International Standard Colored Edition

Based on **INC 2021-22**

II Semester

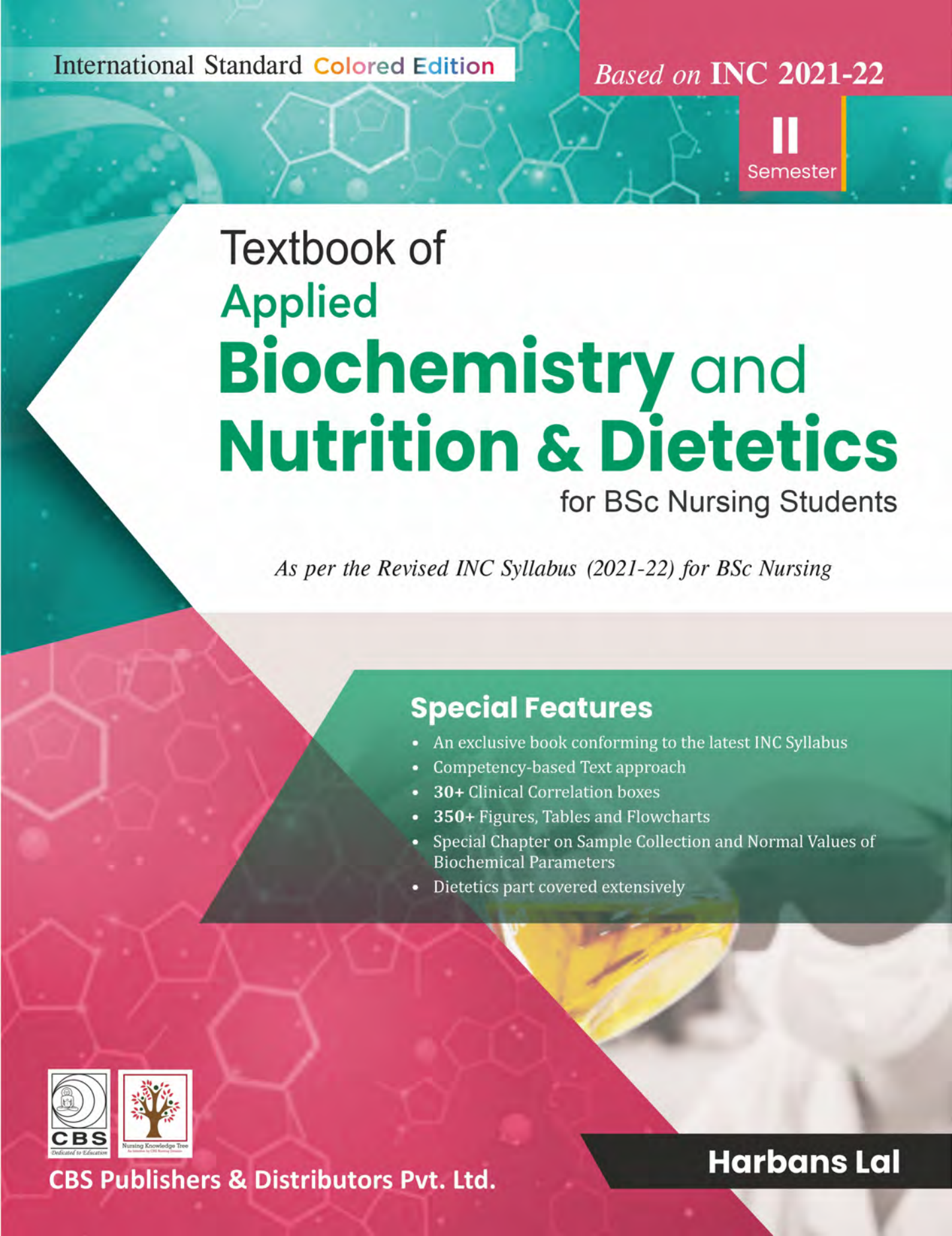
Textbook of Applied Biochemistry and Nutrition & Dietetics

for BSc Nursing Students

As per the Revised INC Syllabus (2021-22) for BSc Nursing

Special Features

- An exclusive book conforming to the latest INC Syllabus
- Competency-based Text approach
- **30+** Clinical Correlation boxes
- **350+** Figures, Tables and Flowcharts
- Special Chapter on Sample Collection and Normal Values of Biochemical Parameters
- Dietetics part covered extensively



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Harbans Lal

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Preface

A lot of encouragement and support of the faculty members and the students of several Nursing Colleges to my titles "Essentials of Biochemistry for BSc Nursing Students" and "Food & Nutrition", inspired me to present this book entitled **Textbook of Applied Biochemistry and Nutrition & Dietetics for BSc Nursing Students**. The book has been prepared as per **competencies-based new syllabus** prescribed by the **Indian Nursing Council**.

A major goal of this book is to provide the basic idea of applied biochemistry as well as applied nutrition and dietetics to the BSc Nursing students in a concise and interesting manner.

All the chapters have been thoroughly revised and updated, and the text in each chapter has been supplemented with suitable tables, outlined flowcharts and figures. Some important questions have also been included at the end of each chapter under the Assess Yourself segment.

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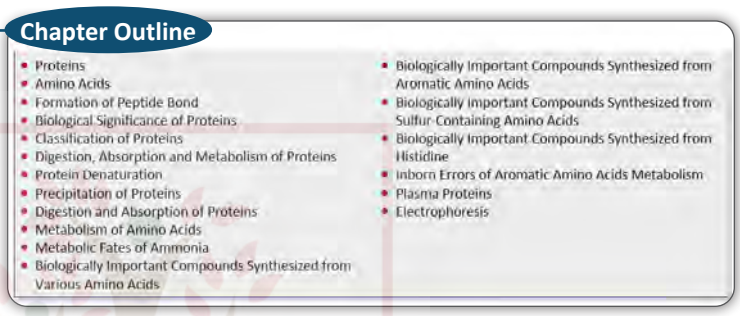
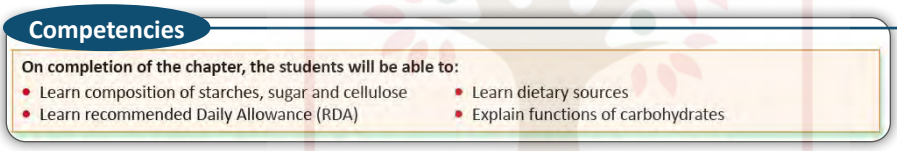
Special Features of the Book

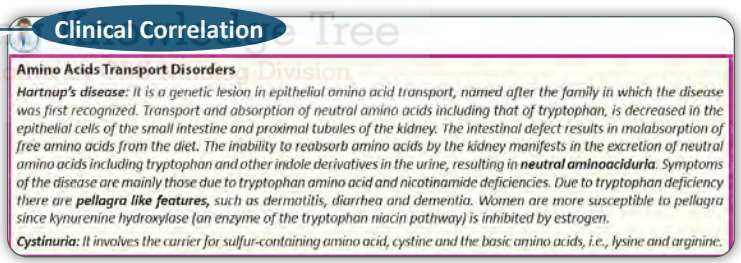
Every chapter starts with a **chapter outline** that gives a glimpse of the content covered in the chapter



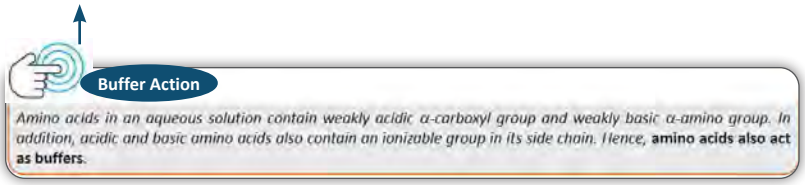
Every chapter contains an **competencies** to give a brief view of the contents covered in it.



