole grain cereals, peas, beans, soybeans, green, leafy vegetables, yeast, milk, egg yolk, meat and liver. Intestinal bacteria also synthesize it. Dried yeast, rice polishings, wheat germ and liver are rich sources. Whole cereals, legumes (pulses), oil seeds and nuts, egg, milk, meat, fish and green leafy vegetable are good sources. Milled cereals, roots, tubers, other vegetables and fruits are fair sources of vitamin B_6.

The vitamin B_6 contents of some foods are presented in Table 7.7

Table 7.7. Vitamin B_6 Content of Foods

Foodstuffs	*Vitamin B_6 mg/100g*
1. *Rich sources:*	
(*i*) Dried yeast	0.7 – 4.0
(*ii*) Rice polishings	0.6 – 0.8
(*iii*) Wheat bran	1.1 – 1.3
(*iv*) Wheat germ	0.8 – 1.4
(*v*) Liver (sheep, beef or pig)	0.5 – 0.7
2. *Good sources:*	
(*i*) Whole cereals	0.3 – 0.5
(*ii*) Legumes	0.2 – 0.5
(*iii*) Nuts and oilseeds	0.3 – 0.6
(*iv*) Milk powder, whole	0.4 – 07
(*v*) Milk skimmed	0.5 – 0.8
(*vi*) Egg, Whole	0.5 – 1.0
(*vii*) Meat	0.2 – 0.3

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(viii) Milk, fresh	0.06 – 0.12
(ix) Leaf vegetables	0.2 – 0.3
3. *Fair sources:*	
(i) Milled cereals	0.04 – 0.10
(ii) Fruits	0.02 – 0.06
(iii) Vegetables	0.02 – 0.07

Recommended Daily Allowance

There are some evidence that the pyridoxine requirements is related to protein intake. The suggested daily intake varies from 0.4 mg for infants to 2.0 mg for adults and 2.5 mg for expectant and no nourishing mothers. The suggested daily intakes of pyridoxine, folate, vitamin B_{12} and ascorbic acid are given in Table 7.8.

Table 7.8. Suggested Daily Intakes of Pyridoxine, Folate, Vitamin B_{12} and Ascorbic Acid

Groups	*Pyridoxine (mg)*	*Folate (μg)*	*Vitamin B_{12} (μg)*	*Ascorbic acid (mg)*
Adult man and woman	2.0	100	1	40
Pregnant woman	2.5	400	1	40
Lactating woman	2.5	150	1.5	80
Infants				
(0–6 months)	0.3	25	0.2	25
(6–12 months)	0.4			
Preschool children				
1–3 years	0.9	40		
4–6 years		50		
School children				
7–9 years	1.6	60	0.2 to 1.0	40
10–12		70		
Adolescents				
13–15 years	2.0	100		
16–18 years		100		

Effects of Deficiency of Vitamin B_6

(i) The deficiency of vitamin B_6 causes dermatitis, anaemia, convulsions, nausea, vomiting, weakness and dizziness.

(ii) Seborrhoea like skin lesions develop around the eyes, nose and mouth.

(iii) Children show nervous irritability and convulsive seizures. The symptoms of vitamin B_6 deficiency are cured by the administration of pyridoxine.

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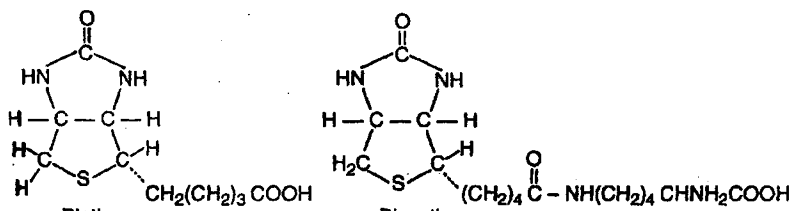
(*f*) Biotin (vitamin H or vitamin B_7)

Biotin is also known *vitamin* H, *vitamin* B_7, *anti egg white injury factor* and *coenzyme* R. The essential nature of biotin was established by its ability to serve as a growth factor for yeast and certain bacteria. In animals, the biotin requirement is met by the intestinal bacteria that can synthesize the vitamin. In 1927, *Boas* made an important observation that a nutritional deficiency of biotin may be induced, in animals by feeding them large amount of avian egg white, Egg white contains a basic protein called *avidin* that has a remarkably high affinity for biotin or its simple derivatives. Avidin is, therefore, an extremely effective inhibitor of biotin requiring systems. Hence, biotin is also called 'anti–egg white injury factor' Gyorgy (1931) gave the name 'vitamin H' to this factor.

The vitamin occurs mainly in combined forms bound to protein through the E-N-lysine moiety. Biocytin, E-N- biotinyl. L. lysine, has been isolated as a hydrolysis product from biotin containing proteins. Biotin is freely soluble in hot water and fat solvents. It is stable to autoclaving at 120°C for 30 minutes in aqueous medium.



Biotin   Biocytin

Physiological Functions of Biotin

(*i*) It serves as coenzyme needed for protein and fatty acid synthesis.
(*ii*) It helps to maintain the skin and nervous system in sound condition.
(*iii*) It is essential for gestation and lactation in experimental animals.

Dietary Sources of Biotin

Biotin occurs widely both in foods of vegetable and animal origin. A large portion of the human biotin requirement is supplied from the intestinal bacteria. The biotin currents of some foods are presented in Table 7.9.

Table 7.9. Biotin Content of Foods

Foodstuffs	*Biotin (mg/100g)*
1. *Rich sources:*	
(*i*) Dried yeast	100–200
(*ii*) Rice polishings	57–60
(*iii*) Wheat germ	55–66

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(*iv*) Liver (sheep, goat, ox)	100–127
(*v*) Peanut	35–40
(*vi*) Soybean	45–55
2. *Good sources:*	
(*i*) Whole cereals	6–15
(*ii*) Legumes	12–18
(*iii*) Mutton	5–8
(*iv*) Eggs	20–22
(*v*) Milk, cow's fresh	5–6
3. *Fair sources:*	
(*i*) Milled cereals and cereal flour	1.5–3.0
(*ii*) Vegetables	3–5
(*iii*) Fruits	1.7–2.5
(*iv*) Milk, human	0.4–0.5

Recommended Dietary Allowance

Since biotin deficiency has not so far been reported in normal humans, it may be presumed that the normal diets provide adequate amounts of biotin. The biotin content of poor diets consumed in the developing countries is about 50–60 μg while that of diet consumed in the developed countries vary from 150–300 μg.

Effects of Deficiency of Biotin

Biotin deficiency does not occur normally because a large portion of the human biotin requirement is probably supplied from the intestinal bacteria. Its deficiency is caused by prolonged use of antibacterial drugs (*e.g.*, antibiotics and sulpha drugs) which reduce the intestinal bacterial flora. Biotin deficiency also occurs by eating raw egg white in large quantities. Avidin protein present in raw egg white prevents the absorption of biotin. Therefore, egg should not be eaten in raw state. Biotin deficiency causes skin lesions, poor growth, loss of muscular control, loss of appetite, weakness and hair fall.

(g) Folic Acid (Folacin)

Folic acid is also known *folacin, folate, vitamin M, vitamin* B_{10} *pteroyl glutamic acid (PGA)*. The term folic is derived from Latin word *'folium'* meaning the *'leaf'*. It was first obtained from spinach. The term *'vitamin M'* was given to the folic acid by *Day* and his co-workers in 1935.

Chemically, folic acid consists of the heterobicyclic pteridine para-amino benzoic acid (PABA) and glutamic acid. It is highly soluble in water and stable to heat.

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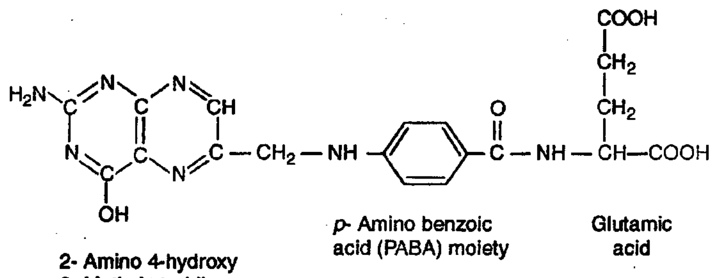

Folic acid (Pteroyl-L-glutamic acid)

Physiological Functions of Folic Acid

(*i*) Folic acid forms a number of coenzymes which play important roles in a variety of metabolic reactions.

(*ii*) It is involved in the formation of purine ring and pyrimidine ring, constituents of nucleic acid (DNA and RNA). Thus it helps in the synthesis of nucleic acids.

(*iii*) It is essential for the maturation of red blood corpuscles (RBCs).

Dietary Sources of Folic Acid

Folic acid occurs widely in foods of both plant and animal origin. Green leafy vegetables, liver, legumes and yeast are rich sources of folic acid. It is relatively stable vitamin but storage and cooking losses can be as high as 50 per cent, especially if cooking water is discarded. The free folic acid contents of some common foods are given in Table 7.10.

