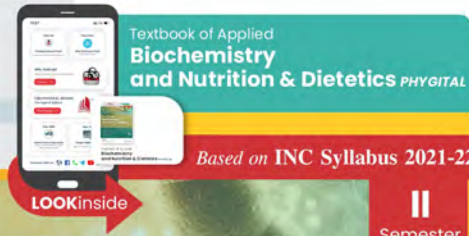

Based on **INC Syllabus 2021-22**

II
Semester

Textbook of **Applied**

Biochemistry and Nutrition & Dietetics

for BSc Nursing Students

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

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8

Organ Function Tests

LEARNING OBJECTIVES

After the completion of the chapter, the readers will be able to:

- Explain renal, liver and thyroid function tests.
- Describe the biochemical parameters of renal, liver and thyroid functions.

CHAPTER OUTLINE

Renal Function Tests
- Functions of the Kidneys
- Biochemical Parameters for the Evaluation of Kidney Functions

Liver Function Tests
- Commonly Used Biochemical Parameters for the Evaluation of Liver Functions
- Normal Values of Some Biochemical Parameters of Liver

Thyroid Function Tests
- Thyroid Hormones
- Commonly Used Biochemical Parameters for the Evaluation of Thyroid Functions
- Normal Values of Some Biochemical Parameters of Thyroid Function

KEY TERMS

Glomerular filtration rate: The volume of plasma that is filtered by the glomeruli per unit of time, and is usually measured by estimating the rate of clearance of a substance from the plasma.

Renal clearance: Renal clearance is a measure of the rate at which a substance is cleared from the blood by the kidneys through urine production. It is used to estimate the kidney's ability to remove that specific substance from the bloodstream.

RENAL FUNCTION TESTS

Various metabolic processes occurring in the body produce a number of substances, many of which, such as CO_2, water, nitrogenous compounds and inorganic salts, are waste products. If not regularly removed from the body, these toxic metabolites may severely affect normal health. The kidneys excrete most of the water, and organic and inorganic substances, whereas CO_2 is expired through lungs.

FUNCTIONS OF THE KIDNEYS

Kidneys perform several biochemical functions (Table 8.1).

TABLE 8.1: Important functions of the kidney

- Filtration of blood and preparation of ultrafiltrate fluid as urine.
- Reabsorption of useful substances such as glucose, amino acids, electrolytes, etc.
- Homeostasis of the extracellular volume.
- Maintenance of the acid-base status, water and electrolytes
- Endocrine functions and activation of hormones such as synthesis of erythropoietin, activation of vitamin D, etc.

Excretion of Waste Products

Urine is an ultrafiltrate of plasma. It is formed in the kidney, a paired organ, which is meant for filtration, concentration and reabsorption of various constituents. Each kidney has nearly one million basic filtration units called nephrons.

Filtration of Blood

Filtration is carried out in the nephron through glomeruli. As blood passes through the glomeruli, non-colloidal substances (usually of low molecular weight), filter through capillaries, with the retention of protein (not normally found in the urine).

Total amount of the filtrate formed per minute, by all the nephrons of both the kidneys, is known as **glomerular filtration rate** (GFR). Under normal physiological conditions, **GFR is 125 mL/min**.

Reabsorption of Useful Substances

About 150–200 L of the ultrafiltrate passes through the glomeruli in 24 hours. Reabsorption of water and solutes in various regions of the tubule reduces its volumes to nearly 500–1800 mL/day, as urine.

In the proximal tubule, nearly 60–80% of the ultrafiltrate is absorbed in an obligatory fashion, along with **Na^+, Cl^-, HCO_3^-, Ca^{2+}, HPO_4^{2-}** and other ions. **Glucose** is reabsorbed almost completely, predominantly in the proximal tubule by a Na^+-dependent active transport process. **Uric acid** is also reabsorbed in the proximal tubule. When blood level of creatinine increases above normal, creatinine is secreted in this region.

- **In the loop of Henle**, Cl^- and more of the Na^+ but without water are reabsorbed, resulting in diluted urine. Water reabsorption is then regulated in the distal tubule and collecting duct by antidiuretic hormone (ADH or vasopressin).
- **In the distal tubule**, **secretion** is the prominent activity as organic ions; K^+ and H^+ are transported from the blood in the efferent arteriole into the tubular fluid. This region also secretes H^+ and reabsorbs Na^+ and HCO_3^-.

At the same time, certain solutes are added to the fluid by an excretory function of the tubule. These include hippuric acid and other organic waste products.

Substances, which are reabsorbed by the renal tubules, are divided into two groups, according to their threshold value:

1. **High threshold substances:** These compounds are vital for life and body cannot afford to lose them. Such substances are completely reabsorbed by the renal tubule, e.g., glucose, amino acids, etc.
   - **Glucose** is reabsorbed in the tubular epithelial cells.
   - **Sodium, potassium, amino acids** and other substances are reabsorbed, apparently by specific transport mechanisms.
   - Transfer of **carbon dioxide and bicarbonate** is controlled by carbonic anhydrase.
2. **Low threshold substances:** These compounds are not required by the body and are reabsorbed to a very small extent only, e.g., urea, creatinine, etc.
   Urine thus, carries off:
   - Water and salts in such amount so as to maintain normal equilibrium between extracellular and intracellular fluids,
   - Acids or bases, to maintain a normal acid-base balance,
   - Waste products
   - Toxic and detoxified substances, and
   - Other substances, those are present in the blood in excessive amount.

Regulation of Water and Electrolytes

Regulatory functions of the kidney have a major role in homeostasis, by maintaining constant optimal chemical composition of the blood as well as interstitial and intracellular fluids.

Regulation of Water

The kidney plays an important part in regulating water balance. If excessive amount of water (fluid) is ingested, kidney excretes the same. On the other hand, if intake is low, kidney excretes more concentrated urine.

- Water homeostasis is intrinsically linked to renal urea handling. Only 40–50% of the filtered load of urea is reabsorbed.
- Most of the glomerular filtrate is reabsorbed through tubule cells.

  About 90% of water is reabsorbed as a result of the difference in pressure. The remaining 10% of water is reabsorbed actively, by tubular cells, as a result of the action of ADH.
- In the absence of ADH, little water and urea are reabsorbed, and a large amount of water is excreted. On the other hand, in the presence of ADH only 1.0–1.5 L of the filtrate is excreted as urine.

  Regulation of ADH excretion is thus of vital importance to fluid homeostasis.

Regulation of Electrolytes

The kidney plays an important role in the maintenance of electrolyte balance. Salts are either excreted or conserved by the kidney by tubular reabsorption, depending upon dietary intake and physiological need.

Plasma electrolytes pass through the glomerulus but some potassium leaves the blood by way of tubules, by active secretion.

Sodium and Chloride

Sodium and chloride ions predominate in the glomerular filtrate, as in plasma. As the glomerular filtrate flows through tubule, these electrolytes are absorbed into the blood.

Reabsorption of Na^+ is required for the reabsorption of water, Cl^-, glucose, HCO_3^-, urea and amino acids.

The proximal tubule is highly permeable to Na^+. Approximately 80% of the Na^+ entering tubular cells do so in exchange for H^+ secretion, which, in turn, leads to the entry of both Cl^- and HCO_3^- into the cells.

