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Essentials of **Anatomy & Physiology**

for GNM Nursing Students

(As per the INC Syllabus for GNM Nursing)

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**Krishna Garg
Medha Joshi**

Essentials of

Anatomy and Physiology

for GNM Nursing Students

(As per the INC Syllabus for GNM Nursing)



Nursing Knowledge Tree
An Initiative by CBS Nursing Division

— | **Second Edition** | —

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Essentials of

Anatomy and Physiology

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Preface to the Second Edition

We are delighted to present the second edition of our book, which aims to provide nursing students with a comprehensive understanding of anatomy and physiology. We are grateful for the overwhelming response and positive feedback we received for the first edition, which encouraged us to further enhance and expand upon the content.

Anatomy and physiology continue to serve as the foundation for all medical disciplines, enabling students to grasp the normal structure and functioning of the body's various systems. By comprehending these fundamental aspects, nursing students can effectively recognize deviation from the norm that leads to different illnesses. Nurses, as the backbone of any medical setting, play an indispensable role and are the vital link between doctors, patients, and their families. Their expertise and compassionate care significantly contribute to the overall well-being of individuals and society at large.

In this second edition, we have meticulously refined each chapter to provide a deeper understanding of the subject matter. The book begins by introducing the various systems and presenting specific anatomical terminology in Chapter 1. Chapter 2 of the book provides a comprehensive introduction to cell structure and the microscopic anatomy of basic tissues. Subsequently, Chapters 3 to 14 delve into the intricacies of the different systems of the body. For easy comprehension, each chapter commences with an exploration of normal anatomy, followed by an in-depth examination of physiological processes. Finally, the clinical aspects, including alterations in structure and function that contribute to disease processes, are emphasized.

To aid visual learning, the text is complemented by high-quality color diagrams, tables, flowcharts, and graphs. These visual aids not only enhance understanding but also facilitate easy reproduction. We have taken great care to present the material in a clear and concise manner, ensuring that students can readily absorb, retain, and recall the information during their theory, practical, and viva voce examinations. To facilitate self-assessment, we have included multiple-choice questions (MCQs) at the end of each chapter, enabling students to gauge their progress and reinforce their learning.

In response to valuable feedback, we have added a separate section featuring important histological slides. Each slide is accompanied by three key identification points, enabling students to familiarize themselves with organ structures in a practical and interactive manner. Furthermore, recognizing the importance of nutrition, we have incorporated basic concepts in the Digestive System chapter, providing students with a foundational understanding of this vital area.

We genuinely appreciate your continued support and encourage you to share your suggestions and views for the further improvement of this book. Your feedback is invaluable in our pursuit of simplifying these two fascinating subjects for students. Please feel free to reach out to us at dr.krishnagarg@gmail.com.

We sincerely hope that this second edition will prove to be even more beneficial and user-friendly for nursing students, helping them develop a strong foundation in anatomy and physiology. May this knowledge empower them to become compassionate caregivers, fostering optimal patient care and making a positive impact on society.

Krishna Garg
Medha Joshi

Preface to the First Edition

Anatomy and physiology form the plinth of all medical subjects. Basic knowledge of these subjects helps the nursing students understand the normal structure and functioning of the various systems of the body. It thus helps them to understand the deviation from the normal leading to various illnesses.

Nurses are the backbone of any medical setup, a dispensary, a nursing home or a hospital. They are omnipresent, forming an important link between the doctor, the patient and the family. They form an integral part of the setup and an important aspect of health care. Hence, it becomes essential for them to have the knowledge of the basic subjects and understanding of the disease mechanism. This helps them to be kind and compassionate caretakers of the patients and the society in general.

As anatomy and physiology are the basic building blocks, this book has been written encompassing the basic aspects of these subjects. Each chapter begins with anatomy, i.e., normal structure, followed by physiology or the normal functioning. At the end, the clinical aspects or alterations in structure or function or both resulting in disease process have been highlighted. This is important for the proper management of the patient, which includes medical personnel, i.e., doctors, nurses and other support staff.

The book contains 14 chapters. Chapter 1 gives a brief idea about the various systems and specific or typical terms used in anatomy; Chapter 2 provides the complete introduction to structure of cells and the microscopic anatomy of the basic tissues; and Chapters 3–14 describe the various systems. The text has been well illustrated with high quality color diagrams, tables, flowcharts, graphs, etc. These are easily reproducible. The text has been written in very simple language so that the students can easily understand, retain and reproduce the same in their theory, practicals and *viva voce* examinations. MCQs have been added at the end of every chapter to help students assess their learning. Fourteen most important histological slides, along with their 3 important identification points have been added as a separate section for the students to get acquainted with the structures of the organs. Basic concepts of Nutrition have been added in the chapter, Digestive System, for giving a basic know-how of the same.