Table 7.10. Folic acid Content of Foods

Foodstuffs	*Folic acid 'Free' (μg/100g)*	*Foodstuffs*	*Folic acid 'Free' (μg/100g)*
• *Cereals:*		• *Pulses (legumes):*	
Bajra	14.7	Bengalgram, whole	34.0
Italian Millet	4.2	Bengalgram dhal	32.0
Jowar	14.0	Bengalgram (roasted)	22.0
Maize, dry	14.0	Blackgram dhal	24.0
Oatmeal	32.0	Cowpea	69.0
Ragi	5.2	Green gram dhal	24.0
Rice, parboiled	8.0	Lentil	14.5
Rice, raw, milled	4.1	Peas, dry	4.6
Samai	2.2	Red gram	19.0
Varagu	7.4	Soyabean	8.7
Wheat, whole	14.2	• *Leafy vegetables:*	
Wheat flour (whole)	12.1	Amaranthus	41.0
		Cabbage	13.3
		Curry leaves	23.5
		Mint	9.7

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Spinach	51.0	• *Fruits:*	
• *Roots and Tubers:*		Tomato, ripe	14.0
Carrot	5.0	Fish and other sea foods:	
Colocasia	16.0	Mrigal	9.7
Onion, big	1.5	Shrimp, fresh	15.7
Potato	3.0	• *Other flesh foods:*	
Yam (ordinary)	0.9	Buffalo meat	4.6
• *Other vegetables:*		Egg, duck	80.0
Brinjal	5.0	Egg. hen	70.3
Cluster beans	50.0	Fowl	3.2
Cucumber	12.6	Goat meat	0.5
French beans	15.5	Liver, goat	61.2
Kovai	18.0	Liver, sheep	65.6
Ladies fingers	25.3	Mutton	1.0
Plantain, green	1.6	• *Milk and Milk products:*	
Pumpkin	3.0	Milk, buffalo	3.3
Snake gourd	7.5	Milk, cow	5.6
• *Nuts and Oilseeds:*		Milk, goat	0.7
Coconut, dry	15.3	Milk, human	1.3
Coconut, fresh	11.7	Curd, (buffalo milk)	3.3
Gingelly seeds	51.0	• *Miscellaneous Foods:*	
Groundnut	16.0	Betel leaves	3.1
		Yeast, dried	150.0

Recommended Dietary Allowance

The daily allowances of free folic acid are given in Table 7.10. It is 25 μg/day for infants, 40 μg/day for children and 100 μg/day for adolescents and adults. While the requirement for pregnant woman is 400 μg/day.

Effects of Deficiency of Folic Acid

(*i*) Folic acid deficiency decreases multiplication and maturation of red blood corpuscles in the bone marrow causing *megaloblastic anaemia* (enlarged or malformed RBCs).

Megaloblastic anaemia is prevalent in the pregnant women of low income groups. It has also been reported to occur in malnourished children.

(*ii*) Its deficiency causes sprue (ulceration of mouth), ulceration of bowel (intestine) and inability to absorb, especially fats (diarrhoea).

Foliate deficiency is probably the most common vitamin deficiency in USA.

Treatment of Megaloblastic Anaemia

The megaloblastic anaemia in infants is treated by oral administration of folic acid (1–2 mg daily), iron salt (6 mg iron/kg body weight) and vitamin B_{12} (100 μg once a week) intramuscularly. In adult the anaemia can be cured by the administration of both folic acid 5 mg/day orally and vitamin B_{12} (500 μg) by intramuscular injection.

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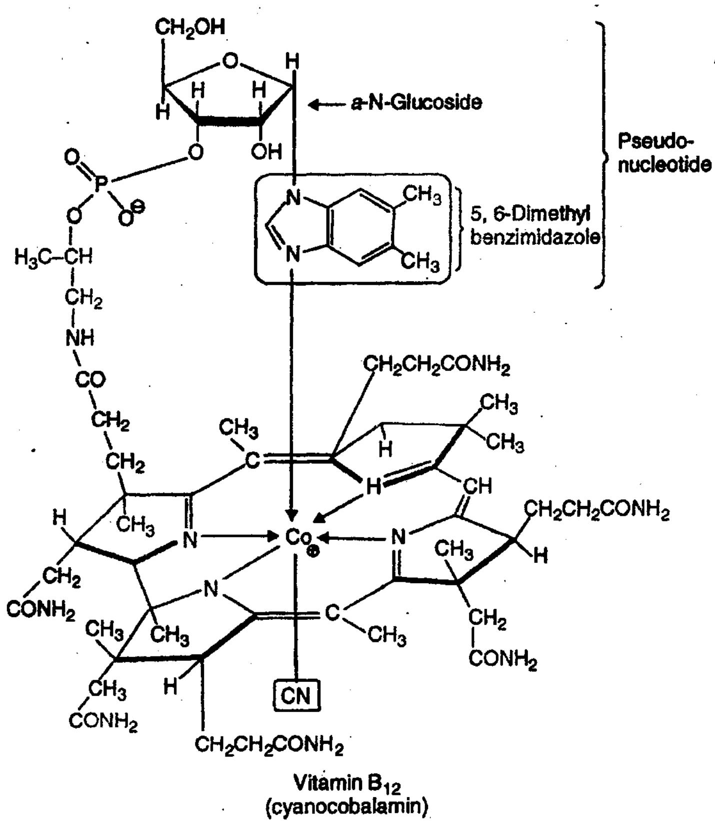
(h) Vitamin B_{12} (Cyanocobalamin or Cobalamin)

Vitamin B_{12} was the last member of the B vitamins in 1948. It is a dark red compound containing cobalt. Vitamin B_{12} is also known *cyanocobalamin, cobalamin, anti pernicious anaemia factor, castle's extrinsic factor* and *animal protein factor (APF)*.

Vitamin B_{12} was discovered through studies of pernicious anaemia, a condition that begins with a megaloblastic anaemia and lead's to an irreversible degeneration of the central nervous system. ***Mniot*** and ***Murphy*** (1926) found that this anaemic condition could be reversed by feeding affected patients large amounts of raw liver. The active substance in the liver was found to be vitamin B_{12}, which is present only in very small amount. *Castle* suggested that parietal cells of gastric mucosa secrete a glycoprotein (carbohydrate rich protein) called *intrinsic factor* (also called *castle's intrinsic* factor) is required for the absorption of vitamin B_{12}. *D. C. Hodgkin*, British chemist won the 1964 Noble Prize for chemistry for the analysis of structure of vitamin B_{12}.

Vitamin B_{12}, contains cobalt (4.5 per cent). It has emperical formula $C_{63}H_{88}N_{14}O_{14}$. It contains a tetra pyrrole ring system, which is chemically very similar to the porphyrin ring system of the haeme compounds. It is sparingly soluble and stable to heat at 100°C for 30 minutes. Vitamin B_{12} isolated from liver has the following structure.



Vitamin B_{12}
(cyanocobalamin)

Physiological Functions of Vitamin B_{12}

(*i*) Vitamin B_{12} stimulates the bone marrow to produce RBCs. Thus, it is important for the formation and maturation of RBCs.

(*ii*) It plays an important role in the synthesis of nucleic acid (DNA and RNA).

(*iii*) It plays a role in the conversion of carbohydrate to lipid.

(*iv*) Vitamin B_{12} stimulates protein synthesis, especially incorporation of amino acids into proteins.

(*v*) It is also necessary for the formation of myelin sheath over the myelinated nerve fibres.

Dietary Sources of Vitamin B_{12}

Vitamin B_{12} is not found in plants, however, it is considered that *Spirulina* (an alga) contains B_{12}. Strict vegetarians may be at risk for vitamin B_{12} deficiency. Liver and kidneys are the richest sources of vitamin B_{12}. Milk, cheese and eggs are good sources of vitamin B_{12}. Meat and fish also contain this vitamin. It is also synthesized by intestinal bacteria, which are in fact main source of Vitamin B_{12}. Vitamin B_{12} content of foods are given in Table 7.11.

Table 7.11. Important Dietary Sources of Vitamin B_{12}.

Foodstuff	*Vitamin B_{12} (μg / 100g)*
1. *Rich sources:*	
(*i*) Liver, goat	120
(*ii*) Liver, ox	118
(*iii*) Liver, pig	59
(*iv*) Liver, sheep	133
2. *Good sources:*	
(*i*) Meat, goat	11
(*ii*) Meat, sheep	30
(*iii*) Fish	23
(*iv*) Egg, hen's	11
(*v*) Egg. duck's	9
3. *Fair sources:*	
(*i*) Whole milk powder	2.4
(*ii*) Skimmed milk powder	3.2
(*iii*) Cow's milk, fresh	0.5
(*iv*) Buffalo milk, fresh	0.4
(*v*) Goat's milk, fresh	0.1
(*vi*) Human milk	0.02

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Recommended Dietary Allowances of Vitamin B_{12}

The recommended daily allowances of vitamin B_{12} are given in Table. It is 0.2 μg// day for the infants, 0.2 to 1.0 μg / day for children and adolescents, 1 μg / day for adults and 1.5 μg / day for the lactating woman.

Effects of Deficiency of Vitamin B_{12}

(*i*) Deficiency of vitamin B_{12} causes the disease '*pernicious anaemia*' (*pernicious* = injurious, *anaemia* = great decrease in the RBCs formation in the bone marrow). The disease is characterized by low RBC count and low haemoglobin content, soreness and inflammation of the tongue, numbness and tingling of fingers and toes. Degeneration of the spinal cord in also observed is some cases.

(*ii*) Its deficiency disturbs normal synthesis of nucleic acids particular DNA.

(*iii*) It also causes nervous disorder.

Treatment of Deficiency of Vitamin B_{12}

Pernicious anaemia caused by vitamin B_{12} deficiency, is treated by administration of 1000 μg of vitamin B_{12} by injection twice in the first week, followed by 250 μg every week for about 2 months. Subsequently a dose of 250 μg every month for a few months will prevent recurrence.