Clinical correlation boxes are used to highlight the important facts in the chapters wherever required.



Key point boxes are used to highlight the important facts in the chapters wherever required.



Numerous **tables** have been used in the chapters to facilitate learning in a quick way.

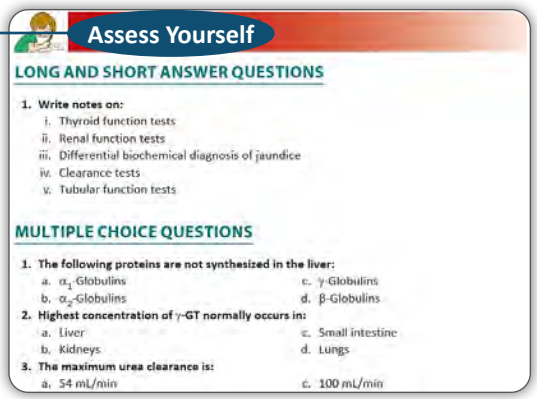
Table 8.1: Essential nutrients and approximate percentage of daily calories intake, their functions and sources for a healthy balanced diet

Nutrients	% of daily calories intake	Functions	Sources
Carbohydrates	50–70%	Provide energy	Grains (both, refined and unrefined) such as wheat, maize, corn, millet, oats, rice, flour, pasta, noodles; potatoes; sweet potatoes, and fruits
Protein	10–15%	Tissue growth and maintenance	Meat, fish, nuts, eggs, beans and pulses
Fat	20–30%	Energy, essential fatty acids, fat soluble vitamins	Nuts, oilseeds, vegetable oils, dairy products (milk, cheese, etc.)
Fiber	40-50 g	Regulates blood sugar levels and bowel health	Peas, beans, vegetables, fruits, whole grain cereals
Vitamins and minerals		Regulation of metabolism and other biochemical functions	Specific to each vitamin/mineral. Fruits and vegetables, lean meat, nuts and whole grain cereals
Water		For maintaining hydration and regulation of body temperature	Drinking water and beverages. About 20% of water intake comes from food

Fig. 10.4: Health problems associated with obesity

The book is well illustrated with relevant **figures**, **tables**, etc.

At the end of chapters, **Assess yourself** section is given which contains frequently asked questions in exams and multiple choice questions to help you attain mastery over the subject.



Assess Yourself

LONG AND SHORT ANSWER QUESTIONS

1. **Write notes on:**
   - i. Thyroid function tests
   - ii. Renal function tests
   - iii. Differential biochemical diagnosis of jaundice
   - iv. Clearance tests
   - v. Tubular function tests

MULTIPLE CHOICE QUESTIONS

1. **The following proteins are not synthesized in the liver:**
   - a. α_1-Globulins
   - b. α_2-Globulins
   - c. γ-Globulins
   - d. β-Globulins
2. **Highest concentration of γ-GT normally occurs in:**
   - a. Liver
   - b. Kidneys
   - c. Small intestine
   - d. Lungs
3. **The maximum urea clearance is:**
   - a. 54 mL/min
   - c. 100 mL/min

Syllabus

Placement: II Year **Time:** Theory 40 Hours

Applied Biochemistry

Description: The course is designed to assist the students to acquire knowledge of the normal biochemical composition and functioning of human body, its alterations in disease conditions and to apply this knowledge in the practice of nursing.

Unit	Time (Hrs)	Learning outcomes	Content	Teaching/learning activities	Assessment methods
I	8 (T)	Describe the metabolism of carbohydrates and its alterations	**Carbohydrates** • Digestion, absorption and metabolism of carbohydrates and related disorders • Regulation of blood glucose • Diabetes Mellitus—type 1 and type 2, symptoms, complications and management in brief • Investigations of diabetes mellitus ▪ OGTT—Indications, procedure, interpretation and types of GTT curve ▪ Mini GTT, extended GTT, GCT, IV GTT ▪ HbA1c (Only definition) • Hypoglycemia—Definition and causes	• Lecture cum discussion • Explain using charts and slides • Demonstration of laboratory tests	• Essay • Short answer • Very short answer
II	8 (T)	Explain the metabolism of lipids and its alterations	**Lipids** • Fatty acids—Definition, classification • Definition and clinical significance of MUFA and PUFA, essential fatty acids, trans fatty acids • Digestion, absorption and metabolism of lipids and related disorders • Compounds formed from cholesterol • Ketone bodies (name, types and significance only) • Lipoproteins—types and functions (metabolism not required) • Lipid profile • Atherosclerosis (in brief)	• Lecture cum discussion • Explain using charts and slides • Demonstration of laboratory tests	• Essay • Short answer • Very short answer

Contd...

Unit	Time (Hrs)	Learning outcomes	Content	Teaching/learning activities	Assessment methods
III	9 (T)	• Explain the metabolism of amino acids and proteins • Identify alterations in disease conditions	**Proteins** • Classification of amino acids based on nutrition, metabolic rate with examples • Digestion, absorption and metabolism of protein and related disorders • Biologically important compounds synthesized from various amino acids (only names) • Inborn errors of amino acid metabolism – only aromatic amino acids (in brief) • Plasma protein—types, function and normal values • Causes of proteinuria, hypoproteinemia, hypergammaglobinemia • Principle of electrophoresis, normal and abnormal electrophoretic patterns (in brief)	• Lecture cum discussion • Explain using charts, models and slides	• Essay • Short answer • Very short answer
IV	4 (T)	Explain clinical enzymology in various disease conditions	**Clinical Enzymology** • Isoenzymes—Definition and properties • Enzymes of diagnostic importance in ▪ Liver diseases—ALT, AST, ALP, GGT ▪ Myocardial infarction—CK, cardiac troponins, AST, LDH ▪ Muscle diseases—CK, aldolase ▪ Bone diseases—ALP ▪ Prostate cancer—PSA, ACP	• Lecture cum discussion • Explain using charts and slides	• Essay • Short answer • Very short answer
V	3 (T)	Explain acid base balance, imbalance and its clinical significance	**Acid Base Maintenance** • pH—definition, normal value • Regulation of blood pH—blood buffer, respiratory and renal • ABG—normal values • Acid base disorders—types, definition and causes	• Lecture cum discussion • Explain using charts and slides	• Short answer • Very short answer
VI	2 (T)	Describe the metabolism of hemoglobin and its clinical significance	**Heme Catabolism** • Heme degradation pathway • Jaundice—type, causes, urine and blood investigations (Van den Berg test)	• Lecture cum discussion • Explain using charts and slides	• Short answer • Very short answer
VII	3 (T)	Explain different function tests and interpret the findings	**Organ Function Tests (Biochemical Parameters and Normal Values Only)** • Renal • Liver • Thyroid	• Lecture cum discussion • Visit to lab • Explain using charts and slides	• Short answer • Very short answer
VIII	3 (T)	Illustrate the immunochemistry	**Immunochemistry** • Structure and functions of immunoglobulin • Investigations and interpretation – ELISA	• Lecture cum discussion • Explain using charts and slides • Demonstration of laboratory tests	• Short answer • Very short answer

Applied Nutrition and Dietetics

Placement: II Year

Time: Theory 45 Hours
Lab: 15 Hours

Description: The course is designed to assist the students to acquire basic knowledge and understanding of the principles of Nutrition and Dietetics and apply this knowledge in the practice of Nursing.