Sodium transport is regulated by many factors:

- Protein kinase-dependent phosphorylation
- Aldosterone
- Na^+, K^+-ATPase
- Na^+-H^+ exchanger
- H^+-ATPase

Calcium and Phosphorus

Approximately 98% of filtered Ca^{2+} is reabsorbed. Out of which 65–75% in the proximal tubule, 20–25% in the thick ascending limb of the loop of Henle, 10% in the distal tubule and a small amount in the collecting duct.

A passive process that is linked to active Na^+ reabsorption predominantly absorbs calcium. However, in the distal tubule, Ca^{2+} reabsorption is an active process catalyzed by Ca^{2+}-ATPase.

Reabsorption of Ca^{2+} is increased by the action of PTH and calcitonin.

Normally, less than 20% of the filtered load of phosphorus is excreted in the urine. Its excretion is directly related to the filtered load when plasma phosphorus concentration is above normal.

Reabsorption of phosphorus, though dependent on Na^+ reabsorption, is regulated by:

- Protein kinase C-dependent phosphorylation
- PTH
- Active vitamin D
- Calcitonin, and
- Dopamine and serotonin

Maintenance of Acid-Base Balance

Oxidation of various metabolites in the living organism results in the formation of a variety of acids as well as bases. For example, protons are generated from ionization of various substances such as organic acids (produced during metabolism of glucose, fatty acids and amino acids), uric acid (from purines), sulfates (from sulfur-containing amino acids) and carbonic acid (from CO_2).

Similarly, bases arise during catabolism of various metabolites such as ammonia (from amino acids), bicarbonate, phosphates, acetate and citrates.

All these substances enter blood plasma and other extracellular fluids for disposal. In spite of the entry of these acids and bases, pH of the blood does not alter much and remains within the normal limit of 7.35–7.45. This is due to the presence of various defense mechanisms, which include:

- Buffer systems of the blood, tissue fluids and cells
- Excretion or retention of CO_2 by lungs
- Excretion of an acid or alkaline urine
- Formation and excretion of ammonia as well as organic acids

Regulation of Acid-Base Balance

Four reactions are mainly involved in the regulation of acid-base balance by the kidneys:

1. ***Exchange of H^+ for Na^+***
   - Na^+ that is present in the lumen of the renal tubule, i.e., in the ultrafiltrate of plasma, is exchanged for H^+, which is formed in the tubular epithelial cells from CO_2 and H_2O. Na^+ is transported from the epithelial cells into the blood plasma for recycling. This transport of Na^+ is mediated by sodium pump.
   - In the presence of carbonic anhydrase, CO_2 and H_2O form carbonic acid, which is dissociated into H^+ and HCO_3^-. HCO_3^- diffuses from the epithelial cells into the blood plasma as the accompanying ion to Na^+, and thus, HCO_3^- is conserved.
2. ***Reabsorption of HCO_3^- from the tubular urine***
   - The H^+ that is exchanged into the tubular urine reacts with HCO_3^- in the plasma ultrafiltrate and forms H_2CO_3.
   - This is dissociated to CO_2 and H_2O from where CO_2 diffuses back into the epithelial cells.
3. ***Formation and excretion of NH_3***
   - Glutamine is extracted from the renal blood plasma of the peritubular capillaries and is deaminated by glutaminase in the tubular epithelial cells, to release NH_3 and glutamate.
     NH_3 so formed is diffused into the tubular urine and binds with H^+ to form NH_4^+.
4. ***Excretion of H^+***
   - The H^+ ions that are exchanged for Na^+ bind to HPO_4^{2-} to form $H_2PO_4^-$ (titratable acid). Both $H_2PO_4^-$ and NH_4^+ are then excreted in the urine.
   - The accompanying ions are predominantly, Na^+ and Cl^-, respectively.
   - Kidney, thus, participates in the regulation of acid-base balance, primarily, by maintaining the HCO_3^- concentration in the plasma.
   - In the event of acidosis, excretion of both $H_2PO_4^-$ and NH_4^+ are increased in the urine while the reverse occurs in alkalosis, until acid-base balance is restored (Chapter 6).

Synthesis and Activation of Hormones

Kidney synthesizes some hormones such as erythropoietin, renin and prostaglandins. It is also the site for the activation of vitamin D.

BIOCHEMICAL PARAMETERS FOR THE EVALUATION OF KIDNEY FUNCTIONS

Commonly used biochemical parameters for the assessment of the functions of kidney are shown in Table 8.2.

TABLE 8.2: Commonly used biochemical tests for the assessment of the kidney functions

Routine laboratory tests	Tests for glomerular functions	Tests for tubular functions
Urine • Volume • pH • Normal constituents • Abnormal constituents **Blood** • Urea • Creatinine • pH, gases and electrolytes	**Renal clearance test** • Insulin clearance • Urea clearance • Creatinine clearance **Renal plasma flow**	• Urine concentration test • Urine dilution test • Urine acidification test

Examination of Urine

Physical Examination of Urine

Volume

Volume of the urine varies from person to person and time to time.

- Average volume of urine, excreted by a normal individual, over a period of 24 hours, is **1000–1500 mL**. It is influenced by diet, particularly, ingestion of fluids. Strenuous physical exercise, hot weather and fever diminish urine output.
- Certain pathological conditions alter urine output. If 24 hours volume is increased, the condition is called **polyuria**, such as seen in diabetes and early renal failure.
- When urine output is decreased, it is termed **oliguria** such as seen in acute renal failure, dehydration (diarrhea and vomiting), edema and urinary obstruction.
- In acute renal failure or shock, urine is usually not formed. This condition is called **anuria**.

Color

Normal urine is usually pale, straw-yellow colored, due to the presence of urochrome, uroerythrin and urobilin.

- Change in color may be due to some pathology, secondary to the intake of some drug or a particular type of food.
- In fever it is usually dark in color, if there is blood in the urine (due to hemorrhage in the kidney or the urinary tract), urine becomes red in color. In jaundice urine may be dark-yellow or green due to the oxidation of bilirubin to biliverdin.

General Appearance and Odor

Freshly excreted urine is normally clear and transparent, as all the substances are present in the soluble form. On standing, it becomes turbid due to precipitation of phosphates.

Pathological urine may be turbid due to the presence of fat globules or pus cells.

- **Odor of the urine is usually aromatic,** due to the presence of volatile acids. On standing, urine may develop pungent odor due to formation of ammonia from urea because of its decomposition by bacteria.
- In acidosis and diabetes mellitus, urine has a peculiar sweet smell due to the presence of ketone bodies.

Specific Gravity

Specific gravity of urine normally varies between 1.010 and 1.030. Volume has a great influence on specific gravity of urine.

- Low values (up to 1.003) are observed after large water intake, on diuretic therapy or excretion of large amount of ketone bodies.
- High values (up to 1.040) are seen in dehydration or due to the presence of large amount of glucose.

Specific gravity of urine is measured by means of hydrometer, known as urinometer. Mark on the urinometer, in contact with surface of urine, indicates specific gravity of the sample.

pH (Reaction)

Under normal circumstances urine is slightly acidic in reaction, with a **mean pH of about 6.0 (ranging from 4.8 to 8.0)**

The pH of urine varies widely depending upon the nature of the food taken. High protein diet leads to acidic urine while alkaline urine is excreted after a vegetarian diet, particularly after large intake of vegetables and fruits.