(i) Choline

The importance of choline in nutrition was established by *Best* and *Huntsman* (1934), who discovered that choline deficiency in the rat produces fatty liver. Choline is an integral part of phospholipids.

Chemically, choline is hydroxy trimethylammonium hydroxide. It is a colourless crystalline compound, which is highly soluble in water and alcohol.

Physiological Functions of Choline

(*i*) Choline is a constituent of phospholipids, which form the cell membrane.

(*ii*) Acetyl choline is a neurotransmitter, which play important role in the transmission of nerve impulse.

(*iii*) Choline is involved in transmethylation reaction in the formation of methionine from homocystine.

Dietary Sources of Choline

Choline is present in food of both plant and animal origin, foods of animal origin are rich and good sources of choline. The choline contents of different foods are presented in Table 7.12

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Table 7.12. Important Dietary Sources of Choline

Foodstuffs	*Choline (mg/100g)*
1. *Rich sources:*	
(*i*) Egg, whole	504
(*ii*) Egg, yolk	1490
(*iii*) Liver (pork, beef, goat)	550–660
(*iv*) Wheat germ	406–450
(*v*) Legumes	210–340
2. *Good sources:*	
(*i*) Mutton (lamb, beef, pork)	84–96
(*ii*) Whole cereals	110–146
(*iii*) Rice polishings	150–180
(*iv*) Nuts and oilseeds	95–165
3. *Fair sources:*	
(*i*) Milled cereals	50–60
(*ii*) Vegetables	20–80
(*iii*) Fruits	12–24
(*iv*) Milk	15–18

Requirements

The requirements of choline is not known. The commonly consumed foods contain adequate amounts of choline, hence choline deficiency is less likely to occur in human beings.

However, the deficiency of choline in rats produces fatty liver and haemorrhagic degeneration of kidneys.

(*j*) *Para-Amino Benzoic Acid (P-aminobenzoic Acid or PABA)*

P-amino benzoic acid (PABA) was discovered to be essential for normal growth of rats by *Ansbacher* in 1941. PABA was also found essential for normal lactation. It prevents greying of hair in black rats.

PABA is a crystalline substance soluble in water and alcohol.

Physiological Functions of PABA

(*i*) In some animals PABA increases the activity of insulin.
(*ii*) It prevents oxidative destruction of adrenaline in the tissues.
(*iii*) It inhibits the production of thyroid hormone.

Requirements

The requirements of PABA for human beings are not known. Common diets provide adequate amounts of PABA.

Effects of Deficiency of PABA

Deficiency of PABA retards growth in rats and reduces the production of milk in lactating rats. It also causes greying of hair.

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(k) Inositol

Inositol as an essential factor for the growth was reported for the first time by *Woolley* et. al. (1940).

Inositol is also called *meso–inositol* or *myo–inositol.* Chemically, it is hexahydroxy cyclohexane. It is a crystalline compound highly soluble in water and has a sweet taste.

Physiological Functions of Inositol

(*i*) Inositol is required for the growth of fibroblasts.

(*ii*) It is a constituent of certain phospholipids.

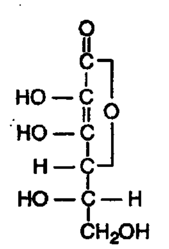
(*iii*) Inositol occur in the mammalian heart muscles. Its higher concentration increases the amplitude and rate of cardiac muscle contraction.

Effects of Deficiency of Inositol

The absence of ionositol from the diet causes *alopecia* (loss of hair) and dermatitis in mice and *'spectacle eyes'* (a condition due to loss of hair around the eye) in rats.

7.3 VITAMIN C (ASCORBIC ACID)

Szent Gyorgy in 1928 isolated a substance from cabbage, orange and adrenal glands with strong reducing property. He called it 'hexuronic acid'. It was later identified as *vitamin C* by *Wangh* and *King* (1932). Vitamin C was called *ascorbic acid* or anti scorbutic vitamin due to anti–scorbutic properties. Ascorbic acid closely resembles glucose in structure. It is optically active. Only L ascorbic acid occurring in foods possesses vitamin activity. D ascorbic acid has no vitamin activity. Ascorbic acid is a white crystalline, odourless compound readily soluble in water. It is strong reducing agent. It is comparatively stable in an acid medium but is destroyed by the action of heat, oxygen and catalysts such as copper.



L-Ascorbic Acid (Vitamin - C)

Physiological Functions of Vitamin C

Vitamin C is probably the least stable of water soluble vitamins. No coenzyme relationship of vitamin C has been established. Vitamin C performs following physiological functions.

(*i*) Vitamin C helps in the formation of normal collagen, bone matrix, tooth dentine and other extra–cellular materials. Obviously, it is essential for formation and growth of connective tissues, cartilages, bones, teeth, etc.

(*ii*) It is necessary for healthy gums and teeth.

(*iii*) Ascorbic acid present in food helps in the absorption and utilization of iron by converting the inorganic ferric ions to the ferrous form.

(*iv*) Adrenal cortex shows high concentration of this vitamin. It indicates that vitamin C is required for the normal function of adrenal glands.

(*v*) It is also essential for the formation of RBCs and the production of antibodies. Thus, it maintains immune defence system.

(*vi*) It also maintains the strength of the walls of blood capillaries.

(*vii*) Vitamin C helps in healing of the wounds.

(*viii*) It has anti-oxidant property.

(*ix*) It helps in the synthesis of neuro transmitters.

(*x*) It helps in the metabolism of many organic acids.

(*xi*) It helps body to withstand injury from burns and toxicity.

Dietary Sources of Vitamin C

Citrus fruits (such as lemon and orange), amla (Indian gooseberry), guava, tomato, potato, peppers, fresh green vegetables and salad vegetables like cabbage, lettuce, spinach etc., are the good source of vitamin C. (Fig. 7.3). Amla (Indian gooseberry) is the richest source of natural vitamin C. Vitamin C is now made synthetically from D. sorbose.

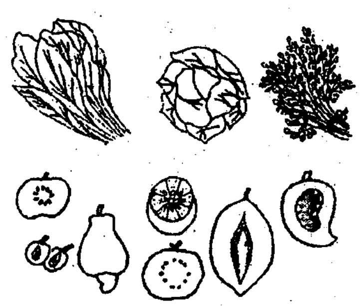


Fig. 7.3. *Some fruit and vegetable sources of vitamin C.*

NOTES

The Vitamin C contents of common food stuffs are given in Table 7.13

Table 7.13. Ascorbic Acid Contents of Foods

Saurces	*Ascorbic acid mg/100g*
1. *Fruits: Rich sources:*	
(*i*) Amla (Indian Gooseberry)	700
(*ii*) Guava	300
2. *Good sources:*	
(*i*) Lime juice	63
(*ii*) Orange	68
(*iii*) Pineapple	63
(*iv*) Mango, ripe	24
(*v*) Papaya, ripe	46
(*vi*) Cashew fruit	60
(*vii*) Tomato, ripe	32
3. *Green leafy vegetables:*	
(*i*) Amaranth leaves	173
(*ii*) Brussels sprouts	72
(*iii*) Cabbage	124
(*iv*) Coriander leaves	135
(*v*) Drumstick leaves	220
(*vi*) Ipomoea leaves	137
(*vii*) Spinach	48
(*viii*) Radish leaves	65
4. *Fair sources:*	
(*i*) Apple	2–8
(*ii*) Banana (Plantain, ripe)	2–6
(*iii*) Jackfruit	10

Recommended Dietary Allowances of Vitamin C

Ascorbic acid cannot be stored in the body. The requirement has to be supplied daily. Even if excess is ingested, it is excreted in the urine. The recommended daily allowance increases with age from 20 to 40 mg/day for children and 40 mg/day for adults. An intake of 80 mg/day is recommended for a nursing mother (Table 7.13). The amount recommended is liberal, as ascorbic acid is a very labile nutrient.

Effects of Deficiency of Vitamin C

Vitamin C deficiency causes *scurvy*, which is characterized by spongy and bleeding gums (gums bleed on slightest pressure), loose and falling teeth, fragility of blood capillaries, extensive sub-cutaneouos haemorrhages fragility of bones, delaying in wound healing due to deficiency in the formation of collagen, swollen and painful joints, mild anaemia and nervous disorder.

People depending solely upon milk, meat, eggs and cereals for food usually suffer from scurvy. Vegetable eaters never get scurvy.

The scurvy in infants is called *infantile scurvy*. It is characterised by loss of appetite, swelling at the ends of long bones and haemorrhage under the skin. Infant cries when its legs and arms are moved. Convulsions may occur resulting death of the infant.

It is said that *Vasco-de-Gamma (1498)* sailed to explore India with 180 companions, but more than hundred people died due to scurvy at the high sea before landing upon Indian coast.

Treatment of Scurvy

Scurvy in adults should be treated by administrating 100 mg of ascorbic acid, twice daily through injection for a week followed by oral administration of 500 mg of ascorbic acid daily for one month. For infants, 50 mg of ascorbic acid should be given intramuscularly twice a day for a week followed by oral administration of 100 mg of ascorbic acid daily for a month.

7.4 VITAMIN P (BIOFLAVONOIDS)

Vitamin P is also known *hesperidin, citrin* and *rutin*. In 1936. *Szent Gyorgy* prepared an extract from paprika and lime juice and found it essential in addition to ascorbic acid, in preventing capillary fragility in human beings. He called 'Vitamin P' to this factor.

Vitamin P represents a group of compounds which are chemically flavonoids. Citrin extracted from lemon peel is a mixture of two fluvanone glucosides – hesperidin and eriodictin. Rutin is another bioflavonoid occurring in nature.