Unit	Time (Hrs)	Learning outcomes	Content	Teaching/learning activities	Assessment methods
I	2 (T)	Define nutrition and its relationship to health	**Introduction to Nutrition** ***Concepts*** • Definition of nutrition and health • Malnutrition—under nutrition and over nutrition • Role of nutrition in maintaining health • Factors affecting food and nutrition ***Nutrients*** • Classification • Macro and micronutrients • Organic and inorganic • Energy yielding and non-energy yielding ***Food*** • Classification—food groups • Origin	• Lecture cum discussion • Charts/slides	• Essay • Short answer • Very short answer
II	3 (T)	Describe the classification, functions, sources and recommended daily allowances (RDA) of carbohydrates	**Carbohydrates** • Composition—starches, sugar and cellulose • Recommended daily allowance (RDA) • Dietary sources • Functions	• Lecture cum discussion • Charts/slides • Models • Display of food items	• Essay • Short answer • Very short answer
		Explain BMR and factors affecting BMR	**Energy** • Unit of energy—Kcal • Basal metabolic rate (BMR) • Factors affecting BMR		
III	3 (T)	Describe the classification, functions, sources and RDA of proteins	**Proteins** • Composition • Eight essential amino acids • Functions • Dietary sources • Protein requirements—RDA	• Lecture cum discussion • Charts/slides • Models • Display of food items	• Essay • Short answer • Very short answer
IV	2 (T)	Describe the classification, functions, sources and RDA of fats	**Fats** • Classification—saturated and unsaturated • Calorie value • Functions • Dietary sources of fats and fatty acids • Fat requirements—RDA	• Lecture cum discussion • Charts/slides • Models • Display of food items	• Essay • Short answer • Very short answer

Contd...

Unit	Time (Hrs)	Learning outcomes	Content	Teaching/learning activities	Assessment methods
V	3 (T)	Describe the classification, functions, sources and RDA of vitamins	**Vitamins** • Classification—fat soluble and water soluble • Fat soluble—vitamins A, D, E, and K • Water soluble—thiamine (vitamin B1), riboflavin (vitamin B2), nicotinic acid, pyridoxine (vitamin B6), pantothenic acid, folic acid, vitamin B12, ascorbic acid (vitamin C) • Functions, dietary sources and requirements—RDA of every vitamin	• Lecture cum discussion • Charts/slides • Models • Display of food items	• Essay • Short answer • Very short answer
VI	3 (T)	Describe the classification, functions, sources and RDA of minerals	**Minerals** • Classification—major minerals (Calcium, phosphorus, sodium, potassium and magnesium) and trace elements • Functions • Dietary sources • Requirements—RDA	• Lecture cum discussion • Charts/slides • Models • Display of food items	• Short answer • Very short answer
VII	7 (T) 8 (L)	Describe and plan balanced diet for different age groups, pregnancy, and lactation	**Balanced Diet** • Definition, principles, steps • Food guides—basic four food groups • RDA—definition, limitations, uses • Food exchange system • Calculation of nutritive value of foods • Dietary fiber **Nutrition Across Life Cycle** • Meal planning/menu planning—definition, principles, steps • Infant and young child feeding (IYCF) guidelines—breastfeeding, infant foods • Diet plan for different age groups—children, adolescents and elderly • Diet in pregnancy—nutritional requirements and balanced diet plan • Anemia in pregnancy—diagnosis, diet for anemic pregnant women, iron and folic acid supplementation and counseling • Nutrition in lactation—nutritional requirements, diet for lactating mothers, complementary feeding/weaning	• Lecture cum discussion • Meal planning • Lab session on ▪ Preparation of balanced diet for different categories ▪ Low cost nutritious dishes	• Short answer • Very short answer

Contd...

Unit	Time (Hrs)	Learning outcomes	Content	Teaching/learning activities	Assessment methods
VIII	6 (T)	Classify and describe the common nutritional deficiency disorders and identify nurses' role in assessment, management and prevention	**Nutritional Deficiency Disorders** • Protein energy malnutrition—magnitude of the problem, causes, classification, signs and symptoms, severe acute malnutrition (SAM), management and prevention and nurses' role • Childhood obesity—signs and symptoms, assessment, management and prevention and nurses' role • Vitamin deficiency disorders—vitamin A, B, C and D deficiency disorders—causes, signs and symptoms, management and prevention and nurses' role • Mineral deficiency diseases—iron, iodine and calcium deficiencies—causes, signs and symptoms, management and prevention and nurses' role	• Lecture cum discussion • Charts/slides • Models	• Essay • Short answer • Very short answer
IX	4 (T) 7 (L)	Principles of diets in various diseases	**Therapeutic Diets** • Definition, objectives, principles • Modifications—consistency, nutrients • Feeding techniques • Diet in diseases—obesity, diabetes mellitus, CVD, underweight, renal diseases, hepatic disorders constipation, diarrhea, pre- and post-operative period	• Lecture cum discussion • Meal planning • Lab session on preparation of therapeutic diets	• Essay • Short answer • Very short answer
X	3 (T)	Describe the rules and preservation of nutrients	**Cookery Rules and Preservation of Nutrients** • Cooking—methods, advantages and disadvantages • Preservation of nutrients • Measures to prevent loss of nutrients during preparation • Safe food handling and storage of foods • Food preservation • Food additives and food adulteration • Prevention of Food Adulteration Act (PFA) • Food standards	• Lecture cum discussion • Charts/slides	• Essay • Short answer • Very short answer

Contd...

Unit	Time (Hrs)	Learning outcomes	Content	Teaching/learning activities	Assessment methods
XI	4 (T)	Explain the methods of nutritional assessment and nutrition education	**Nutrition Assessment and Nutrition Education** • Objectives of nutritional assessment • Methods of assessment—clinical examination, anthropometry, laboratory and biochemical assessment, assessment of dietary intake including food frequency questionnaire (FFQ) method • Nutrition education—purposes, principles and methods	• Lecture cum discussion • Demonstration • Writing nutritional assessment report	• Essay • Short answer • Evaluation of nutritional assessment report
XII	3 (T)	Describe nutritional problems in India and nutritional programs	**National Nutritional Programs and Role of Nurse** • Nutritional problems in India • National nutritional policy • National nutritional programs—Vitamin A supplementation, Anemia Mukt Bharat Program, Integrated Child Development Services (ICDS), Mid-day Meal Scheme (MDMS), National Iodine Deficiency Disorders Control Program (NIDDCP), Weekly Iron Folic Acid Supplementation (WIFS) and others as introduced • Role of nurse in every program	• Lecture cum discussion	• Essay • Short answer • Very short answer
XIII	2 (T)	• Discuss the importance of food hygiene and food safety • Explain the acts related to food safety	**Food Safety** • Definition, food safety considerations and measures • Food Safety Regulatory Measures in India—Relevant Acts • Five keys to safer food • Food storage, food handling and cooking • General principles of food storage of food items (E.g., milk, meat) • Role of food handlers in food borne diseases • Essential steps in safe cooking practices	• Guided reading on related acts	• Quiz • Short answer

Contents

Chapter 7

Heme Catabolism

Chapter Outline

- Hemoglobin
- Heme Degradation Pathway
- Bilirubin

Competencies

On completion of the chapter, the students will be able to:

- Describe the metabolism of hemoglobin and its clinical significance
- Describe bilirubin, its metabolism and the disorders

HEMOGLOBIN

Hemoglobin is a globular protein, which is present in high concentration in red blood cells. It binds oxygen in the lungs and transports it to different cells in the body. A molecule of hemoglobin consists of four heme groups along with the four polypeptide chains, which are synthesized separately and subsequently, bind to four heme groups.