Following meal, pH of the urine becomes alkaline due to the production and secretion of HCl by the stomach.

- Alkaline urine is seen in patients with systemic alkalosis since body attempts to conserve H^+ ions and remove fixed bases.
- Strongly acidic urine is seen in patients with systemic acidosis, e.g., diabetes mellitus, due to the excretion of large amount of ketone bodies.
- An increase in pH, greater than 8.0, indicates urinary tract infection by an organism that splits urea to ammonia.

The pH of urine is routinely checked with the help of pH paper. Its reaction can be tested with the help of litmus paper.

Chemical Examination of Urine

Normal Constituents

Major constituents of normal urine are shown in Table 8.3.

Normally, 50–60 g of solids are excreted in the urine over a period of 24 hours. About half of the total solids are urea. It comprises of nearly 80–90% of total organic substances. Other organic constituents of normal urine include creatinine, uric acid, hippuric acid and ethereal sulfates.

Major inorganic substance excreted is chloride (as sodium chloride). It constitutes about 25% of the total solids excreted in 24 hours. Other inorganic constituents normally excreted in the urine include ammonia, phosphates and sulfates.

In certain pathological conditions these constituents may be excreted in abnormal amounts.

TABLE 8.3: Normal constituents of urine

Constituent	Daily excretion (g/24 hours)
Water	1000–1500 mL
Total solids	50–60
Organic substances	30–35
Urea	25–30
Uric acid	0.5–1.0
Creatinine	1.0–2.0
Free amino acids (as amino acid N)	0.15–0.20
Inorganic substances	20–25
Chloride (as NaCl)	10–15
Total sulfates (as sulfur)	0.7–1.0
Total phosphates (as inorganic phosphorus)	0.8–1.1
Ammonia	0.5–0.7

Organic Substances

- **Urea:** Urea is a principal end product of protein catabolism in mammals. An adult man excretes 25–30 g of urea under normal conditions, in 24 hours.
  - Urea excretion is increased on high protein diet or in protein catabolic states such as fever.
  - On low protein diet, urea excretion is reduced. Decrease in urea excretion is also observed in disorders which are associated with impaired liver function, such as cirrhosis as well as in a kidney disease, such as nephritis.

- **Uric acid:** Uric acid is derived from nucleic acids by the oxidation of purine bases. It is found in urine to the extent of 0.5–1.0 g/24 hrs. Its daily excretion, however, varies, depending upon the diet and several other factors.
  - On a purine-free diet, uric acid output may be reduced up to 0.1 g/24 hrs.
  - On a high purine diet, uric acid excretion may be increased up to 2.0 g/24 hrs.

  Pathologically, uric acid excretion is increased in gout and leukemia.
- **Creatinine:** Creatinine (a waste product) is anhydride of creatine. Creatinine is present in considerable amount in muscle, in the form of creatine phosphate. Very little of creatine is found in the urine.

  On the other hand, about 1.0–1.8 g of creatinine is excreted by an adult in 24 hours. Excretion of creatinine is related to the amount of body creatine, i.e., muscle mass. Daily excretion of creatinine is, therefore, fairly constant and is used to check the accuracy of 24 hours urine collection.
  - Creatinine content of urine is increased in conditions associated with increased muscular activity.
  - A decrease in creatinine excretion may be observed in disorders, which are associated with muscular weakness as well as in a kidney disease.
- **Amino acids:** Due to high thresh-hold, normally only small amount of free amino acids are found in the urine. Their daily excretion (as amino acid nitrogen) is about 150–200 mg. Infants excrete more amino acids as compared to adults. During pregnancy excretion of amino acids is increased.

Aminoaciduria may be prominent in certain liver diseases and after poisoning by chloroform or carbon tetrachloride.

In certain metabolic diseases increased excretion of some of the amino acids may be observed, such as arginine, cystine, lysine and ornithine in cystinuria.

Inorganic Substances

- **Chloride:** It is a major inorganic constituent of the normal urine. Its excretion is dependent upon chloride content of the food. On an average daily output of chloride (expressed as sodium chloride) varies between 10 and 15 g. Fasting and excessive perspiration decreases its urinary output.

  Pathologically, its excretion may be decreased in chronic nephritis, fever, burn, diarrhea and vomiting.
- **Phosphates:** These are present in the urine in various forms, e.g., alkaline phosphates, such as sodium, potassium and ammonium phosphates, which are derived from the ingested inorganic phosphate or earthy phosphates such as phosphates of calcium and magnesium. These are insoluble phosphates and get precipitated in alkaline urine.
  - Excretion of phosphorus is dependent upon diet but on an average nearly 1 g of phosphates (as inorganic phosphorus) is excreted in 24 hours.
  - Urinary phosphorus is increased in acidosis and certain bone diseases, e.g., rickets and osteomalacia.
  - Phosphorus excretion is reduced in pregnancy, renal and infectious diseases as well as in hyperparathyroidism.
- **Sulfates:** These arise in the urine from the oxidation of sulphur, which is obtained from the sulphur-containing amino acids. Only a small amount of the ingested sulphur is excreted.
  - Sulfates are present in the urine in various forms, e.g., **inorganic sulfates** such as sodium, calcium and magnesium sulphates; **ethereal sulfates** which are mostly the detoxification products, and **neutral sulfates**, e.g., cystine, taurine, etc.
  - Under normal conditions about 1 g of sulfates (as sulfur) are excreted in the urine daily.
- **Ammonia:** Tubular cells of the kidney form ammonia. Precursor for ammonia is the amide nitrogen of glutamine. A decrease in blood pH speeds up ammonia production.
  - Normally, about 0.5–0.7 g of ammonia is excreted in 24 hours. Although very little of it is present in a fresh sample of the urine, its level increases on standing, due to bacterial decomposition of urea.
  - Ammonia excretion is decreased in a kidney disease while its excretion is increased in acidosis such as in diabetic ketoacidosis.

Abnormal Constituents of Urine

In the process of filtration of plasma through glomeruli, large molecular weight substances such as proteins are retained while small molecular weight substances, which are useful for the body, are reabsorbed. Normally, their amount is so low that it is not detectable, by the routine laboratory tests.

Under certain pathological conditions, when either their metabolism is disturbed or a tubular damage occurs, large quantities of these substances are excreted in the urine. Hence, these substances are called **abnormal constituents of urine.** These include sugar (glucose), ketone bodies, protein (albumin), blood, bile salts and bile pigments (Table 8.4).

TABLE 8.4: Abnormal constituents or urine

Constituent	Conditions in which excreted
Sugar (glucose)	Diabetes mellitus, renal glycosuria
Ketone bodies	Prolonged starvation, low-carbohydrate high-fat diet, diabetic ketoacidosis
Protein (albumin)	Nephrotic syndrome, glomerulonephritis
Blood	Hematuria, hemoglobinuria
Bile salts/pigments	Different types of jaundice

Sugar

Excretion of, readily detectable amount of sugar in the urine is known as mellituria or glycosuria whereas **excretion of glucose** is referred to as **glucosuria**.