Physiological Functions of Bioflavonoids

(*i*) Bioflavonoids help in maintaining resistance in the walls of blood capillaries.

(*ii*) Citrin cures intestinal haemorrhages in scorbutic guinea pigs when administered along with ascorbic acid.

(*iii*) The effects of bioflavonoids are considered to be indirect based on their inhibitory effect on the oxidation of adrenaline.

Dietary Sources of Bioflavonoids

Bioflavonoids occur mainly in fresh fruits and vegetables citrus fruits, green vegetables, lemon rind (tough outer covering) are good source of bioflavonoids.

NOTES

Effects of Deficiency of Bioflavonoids

The symptoms of deficiency of bioflavonoids include decreased capillary resistance leading to **petechical** bleeding accompanied by pain across the shoulders and in the legs, and fatigue.

Administration of bioflavonoids orally about 200 mg four times a day is effective in curing the above symptoms.

7.5 SUMMARY

- Water soluble vitamins have no stable storage form and must be provided continuously in the diet. Water soluble vitamins include vitamin B complex, vitamin C and vitamin P. Vitamin B complex in a group of vitamins, each has separate name, structure and functions.
- Most of the vitamins of B group are involved in the formation of coenzymes, and play significant roles in cell metabolism and body functions. These vitamins occur in different amounts in food of both plant and animal origin. Deficiency of these vitamins cause different types of disorders. The deficiencies of vitamin B_1 causes beri-beri, vitamin B_2 causes chilosis, vitamin B_3 causes pellagra and many others. Vitamin C is obtained from sour fruits and fresh vegetables. The deficiency of vitamin C causes scurvy. Vitamin P also occur in fresh fruits and vegetables. Its deficiency decreases capillary resistance.

7.6 GLOSSARY

- **Thiamin:** Thiamin occurs in the outer coats of the seeds of many plants including the cereal grains.
- **Korsakoff's Syndromes:** It is wernick's syndrome, characterised by mental disturbance, paralysis of eye movements and loss of power of muscular coordination.
- **Dementia:** It is characterised by mental deterioration which may lead to madness.
- **Seborrhoea:** In which skin develop around the eyes, nose and mouth.

7.7 REVIEW QUESTIONS

I. Very Short Answer Type Questions:

1. Why should water soluble vitamins be provided continuously in the diet?

NOTES

2. What is the cause of the diseases beri–beri?
3. What is Wernick's syndrome?
4. How is disease scurvy caused?

II. Short Answer Type Questions:

1. Write the physiological roles of thiamin.
2. What are the physiological functions of vitamin B_2?
3. What are the effects of deficiency of riboflavin?
4. List the main sources of.
   (*i*) Thiamin (*ii*) Riboflavin (*iii*) Niacin
5. Describe the symptoms of deficiency of.
   (*i*) Thiamin (*ii*) Riboflavin (*iii*) Niacin
6. Mention the physiological functions of.
   (*i*) Folic acid (*ii*) Pyridoxine (*iii*) Cyanmo colabain
7. Discuss the functions of vitamin C.
8. Write the recommended daily allowances of.
   (*i*) Thiamin (*ii*) Riboflavin (*iii*) Niacin

III. Long Answer Type Questions:

1. Give an account of physiological functions, dietary sources and deficiency disorders of vitamin B_1
2. Write the functions, sources and deficiency disorder of vitamin C.
3. Describe the functions, dietary sources and deficiency disorders of riboflavin.

7.8 FURTHER READINGS

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- *Fundamentals of Food, Nutrition and Diet Therapy;* S.R. Mudambi, M.U. Rajagopal; New Age. Int. Pub, New Delhi; 2008.
- *Handbook of Food and Nutrition:* M. Swaminathan: The Bangalore Printing & Pub. Co. Ltd. Bangalore; 2007.

UNIT–IV

CHAPTER 8 MINERALS

Objectives

After going through this chapter, you should be able to:

- define, different types of minerals
- know about general functions of minerals in human body
- give description about macro and micro elements
- explain physiological functions and dietary sources of macro and micro elements
- give RDA.

Structure

8.1 INTRODUCTION

Besides organic compounds, our body also need some inorganic substances called **minerals**. At least 29 mineral elements are found in our body. Minerals do not supply energy, but are essential for the proper functioning of the body.

The minerals can be grouped into two categories—**essential** and **non-essential**. An essential mineral is one, which plays a direct role in the structure and functioning of the organism. Its deficiency or absence produces disorders, which can be rectified only by the supply of that mineral. A non-essential mineral is one that is not involved in the metabolism, structure or functioning of the organism. The organism does not show any disorder in absence of that mineral. Both plants and animals have a variety of minerals in their body. In the living beings, minerals occur in two state: (*i*) complex state as a component of organic and inorganic molecules or salts and (*ii*) ions. Living beings maintains a balance between the amounts of a mineral present as ions and complexes (*i.e.*, salts etc.). The inorganic molecules or salts found in the cells are mostly phosphates, nitrates, bicarbonates, borate, chlorides, sulphates, molybdate etc., of calcium, magnesium, sodium, potassium, iron, zinc, manganese etc. These mostly occur in ionised phase.

8.2 TYPES OF MINERALS

Minerals are present in all body tissues and fluids. They constitute about 5 percent of the weight of our body. This means that about 2–3 kg of our body weight consists of minerals. Of this, 90 per cent is accounted for by several minerals *i.e.*, calcium, phosphorus, magnesium, potassium, sodium, sulphur, and chlorine. Thus based on requirement of the body minerals are classified into two categories: major and trace minerals.

1. **Major Minerals (Macro elements):** The minerals, which are present in our body in large quantities are called major minerals. It is suggested that we consume 0.1 gm of each such mineral per day. These include calcium, phosphorus, magnesium, potassium, sodium, sulphur and chlorine.
2. **Trace Minerals (Micro elements):** The minerals, which are needed in only small amount to the body are called trace elements. It is suggested that we consume 0.01 gm of each such mineral per day. The important trace elements are copper, cobalt, chromium, flourine, iodine, iron, manganese, molybdenum, selenium, zinc. etc.

8.3 GENERAL FUNCTIONS OF MINERALS

Minerals play a number of roles in human body. Some minerals perform a number of different functions. Some of the important functions are:

- form part of cellular structure *e.g.*, calcium and phosphorus as constituent of bones and teeth; sulphur in some amino acids and thus in proteins
- constitute biologically active substances, *e.g.*, iron is a part of haemoglobin, iodine is a constituent of thyroid hormone
- required for activity of a number of enzymes

- maintenance of fluid balance in the body
- functioning of muscles and nerves
- clotting of blood
- maintenance of acid-base balance of cellular fluid.

8.4 MACRO MINERALS (MAJOR MINERALS)

1. Calcium

Among different minerals, calcium is present in the highest amounts in the body. About 99 percent calcium is present in the bones and teeth and the remaining 1 percent in soft tissues. Approximately 1,000–1,200 g of calcium is present in the body of an adult human.

Physiological Functions

The main functions of calcium in the body are:

- imparts strength and rigidity to the bones and teeth by getting deposited in them along with phosphates
- regulates the permeability of capillary walls
- helps in normal clotting of blood
- involved in the contraction of muscles including those present in the heart
- involved in the transmission of nerve impulse
- ensures the absorption of vitamin B_{12}.

Dietary Sources

Milk and milk products are the best sources of calcium. The calcium in milk is accompanied by a favourable proportion of phosphorus, hence, it is very well utilized in the body.

Ragi (a millet), sesame seeds (til) and green leafy vegetables are good source of calcium, though only a part of calcium from these is available to the body. Since green leafy vegetables are also very rich source of carotenes and ascorbic acid, they should be included in the diet as a source of all the above nutrients.

Small fresh fish as well as dried fish eaten along with bones is an excellent source of calcium.

Some species such as cumin seeds (jeera), coriander seeds (dhaniya) also provide calcium in the diet.

The dietary sources of calcium are presented in Table 8.1.

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Table 8.1. Important Dietary Sources of Calcium

Foodstuffs	*Calcium Content mg/100g*
1. *Milk and milk products:*	
(*i*) Milk, cow	120
(*ii*) Milk, buffalo	210
(*iii*) Milk, goat	170
(*iv*) Curd from cows or buffalo milk	120–210
(*v*) Milk powder, whole	1200
(*vi*) Milk powder, skimmed	1370
(*vii*) Cheese	790
(*viii*) Khoa (from buffalo milk)	650
2. *Oilseeds and nuts:*	
(*i*) Sesame seeds	1450
(*ii*) Sesame seed (without skin)	150
3. *Cereals:*	
Ragi330	
4. *Green leafy vegetables:*	
(*i*) Agathi	1130
(*ii*) Fenugreek (methi)	397
(*iii*) Amaranth leaves	500
(*iv*) Drumstick leaves	810
5. *Fish:*	
Small fish, dried	1800
6. *Condiments:*	
(*i*) Cumin seeds (jeera)	1040
(*ii*) Coriander seeds (dhania)	630

Utilisation of Calcium and Factor Affecting Calcium Absorption

Calcium is absorbed mainly in the small intestine. Presence of substances such as vitamin D, ascorbic acid and milk sugar (lactose) favour absorption of calcium. During the periods of rapid growth, the utilisation of calcium become more efficient.

The presence of substances which form insoluble salts of calcium may hinder calcium absorption. For example, oxalic acid (in leafy vegetable), phytic acid (in cereal bran) and excess of fat in the diet interfere with calcium absorption. Excess of fibre in the digestive tract may increase faecal excretion of calcium, thus reducing calcium utilisation.