HEME DEGRADATION PATHWAY

Red blood cells have limited lifespan of approximately 100–120 days. These senescent cells are recognized by their membrane changes, removed and engulfed by the reticuloendothelial system, at the extravascular site. Degradation of red blood cell occurs in spleen, bone marrow, liver and lymph glands.

Degradation of heme occurs mainly, in the liver. If degradation of red blood cells occurs in the tissues other than the liver, hemoglobin is transported to the liver by means of haptoglobulin.

After the aged red blood cells are recognized by macrophages, they are rapidly engulfed by the phagocytes and form phagosomes. They fuse with the primary lysosomes and form secondary lysosomes. Lysosomal cathepsin results in complete degradation of the cellular proteins, including globin of hemoglobin, to the constituent amino acids, which are utilized for general metabolic needs.

Heme is degraded in the reticuloendothelial cells, to a linear tetrapyrrole (biliverdin IXa), by the microsomal enzyme system, which is designated as **heme oxygenase.** This enzyme requires molecular oxygen and NADPH, and is induced by heme. Heme oxygenase catalyzes the cleavage of α-**methenyl bridge** which **is quantitatively converted to carbon monoxide** (CO) that is trapped by the hemoglobin and eventually exhaled.

Biliverdin is reduced to bilirubin by the enzyme biliverdin reductase (Fig. 7.1).

One gram of hemoglobin yields about 35 mg of bilirubin.

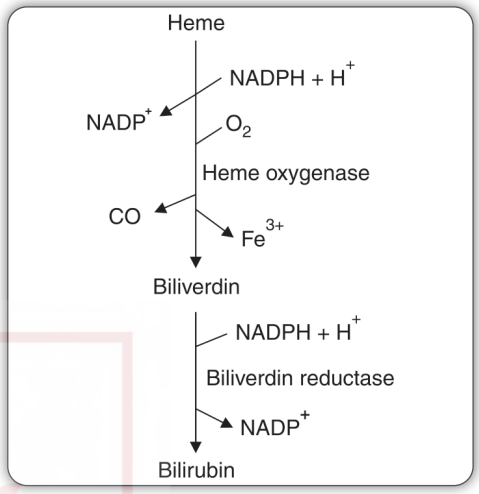


Fig. 7.1: Degradation of heme to bilirubin.

BILIRUBIN

Bilirubin is an orange-yellow pigment, derived from the breakdown of red blood cells in the liver, spleen and bone marrow. Its daily production, in men, averages from 250 mg to 300 mg. Approximately, 85% of this is derived from the heme moiety of hemoglobin, which is released from the erythrocytes that are destroyed in the reticuloendothelial cells while rest of it is formed from catabolism of other heme containing proteins, such as myoglobin, cytochromes and other heme containing enzymes.

Metabolism of Bilirubin

Bilirubin, normally present in the blood, is bound to albumin and is transported to the liver.

Hepatocytes trap bilirubin by means of a specific binding protein, called **ligandin. In the hepatocytes, bilirubin** gets **conjugated with UDP-glucuronate,** which is derived from the oxidation of UDP-glucose. **This reaction is catalyzed by UDP-glucuronyltransferase** (Fig. 7.2).

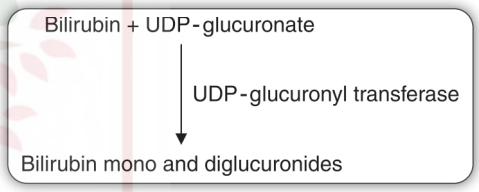


Fig. 7.2: Conversion of bilirubin to bilirubin-glucuronides.

Clinical Correlation

Thalassemias

Thalassemia is a family of related genetic disorders that arise due to the deletion of one or more globin-like genes in either the globin gene cluster or a defect in transcription, and/or processing of mRNA of the globin gene. If there is reduced synthesis or total lack of synthesis of α-globin mRNA, the disease is classified as α-thalassemia. On the other hand, if β-globin mRNA level is affected, it is called β-thalassemia.

One to four α-globin genes may be missing in the patients with α-Thalassemia. If one α-globin gene is missing, the condition is called α-thalassemia 1 (α-thal 1). When two α-globin genes are missing, it is called α-thal 2. Both the conditions are associated with mild to moderate anemia. On the other hand, if three α-globin genes are missing it results in the synthesis of more β-globin molecules, forming a tetramer containing four β-globin sub-units. This condition is called HbH disease. When all the four α-globin genes are absent, it results in a fatal condition called hydrops fetalis.

β-thalassemias also exhibit different degrees of severity and can be caused by a variety of defects or deletions.

In the normal bile, bilirubin diglucuronide is the major form of excreted bilirubin with only a small amount of the bilirubin monoglucuronide. As bilirubin diglucuronide is much more water soluble than free bilirubin, transferase thus facilitates the excretion of bilirubin, via bile duct, into the intestine.

Enterohepatic Circulation

As **bilirubin diglucuronide** is poorly absorbed by the intestinal mucosa, glucuronide residues are **released in the terminal ileum and large intestine, by intestinal β-glucuronidases and by the enzymes produced by anaerobic bacteria. It is reduced to** colorless linear tetrapyrroles, called stercobilinogen, mesobilinogen and urobilinogen. These compounds are collectively referred to as urobilinogens.

A large portion of **urobilinogens are excreted in the feces.**

Majority of these re-circulating pigments are taken up by the liver and re-excreted in the bile. Some of the urobilinogens (only up to 2%) are also reabsorbed passively from the colon and return to the liver via the portal venous blood. This is referred to as **enterohepatic circulation of urobilinogen** (Fig. 7.3).