This book should be sufficient for GNM students. This book can be of use to the students of allied health sciences as well.

Nursing Knowledge Tree
An Initiative by CBS Nursing Division

Krishna Garg
Medha Joshi

Acknowledgments

Our special thanks are due to **Mr Satish Kumar Jain** (Chairman) and **Mr Varun Jain** (Managing Director), M/s CBS Publishers and Distributors Pvt Ltd for their wholehearted support in publication of this book. We have no words to describe the role, efforts, inputs and initiatives undertaken by **Mr Bhupesh Aarora** [Sr. Vice President – Publishing & Marketing (Health Sciences Division)] for helping and motivating us.

We want to extend our special thanks to **Meenakshi Saran** (Former Senior Dietician, Max Smart Super Speciality Hospital, Saket, New Delhi) for contribution of the Nutrition topic in Chapter 7 Digestive System and Nutrition.

Last but not least, we sincerely thank the entire CBS team for bringing out the book with utmost care and attractive presentation. We would like to thank Ms Nitasha Arora (Publishing Head and Content Strategist – PGME&N) and Dr Anju Dhir (Product Manager cum Commissioning Editor – Medical) for their editorial support. We would also extend our thanks to Mr Shivendu Bhushan Pandey (Sr. Manager and Team Lead), Mr Ashutosh Pathak (Sr. Proofreader cum Team Coordinator) and all the production team members for devoting laborious hours in designing and typesetting the book.

The logo features a stylized tree with a thick, grey trunk and branches. The leaves are represented by light pink and light green shapes. The tree is enclosed within a thin, light pink rectangular border.

Nursing Knowledge Tree
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CBS Nursing Knowledge Tree

Extends its Tribute to

Florence Nightingale

*For glorifying the role of women as nurses,
For holding the title of “The Lady with the Lamp,”
For working tirelessly for humanity—
Florence Nightingale will always be
remembered for her
selfless and memorable services to the
human race.*



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Florence Nightingale
(May 1820 – August 1910)



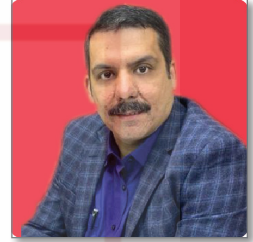


Nursing Knowledge Tree

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*"Coming together is a beginning. Keeping together is progress.
Working together is success!"*

It gives us immense pleasure to share with you that Nursing Knowledge Tree—An initiative by CBS Nursing Division, has successfully established itself in the field of nursing as we have been standing as a strong contender by sharing approximately 50% of market share. This growth could not have been possible without your invaluable contribution as our reader, author, reviewer, contributor and recommender, and your outstanding support for the growth of our titles as a whole. Before I enunciate in detail, I would like to thank each and every Clinical Nurse, Academician and Nursing Student for the phenomenal support during the COVID-19 pandemic. It is all your support that instilled a sense of responsibility in us and provided us with strength and motivation to survive under the worst circumstances of the pandemic.



The last 2–3 years were the most crucial phase when the entire world stood still due to adversity of COVID-19. The normal life was in turmoil, and people had no idea what would be their next step and how long this crisis would persist. In the midst of all, a few things which nobody could stop is 'Change', which is inevitable. During these years, we have done a lot of innovations and put our best efforts in implementing those innovations to bring quality education and make sure that every person should have access to best possible education.

It is worth mentioning that with all your support we have made some remarkable innovations in the field of nursing education, which are:

1. More quality books by the top Authors from the top institutes
2. Entered into Nursing EdTech Segment with NNL App (Nursing Next Live Application)
3. NN Social
4. Phygital Books
5. Social Media Presence
6. Built Strong Community (Faculty/Student Ambassador Program)

As a publisher, we have been contributing to the field of Medical Sciences, Nursing and Allied Sciences and have many established titles in the market. Tradition is carrying forward the legacy of the old pattern and approach in the contemporary time. We broke the boundary of being a traditional publisher through innovations and changes. As far as publishing industry is concerned, we are the first to enter the **Nursing EdTech** with the Launch of **Nursing Next Live App**.