When blood glucose concentration exceeds 180 mg/100 mL such as in diabetes mellitus, reabsorptive capacity of the tubule is reduced and glucose appears in the urine. Glucose may also be found in the urine in hyperthyroidism, hyperpituitarism, hyperadrenalism or I-cell disease of the pancreas.

- Glucosuria may also be observed in a proximal tubular disease that impairs re-absorptive mechanism. This is known as **renal glucosuria**. In this condition, glucose utilization as well as blood glucose level may be normal.

Besides glucose, other sugars that may be excreted in the urine include lactose, galactose, fructose or pentoses.

- **Lactosuria** may be observed in lactating women.
- **Fructose** may be present in the urine after ingestion of large quantity of honey. Essential fructosuria is an inborn error of metabolism due to the deficiency of the enzyme fructokinase.
- **Pentoses** may be found after ingestion of large quantities of fruits like plums and cherries. Pentosuria, referred to as L-xylulosuria, is an inborn error of metabolism due to the deficiency of xylitol dehydrogenase.
- **Galactosuria** may be observed in infants suffering from congenital galactosemia. Galactosuria may also be seen in infants as well as adults with a liver disease.

Ketone Bodies

Ketone bodies (acetoacetate, β-hydroxybutyrate and acetone) are formed in considerable amounts when fat is metabolized, excessively.

- Their accumulation in the blood is called ketonemia while their excretion in the urine is referred to as ketonuria.
- Ketonemia and ketonuria occur in a condition, which is referred to as ketosis.
- Ketosis may occur during prolonged fasting or carbohydrate deprivation. Pathologically, ketone bodies appear in the urine in diabetic ketoacidosis.

Proteins

Normal urine contains only traces of protein, which cannot be detected by routine procedures. When readily detectable amount of protein is seen in urine, this condition is called proteinuria. Since it is mainly the albumin that is detected abnormally, hence, proteinuria may also be referred to as albuminuria.

- Proteinuria or albuminuria may be physiological (benign albuminuria) or pathological (renal albuminuria).
- **Physiological proteinuria** is usually transitory. There is no evidence of kidney damage but proteinuria may be observed after severe exercise, high protein diet, pregnancy or postural effect (when an individual assumes an upright position for a long period). The latter is called **orthostatic** or **postural proteinuria**.
- **Pathological proteinuria** may be classified as:
  - ***Prerenal proteinuria:*** Pre-renal proteinuria may be observed in conditions that are primarily not related to the kidney, e.g., a cardiac disease, by affecting the circulation of the kidney, may lead to proteinuria. Besides, fever, convulsions, anemia and liver diseases may also result in proteinuria.
  - ***Renal proteinuria:*** Renal proteinuria may be observed due to inflammation of the kidney (nephritis) or kidney damage (nephrosis). Proteinuria due to a glomerular disease can lead to nephrotic syndrome where large amount of protein is excreted.
    Acute tubular necrosis and pyelonephritis also lead to proteinuria, which is generally mild.
  - ***Postrenal proteinuria:*** Post-renal proteinuria may occur due to some inflammatory, degenerative or traumatic lesions of the pelvis of the kidney, ureter, bladder, prostate or urethra.

Blood

Either intact red blood cells or hemoglobin may be present in the urine.

Presence of red blood cells in the urine is referred to as **hematuria**. It can be confirmed by the presence of red blood cells by microscopic examination of the urine. RBCs may be seen in acute glomerulonephritis or trauma to the urinary tract.

Hemoglobinuria may be observed due to intravascular hemolysis. This, in turn, results in the liberation of the hemoglobin which is filtered in the glomerulus and appears in the urine. Hemoglobinuria may occur under various pathological conditions such as mismatched transfusion of blood, hemolytic jaundice, typhoid or malaria.

Bile

Bile is produced in the liver. It is secreted through biliary tract and enters duodenum. It is alkaline in reaction and bitter in taste. Its color varies from yellowish-brown to dark green. Important constituents of the bile are bile salts, bile pigments, lipids particularly phospholipids and cholesterol, proteins like mucin, urea and certain inorganic salts such as sodium chloride and bicarbonate.

- **Bile salts** are the sodium and potassium salts of glycocholic and taurocholic acids. Cholic acid has the basic ring structure of cyclopentanoperhydrophenanthrene, like cholesterol. In glycocholic acid, glycine is conjugated with cholic acid through a peptide linkage. Similarly, in taurocholic acid, taurine is conjugated with cholic acid. Bile salts are essential for the digestion of fat. Since fat is insoluble in water, it is not digested in the absence of bile salts. Bile salts emulsify fat by lowering surface tension of water and help to bring fat in intimate contact with the lipase.
- **Bile pigments** are the degradation products of hemoglobin. When hemolysis of red blood cells takes place, hemoglobin is dissociated into heme and globin. Globin is hydrolyzed to amino acids by the proteolytic enzymes, while heme loses its iron, which is reutilized for heme synthesis. The tetrapyrrole ring (protoporphyrin) is broken down to biliverdin, which is further oxidized to bilirubin. Bilirubin is predominant in human bile. When it enters the intestine, further changes take place due to bacterial action and a number of pigments are formed. Some of these are reabsorbed into blood through the intestine, modified and excreted through urine.

Urobilinogen

Urobilinogen is an important constituent of the freshly voided normal urine. Following its oxidative degradation, it disappears quickly. Increased amount of urobilinogen may be seen in the urine of patients with hemolytic jaundice.

Estimation of Some Biochemical Parameters of Blood

Blood Urea

Urea is a major nitrogenous metabolic product of protein catabolism in man, accounting for more than 75% of the nonprotein nitrogen which is eventually excreted. Urea is freely filtered by the glomeruli. In a normal kidney, 40–70% urea moves passively out of the renal tubule into the interstitium.

Blood urea level, in a normal individual, may vary between 15 and 40 mg/dL. In patients with untreated chronic renal failure, blood urea level may be increased to 100–150 mg/dL.

Measurement of blood urea is widely used as a test of renal function. However, a number of non-renal factors influence circulating urea concentration. For example, urea production and consequently blood urea concentration are increased on a high protein diet, in protein catabolic states, gastrointestinal hemorrhage and treatment with cortisol in some cases of chronic liver disease and with decreased perfusion of the kidney. Blood urea also depends upon the state of hydration of the patient.

Estimation of plasma urea concentration, however, is a less valuable test of renal function than plasma creatinine concentration. This is due to the reason that nearly 50% of the urea, filtered at the glomerulus, is passively reabsorbed through the tubules and this fraction increases if urine flow rate increases, such as in dehydration. Plasma urea concentration is also more affected by diet than plasma creatinine.

- **Low blood urea** concentration may be observed in several situations, such as reduced synthesis, e.g., on a low protein diet or in an acute liver disease. Blood urea level may also fall as a result of water retention.
- **High blood urea** concentration may be due to several causes, which may be subdivided into pre-renal, renal and post-renal:
  - ***Pre-renal causes*** of increase in blood urea concentration include increased production by the liver (such as on a high protein diet), hemorrhage in the upper gastrointestinal tract, or in protein catabolic states (e.g., due to trauma, major surgery, or starvation). It may also be due to impaired renal perfusion (e.g., extracellular fluid loss, cardiac failure, hypoproteinemia, etc.).
  - ***Renal causes*** of increase in blood urea concentration include acute or chronic renal failure with reduction in glomerular filtration.
  - ***Post-renal causes*** include obstruction to urine flow, such as stone, benign prostatic hypertrophy, malignant stricture, or obstruction.