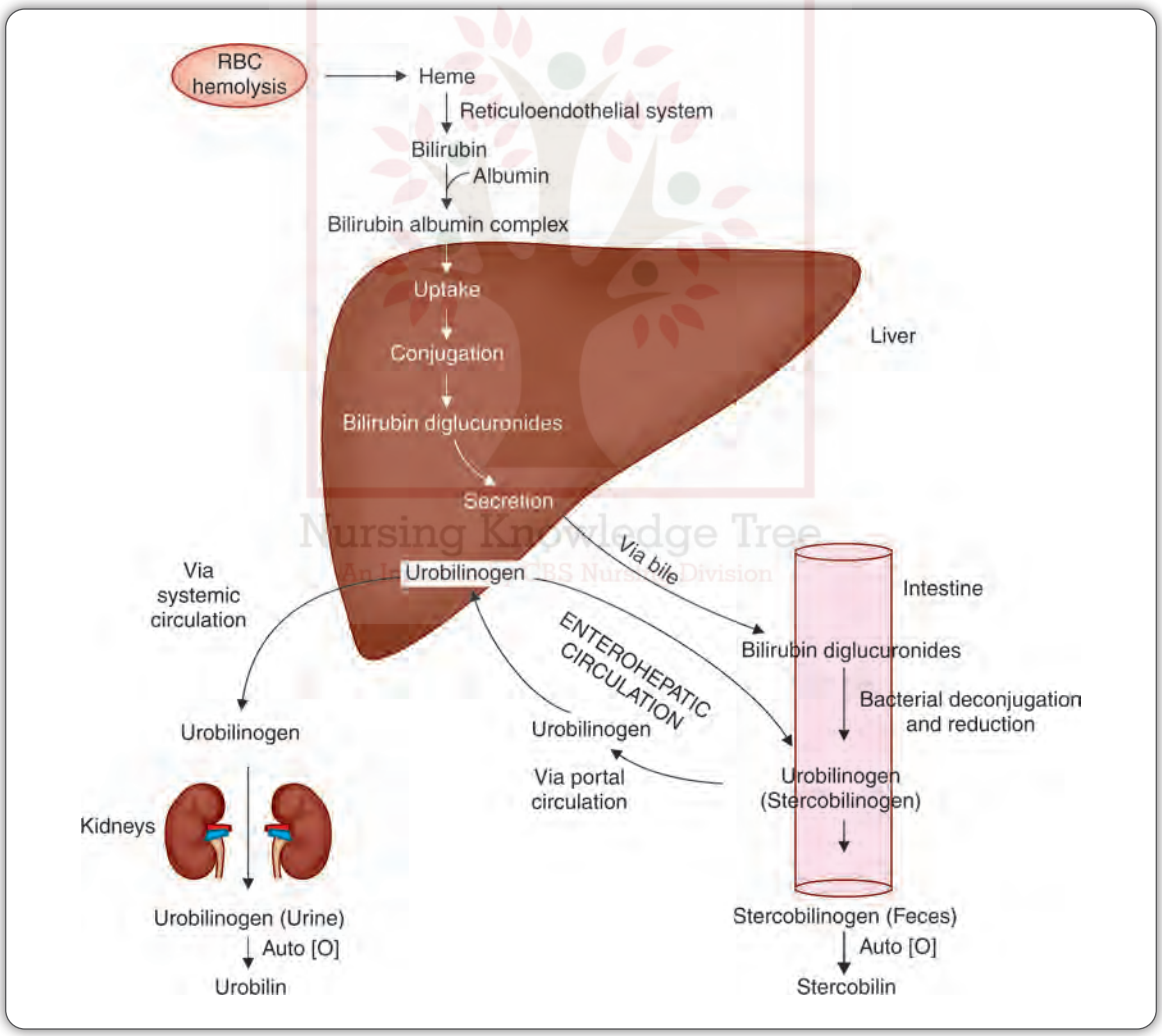


Fig. 7.3: Formation, conjugation and enterohepatic circulation of bilirubin.

Most of the reabsorbed urobilinogen is taken up by the liver and is re-excreted in the bile. **A small portion of urobilinogen (2–5%),** however, escapes hepatic extraction, **reaches the peripheral circulation and is excreted in the urine**.

Serum thus contains two different forms of bilirubin, which are referred to as:

- **Unconjugated** (lipid soluble) form that is bound to albumin and is transported from the reticuloendothelial system to the liver, and
- **Conjugated** (water soluble) form that is regurgitated from the liver into the plasma

Normal value, for the sum of the unconjugated and conjugated forms, is 0.1–1.0 mg/100 mL of serum or plasma.

Normally, almost all the bilirubin in plasma is unconjugated.

Disorders of Bilirubin Metabolism

Disorders of bilirubin metabolism lead to **hyperbilirubinemia** where serial measurement of bilirubin is helpful in knowing the severity of a liver disease.

Bilirubin fractionation is also helpful in differential diagnosis of **jaundice**.

Jaundice

Jaundice is a physical sign characterized by yellow appearance of the patient and is the most characteristic clinical manifestation of hyperbilirubinemia. It results from the deposition of bilirubin (bile pigment) in the skin, mucous membrane and sclera of the patient (Fig. 7.4).

Jaundice is apparent clinically, when serum bilirubin level is more than 2 mg/dL. If serum bilirubin is below 2 mg/dL, it is called **latent jaundice** (subclinical jaundice) since it is not detectable at this stage, clinically.

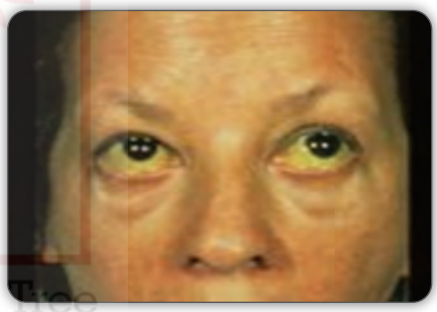


Fig. 7.4: Clinical manifestation of hyperbilirubinemia (Jaundice).

Types and Causes of Jaundice

There are three types of jaundice, referred to as pre-hepatic, hepatic and post-hepatic jaundice.

1. **Pre-hepatic jaundice:** Pre-hepatic jaundice is also called **hemolytic jaundice**. It is characterized by the excessive presence of **unconjugated bilirubin**. It may be a result of increased production of unconjugated bilirubin such as in hemolysis, decreased uptake of unconjugated bilirubin across the hepatocyte membrane as in Gilbert's syndrome, or decreased biotransformation such as in neonatal jaundice, Crigler-Najjar syndrome, etc.
   - **Hemolysis:** In disorders associated with hemolysis (hemolytic anemia), rate of bilirubin production is increased, which may exceed the amount that cannot be removed by the liver.
   - **Gilbert's syndrome:** This is a heterogeneous group of disorders inherited as autosomal recessive trait. Several defects include deficiency of the enzyme bilirubin-glucuronyl transferase, a defect in hepatic uptake of bilirubin, or a decrease in red cell survival.
   - **Neonatal jaundice:** Neonatal jaundice is also called physiological jaundice of the newborn. Every infant exhibits some transient unconjugated hyperbilirubinemia (about 5 mg/dL) between the second and the fifth day of life, as at this stage hepatic glucuronyltransferase activity is not

fully developed. Activity of the enzyme increases within 2 weeks after birth when serum bilirubin returns to normal. Neonatal jaundice is more pronounced in a premature infant.

> Unconjugated bilirubin levels above 18 mg/dL lead to deposition of bilirubin in the lipid-rich basal ganglia. This is referred to as **kernicterus**.

- **Crigler-Najjar syndrome:** This disorder is known to exist in two forms:
  Type I: It is clinically more severe form of the disease. It is due to complete absence of glucuronyltransferase.
  Type II: It has moderate clinical findings and is due to partial deficiency of the enzyme. In both the conditions, unconjugated bilirubin is significantly raised.

2. **Hepatic jaundice:** Plasma, usually, shows elevated levels of **both conjugated as well as unconjugated bilirubin**.
   - **Some primary diseases**: Hepatic jaundice is due to a primary disease, e.g., in **viral hepatitis**, **liver cirrhosis**, etc. In these conditions, there is also an increase in ALT and AST levels.
   - **Dubin-Johnson syndrome:** Elevated levels of conjugated as well as unconjugated bilirubin along with the dark-brown pigmentation, in the liver cells, are also observed in a benign, autosomal recessive condition known as Dubin-Johnson syndrome.
   - **Liver injury due to some chemicals:** Inhalation, ingestion or parenteral **administrations of** several **pharmacological** and **chemical agents**, such as **carbon tetrachloride**, **acetaminophen**, **isoniazid** or **chlorpromazine**, which result in **liver injury**, also lead to hepatic jaundice.
3. **Post-hepatic jaundice:** Post-hepatic jaundice is also referred to as **obstructive jaundice** or **post-hepatic cholestasis**. It is caused by obstruction of the bile duct, may be due to gallstones, carcinoma of the head of pancreas or carcinoma of the bile duct. Serum of such a patient shows excessive amount of conjugated bilirubin. It is also characterized by the presence of the excessive amount of bilirubin (bile pigment) in the urine.