Parathyroid hormone (PTH) along with thyrocalcitonin (TCT) regulates calcium level in the blood. Parathyroid increases the calcium level in the blood by stimulating the process of bone reabsorption (demineralisation of bones). It also stimulates reabsorption of calcium by the renal tubules and increases calcium absorption from the digested food.

Recommended Dietary Allowances

The studies have shown that the population groups in many developing countries consume diets providing 300–500 mg of calcium. Metabolic studies have shown that they maintain a positive calcium balance on such diets. The RDA for Ca, as recommended by the ICMR Nutrition Expert Group (1989), is given in Table 8.2.

Table 8.2. Recommended Dietary Allowances for Calcium

Groups	*Recommended Allowances (mg/day)*
Infants (0 – 12 months)	500
Children (1 – 9 years)	400
Children (10 – 15 years)	600
Adolescents (16 – 19 years)	500
Adults	400
Pregnancy and lactation	1000

Effects of Calcium Deficiency

The deficiency of calcium manifests itself, only after years of insufficient intake of calcium.

- In young children the deficiency of calcium leads to (*i*) negative calcium balance (*ii*) decreased growth (*iii*) loss of calcium from bones leading to **rickets** (*iv*) hyper irritability and tetany leading to death.
- In adults, the deficiency of calcium causes decalcification of bones leading to **osteoporosis.** If adequate calcium is not provided in the diet, during pregnancy and lactation the bones of woman get porous due to loss of bone mass causing osteoporosis. In the later years of life these woman suffer from loss of stature with bent back and high susceptibility to fracture of hip and wrist. It also result in compression of vertebrae.

The best way to prevent osteoporosis is to maintain adequate calcium intake, physical activity and exposure to sunlight to ensure vitamin D synthesis to aid calcium absorption.

2. Phosphorus

An adult human body contains about 400 to 700 g of phosphorus as phosphates. A major part of this (*i.e.*, 85 percent) is present in bones and teeth and the rist (*i.e.*, 15 percent) in other tissues. It is present in the body as inorganic phosphate salts or in combination with organic compounds.

Physiological Functions

The main functions of phosphorus in the body are:

- occurs as a constituent in the form of calcium phosphate in bones and teeth and as phosphates of sodium and potassium in soft tissues and body fluids
- occurs as a part of nucleic acids (DNA and RNA) that controls the heredity and metabolism
- involved in the energy transfer processes being a constituent of energy molecules (ATP and ADP)
- helps in maintaining acid-base balance in the body being a part of buffer salts
- involved in carbohydrate, fat and protein metabolism as a part of enzymes
- occurs as a constituent of cell membranes in the form of phospholipids
- act as intermediate in fat transport and metabolism.

Dietary Sources

Milk, eggs, meat and fish are rich source of phosphorus, cereals, legumes, nuts and green leafy vegetable also sufficient phosphorus to the body. Many processed foods and soft drinks have added phosphates.

Phosphorus is absorbed in the small intestine as inorganic phosphates. Phosphorus present in animal foods (such as milk, meat and eggs) is absorbed to a greater extent than that present in cereals and legumes.

Requirements

Phosphorus requirements depend on the availability of phosphorus in the diets. The phosphorus requirement of a person consuming predominantly cereal based diets, will be greater than those consuming large quantities of milk, meat, eggs and fish. The optimal Ca : P ratio for infants and children is 1 : 1 and for adults is 1 : 2.

3. Magnesium

The adult human body contains about 25 g of magnesium. About 60 percent of this is present in the bones in combination with phosphate and carbonate.

Physiological Functions

Besides body building magnesium is involved in the contraction of muscles and transmission of nerve impulse. It also acts as activator for many enzymes involved in metabolism.

Dietary Sources

Green leafy vegetables are rich source of magnesium, because magnesium is a constituent of chlorophyll. Other plant foods are also good source of magnesium.

Requirements

Magnesium requirements for different age groups are given below.

Adults	200–300 mg/day
Children	150–200 mg/day
Infants and preschool children	100–150 mg/day

However, no deficiency of magnesium have been observed with Indian population, no specific recommendations are made for Indian population.

Effects of Magnesium Deficiency

Magnesium deficiency has been reported in chronic alcoholics which is characterised by low serum magnesium and muscular wholeness. **Valee** *et.al* (1960) have reported the occurrence of muscular tremors, delirium and tetany in human subjects suffering from magnesium deficiency. The apathy and weakness found in Kwashiorkor is believed to contributed by magnesium deficiency. The symptoms were cured when magnesium salts were administered parenterally.

4. Sodium

About 100 g of sodium is present in the adult human body. It mainly occurs in extra cellular fluids like plasma, lymph and tissue fluid. On the average 5–10 g of sodium corresponding to about 10–12 g NaCl is ingested per day in an average diet.

Functions

The various functions of sodium are:

- along with chlorine, it maintains proper osmotic concentration in the blood to dissolve blood proteins and to keep red blood corpuscles turgid
- maintains the osmotic concentration of tissue fluid
- along with potassium, it maintains membrane permeability and membrane potential

NOTES

- along with potassium, it is essential for conduction of nerve impulses.

Dietary Sources

Sodium is present in almost all plant and animal foods. It is also available in table salt (sodium chloride). Sodium chloride is the only mineral which is taken in more or less pure form in addition to the amount present in natural foods.

On an average diet about 3–5 g of sodium (corresponding to 8–1 g NaCl) is excreted in urine. On a low salts diets and in starvation, urinary excretion may fall to very low levels. Patients suffering from high blood pressure are prescribed low sodium diet.

5. Potassium

The adult human body contains about 250 g potassium. It is mainly present in the cells of different tissues, muscles etc. Only small quantities are present in extra cellular fluid.

Functions

The important functions include:

- regulation of pH in the cell
- regulation of osmotic pressure of the cell
- movement of cardiac muscles
- acts as an antagonist to calcium ion.

Potassium occurs in abundance in various foods, hence its deficiency seldom occurs in normal human beings. Both deficiency and excess of potassium in diets cause weakness and muscular paralysis.

8.5 MICRO MINERALS (TRACE-ELEMENTS)

1. Iron

The adult human body contains 3–4 g of iron. Most of the body iron exists in complex form in a member of biologically important compounds, which include:

- porphyrin (heme) compounds *e.g.,* haemoglobin in RBCs, and myoglobin (in muscles)
- hence enzymes. *e.g.,* cytochrome, catalase, peroxidase.
- flavin enzymes *e.g.,* succinic dehydrogenase, aconitase.
- transport and storage proteins, *e.g.,* transferri, ferritin.

Only a small amount of iron occur in the body as free inorganic ions.

Functions

The important functions of iron are:

- as a constituent of haemoglobin, iron helps transport of oxygen.
- as a constituent of myoglobin, it stores oxygen.
- as a constituent of cytochromes, it takes part in electron transport.
- as a part of certain enzyme, it participate in number of metabolic reactions.

Dietary Sources

Eggs, liver and meat contain iron in a readily available form. Among the plant foods, leafy vegetables, cereals, millets, pulses, nuts and green leafy vegetables are good source of iron. Jaggery is also a good source of iron. The important dietary sources of iron are given in Table 8.3.

Table 8.3. Important Dietary Sources of Iron

Food items	*Iron (mg / 100g)*
1. Green leafy vegetables	5–60
2. Whole wheat flour, rice flakes,	10–20
3. Millets	3–6
4. Pulses and nuts	5–10
5. Flesh foods (liver, meat) eggs	2–6
6. Other vegetables	2–5
7. Fruits	1–3

Utilisation of Iron. Iron needs of the body are met by

- absorption of iron from the diet
- iron released from red blood corpuscles (RBCs)
- from stored ferritin

Absorption of iron from food takes place mostly in the duodenum and the small intestine. Only 3–10 percent of iron is absorbed by a well nourished adult. Higher percentage is absorbed during the growing stages and by anaemic persons when need of the body is high. If the supply of iron is more than what is required by the body, it is stored in the intestinal mucosa as ferritin.

Diet supplies only about 1 mg of iron as compared to the reutilisation of iron from the breakdown of haemoglobin, which is about 25 mg. Since most of the iron is reutilised from the breakdown of haemoglobin, iron is known as **one way element.** The uptake of iron in the intestine is affected by a number of factors. Excess of phosphates and phytates lowers the absorption of iron by forming insoluble salts. Excess of calcium also interferes in the absorption of iron. Oxalic acid present in some foods interferes in the absorption of iron by forming insoluble oxalates.

Recommended Dietary Allowances

The requirements of iron are influenced by the availability of iron present in foods. The iron present in plant foods is available in the lesser amounts, due to the presence of phytates and oxalates, than that present in animal foods. Therefore, iron requirements of person consuming a predominately cereal based diet, will be greater than those consuming animal foods in larger quantities.

The recommended dietary allowances for iron are presented in Table 8.4. Higher amount of iron is recommended during pregnancy and for the infants after six months of age. In general higher quantities of iron is recommended for girls and woman, as they suffer blood loss during menstruation, persons who suffered blood loss due to surgery, accident or after blood donation also need more iron in their diets than their normal intake.