Through Nursing Next Live, we made possible the reach of quality education from Jammu and Kashmir to Kanyakumari and from Gujarat to Arunachal Pradesh.

We started with the mission:

"We are bringing Learning to the People Instead People are going for the Learning."

When pandemic halted everything, the future seemed to be doomed, Nursing Next Live made it possible for the Nursing Professionals across the nation to keep continuing their learning and helped them to achieve their dream career.

In a step toward strengthening the Nursing Segment, we have melded the four important pillars—Print, Digital, Nursing Professionals and Social Media—to work in a homogenized manner for the better future of the nursing education through:

NN Social, a community of 20K+ professionals, is an initiative of Nursing Next Live as India's knowledge-sharing network platform for the nursing segment. Nursing Next Social is curated with the aim to bring all the

nursing faculty members across the nation closer and together on a single platform. Through **NN Social**, we aim to connect the sharp minds across the nation to use their knowledge for the better future of Nursing Profession. With NN Social **India's top-notch societies, like TNAI, SOCN, NTA, KINS, etc. are associated with us.** Apart from this, NN Social has a strong network of 100+ authors, 500+ reviewers and contributors. They all are dedicated and committed as we are, toward imparting quality nursing education.

In the era of digitalization, to make study interactive and convenient, we have conceptualized the idea of **Phyigital Edition of the books.** In this series, our many bestselling titles are available in the phyigital form. This phyigital learning is a blended learning wherein printed booklets are thoughtfully integrated with the digital support to reconceptualize the learning method in a more interactive manner with added values to knowledge. Phyigital edition is an endeavor to facilitate the next level of preparation for any nursing competitive exams through quality content, flexibility, customization and engaging interactive learning experiences.

We have also increased our **social media presence** through meaningful and innovative ideas and are committed to assist the nursing professionals in gaining and sharing the knowledge. We have taken the initiative to learn from the experience of the others and started **NNL Talks.** It is a platform where every nursing professional who has done exceptionally well in his/her career, toppers of any Nursing Exams and those who manage themselves in all the odds and stand firm and determined and succeed in his/her life, can share the success journey. We aim to motivate, educate and encourage the nursing professionals through various activities and posts on our social media platform.

Whatever initiative we take, we always make sure that it is for a noble cause of promoting the quality education accessible to everyone.

Today we can say this with confidence, we "CBS Publishers & NNL" have an edge over all other Indian and International Publishers. Our Approach, Vision, Mission, Concept, Content, Reach, Ideas all have a single goal that is better nursing education can lead to a better healthcare system.

Long way to go.... Together!

Looking forward to invite more young and experienced minds who can join us as Authors, Reviewers, Contributors, and Faculties and accomplish our mission of providing quality nursing education to all.

With Best Wishes

Mr Bhupesh Aarora

Sr. Vice President – Publishing & Marketing
(Health Sciences Division)



Nursing Knowledge Tree
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Special Features of the Book

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

Learning Objectives

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

- Draw histological structure of lung.
- Name the structures at the hila of lungs.
- Discuss the respiratory movements and the muscles responsible for these movements.

Chapter Outline

- Organs of Respiration
- Mechanism of Respiration
- Lung Volumes
- Characteristics of Normal Respiration
- Gas Exchange in Lungs

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

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

Key Terms

Arteries: These take blood from heart to the organs. The large arteries are elastic, limb arteries are muscular and the smallest ones are the arterioles.

AV valves: Prevent blood of ventricles going back into the atria.

Blood pressure: Lateral pressure exerted by blood on the arterial walls. It is recorded by auscultating brachial artery universally.

Capillaries: Minute channels through which exchange of gases and nutrients occur.

Table 4.2: Differences between artery and vein

Artery	Veins
Blood flow is in spurts	Continuous blood flow
Flow is at high pressure	At low pressure
Carries blood from heart to capillaries	Carry blood from capillary to heart
Offers resistance under pressure	Easily flattened under pressure

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

Well-illustrated relevant colorful **Figures** have been included to understand the concepts in an easy way.