Blood and Urine Investigations for Jaundice

Blood Investigations

- **Serum Bilirubin:** It refers to the estimation of the levels of total bilirubin, direct bilirubin and indirect bilirubin.
  - **Indirect bilirubin** refers to the bilirubin formed by the breakdown of red blood cells which travels from the blood to the liver. It is the **lipid soluble** form and is bound to albumin. It is also referred to as **unconjugated bilirubin**. Majority of the bilirubin in plasma is unconjugated. Its serum level is increased in conditions associated with pre-hepatic jaundice.
  - **Direct bilirubin** refers to the bilirubin which undergoes chemical change (conjugation) in the liver. It is the **water soluble** form which has been regurgitated from the liver into the plasma. It moves to the intestine and is then removed through stools. Its serum level is increased in conditions associated with post-hepatic jaundice.
  - Serum levels of both, i.e., unconjugated as well as conjugated bilirubins are increased in conditions associated with hepatic jaundice.
- **Serum enzymes and proteins:** If elevated levels of bilirubin are found, various liver function tests can be performed to determine the underlying cause of jaundice, by estimating serum **ALT**, **AST** and **ALP**,

and **albumin** and **total proteins**. None of these parameters are altered in pre-hepatic jaundice. Serum ALT and AST levels are increased while serum albumin and total protein concentrations are decreased in conditions associated with hepatic jaundice. On the other hand, serum ALP levels are significantly increased in post-hepatic jaundice.

Urine Investigations

- **Bilirubin: Unconjugated bilirubin** is hydrophobic and, therefore, **cannot be excreted in urine**. Conversely, **conjugated bilirubin** is hydrophilic and, thus, can be **excreted in the urine**, i.e., as bile pigment. Presence of bilirubin in urine indicates liver dysfunction.
- **Urobilinogen:** Normally, 0.5–4.0 mg of urobilinogen is excreted in the urine in 24 hours. Increased excretion of urobilinogen occurs when hepatocellular function is impaired. Urobilinogen may also increase in the urine if there is an excess of urobilinogen in the gastrointestinal tract that exceeds the capacity of the liver to re-excrete it, e.g., in hemolysis, viral hepatitis and cirrhosis. In contrast, when biliary excretion of bilirubin is impaired, e.g., in cholestasis, urinary excretion of urobilinogen is decreased due to limited delivery of bilirubin to the gut and due to low rate of urobilinogen production. This also results in clay-colored or chalky white, stool of patients with cholestatic jaundice.

Blood and urine investigations for biochemical differentiation of the three types of jaundice are shown in Table 7.1.

TABLE 7.1: Blood and urine investigations for biochemical differentiation of the three types of jaundice

Investigation	Pre-hepatic jaundice	Hepatic jaundice	Post-hepatic jaundice
Total serum bilirubin	Normal/increased	Increased	Increased
Conjugated bilirubin	Normal	Increased	Increased
Unconjugated bilirubin	Normal/increased	Increased	Normal
Urine Urobilinogen	Normal/increased	Decreased	Decreased/negative
Urine color	Normal	Dark (urobilinogen, conjugated bilirubin)	Dark (conjugated bilirubin)
Stool color	Brown	Slightly pale	Pale, white
Alkaline phosphatase level	Normal	Increased	Highly Increased
ALT and AST levels		Highly Increased	Increased
Conjugated bilirubin in urine	Not present	Present	Present

Van den Bergh Test

Van den Bergh test is a chemical reaction used to measure bilirubin levels in blood. This test helps to identify the type of jaundice; **more specifically**, it determines the amount of **conjugated bilirubin in the blood**.

In the normal state, plasma bilirubin concentration is 0.3–1.0 mg/dL. Almost all of this is **unconjugated** (bound noncovalently to albumin) and does not react, until it is released by the addition of an organic solvent such as methanol. **Unconjugated bilirubin** binds so tightly to serum albumin and lipid that it does not diffuse freely in plasma, and, therefore, does not lead to an elevation of bilirubin in the urine.

The reaction with diazonium salt yields azo dye after the addition of methanol and is called **indirect Van den Bergh reaction**.

Conjugated bilirubin is relatively water soluble and elevation of conjugated bilirubin leads to its high urinary excretion with the characteristic deep yellow-brown color to the urine. The conjugated bilirubin is also referred to as **direct bilirubin**, because it can be coupled readily with diazonium salt to yield azo dye. This is called **direct Van den Bergh reaction**.

In **Van den Bergh** test, bilirubin reacts with diazotised sulfanilic acid to produce purple colored azobilirubin. The serum of patient is mixed with diazo reagent:

- If red colour develops immediately, it is called **direct positive**. It happens if **conjugated bilirubin** is present.
- In **indirect positive** test, patient's serum is first treated with alcohol and later mixed with diazo reagent. This causes development of red color. It is seen if **unconjugated bilirubin** is present.
- If **both, conjugated and unconjugated bilirubin** are present, the reaction is termed as **biphasic reaction**.

Assess Yourself

LONG AND SHORT ANSWER QUESTIONS

1. **Describe the process of heme degradation.**
2. **Describe types and causes of jaundice.**
3. **Write notes on:**
   i. Conjugated bilirubin
   ii. Unconjugated bilirubin
   iii. Van den Bergh test
   iv. Thalassemias
   v. Jaundice

MULTIPLE CHOICE QUESTIONS

1. **Conjugated bilirubin in urine in the absence of urobilinogen suggests:**
   a. Hemolytic jaundice
   b. Hepatocellular jaundice
   c. Obstructive jaundice
   d. None of the above
2. **Which of the following is correct about breakdown of hemoglobin (Hb)?**
   a. Hb-Heme-bilirubin-urobilinogen
   b. Heme-Hb-biliverdin-bilirubin-urobilinogen
   c. Hb-Heme-biliverdin-bilirubin-urobilinogen
   d. Hb-Heme-bilirubin-urobilinogen-biliverdin
3. **In the plasma, conjugated bilirubin is bound to:**
   a. α_2-Globulin
   b. α_1-Globulin
   c. β-Globulin
   d. None of the above
4. **The following is not true for heme oxygenase system:**
   a. Requires oxygen
   b. Requires NADPH
   c. Produces CO
   d. Repressed by heme

Chapter 13

Energy

Chapter Outline

- Unit of Energy
- Energy Requirements
- Energy Balance
- Components of Energy Requirement
- Energy Requirements for Different Categories of People
- Measurement of Energy Content of Food
- Measurement of Heat Given-off
- Body Mass Index

Basal Metabolic Rate

- Determination of BMR
- Factors Affecting BMR

Competencies

On completion of the chapter, the students will be able to:

- Explain unit of energy
- Explain Basal Metabolic Rate (BMR)
- Explain factors affecting BMR
- Explain energy requirements for different categories of people

Energy is a prime requisite for body functions and growth. Energy is also required for doing physical work. Body gets energy from the combustion of carbohydrates, fat and proteins. Energy, present in these macronutrients is locked in chemical bonds, and is released when food is metabolized. Thus, body converts chemical energy present in food to mechanical, electrical or heat energy.