Table 8.4. Recommended Dietary Allowances of Iron Per Day (I CMR Expert Group; 1968)

Groups	*mg/kg wt*
Birth to 1 year	1
1–5 years	15 – 20
6–12 years	15 – 20
13–18 Boys	25
13–18 Girls	35
Man	20
Woman	30
Woman Pregnancy	40
Woman Lactation	30

Deficiency Disorders

The deficiency of iron is widely prevalent among children, adolescent girls and expectant and nursing mothers in almost all developing countries. It leads to anaemia characterised by low haemoglobin content (5 to 9 g/100 mL blood) general fatigue, lassitude, breathlessness or exertion, giddiness and pallor of skin. In severe cases these may be some oedema of the ankles.

NOTES

Treatment

Ferrous sulphate tablets (0.2 g) 3 times a day is recommended for anaemic women. Anaemic children below 12 months of age can be treated with 0.2 g ferrous ammonium citrate sweetened with sugar three times a day for children of 1–5 years of age 0.4–0.9 g of ferrous amononium citrate is effective in curing anaemia.

2. Iodine

There is present 25–30 mg of iodine in the body of this about one third is present in thyroid gland. Iodine is a constituent of thyroid hormones, tri-iodothyroxine (T_3) and thyroxine (T_4). The thyroid hormones are involved in regulations of metabolism and body temperature, and development of mental faculties.

Dietary Sources of Iodine

Iodine is present only in small amounts in common foods. The quantity of iodine present in the foods of region depends on the iodine content of the soil. The soil of mountainous regions usually contains less iodine due to continuous washing of the soil by rains the soil of plains and coastal regions contain sufficient iodine. Sea fish and crude common salt prepared from seawater are good source of iodine.

STUDENT ACTIVITY

1. How do different factors affect absorption of calcium?

2. Why is iodine important in human nutrition?

Recommended Dietary Requirements

NOTES

The daily requirement for iodine for adults is about 0.15–0.2 mg and for infants and children 0.05–0.10 mg. This amount is generally provided by an ordinary well balanced diet and water. However, it is not applicable in mountainous regions where the food and water are deficient in water.

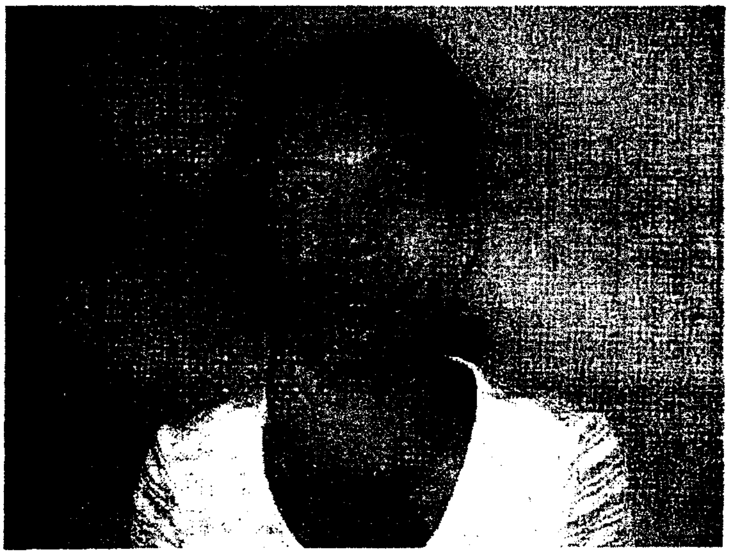

Fig. 8.1 *A case of simple goitre.*

Deficiency Disorders

The deficiency of iodine is marked by a swelling of the neck with the enlargement of thyroid gland. This condition is called **simple goitre** (Fig. 8.1) In goitre, the thyroid gland may weigh as much as 200–500 g or even more as compared to normal thyroid which weighs about 25 g. The gland shows diffuse over growth of the glandular tissue due to hyperplasia. The vesicles of the gland contain little or no colloid.

It has been observed that goitre is generally restricted to the regions deficient of iodine in water and food. In our country, goitre is found among people living in the hilly regions along the food of the Himalayas, *i.e.* in Kashmir and Kangra vallies. Similarly, the salts mined in these regions, known as rock salt, do not contain iodine.

Prevention of Goitre

Goitre can be prevented by the regular use of iodised salt (1 G of sodium iodate added to 1,00,000 g of common salt). Through iodised salt goitre has been prevented in several countries including India.

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3. Copper

The healthy human body contains about 100–150 mg of copper. It exists in the form of copper protein complex — **haemocuprin** in red blood corpuscles and **ceruloplasmin** in plasma. Copper is also a constituent of several enzymes.

Copper is required for the synthesis of haemoglobin. It is a constituent of cytochrome oxidase and some other enzymes.

Dietary Sources

Almost all plant foods contain sufficient quantity of copper, milk and mutton also contain copper. The daily intake in adult diets ranges from 2–3 mg in U.S. and U.K. diets and 4.5–5.8 mg in Indian diets. The high intake in Indian diets may be due to cooking meals in copper containing brass vessels.

Requirements

The requirements of copper for different groups are presented in Table 8.5.

Table 8.5. Requirements of Copper for Different Groups

Groups	*Requirements (mg/day/caput)*
Adults	2
Pregnancy	3
Lactation	3
Infants (1–12 months)	0.5–1.0
Children	2
Adolescents	3

The deficiency of copper causes anaemia, as it affects haemoglobin formation. In Indian population, copper deficiency hardly observed as their meals are prepared in copper containing brass vessels. However, infants fed exclusively on milk diet may show deficiency of copper. Anaemia due to deficiency of copper in infants fed exclusively on milk can be cured by giving copper salts along with iron.

4. Zinc

The body of a normal healthy man contain 1.4–2.3 g of zinc. It is present in small amounts in all tissues. However, bones, teeth and pancreas contain slightly higher amounts than other tissues.

Functions

Zinc is a constituent of the enzyme, carbonic anhydrase present in Red Blood Corpuscles (RBC), hence plays a significant role in respiration.

As a part of the hormone insulin, it is involved in carbohydrate metabolism. It is also a constituent of several other enzyme is *viz* carboxypeptidase, alkaline phosphatase, etc., hence play significant role in metabolism.

Requirements

The daily requirement of an adult is 15 mg and for infants is 3–5 mg. It is 20–25 mg during pregnancy and lactation. This requirement is generally met with a normal balanced diets, which contain about 10–15 mg zinc.

Deficiency Disorders

The deficiency of zinc causes anaemia, retarded growth (dwarfism) and delayed genital maturation in children. Such disorders have been reported only from middle east countries.

5. Manganese

The normal healthy human body contains about 12–20 mg of manganese, which is distributed throughout the body tissues and fluids. However, bones, kidney, liver, pancreas and pituitary contain more manganese than other tissues. Like other trace element, manganese functions as an essential parts of cell enzymes. Peanuts, whole wheat bread contain sufficient manganese.

Deficiency Disorder and Toxicity

The effects of manganese deficiency have been studied by feeding the human subjects on low manganese diets. In such cases impaired growth, skeletal abnormalities and depressed reproductive function were observed.

Manganese toxicity have been observed in the workers working in mines of manganese ores, due to inhalation of the dust of ore. The toxicity is characterised by blurred speech, tremors of the hands and spastic gait.

6. Cobalt

Cobalt occurs in small amounts in almost all tissues, with higher concentrations in liver and kidney. Its maximum quantity is present in vitamin B_{12} (Cyanocobalamin).

Deficiency Disorder and Toxicity

Cobalt deficiency has not been observed in human beings. Most of the cobalt requirements, if any, appear to be met by vitamin B_{12} present in foods.

Excess of cobalt is toxic and causes polycythemia (increased number of RBC in the blood).

NOTES

7. Fluorine

The importance of fluorine in nutrition was established in 1925 by Mc Collum and co-workers, when they observed dental caries in rats fed with fluorine deficient diets. The surveys carried out on the incidence of dental caries in human beings have showed high incidence of the disorder in children in areas where the drinking water contained less than 0.5 ppm fluorine, and low incidence in areas where the water contained 1–2 ppm fluorine. Addition of fluorine to drinking water at a level of 1 ppm. brought about a significant reduction in the incidence of dental caries.

Fluorine is mostly available in drinking water. It is essential for the formation of enamel of the teeth.

Deficiency Disorder

Deficiency of fluorine causes dental caries.

Fluorine Toxicity

Excess of fluorine is harmful. It causes **dental** and **skeletal fluorosis.**

- Dental fluorosis (mottling of teeth) is caused due to excess amount of fluorine (3–5 ppm) in drinking water. Dental fluorosis is characterised by the loss of lustre of the enamel of teeth, yellow or brown irregular patch over the surface of teeth along with pitting or corroded appearance.
- Skeletal fluorosis is caused due to fluorine intoxication through drinking water (more than 10 ppm). There is increased density and hyper calcification of the bones of spine, and swellings of knee bones; pelvis and limbs, there may be ossification of tendinous insertion of muscles. It results in deformity of bones leading to crippling of the human body. Skeletal fluorosis is not limited to human being along, but is also present in domestic animals.

8. Chromium

Approximately, 6 mg of chromium is present in an adult human body. Chromium plays a significant role in carbohydrate, lipid and protein metabolism.

Deficiency of chromium results in disturbances in glucose, lipid and protein metabolism and impaired growth.

8.6 SUMMARY

- At least 29 mineral elements are found in our body. Minerals do not supply energy, but are essential for the proper functioning of the body. Based on requirement of the body, minerals are classified as macro minerals and micro minerals.