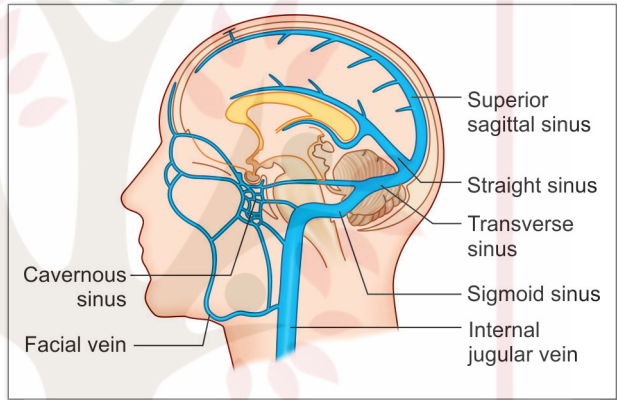


Figure 4.5: Veins of head and neck

Clinical Aspects

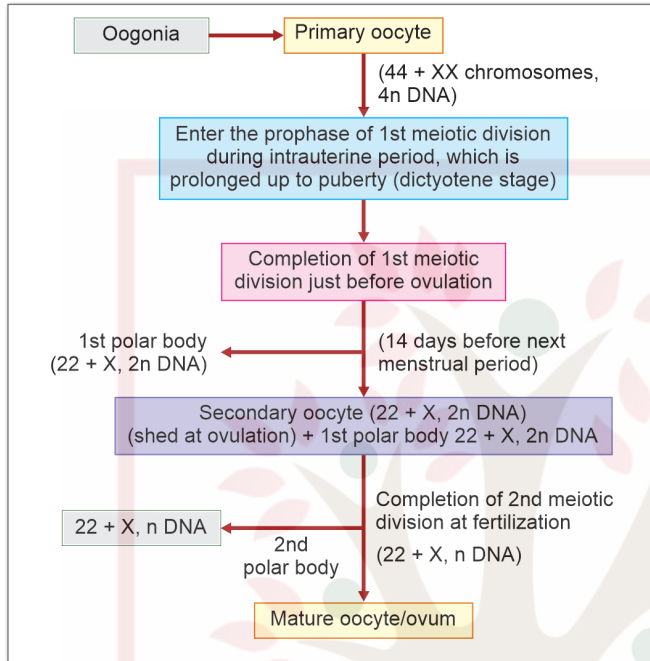
Sexually Transmitted Diseases (STDs)

STDs are a group of communicable diseases that are transmitted predominantly by sexual contact. These are caused by a wide range of bacterial, viral, protozoal and fungal agents. They have a higher incidence in 20–30 years age group. Syphilis, gonorrhoea, chlamydia and human immunodeficiency virus (HIV) constitute major STDs in India.

Syphilis

Syphilis is caused by spirochaete *Treponema pallidum*. The organism after penetrating the genital mucosa produces local as well as distant lesions.

Clinical Aspects highlight clinically important diseases and facts.

Flowchart 10.1: Oogenesis

Flowcharts are included to give a concise view of a long process.

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 Answer Questions

1. Discuss the structure and functions of the breast.
2. Describe the phases of menstrual cycle.

Short Answer Questions

1. Write brief description of stages of syphilis.
2. Briefly describe the parts of a spermatozoa.

Multiple Choice Questions

1. Of the 46 chromosomes in the human cells, _____ are autosomes, and _____ are sex chromosomes.
 - a. 40, 6
 - b. 42, 4
 - c. 43, 3
 - d. 44, 2

ANATOMY AND PHYSIOLOGY (THEORY)

Course Description

This course is designed to help students to gain knowledge of the structure and functions of the human body and recognize any deviation from normal health in order to render effective nursing services.

General Objectives

Upon completion of the course, the student shall be able to:

- Describe in general the structure and functions of the human body.
- Describe in detail the structure and functions of the different organs and systems in the human body.
- Apply the anatomical and physiological principles in the practice of nursing.

Placement – First Year

Total Hours – 90

Unit No.	Learning objectives	Content	Hours	Teaching learning activities	Assessment methods
I	Define and spell various anatomical terms	Introduction to Anatomical Terms, Organization of the Human Body <ul style="list-style-type: none"> • Anatomical terms • Systems and cavities of the human body 	4	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts • Record book 	<ul style="list-style-type: none"> • Short answer questions • Objective type
II	Describe different organs of the body, systemic functions and their inter-relationship	Introduction to the Detailed Structure of the Body <ul style="list-style-type: none"> • The cell: Structure, reproduction and function • Tissues including membranes and glands: Types, structure and functions • Body cavities and their contents 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using microscopic slides, skeleton and torso 	<ul style="list-style-type: none"> • Short answer questions • Objective type

Contd...