Serum Creatinine

Creatinine is a waste product of creatine. Its daily excretion is related to muscle mass and does not vary greatly from day to day. Hence, its level in the blood remains fairly constant. Creatinine is freely filtered at the glomerulus. Although it is not reabsorbed to any great extent by renal tubules but a small amount of it is secreted. Its secretion is increased with the increasing level of plasma creatinine.

Normal serum creatinine concentration varies between 0.8 and 1.5 mg/dL.

Meal, containing meat may increase serum creatinine concentration. Certain drugs, e.g., salicylates, cimetidine, etc., also increase serum creatinine level.

Serum creatinine values are lower in children than in adults, in women than in men, and during pregnancy. Determination of serum creatinine gives a useful indication of the degree of renal failure.

An increase in serum creatinine, due to fall in GFR is observed when:

- There is decreased renal perfusion, e.g., reduced blood pressure, fluid deprivation or renal arterial stenosis.
- There is a loss of functional nephrons, e.g., in acute and chronic glomerulonephritis, and
- Pressure is increased on the tubular side of the nephron, e.g., in urinary tract obstruction due to prostate enlargement.

Serum creatinine concentration is a more precise measurement than creatinine clearance and is usually sufficient for following the progress of patients with renal disease. Because:

- Plasma creatinine concentration normally remains fairly constant throughout adult life whereas creatinine clearance declines with advancing age.
- Plasma creatinine concentration correlates well with GFR as does creatinine clearance in patients with renal disease.
- Measurements of plasma creatinine concentration are as effective in detecting early renal disease as creatinine clearance, and
- Sequential plasma creatinine concentration measurements enable the progress of renal disease to be followed with better precision than creatinine clearance.
- **Reduced plasma creatinine** concentration is found in subjects with a small total muscle mass. Thus, a lower value is found in children. Values are, on average, normally lower in women than in men. Abnormally low values may be found in wasting diseases (reduced muscle bulk) and starvation, and in patients on steroid therapy, due to their protein catabolic effect. Plasma creatinine concentration is also usually low in pregnancy.
- **Increased plasma creatinine** concentration may be observed in several non-renal situations. For example:
  - High meat intake can cause temporary rise in plasma creatinine level.
  - Transient small increase in plasma creatinine level may occur after vigorous exercise.
  - Some drugs, e.g., salicylates, cimetidine, etc., reduce tubular secretion of creatinine hence, exhibit elevated plasma creatinine concentration.
  - High concentration of certain compounds, such as acetoacetate or cephalosporin antibiotic exhibit analytical interference and result in its overestimation.

An increased plasma creatinine concentration indicates a fall in GFR. Renal causes of increased plasma creatinine level include:

- A disease, in which there is impaired renal perfusion, e.g., reduced blood pressure, fluid depletion, renal artery stenosis, etc.
- Diseases in which there is loss of functioning nephrons, e.g., glomerulonephritis
- Urinary tract obstruction due to prostatic enlargement.

Blood pH and Gases

Diminished capacity of the kidney to excrete H^+ results in metabolic acidosis, the severity of which may be assessed by measuring arterial pH (H^+), HCO_3^- and pCO_2 concentrations.

Serum Electrolytes

Estimation of serum electrolytes, i.e., sodium and potassium are also of value in certain kidney conditions, e.g., chronic renal failure or metabolic acidosis accompanied by hyponatremia or hyperkalemia.

Renal Clearance Tests

Clearance is defined as the volume of plasma that is cleared-off a particular substance by the two kidneys in one minute. It is calculated by the following mathematical relationship:

$$C = \frac{U \times V}{P}$$

where:

C = Clearance of the substance (mL/min)
U = Concentration of the substance (mg/dL) in urine
V = Rate of flow of urine (mL/min)
P = Concentration of the substance (mg/dL) in plasma, blood or serum

Inulin Clearance Test

Inulin is a polymer of fructose. It is filtered by the glomeruli, but is neither reabsorbed nor secreted by the tubule. Inulin clearance, therefore, is nearly equal to glomerular filtration rate (GFR).

Normal value for GFR, as per inulin clearance, found in adults, is about 125 mL/min.

Although inulin meets most of the criteria for measuring GFR, it is not suitable for routine use, because it is an exogenous substance and has to be administered intravenously.

Urea Clearance Test

Urea is an end product of protein catabolism. Its concentration varies depending on dietary protein intake. Further, after filtration from the glomeruli, it is both, secreted from as well as reabsorbed by the tubules, thus, its excretion is affected by the rate of flow of urine.

As both, blood urea as well as urine urea concentrations are variable; accordingly, urea clearance is calculated in two different ways, depending upon the rate of flow of urine, i.e., as standard urea clearance and maximum urea clearance.

Standard Urea Clearance

Standard urea clearance is calculated with standard rate of urine flow (approximately 1 mL/min), i.e., when the value of urine volume is below 2 mL/min:

$$\text{Standard urea clearance (mL/min)} = \frac{U}{B} \times \sqrt{B}$$

where *U* and *B* are concentrations of urea (mg/100 mL) in urine and blood, respectively, while B square root is the volume of urine excreted (mL/min). Mean value for standard urea clearance is 54 mL/min.

Maximum Urea Clearance

Maximum urea clearance is calculated when volume of urine excreted is 2 mL/min or more. It is calculated by putting the actual value of V in the above equation, instead of $\sqrt{V}$.

$$\text{Maximum urea clearance} = \frac{U}{B} \times V$$

Mean value for maximum urea clearance is 75 mL/min.

As discussed above, urea clearance depends upon the rate of urine flow and that blood urea concentration is affected by dietary protein, urea clearance test is not preferred to determine GFR.

Creatinine Clearance Test

Creatinine is produced endogenously from creatine and gains access to the urine by glomerular filtration. Its clearance is not affected by the volume of urine flow. Also, serum creatinine concentration is not affected by diet. Thus, creatinine clearance is preferred as a measure of GFR. Normal value for creatinine clearance is 95–105 mL/min.

> Creatinine clearance (per 1.73 m^2 surface area) is low at birth (35–40 mL/min) and reaches the normal adult value (80–120 mL/min) by 6 months of age. It further declines with age. Creatinine clearance is increased by 20% during pregnancy.

Normal Values of Some Biochemical Parameters of Renal Function

Normal values of biochemical parameters of significance in renal function tests are shown in Table 8.5.

TABLE 8.5: Normal values of some biochemical parameters related to renal function tests

Biochemical parameter	Normal value
Blood urea	15–40 mg/dL
Serum creatinine	0.8–1.3 mg/dL
pH	7.35–7.45
pCO_2	35–45 mm Hg
HCO_3^-	22–26 mEq/L
Na^+	136–145 mEq/L
K^+	3.5–5.0 mEq/L

LIVER FUNCTION TESTS

The liver is a multifunctional organ that is involved in a number of excretory, synthetic and metabolic functions (Table 8.6).