- The minerals which are present in our body in large quantities are called macrominerals. These include calcium, phosphorus, magnesium, potassium, sodium, sulphur and chlorine. The minerals which are needed in only small amount to the body are called micro minerals. The important micro element are iron, iodine, copper, zinc, manganese, cobalt, fluorine and chromium.
- Calcium is a component of bones and teeth and is involved in the muscle contraction and conduction of nerve impulse. Milk, ragi, green leafy vegetables and small dried fish provide calcium. The deficiency of calcium cause rickets and osteoporosis. Phosphorus is a constituent of bones and teeth, nucleic acids and co-enzymes and is available from milk, egg, meat, fish and leafy vegetables. Magnesium is involved in contraction of muscles and transmission of nerve impulse. Sodium and potassium maintain osmotic concentration of tissue fluid.
- Most of the microelements are the constituents of enzymes and are involved in cell metabolism. Deficiency of iron cause anaemia while that of iodine cause goitre. Deficiency of fluorine in drinking water causes dental caries, while its excess causes dental and skeletal fluorosis. Deficiency disorders of different types of minerals can be prevented by proper dietary intake.

8.7 GLOSSARY

- **Essential Mineral:** An essential mineral is one, which plays a direct role in the structure and functioning of the organism.
- **Rickets:** A deficiency disease of calcium which leads hyper irritability and tetany lending to death of sufferers.
- **Kwashiorkor:** A disease characterised by low serum magnesium and muscular wholeness.
- **One Way Element:** Termed for iron because it is reutirised from the breakdown of haemoglobin.
- **Simple Goitre:** A deficiency disease of iodine is marked by a swelling of the neck with the enlargement of thyroid gland.
- **Dental Fluorosis:** It is characterised by the loss of lustre of the enamel of teeth, yellow or brown irregular patch over the surface of teeth along with pitting or corroded appearance.

8.8 REVIEW QUESTIONS

I. Very Short Answer Type Questions

1. What are essential minerals?

NOTES

2. What are trace elements?
3. What are dietary sources of calcium?
4. Which mineral is present in maximum quantity in bones and teeth?
5. What is meant by dental caries? How is it caused?

II. Short Answer Type Questions

1. Differentiate between
   (*i*) Macro-mineral and micro-minerals.
   (*ii*) Osteoporosis and skeletal fluorosis.
2. Give the general functions of minerals.
3. Write the physiological functions of
   (*i*) Calcium (*ii*) Phosphorous
   (*iii*) Sodium (*iv*) Iron
4. Discuss the deficiency disorder of
   (*i*) Calcium (*ii*) Iodine
   (*iii*) Iron (*iv*) Magnesium

III. Long Answer Type Questions

1. What are the source of iron to the body? Why iron is called a one way element?
2. What are dietary sources of calcium? What are the functions of calcium in the body?
3. Give an account of functions of trace elements and their deficiency disorders.

8.9 FURTHER READINGS

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UNIT–V

CHAPTER 9 GOVERNMENT PROGRAMMES FOR NUTRIENT DEFICIENCY DISEASES

OBJECTIVES

After going through this chapter, you should be able to:

- explain government aided programmes
- define iodine deficiency disorders
- define NPAG
- describe the mid-day meal scheme
- explain national programme for nutrition support to primary education
- know about Naandi foundation mid-day meal programme.

STRUCTURE

9.1 INTRODUCTION

There are more than 50 known nutrients in food. Nutrients enable body tissues to grow and maintain themselves. They contribute to the energy requirements of the individual organism and they regulate the process of the body. Nutrient deficiency diseases occur when there is an absence of nutrients which are essential for growth and health.

Lack of food leading to either malnutrition or starvation gives rise to deficiency diseases. Other cause for a deficiency disease may be due to a structural or biological imbalance in the individual's metabolic system.

NOTES

9.2 GOVERNMENT AIDED PROGRAMMES

Government aided schemes and programmes are nut by the central government for the health and welfare of the citizens. The people of the country are one of its most valuable resources. These programmes are aimed at increasing the standard of health of the people and decreasing the incidence of disease and death due to illness. The government aided schemes include immunization drives special steps to deal with epidemics, programmes for elimination of dangerous diseases, and numerous education and training programmes.

According to the Indian Constitution, the subject of 'health' comes under the purview of state governments, this means that the state governments are responsible for maintaining and bettering the health of the people who live under its jurisdiction. The main policy, frames work and support is enumerated by the centre, while the states devise their models of accomplishing the central government's health related goals.

9.3 IODINE DEFICIENCY DISORDERS

Iodine Deficiency Disorders or IDD is the most common cause of preventable brain damage and mental retardation in the world. It is also known to cause goitre, decrease child survival and weaken growth and development. In pregnant women, a lack of iodine usually causes stillbirths, miscarriages and other complications. Children with Iodine Deficiency Disorders may grow up into listless, stunted, mentally retarded individuals who are incapable of normal movements, speech or hearing.

A teaspoon of iodine is all a person requires during his or her lifetime. However, the thyroid gland does not have the capacity to amass this amount, so small amounts of iodine must be eaten regularly through a balanced diet overtime.

Prevention

Even though Iodine Deficiency Disorders cannot be cured, they can be easily prevented. This is done through the consumption of foods rich in iodine such as:

- Iodized or iodated salt
- Seafood and Seaweed
- Eggs, Meat and Dairy Products

- Cereals and Green Leafy Vegetables (depending on the amount of iodine present in the soil they were grown in)
- Iodine Supplements (usually recommended for pregnant women)

9.4 GOVERNMENT PROGRAMME TO DEAL WITH IODINE DEFICIENCY DISORDERS

Iodine Deficiency Disorders or IDD is the single most common cause of preventable mental retardation and brain damage in the world. It also decreases child survival, causes goitre and impairs growth and development.

The Government of India launched the **National Goitre Control Programme (NGCP)** in 1962 to combat this problem. The major objectives of this programme included conduction of surveys to assess the magnitude of Iodine Deficiency Disorders and the provision of iodated salt in place of common salt.

In 1992, the NGCP was renamed as the **National Iodine Deficiency Disorders Control Programme (NIDDCP).** On the recommendations of Central Council of Health in 1984, the Government took a policy decision to add iodine to edible salt in the country. The government also runs extensive educational and training programmes to make people aware of Iodine Deficiency Disorders and their prevention.

Pilot Project Against Micronutrient Malnutrition

Micronutrient malnutrition is a global public health problem. There is problem of iodine, iron, zinc, and fluorine deficiency leading to many clinical manifestations in the population. The pilot project programme against micronutrient malnutrition is being started, in the year 1995 in Assam along with four other states—Bihar, Orissa, West Bengal and Gujarat. This project has been merged with National Iodine Deficiency Disorder Control Programme (NIDDCP).

Objectives

- To access the magnitude of fluorosis and dental caries beside assessing the iron and vitamin A deficiency in the project area;
- To assess and improve iron and vitamin A status in school going children, adolescent, boys and girls, non-pregnant women, adult males and geriatric population;
- To launch extensive information, education and communication strategy through mass media to improve the dietary habits of the populations; and
- To study zinc level in various food products and soil.
- To coordinate with similar ongoing programme being implemented in the country.

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9.5 VITAMIN A SUPPLEMENTATION PROGRAMME

Vitamin A Deficiency (VAD) is only seen amongst the young children in underprivileged communities in India. The risk of deficiency is high in these children because their requirements are relatively move due to increased physical growth and intake is lone. Also, the episodes of illness such as diarrhoea, acute respiratory tract infection and measles, are common in this age group, which deplete vitamin A (V A) from the body.

A vitamin A supplementation programme has been in operation in India since 1970. Under this programme, which is sponsored by the **Ministry of Health and Family Welfare** (MHFW), children between nine months to three years are given six monthly doses of vitamin A. The administration of the first two doses is linked with routine immunisation. Although the supplementation programme was started as a short-term measure to prevent blindness in children, it has been going on for the last three decades and its continuation has become a subject of national debate. The recent reports of child deaths after the administration of vitamin A during a mass campaign in Assam triggered a fresh controversy over the programme. The controversy is not confined to the campaign-type approach to vitamin A distribution. Also in question is the very existence of Vitamin A Deficiency (VAD) as a public health problem in India and the need for supplementation. Such debates often confuse the policymakers and cause setbacks to the ongoing programme, the implementation of which is already behind schedule.

9.6 NUTRITION PROGRAMME FOR ADOLESCENT GIRLS (NPAG)

To address the problem of undernutrition among adolescent girls and pregnant women and lactating mothers, the Planning Commission, in the year 2002–03, launched the Nutrition Programme for Adolescent Girls (NPAG), on a Pilot Project basis in 51 districts in the country. Under this scheme, 6 kg of foodgrains were given to under nourished adolescent girls, pregnant women and lactating mothers. Eligibility was determined on the basis of their weight. The Pilot Project was continued in the year 2003–04 also. It however, could not be continued in the year 2004–05. The Government approved the implementation of NPAG, through the Department of Women and Child Development, in 51 backward districts identified by the Planning Commission in the year 2005–06 to provide 6 kg of free foodgrains to undernourished adolescent girls only (pregnant women and lactating mothers are not covered as these are targeted under Integrated Child Development

Services ICDS). The scheme is being continued for the Annual Plan 2006–07 on pilot project basis.

The funds are given as 100% grant to States/UTs so that they can provide foodgrains through the Public Distribution System free of cost to the families of identified undernourished persons. The success of the intervention is dependent on effective linkages with the Public Distribution System (PDS).

Target Group

Adolescent girls (11–19 years) (weight < 35 Kg).

Services

(*i*) 6 kg of free foodgrains (wheat/rice/maize based on habitual consumption pattern of the state) per month per beneficiary.

(*ii*) Nutrition and Health Education to the beneficiaries and their families.