Unit No.	Learning objectives	Content	Hours	Teaching learning activities	Assessment methods
III	Describe the composition of blood and its functions	Blood <ul style="list-style-type: none"> • Composition and formation of blood • Functions of blood • Blood clotting, blood grouping and cross matching • Blood products and their use 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using microscopic slides • Demonstration of blood grouping and cross-matching, Hb estimation 	<ul style="list-style-type: none"> • Short answer questions • Objective type • Essay type
IV	Describe the structure and functions of heart and blood vessels	The Circulatory System <ul style="list-style-type: none"> • Heart: Structure, functions including conduction system and cardiac cycle • Blood vessels: Types, structure and position • Circulation of blood • Blood pressure and pulse 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, models and specimens 	<ul style="list-style-type: none"> • Short answer questions • Objective type • Essay type
V	Describe structure and functions of lymphatic system	The Lymphatic System Structure and functions of lymph vessels, lymph nodes, and lymph circulation, lymphatic tissue—spleen and thymus	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts and models 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
VI	Describe the structure and functions of respiratory system	The Respiratory System <ul style="list-style-type: none"> • The structure and functions of respiratory organs • The physiology of respiration • Characteristics of normal respiration and deviation 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts and models, specimens • Demonstration of spirometry 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
VII	Describe the structure and functions of digestive system	The Digestive System <ul style="list-style-type: none"> • Structure and functions of the alimentary tract and its accessory organs • The process of digestion, absorption, and metabolism of food constituents 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, models, and videos 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type

Contd...

Unit No.	Learning objectives	Content	Hours	Teaching learning activities	Assessment methods
VIII	Describe the structure and functions of organs of excretory system	The Excretory System <ul style="list-style-type: none"> • Structure and functions of the kidney, ureters, urinary bladder, and the urethra • Formation and composition of urine • Fluid and electrolyte balance • Structure and functions of the skin • Regulation of the body temperature 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, slides models, and videos 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
IX	Describe the structure and functions of endocrine glands	The Endocrine System The structure and functions of the pituitary, thyroid, parathyroid and adrenal glands, pancreas (islets of Langerhans), ovaries and testes	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts and models 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
X	Describe the structure and functions of male and female reproductive system and accessory organs	The Reproductive System <ul style="list-style-type: none"> • Structure and functions of the female reproductive system • Process of menstrual cycle, reproduction and menopause • Structure and functions of breasts • Structure and functions of the male reproductive system • Reproductive health 	8	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, videos, models, and specimens 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
XI	Describe the structure and functions of nervous system	The Nervous System <ul style="list-style-type: none"> • Types of nerves— structure and functions • Brain and cranial nerves • Spinal cord and motor and sensory pathways of the spinal cord, autonomic nervous system 	10	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts and models 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type

Contd...

Unit No.	Learning objectives	Content	Hours	Teaching learning activities	Assessment methods
XII	Describe the structure and functions of sensory organs	The Sense Organs <ul style="list-style-type: none"> • Skin, ear, eye, nose and tongue • Physiology of vision, hearing, smell, touch, taste and equilibrium 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, videos, and models 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
XIII	Describe the structure and functions of skeletal system	The Skeleton <ul style="list-style-type: none"> • Formation and growth of bones • Tendons, ligaments and cartilages • Classification of bones, joints • Joint movement • Axial and appendicular skeleton 	8	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, models, and skeleton 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type
XIV	Describe structure and functions of muscular system	The Muscular System <ul style="list-style-type: none"> • Type, structure and functions of muscle • Origin, insertion, and action of muscles 	6	<ul style="list-style-type: none"> • Lecture cum discussions • Explain using charts, slides, and models 	<ul style="list-style-type: none"> • Short answer • Objective type • Essay type



Nursing Knowledge Tree
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Blood

Learning Objectives

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

- Discuss the composition of blood.
- Enumerate types of WBC with their structure and functions.

Chapter Outline

- Formation of Blood
- Functions of Blood
- Composition of Blood
- Types of Blood Cells
- Blood Clotting
- Blood Products and their Uses
- Blood Groups
- Crossmatching

Key Terms

Blood bank: A bank where blood of different groups is stored.

Hematopoietic stem cell (HSC): All blood cells develop from the progenitor cells called HSC.

Plasma: Blood minus the cellular components is plasma (made of water and solids).

Platelets: Thrombocytes are essential for clotting mechanism.

RBCs: Red blood cells carry oxygen and carbon dioxide from blood to tissues and back.

Serum: Plasma without fibrinogen is serum.

WBCs: White blood cells provide immunity.