- The liver has a major influence on the flow of nutrients to the rest of the body. It controls the release of absorbed material into the systemic circulation and has a central role in carbohydrate, protein and fat metabolism.
- The liver is an important site for the storage of glycogen and for gluconeogenesis.
- Most proteins in plasma including albumin, α- and β-globulins, clotting factors and transport proteins are synthesized by the liver.
- This is also the site for urea synthesis.
- Fatty acids and phospholipids are also taken up from circulation by the liver and are metabolized there.
- Cholesterol is also synthesized and esterified in the liver.
- Liver is also a site for the detoxification of exogenous compounds (such as alcohol, drugs and toxins) as well as endogenous materials (such as bilirubin and hormones) which are excreted via the kidney or the biliary system.
- Bile salts are synthesized in the liver.
- Liver stores various substances, such as vitamins and minerals, and releases them as and when required.
- Liver is also one of the biggest reticuloendothelial organ and has important immune functions.

TABLE 8.6: Important biochemical functions of the liver

Metabolism of nutrients • Carbohydrates • Proteins • Fats
Synthesis of proteins • Albumin • α- and β-globulins • Clotting factors • Transport proteins
Metabolism and excretion of exogenous substances • Alcohol • Drugs • Toxins
Metabolism and excretion of endogenous substances • Bilirubin • Hormones
Storage of vitamins • Vitamin A • Vitamin B_{12}
Storage of Mineral • Iron

COMMONLY USED BIOCHEMICAL PARAMETERS FOR THE EVALUATION OF LIVER FUNCTIONS

Various liver functions tests that are useful in the assessment of a liver disease include the estimation of serum proteins, serum bilirubin, various enzymes and prothrombin time (Table 8.7).

TABLE 8.7: Commonly used biochemical tests for the assessment of liver functions in serum

Total proteins
Albumin
Bilirubin
Prothrombin time
Enzymes • GPT and GOT • Alkaline phosphatase • γ-Glutamyl transpeptidase (γ-GT) • 5′-Nucleotidase • Glutamate dehydrogenase

Serum Bilirubin

Bilirubin is an orange-yellow pigment, derived from the breakdown of red blood cells in the liver, spleen and bone marrow (Chapter 7).

Normal value for the sum of the unconjugated and conjugated forms is 0.1–1.0 mg/100 mL of serum. Normally, almost all the bilirubin in plasma is unconjugated. Bilirubin fractionation is also helpful in differential diagnosis of **jaundice**.

Plasma Proteins

As liver is the primary site of the synthesis of plasma proteins, a disturbance in protein synthesis occurs as a consequence of impaired hepatic function. Decreased synthesis of protein leads to a decrease in their plasma concentration. Pattern of alteration in plasma proteins, however, depends upon the type, severity and duration of the liver injury.

In a severe liver disease, hepatic synthesis of albumin is decreased. In chronic hepatocellular damage also, serum albumin concentration falls.

Serum protein electrophoresis, to determine the proportion of different serum proteins, is also helpful in the diagnosis of a liver disease, e.g., α_2- and β-globulins are increased in cirrhosis due to their increased production and decreased clearance. In cholestasis, there is a small increase in serum γ-globulin with a more increase in α- and β-globulins due, in part, to increase serum lipoproteins.

Serum Enzymes

Serum levels of several enzymes are elevated in liver diseases.

ALT and AST

In viral hepatitis and other forms of a liver disease, which may be associated with hepatic necrosis, serum ALT and AST levels are elevated even before clinical signs and symptoms of the disease appear. Levels of both the enzymes may reach values as high as 100 times the upper normal limit. Peak values occur between day seven and day twelve. Thereafter, their activities gradually decrease and reach toward normal by third to fifth week of recovery.

Five to ten-fold increase in both the enzymes occur in patients with primary metastatic carcinoma of the liver. Although serum levels of both ALT and AST are elevated in a liver disease, however, ALT is more liver specific.

Alkaline Phosphatase

Serum alkaline phosphatase (ALP) levels are important in a hepatobiliary disease as well as in bone diseases that are associated with increased osteoblastic activity.

As biliary obstruction results in induction of the enzyme, rise is more marked in extrahepatic obstruction than in intrahepatic obstruction.

Glutamate Dehydrogenase

Glutamate dehydrogenase (GDH) is found in the liver, heart, muscle and kidney. It is present only in traces in normal serum but increased activity is observed in a liver disease with hepatocellular damage.

5′-nucleotidase

5′-nucleotidase (5′-NT) activity is increased by two to six folds, in some of the hepatobiliary diseases. It may be due to extrahepatic causes such as stone or tumor, obstructing the bile duct or in intrahepatic conditions, e.g., cholestasis that may be caused by chlorpromazine, malignant infiltration of the liver or biliary cirrhosis.

γ-glutamyltransferase

γ-glutamyltransferase is also referred to as γ-glutamyltranspeptidase or γ-GT. It is present in high concentration in the serum in intra-hepatic or post-hepatic biliary obstruction.

Elevated levels of γ-GT are also observed in the sera of people who are heavy drinkers. Accordingly, this enzyme has been shown to be of significance in the detection of an alcohol-induced liver disease.

NORMAL VALUES OF SOME BIOCHEMICAL PARAMETERS OF LIVER

Normal values of biochemical parameters of significance in liver function tests are shown in Table 8.8.

TABLE 8.8: Normal values of some biochemical parameters related to liver function tests

Biochemical parameter	Normal value
Bilirubin	
Total Bilirubin	0.2–0.8 mg/dL
Conjugated Bilirubin	0.0–0.3 mg/dL
Unconjugated Bilirubin	0.2–0.8 mg/dL
Proteins	
Total proteins	6.3–8.0 g/dL
Albumin	3.7–5.3 g/dL
Globulins	1.8–3.7 g/dL
$\alpha_1 + \alpha_2$-Globulins	0.4–1.4 g/dL
β-Globulin	0.5–1.3 g/dL
ϒ-Globulin	0.6–1.5 g/dL
Enzymes	
ALT	8–56 IU/L
AST	8–40 IU/L
ALP	39–117 U/L
GDH	<7.0 U/L
5′-NT	2–15 U/L
ϒ-GT	5–35 U/L

THYROID FUNCTION TESTS

The thyroid is a gland found in the neck. Its **main function is to make thyroid hormones**, the chemicals which are released into the bloodstream.

THYROID HORMONES

Thyroid makes three hormones that it secretes into the bloodstream. Two of these hormones called **thyroxine** (T_4) and **triiodothyronine** (T_3), increase body's metabolic rate. The third hormone calcitonin, helps to control the amount of calcium in the blood.

In order to make $\mathbf{T_3}$ and $\mathbf{T_4}$, the thyroid gland needs iodine, a substance found in the food. It is taken up from bloodstream into the thyroid gland. In the thyroid gland, it undergoes a number of different chemical reactions which result in the production of T_3 and T_4. T_4 is so called because it contains four atoms of iodine. T_3 contains three atoms of iodine. In the cells and tissues of the body most T_4 is converted to T_3. T_3 is the more active hormone; it influences the activity of all the cells and tissues of the body.