UNIT OF ENERGY

The unit of energy is **calorie**. A calorie is defined as the quantity of heat, required to raise the temperature of 1 g of water by 1°C, more specifically from 14.5°C to 15.5°C. Its large unit is Kilocalorie, which is equal to one thousand gram calories (based on one Kilogram of water).

In the context of nutrition, the large unit, i.e., **Kilocalorie (kcal),** is used. The calorie value, we see on a **food** package is actually in Kilocalories or 1000 calories.

The SI unit of energy is **joule (J)**. One calorie is approximately 4.2 J.

ENERGY REQUIREMENTS

Energy requirement of an individual is defined as the level of **energy intake** in relation to **energy expenditure**. Energy intake and energy expenditure of individuals are finely balanced.

ENERGY BALANCE

The relationship between energy intake and energy expenditure is referred as energy balance.

- **Energy intake** is the total amount of calories consumed from the diet.
- **Energy expenditure (energy output)** is the amount of calories used by the body, for basic body functions, processing of food and physical activity.

  Energy balance refers to balance of energy intake and expenditure, i.e., when energy intake is equal to energy output. It results in no change in body weight over a period of time, and is referred to as **energy equilibrium (energy balance)**. Most adults maintain energy equilibrium.
  - **Positive energy balance:** When energy intake is more than the body needs, it is referred as positive energy balance. Positive energy balance leads to weight gain. Any surplus of energy intake than the requirement, is stored as fat, and continuous excess intake of energy leads to obesity.
  - **Negative energy balance:** When energy intake is less than the expenditure, it is referred to as negative energy balance. If an adult fails to meet the requirement, he loses weight. When a child's intake of food falls below a standard reference, growth slows down.

COMPONENTS OF ENERGY REQUIREMENT

Total energy requirement for different categories of people, is made up of three components, which include:

1. **Basal energy expenditure:** The total amount of energy used, over the period of 24 hours, in the state of complete physical and mental rest, at comfortable environment (temperature and humidity), is referred to as **energy requirement during resting condition**. It is also referred as **basal energy expenditure.** It is the amount of energy spent by the body for performing various activities, which are necessary to sustain normal body functions and homeostasis, such as respiration, blood circulation, synthesis of several substances for use in the body, pumping of ions across the membranes as well as maintenance of body temperature. It is expressed in terms of **basal metabolic rate** (**BMR**).
2. **Requirement for physical activities:** It is the most variable component of energy expenditure. Energy expenditure for physical activities varies from 30% to 100% of the basal requirement. It depends upon the duration, type and intensity of physical activity, including the energy expenditure for occupational work. According to the type of occupational work, various individuals are classified into 3 categories as:
   - Light workers (such as those doing office work)
   - Moderate workers (like a student)
   - Heavy workers (such as those performing manual physical labor, rickshaw pullers, etc.)

   Amounts of energy expenditure for different types of physical activities, as per National Institute of Nutrition, Indian Council of Medical Research (NIN–ICMR, 2011) are shown in Table 13.1.
3. **Requirement on account of specific dynamic action of food:** It refers to energy expenditure associated with the consumption of food. Body spends some energy to digest, absorb and metabolize dietary nutrients. It depends upon the type and amount of various nutrients consumed. **Specific dynamic action** (**SDA**) is also referred as **diet-induced thermogenesis or thermogenic effect of food**. SDA is more after the consumption of carbohydrates and proteins than fat. This is due to the reason that fat is metabolized more efficiently compared to proteins. On an average, for a mixed diet, SDA value constitutes about 10% of total energy expenditure.

TABLE 13.1: Energy expenditure for different types of physical activities

Activity zones	Type of activities	Energy expenditure* (kcal/min)
1	Sleeping, resting or relaxing	1.0
2	Sitting (light activities); eating, reading, writing, listening or talking	1.5
3	Standing, standing (light activity); washing face, shaving, combing, or watering plants	2.3
4	Walking (slow), driving, dusting, bathing. dressing, marketing or childcare	2.8
5	Light manual work, sweeping, cleaning utensils, washing clothes or other house chores	3.3
6	Warm-up and recreational activities, walking up/down stairs, cycling or fetching water	4.8
7	Manual work (moderate pace), loading/unloading, walking with load, harvesting, carpentry or plumbing	5.6
8	Practice of non-competitive sport/games, cycling (15 kmph), gymnastics, swimming or digging	6.0
9	High intense manual work and sports activities—tournaments, wood cutting, carrying heavy loads, running or jogging	7.8

*NIN-ICMR (2011)

ENERGY REQUIREMENTS FOR DIFFERENT CATEGORIES OF PEOPLE

Energy requirement varies from individual to individual depending upon age, sex, working conditions, body composition, physical activity and physiological state.

Energy requirements have been laid down by various expert groups of FAO/WHO, which are revised from time to time in light of the new knowledge. Recommended dietary allowances for energy, for Indians, as per NIN–ICMR are shown in Table 13.2.

TABLE 13.2: Recommended dietary allowances for energy for Indians

Group	Category of workers	Energy requirement* (kcal/day)
Man	Sedentary worker Moderate worker Heavy worker	2320 2730 3490
Woman	Sedentary worker Moderate worker Heavy worker Pregnant woman Lactation • 0–6 months • 6–12 months	1900 2230 2850 +350 +60 +520
Infants	0–6 months 6–12 months	92 kcal/kg/day 80 kcal/kg/day
Children	1–3 years 4–6 years 7–9 years	1060 1350 1690
Boys	10–12 years	2190
Girls	10–12 years	2010
Boys	13–15 years	2750
Girls	13–15 years	2330
Boys	16–17 years	3020
Girls	16–17 years	2440

*NIN-ICMR (2011)

Children

Because of their rapid growth, young children require proportionately, more energy for each kilogram of body weight than adults.

Children **above the age of 13 years** need as much energy as adults. This is because they show a good deal of physical activity, almost equal to the work done by adults. This is also the age when puberty sets in, and there is a spurt in growth and increase in metabolic rate.

Adults

Energy requirement decreases with age because of fall in BMR and decrease in physical activity. In general, there is nearly 2% decline of resting metabolism for each decade of life, in adults. FAO/WHO committee suggests that after the age of 40 years, requirement should be reduced by 5%, per each decade, until the age of 60 and by 10% for each decade, thereafter.

Pregnant and Lactating Women

Energy requirement for women is increased during pregnancy (+350 kcal/day) and lactation (+600 kcal/day during first 6 months, i.e., between 0 and 6 months, and +520 kcal/day during the next 6 months, i.e., between 6 and 12 months), over and above their normal requirement. This is to meet extra energy needs that are associated with the deposition of tissues and for secretion of milk, consistent with good health.

MEASUREMENT OF ENERGY CONTENT OF FOOD

As we know that all foods and drinks contain calories. Some foods such as lettuce contain few calories. Other foods like peanuts, contain a lot of calories. We can find out how many calories are present in a food by looking at the components of the food, i.e., how many grams of carbohydrates, proteins and fat the diet contains, as these are the major dietary sources of energy. On an average they supply energy at the following rates, i.e., carbohydrates and proteins, 4 kcal/g, and fat, 9 kcal/g.