FORMATION OF BLOOD

Hematopoiesis is the process of formation of blood cells, i.e., RBCs, WBCs and platelets. It takes place in the bone marrow, liver and spleen (Fig. 3.1).

FUNCTIONS OF BLOOD

Blood is a connective tissue. It helps in communication between cells of different parts of the body and external environment. Its functions are as follows:

- It transports digested food from gastrointestinal tract to tissues and organs.
- It provides clotting factors to prevent loss of blood in case of injury.
- It provides buffers to maintain the blood pH and acid-base balance.
- It distributes hormones released by endocrine glands to various target organs.
- It distributes heat to various parts of the body.
- Blood maintains the internal environment within limits.
- **Red blood cells** carry oxygen and carbon dioxide from blood to tissues and back.
- **White blood cells** protect our bodies from viruses, bacteria and provide immunity by forming antibodies.
- **Platelets** are essential for clotting mechanism.

Lack of iron causes anemia.

Blood makes up 7% of body weight, e.g., it is about 5.6 liters in 70 kg man and is slightly less in females. Blood is always moving within blood vessels. Its continuous flow gives constant environment for the cells of the body.

COMPOSITION OF BLOOD

Blood consists of a cellular part and a liquid part. The latter is called the plasma and constitutes 55% of blood volume. The volume occupied by the cells is packed cell volume and is 45% in normal blood. Plasma contains the following:

- **Proteins:** Albumin, globulin, fibrinogen, clotting factors.
- **Minerals:** Calcium, phosphorus, iron, copper and magnesium.
- **Electrolytes:** Sodium, potassium, chloride and bicarbonate.
- **Nutrients:** Glucose, amino acids, fatty acids, glycerol and vitamins.
- **Waste products:** Urea, uric acid, creatinine.
- **Gases:** Oxygen, carbon dioxide, nitrogen.
- **Hormones:** Thyroxine, cortisone, etc.
- **Enzymes:** Certain clotting factors.

The details of composition are as follows:

Plasma Proteins

The plasma proteins make up about 7% of plasma and are contained within the blood. The plasma proteins exert the osmotic pressure of blood which keeps plasma fluid within the circulation. If level of plasma proteins falls due to any reason, the osmotic pressure of plasma is reduced and fluid exudes out of the capillaries into the tissues causing **edema** or swelling of soft tissues especially of the dependent parts, i.e., around ankles.

Albumins: These are formed in the liver and are responsible for maintenance of normal osmotic pressure.