Thyroid function tests (TFTs) is a collective term for **blood tests** used to check the function of the thyroid. These tests are requested if a patient is thought to suffer from **hyperthyroidism** (overactive thyroid) or **hypothyroidism** (underactive thyroid), or to monitor the effectiveness of either thyroid-suppression or hormone replacement therapy. It is also requested routinely in conditions linked to thyroid disease, such as atrial fibrillation and anxiety disorder.

Hyperthyroidism

Hyperthyroidism, often called **overactive thyroid** and sometimes **hyperthyreosis**, is a condition in which the thyroid gland produces and secretes excessive amounts of the free (not protein bound circulating in the blood) thyroid hormones, T_3 and/or T_4.

A variety of conditions can cause hyperthyroidism. Graves' disease (an autoimmune disorder) is the most common. Other causes of hyperthyroidism include excess iodine (iodine is needed to make T_4 and T_3), inflammation of the thyroid gland (thyroiditis causes T_4 and T_3 to leak out of the gland), tumors of the ovaries or testes, benign tumors of the thyroid or pituitary gland or taking large amount of thyroxine (through dietary supplements or medication).

Graves' Disease

Graves' disease is the most common form or cause of hyperthyroidism. In this condition antibodies stimulate the thyroid to secrete too much hormone, the eyes may look enlarged because the eye muscles swell and push the eye forward. This symptom is called exophthalmos.

Some patients have swelling of the front of the neck from an enlarged thyroid gland. It occurs more often in women and tends to run in families. Other symptoms include weakness, irregular heartbeat, difficulty in sleeping, itching, hair loss, nausea and vomiting, and breast development in men.

Thyrotoxicosis

Hyperthyroidism is one cause of thyrotoxicosis, the hypermetabolic clinical syndrome, which occurs when there are elevated serum levels of T_3 and/or T_4. Thyrotoxicosis can also occur without hyperthyroidism. Some people develop thyrotoxicosis due to inflammation of the thyroid gland (thyroiditis) which can lead to excessive release of thyroid hormone already stored in the gland (without the accelerated hormone production that characterizes hyperthyroidism). Thyrotoxicosis can also occur after ingestion of excessive amounts of exogenous thyroid hormone in the form of thyroid hormone supplements.

Thyrotoxicosis or hyperthyroidism may be asymptomatic but when it is not, symptoms are due to an excess of thyroid hormone. If there is too much thyroid hormone, every function of the body tends to speed up.

- Some of the **symptoms of hyperthyroidism** may be nervousness, irritability, increased perspiration, heart racing, hand tremors, anxiety, difficulty sleeping, thinning of the skin, fine brittle hair and muscular weakness, especially in the upper arms and thighs, unintended weight loss and low serum cholesterol. For women, menstrual flow may lighten and menstrual periods may occur less often.
- **Major clinical signs** include weight loss (often accompanied by an increased appetite), anxiety and intolerance to heat, hair loss (especially of the outer side of the eyebrows), muscle ache, weakness, fatigue, hyperactivity, irritability, hyperglycemia, polyuria, polydipsia, delirium, tremor and sweating.
- The first step to **diagnose hyperthyroidism** is a complete history and physical examination, which can reveal common symptoms such as weight loss, rapid pulse, elevated blood pressure, protruding eyes and/or an enlarged thyroid gland (which can appear either symmetrical or one-sided).
- Other tests may be performed to further evaluate the diagnosis. These include **serum cholesterol** (cholesterol levels vary with the metabolic rate, the rate at which cells use energy. In hyperthyroidism, cholesterol can be low due to the elevated metabolic rate), **T_4 and T_3**, **TSH** (a hormone produced by the hypothalamus that stimulates the thyroid gland to produce thyroid hormones. When thyroid hormones levels are normal or high, TSH should not be elevated).

Hypothyroidism

Hypothyroidism, often called **underactive thyroid** or **low thyroid** and sometimes **hypothyreosis**, is a common endocrine disorder in which the thyroid gland does not produce enough thyroid hormone.

- **Iodine deficiency** is the most common cause of primary hypothyroidism and endemic goiter worldwide.
- In areas of the world with sufficient dietary iodine, hypothyroidism is most commonly caused by the autoimmune disease, **Hashimoto's thyroiditis** (chronic autoimmune thyroiditis). Hashimoto's disease may be associated with a goiter. It is characterized by infiltration of the thyroid gland with T lymphocytes and autoantibodies against specific thyroid antigens such as thyroid peroxidase, thyroglobulin and the TSH receptor. Autoimmune thyroiditis is associated with other immune-mediated diseases such as diabetes mellitus type I, pernicious anemia, myasthenia gravis, rheumatoid arthritis, etc.
- Hyperthyroidism due to certain types of **thyroiditis** can eventually lead to hypothyroidism (lack of thyroid hormone), as the thyroid gland is damaged.
- Also, **radioiodine treatment of Graves' disease** often eventually leads to hypothyroidism. Such hypothyroidism may be treated by regular thyroid hormone testing and oral thyroid hormone supplementation.
- Hypothyroidism can cause a number of symptoms such as tiredness, poor ability to tolerate cold and weight gain. In children, hypothyroidism leads to delays in growth and intellectual development, called **cretinism** in severe cases. Cretin children are dwarf and mentally retarded.
- The diagnosis of hypothyroidism, when suspected, can be confirmed with blood tests measuring TSH and thyroxine levels.

COMMONLY USED BIOCHEMICAL PARAMETERS FOR THE EVALUATION OF THYROID FUNCTIONS

Biochemical tests to establish if there is any thyroid dysfunction, include measurement of thyroid hormones (T_3 and T_4) and TSH in serum. Other tests include radioactive iodine uptake, protein bound iodine, serum cholesterol, etc.

Thyroid Hormones

The thyroid function test panel typically includes thyroid hormones such as thyroid-stimulating hormone (TSH, thyrotropin), and thyroxine (T_4) and triiodothyronine (T_3). Measurement of the concentration of T_4 and T_3 in the serum is used in confirming the diagnosis of hyperthyroidism or hypothyroidism.

Thyroxine

Total thyroxine is rarely measured, having been largely superseded by free thyroxine test. It is generally elevated in hyperthyroidism and decreased in hypothyroidism. It is usually slightly elevated in pregnancy, secondary to increased levels of thyroid binding globulin (TBG). Serum T_4 value in a normal person ranges from 4.5–12.5 mg/dL. In hyperthyroidism, serum T_4 concentration is increased to >12 mg/dL whereas in hypothyroidism the value is <5 mg/dL. Estimation of free thyroxine (FT_4), however, provides more reliable information than does total T_4. Free T_4 is generally elevated in hyperthyroidism and decreased in hypothyroidism.

Triiodothyronine

Total triiodothyronine (Total T_3) is rarely measured, having been largely superseded by free T_3 test. Total T_3 is generally elevated in hyperthyroidism and decreased in hypothyroidism. Normal value for serum T_3 varies between 86 and 187 ng/dL. Serum T_3 concentration is low at birth. The value rises to near adult level in early childhood and then is maintained up to 30 years of age, after which it again falls.

Measurement of reverse T_3 (rT_3, a catabolic product of T_4) may also be helpful in some cases, e.g., in low T_3 syndrome where rT_3 concentration is increased. Free T_3 is generally elevated in hyperthyroidism and decreased in hypothyroidism.