9.7 MID-DAY MEAL SCHEME

Mid-day Meal Scheme is the popular name for school meal programme in India. It involves provision of lunch free of cost to school-children on all working days. The key objectives of the programme are: protecting children from classroom hunger, increasing school enrollment and attendance, improved socialisation among children belonging to all castes, addressing malnutrition, and social empowerment through provision of employment to women. The scheme has a long history especially in Tamil Nadu and Gujarat, and has been expanded to all parts of India after a landmark direction by the Supreme Court of India on November 28, 2001. The success of this scheme is illustrated by the tremendous increase in the school participation and completion rates in the state of Tamil Nadu.

12 crore (120 million) children are so far covered under the Mid-day Meal Scheme, which is the largest school lunch programme in the world. Allocation for this programme has been enhanced from Rs. 3010 crore to Rs. 4813 crore (Rs. 48 billion, 1.2 billion) in 2006–2007.

One of the pioneers of the scheme is the Madras Presidency that started providing cooked meals to children in corporation schools in the Madras city in 1923. The programme was introduced in a large scale in 1960s under the Chief Ministership of K. Kamaraj. However, the first major thrust came in 1982 when the then Chief Minister of Tamil Nadu, Dr. M. G. Ramachandran, decided to universalise the scheme for all children in government schools in primary classes. Later the programme was expanded to cover all children up to class

STUDENT ACTIVITY

1. What is 'mid-day meal scheme'?

2. What are the main symptoms of iodine deficiency disorder?

10. Tamil Nadu's mid-day meal programme is among the best known in the country.

Kerala has computerized the Mid-day Meal Scheme in schools. All the dealings are made online and the accounting become accurate.

Several other states of India also have had mid-day meal programmes. The most notable among them is Gujarat that has had it since the late 1980s. Kerala started providing cooked meals in schools since 1995 and so did Madhya Pradesh and Orissa in small pockets. On November 28, 2001 the Supreme Court of India gave a landmark direction, which made it obligatory for the government to provide cooked meals to all children in all government and government assisted primary schools. The direction was resisted vigorously by state governments initially, but the programme has become almost universal by 2005.

9.8 NATIONAL PROGRAMME FOR NUTRITION SUPPORT TO PRIMARY EDUCATION

Although the programme in Tamil Nadu was initially termed as an act of "Populism", the success of the scheme made the project hugely popular. The success was so spectacular that in 1995, the then Indian Finance minister Manmohan Singh hailed the success of the project and suggested that the scheme be implemented all over the country, and thus began the "National Programme for Nutrition Support to Primary Education".

According to the programme the Government of India will provide grains free of cost and the States will provide the costs of other ingredients, salaries and infrastructure. Since most state governments were unwilling to commit budgetary resources they just passed on the grains from Government of India to the parents. This system was called provision of 'dry rations'. On November 28, 2001 the Supreme Court of India gave a famous direction that made it mandatory for the state governments to provide cooked meals instead of 'dry rations'. The direction was to be implemented from June 2002, but was violated by most states. But with sustained pressure from the court, media and in particular from the Right to Food Campaign more and more states started providing cooked meals.

In May 2004 a new coalition government was formed in the centre, which promised universal provision of cooked meals fully funded by the centre. This promise in its Common Minimum Programme was followed by enhanced financial support to the states for cooking and building sufficient infrastructure. Given this additional support the scheme has expanded its reach to cover most children in primary schools in India. In 2005 it is expected to cover 130 million children.

NOTES

The Supreme Court Direction: In April 2001 People's Union for Civil Liberties (Rajasthan) initiated the now famous right to food litigation. This public interest litigation has covered a large range of issues relating to right to food, but the best known intervention by the court is on mid-day meals. In one of its many direction in the litigation the Supreme Court directed the government to fully implement its scheme of providing cooked meals to all children in primary schools. This landmark direction converted the mid-day meal scheme into a legal entitlement, the violation of which can be taken up in the court of law. The direction and further follow-up by the Supreme Court has been a major instrument in universalising the scheme.

9.9 AKSHAYA PATRA AND PRIVATE SECTOR PARTICIPATION IN MID-DAY MEALS

The State of Karnataka introduced the provision of cooked meals in June 2002. Since then it has successfully involved private sector participation in the programme. One of the successful of the ventures is Akshaya Patra, which started with leadership from both ISKCON and secular leaders in the Bangalore community. The programme, now 100% secular, is an independent organization that cooks and distributes lunch to children in Bangalore Municipal Corporation schools. The Foundation gets a corpus from the State government but meets a major share of its costs with donations from private corporations and individuals in the city.

The programme is managed with an ultra modern centralised kitchen that is run through a public/private partnership. Food is delivered to schools in sealed and heat retaining containers just before the lunch break everyday. The programme contains one of the best menus in school meal programmes in India with tasty sambar, rice, vegetables and some curd on most days.

Since the success of this programme private sector participation in mid-day meals has increased considerably. Software corporations such as Infosys, Bharti and Jindal are major donors to the programme. This model has been successfully replicated in rural Karnataka, Delhi, Hyderabad and other cities.

The foundation is now serving mid-day meals to almost a million children everyday and hopes to feed over 20 million children by 2020.

9.10 NAANDI FOUNDATION MID-DAY MEAL PROGRAMME

Naandi Foundation, is one of the largest and fastest growing social sector organisations in India working to make poverty history. In its effort to eradicate poverty it has been working in the fields of Child rights, Education, Sustainable livelihoods, Mid-day meal and Safe Drinking water since last decade.

To fulfill the motto towards eradicating poverty, Naandi took its first step towards banishing hunger through its Mid-day meal programme. In partnership with state governments and through corporate donations Naandi runs several automated central Mid-day Meal Kitchens across the country. These kitchens prepare and deliver high-nutrition noon meals to lakhs of underprivileged children everyday. Naandi even delivers Mid-day meal in many tribal areas across its project areas in 4 states which includes Andhra Pradesh, Rajasthan, Madhya Pradesh and Orissa. With a highly sophisticated centralised kitchen Naandi delivers food to nearly 8 lakhs children (will touch a million soon) in every working days. The Mid-day Meal menu is decided in consultation with nutritionists from the National Institute of Nutrition. Feedback and suggestions from respective government school teachers are taken into consideration for further improvement. For locations such as Hyderabad, Naandi uses Global Positioning System (GPS), where they identified and mapped all the schools to determine the optimum way to transport food .

Naandi in partnership with the Government of Rajasthan (GoR) started the Hunger-free programme on 1 May 2006 by providing cooked meals to the poorest of the poor at a very nominal price apart from its Mid-day meal programme.

Other aspects of the programme : The programme in Gujarat also includes regular provision of iron tablets (to counter anaemia) and deworming tablets once in six months. In Tamil Nadu also the children are dewormed at regular intervals.

9.11 SUMMARY

- Government aided schemes and programmes are nut by the central government for the health and welfare of the citizens. The people of the country are one of its most valuable resources. These programmes are aimed at increasing the standard of health of the people and decreasing the incidence of disease and death due to illness.
- The pilot-project programme against micronutrient malnutrition is being started in the year 1995 in Assam along with four other states—Bihar, Orissa, West Bengal and Gujarat.
- **Mid-day Meal Scheme** is the popular name for school meal programme in India.
- Naandi Foundation, is one of the largest and fastest growing social sector organisations in India working to make poverty

history. In its effort to eradicate poverty it has been working in the fields of Child rights, Education, Sustainable livelihoods, Mid-day meal and Safe Drinking water since last decade.

9.12 GLOSSARY

- **Nutrient Deficiency Diseases:** It occurs when there is an absence of nutrients which are essential for growth and health.
- **Iodine Deficiency Disorders:** It is the most common cause of preventable brain damage and mental retardation in the world.
- **Mid-Day Meal Scheme:** It is the popular name for school meal programme in India.
- **Naandi Foundation:** It is one of the largest and fastest growing social sector organisations in India working to make poverty history.

9.13 REVIEW QUESTIONS

I. Very Short Answer Type Questions

1. Expand the following
   (*i*) IDD (*ii*) NGCP (*iii*) VAD (*iv*) NPAG
2. What is the single most common cause of preventable mental retardation and brain damage in the world?
3. In India, children of which type of communities generally exhibit vitamin A deficiency?
4. What is the target group for NPAG?

II. Short Answer Type Questions

1. What measures can be taken to prevent iodine deficiency disorder?
2. What is the Government programme to deal with iodine deficiency disorder?
3. Write a note on:
   (*i*) Vitamin A supplemention Programme.
   (*ii*) Nutrition programme for adolescent girls.
   (*iii*) Pilot Project against micronutrient malnutrition.

III. Long Answer Type Questions

1. What is mid-day meal scheme? Describe national programme for nutrition support to primary education?

2. Write an essay on mid-day meal programmes being run in India?

9.14 FURTHER READINGS

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(కత్తిరించి పంపవలెను)

అధ్యాపకుల, విద్యార్థుల సలహాలు, సూచనలు :

అధ్యాపకులు, విద్యార్థులు ఈ స్టడీ మెటీరియల్‌కు సంబంధించిన సలహాలు, సూచనలు, ముద్రణ దోషాలు తెలియపరచినచో, పునర్ముద్రణలో తగు చర్యలు తీసుకొనగలము. తెలియపరచవలసిన చిరునామా : **డిప్యూటీ డైరెక్టర్, దూరవిద్యా కేంద్రం, ఆచార్య నాగార్జున విశ్వవిద్యాలయం, నాగార్జున నగర్ - 522 510.**

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