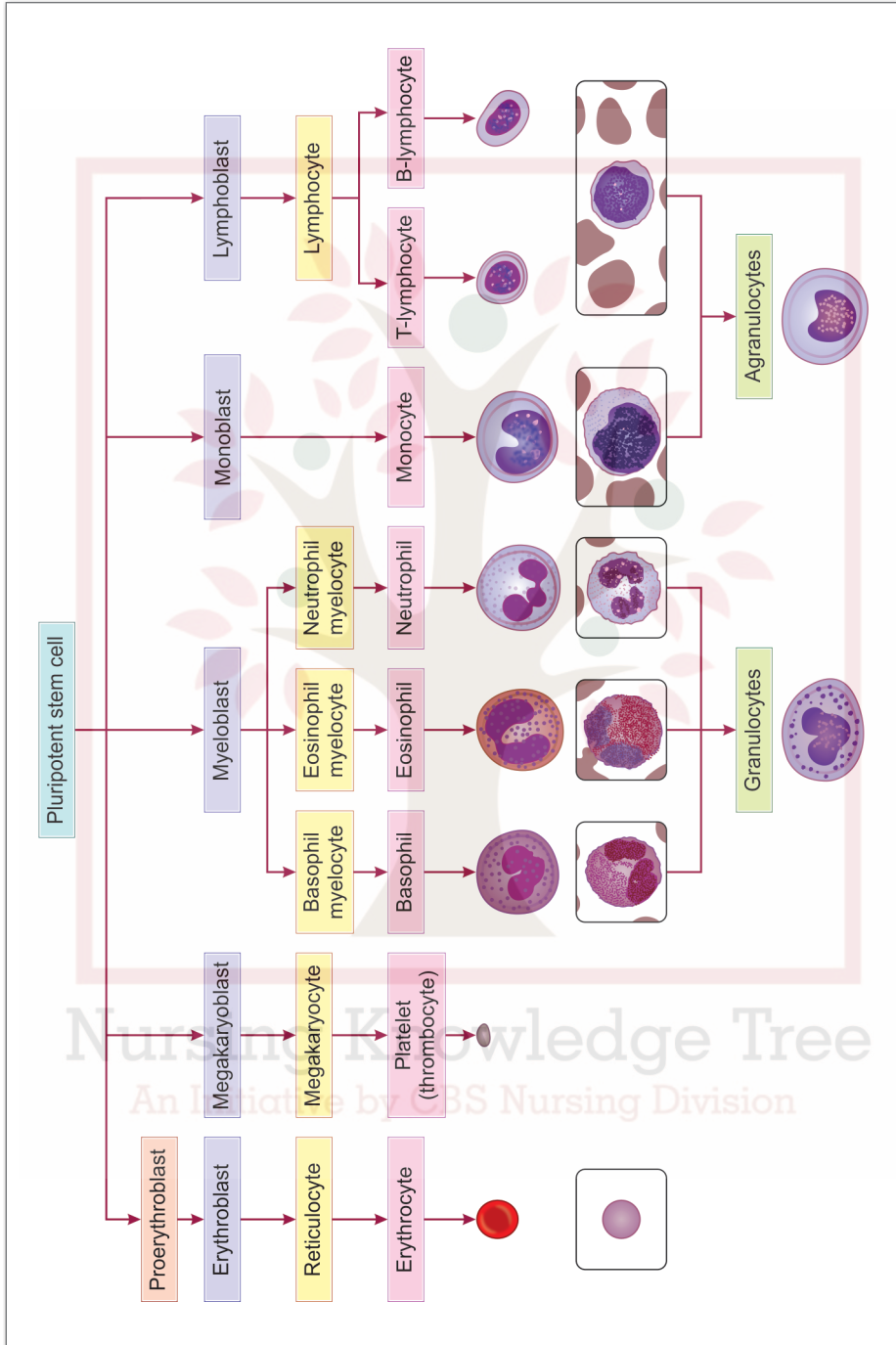


Figure 3.1: Hematopoiesis stem cells

Globulins: These are mainly formed in the liver. The globulins function as:

- Antibodies, i.e., immunoglobulins, which play an important role in immunity.
- Transporting agents of some hormones, e.g., thyroglobulin carries the hormone thyroxine.

Clotting factors: These are required for coagulation of blood. Plasma minus the clotting factors is **serum**. **Fibrinogen** is a very important clotting factor and is synthesized by the liver.

Mineral Salts

These are involved in cell formation, muscular contraction, nerve impulse transmission, and maintenance of pH of blood. The pH of blood is maintained between 7.35 and 7.45 by the various chemical activities involving buffer systems (Fig. 3.2).

Nutrients

Food is digested in the digestive system. The products of absorption are glucose, amino acids, fatty acids, glycerol and vitamins. All these along with mineral salts are required to provide heat and energy for the body besides repair, replacement and synthesis of various cells of the body tissues.

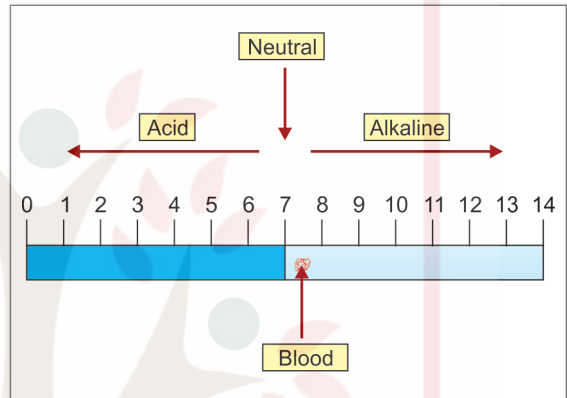


Figure 3.2: pH scale

Waste Products

Urea, uric acid, creatinine are the waste products of protein metabolism. These reach the kidney via blood for excretion. Carbon dioxide released from all the cells reaches lungs via blood for expulsion during expiratory phase of respiration.

Hormones

These are produced by various endocrine glands and use blood as a vehicle to be transported to the target organs.

Gases

Oxygen, carbon dioxide and nitrogen are transported via the plasma.

Oxygen is carried in combination with hemoglobin and carbon dioxide is carried as bicarbonate ions in solution form in the plasma. Nitrogen also enters the body but its concentration is same in inspired air and expired air. It has no physiological function.

TYPES OF BLOOD CELLS

There are three types of blood cells:

1. Erythrocytes or red blood cells (RBC).
2. Leukocytes or white blood cells (WBC). These are granulocytes and agranulocytes.
3. Thrombocytes or platelets.