Thyroid-Stimulating hormone

Thyroid-stimulating hormone (TSH) is the most sensitive test for thyroid hormone function. TSH is produced in the pituitary gland. The production of TSH is controlled by TRH, which is produced in the hypothalamus. TSH levels may be suppressed by excess free T_3 or free T_4 in the blood.

Reference value for serum TSH concentration is in the range of 0.3–5.0 µIU/mL.

Measurement of TSH is most useful and sensitive for primary hypothyroidism.

Thyroxine-Binding Globulin

An increased thyroxine-binding globulin results in an increased total thyroxine and total triiodothyronine without an actual increase in hormonal activity of thyroid hormones. Reference range is 12–30 mg/L.

Serum Cholesterol

Increase in serum cholesterol is observed in hypothyroidism whereas it is decreased in hyperthyroidism or thyrotoxicosis.

Serum Calcium

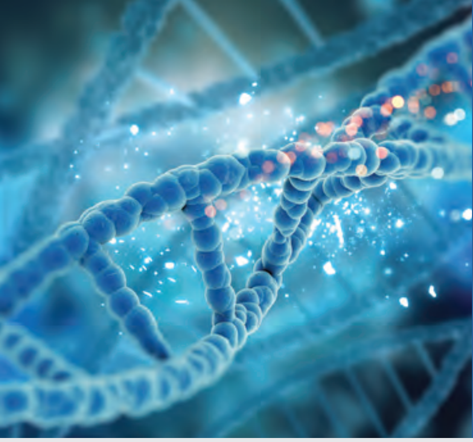
Hyperthyroidism may result in increased plasma calcium along with increased plasma alkaline phosphatase activity.

NORMAL VALUES OF SOME BIOCHEMICAL PARAMETERS OF THYROID FUNCTION

Normal values of biochemical parameters of significance in thyroid function tests are shown in Table 8.9.

TABLE 8.9: Normal values of some biochemical parameters related to thyroid function tests

Biochemical parameter	Normal value
Thyroxine (T_4)	
Total T_4 (T_4)	4.5–12.5 µg/dL
Free T_4 (FT_4)	0.89–1.76 ng/dL
Triiodothyronine (T_3)	
Total T_3 (T_3)	86–187 ng/dL
Free T_3 (FT_3)	2.3–4.2 pg/dL
Thyroid stimulating hormone (TSH)	0.3–5.0 mIU/L (µIU/mL)
Thyroxine-binding globulin (TBG)	1.3–2.0 mg/dL
Serum cholesterol	120–200 mg/dL
Serum calcium	8.5–10.5 mg/dL



STUDENT ASSIGNMENT

LONG AND SHORT ANSWER QUESTIONS

1. Explain biochemical parameters for the evaluation of thyroid functions.
2. **Write notes on:**
   a. Thyroid function tests
   b. Renal function tests
   c. Differential biochemical diagnosis of jaundice
   d. Clearance tests
   e. 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
   b. 75 mL/min
   c. 100 mL/min
   d. 125 mL/min
4. **A useful index of renal plasma flow is:**
   a. Inulin clearance
   b. PAH clearance
   c. Creatinine clearance
   d. Urea clearance

ANSWER KEY

1. c **2.** a **3.** b **4.** b

STUDENT ASSIGNMENT

LONG AND SHORT ANSWER QUESTIONS

1. **Describe dietary sources and functions of:**
   a. Sodium
   b. Potassium
   c. Calcium
   d. Magnesium
   e. Iron
   f. Phosphorus
   g. Zinc
2. **Write short notes on:**
   a. Major minerals
   b. Trace elements

MULTIPLE CHOICE QUESTIONS

1. Which mineral is essential for the formation of healthy bones and teeth?
a. Iron
b. Zinc
c. Calcium
d. Magnesium

2. What is a good dietary source of potassium?
a. Red meat
b. Bananas
c. Cheese
d. White bread

3. Which mineral is important for the proper functioning of enzymes in the body?
a. Iodine
b. Copper
c. Phosphorus
d. Selenium

4. What is the function of iron in the body?
a. Helps in blood clotting
b. Supports immune function
c. Aids in energy production
d. Regulates fluid balance

ANSWER KEY

1. c **2.** b **3.** b **4.** c

Textbook of **Applied**

Biochemistry and Nutrition & Dietetics for BSc Nursing Students

Salient Features

- Completely revised and updated edition aligned with revised INC syllabus of BSc Nursing
- Simple and lucid language has been used throughout the book
- Clinical relevance of the subject has also been provided at different places to help the students correlate basics of the subject with a clinical perspective
- Dietary recommendations have been revised as per ICMR-NIN (2020) guidelines
- Dietetics part has been covered exclusively
- Special chapter on Sample Collection and Normal Values of Biochemical Parameter has been added.

Learning Objectives in the beginning of every chapter help readers understand the purpose of the chapter.

LEARNING OBJECTIVES

After the completion of the chapter, the readers will be able to:
- Understand the history of biochemistry.
- Discuses applications and significance of biochemistry in nursing.

Chapter Outline gives a glimpse of the content covered in the chapter.

CHAPTER OUTLINE

- Introduction
- History of Biochemistry
- Biochemistry and Molecular Biology
- Applications of Biochemistry

Key Terms are added in each chapter to help understand difficult scientific terms in easy language.

KEY TERMS

Biochemical techniques: The use of microorganisms and enzymes in the laboratory methods to study biochemical processes.
Human biochemistry: The application of chemistry in the study of biological processes going on in the human body at the cellular and molecular level.

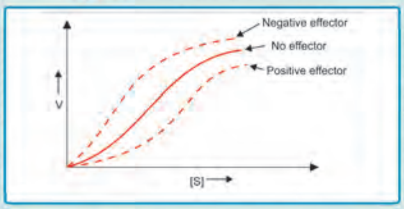
Clinical Correlation boxes covering applied aspects of clinical situations.

Clinical Correlation

Refsum Disease

Genetic **deficiency of α-hydroxylase enzyme** *(a monooxygenase) results in an increase in* **phytanic acid** *in the serum and its accumulation in several tissues. This in turn leads to a neurological disorder called* **Refsum disease.**

The book is well illustrated with relevant colorful **Figures** to add value to the content.



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

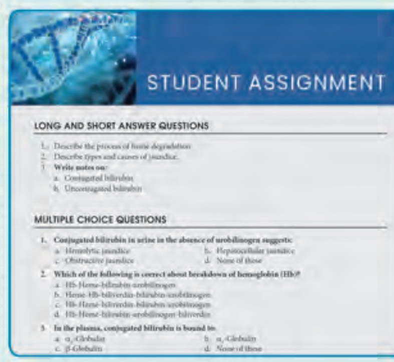
Parameter	Normal value
pH	7.35–7.45
pCO_2	35–45 mm Hg
HCO_3^-	22–26 mEq/L
Base excess	−2.0–3.0 mmol/L

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

Hapten

Low molecular weight substances, such as amino acids, sugars and small polymers that by themselves are not able to initiate antibody formation but can combine with specific carrier molecules (e.g., a protein) and induce a specific antibody response, are called **haptens.**

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



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