To calculate the amount of energy available from food, quantity of carbohydrates, proteins and fat is multiplied 4, 4 and 9, respectively, and thereafter, the results are added up. For example, if one consumes a meal, such as a parantha with cheese or butter, that contains 40 g of carbohydrates, 10 g of proteins and 15 g of fat.

Total energy available from this meal will be:

= (g of carbohydrates × 4) + (g of proteins × 4) + (g of fat × 9)

= 160 + 40 + 135 kcal

= 335 kcal

MEASUREMENT OF HEAT GIVEN-OFF

Measurement of the amount of heat given-off by an individual, i.e., the total energy expenditure is called **calorimetry**. The amount of energy expenditure, in relation to oxygen consumed, can be measured directly or indirectly.

Direct Calorimetry

It measures the amount of heat production, by the body, which is proportional to the total energy use. For this purpose, the subject is put in a small insulated chamber that is surrounded by the circulating water. Thereafter, rise in temperature of the water is measured, which is directly related to energy consumed by the subject. Although, direct calorimetry provides a measure of energy expenditure in the form of heat, it does not provide any information on the kind of food consumed (fuel oxidized). Further, it is very cumbersome procedure, thus, it is not commonly used.

Indirect Calorimetry

It refers to the determination of energy expenditure, by the body without measuring heat production, indirectly. It is comparatively easier and less expensive than the direct calorimetry.

Indirect calorimetry estimates energy expenditure by determining the amount of oxygen consumed, in relation to the amount of carbon dioxide produced by an individual, over a given period of time. Data obtained from indirect calorimetry are used for the calculation by using **respiratory quotient**.

Respiratory Quotient

Respiratory quotient (RQ) refers to the moles of CO_2 expired in relation to the moles of O_2 consumed, i.e.,

RQ = Moles of CO_2 expired/moles of O_2 consumed.

The value, thereafter is converted into kcal (heat produced) per square meter of body surface area/hour, and is extrapolated to energy expenditure per 24 hours.

Value of RQ depends upon the type of food consumed:

- **RQ for carbohydrates** is 1. It is due to the reason that the number of moles of carbon dioxide produced from 1 gram of carbohydrate is equal to the number of moles of oxygen consumed.
- **RQ for protein** is 0.82.
- **RQ for fat** is 0.7.
- **RQ for the mixed diet** is 0.85.

BODY MASS INDEX

Body mass index (BMI) is computed by dividing the weight in kilograms by the square of the height in meters (Chapter 20).

The ideal ranges of weights for a given height are provided by WHO, which is useful for categorizing persons as normal (ideal), undernourished and overweight (or obese).

- BMI ranging from **18.5 to 25** is considered to be **normal**
- A person with a BMI **equal to or more than 25** is considered **overweight**
- A person with a BMI of **30 or more** is, generally considered **obese**.

BASAL METABOLIC RATE

Basal metabolic rate **(BMR)** is the amount of energy expenditure at rest, in a neutrally temperate environment, in the post-absorptive state, by indirect calorimetry in the laboratory setting.

The amount of energy at complete physical and mental rest meets the requirement for the functioning of vital organs, i.e., the heart, lungs, kidneys, nervous system, intestine, liver, sex organs, muscles and skin, etc.

DETERMINATION OF BMR

The BMR is measured, when a person is lying at complete rest but awaken, from a normal overnight sleep, 10 to 12 hours after the last meal, and performing no physical activity.

The BMR remains constant throughout the day under normal conditions and constitutes about 50–75% of the total energy expenditure by an individual. It is expressed in terms of kcal/hr.

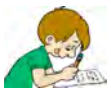
FACTORS AFFECTING BMR

- **Body mass:** Lean body mass refers to the portion of the body, exclusive of the stored fat, i.e., the fat-free mass (metabolically active tissue). Muscles, various other organs, bones and body fluids, make up most of the lean body mass. An individual, with a large lean body mass has higher resting energy expenditure than the one with same weight but having higher proportion of body fat.
- **Age:** BMR is highest during the period of rapid growth, mainly within first two years of life. It is reduced thereafter, but again reaches a peak during puberty and adolescence. BMR is further reduced, by about 2–3% per decade, in adults. This is due to the reason that whereas lean body mass tends to decrease, fat content increases with age.
- **Sex:** Metabolic rate is higher in men (by about 50 kcal/day) than women. This is due to the reason that women have less active muscle mass, for each kg of body weight. Women generally have less lean body mass. Resting metabolic rate also varies during menstrual cycle. It fluctuates from the low point from about one week before ovulation to the high point, just before the onset of menstruation.
- **Other factors:** These factors, however, may be less consistent of shorter duration and limited to individual situations (Table 13.3).

TABLE 13.3: Factors affecting BMR

Factors that increase BMR	Factors that decrease BMR
Total body weight	Growing age
Increased lean body mass	Female gender
Large body surface area	Starvation
Rapid growth	Hypothyroidism
Hot and cold temperature	Sleep
Stress	
Hyperthyroidism	
Caffeine	
Pregnancy and lactation	
Smoking	
Fever	

- BMR falls by about 10% during **sleep**.
- It rises during the period of rapid **growth,** such as in infancy and adolescence.
- **Hormones,** especially, thyroxin and norepinephrine, regulate BMR. Hypothyroidism slows BMR, while hyperthyroidism increases BMR.
- **Excitement and stress**, which cause release of epinephrine, increase cellular activity and, thus, BMR.
- **Pregnancy:** BMR is decreased in early stages of pregnancy, whereas later in pregnancy BMR is increased because of uterine, placental and fetal growth.
- Fever increases BMR by about 7%, for each degree increase in **body temperature** (above 98.4°F).
- **Environment temperature** also affects BMR. During exposure to cold, BMR increases. People living in tropical climate, usually, have higher BMR than those living in the temperate areas.
- During **starvation BMR** declines, as body slows basic functions to conserve energy.
- Some unknown **genetic factors** have also been attributed to the variations in BMR.



Assess Yourself

LONG AND SHORT ANSWER QUESTIONS

1. **Define energy. Describe the unit of energy?**
2. **Define basal metabolic rate (BMR). Describe various factors which affect BMR.**
3. **Write notes on:**
   i. Energy
   ii. Unit of energy
   iii. Energy balance
   iv. Energy requirement and its components
   v. Measurement of energy content of food
   vi. Body mass index
   vii. Basal metabolic rate

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Harbans Lal, *PhD, FACBI, FSOBSI, FIAO,* joined as a Lecturer in Biochemistry at Medical College (presently, Postgraduate Institute of Medical Sciences, Pt BD Sharma University of Health Sciences), Rohtak, Haryana, and after nearly 34 years of service, retired in 2009 from the same institution as Senior Professor. Thereafter, he joined as a Senior Professor and Head, Department of Biochemistry at Maharaja Agrasen Medical College, Agroha, Hisar (Haryana), from where he retired in July 2017. During this period, he supervised a large number of PhD and MD students, wrote 9 textbooks and published more than 150 research papers in various National and International Journals. He is also a peer reviewer of several National and International Research Journals.

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CBS Publishers & Distributors Pvt. Ltd.
4819/XI, Prahlad Street, 24 Ansari Road, Daryaganj, New Delhi 110 002, India
E-mail: feedback@cbspd.com, Website: www.cbspd.com
New Delhi | Bengaluru | Chennai | Kochi | Kolkata | Lucknow | Mumbai | Pune
Hyderabad | Nagpur | Patna | Vijayawada

ISBN: 978-93-90619-41-2