All the blood cells arise from “**pluripotent stem cells**” and pass through different developmental stages.

Each type of blood cell follow separate lines of development.

The blood cells are formed in red bone marrow and the process is called **hemopoiesis**.

Red Blood Cells (RBCs)

The RBCs are circular biconcave discs. These have no nucleus and are $7\ \mu$ in diameter. Certain terms about RBCs are used in clinical practice. These are:

Packed cell volume: Volume of RBCs in 1 liter or $1\ \text{mm}^3$ of whole blood. Normal packed cell volume is $40\text{--}50/\text{mm}^3$.

RBC count: Number of RBC per liter or per mm^3 of blood.

Hemoglobin: Amount of hemoglobin present in whole blood and is measured as grams per 100 mL of blood. This is a very important measurement as it indicates the oxygen carrying capacity of blood. If hemoglobin (Hb) is less than the normal value, the condition is called **anemia**. Normal hemoglobin in males is $13\text{--}18\ \text{g}\%$ and in females is $11.5\text{--}16.5\ \text{g}\%$.

Mean cell volume: Average volume of cells and is measured in femtoliters ($\text{fl} = 10^{-15}$ liter).

Mean cell hemoglobin: Average amount of hemoglobin in each cell and is measured in picograms ($\text{pg} = 10^{-12}$ g).

Mean cell hemoglobin concentration: Amount of hemoglobin in 100 mL of red cells.

Fate of Red Blood Cells

After about 120 days, reticuloendothelial cells cause hemolysis of ‘aged’ RBC. The fate of RBC is shown in **Flowchart 3.1**.

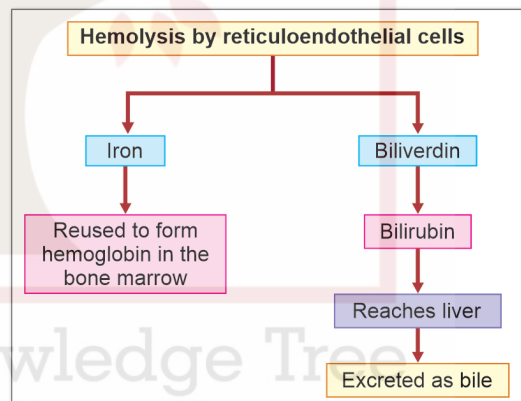
RBCs are formed in the red bone marrow. Before puberty red bone marrow is present in the medullary cavities of all long bones, marrow spaces of flat bones and ends of long bones. After puberty due to decreased need for production of RBC most of the red bone marrow is replaced by fat and is known as yellow bone marrow. However, red bone marrow persists at the ends of long bones and in flat bones like sternum and iliac crest. It is also present in the irregular bones.

The RBCs develop from the pluripotent stem cell to proerythroblast, erythroblast, reticulocyte to mature RBC during a period of 7 days. The cell develops, matures and also acquires hemoglobin within the cell.

During the maturation of RBCs, the size of cell decreases and loses its nucleus as well. For this process, vitamin B_{12} and folic acid are necessary. Life of RBCs is about 120 days.

Hemoglobin is acquired during development of RBC. It is formed by union of a protein called **globin** and an iron containing substance known as **heme**. The hemoglobin is synthesized in the developing RBC.

Flowchart 3.1: Fate of RBC



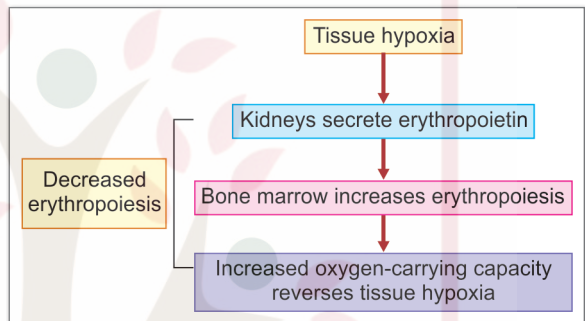
Hemoglobin combines with oxygen to form oxyhemoglobin which gives the typical bright red color to the arterial blood. Oxyhemoglobin carries oxygen to the various cells of body. Each hemoglobin (Hb) molecule has four atoms of iron. Each atom can carry one molecule of oxygen. Therefore, one Hb molecule can carry up to 4 molecules of oxygen.

Hemoglobin also carries some amount of carbon dioxide from the tissues to the lungs to be expelled out. Rest of the carbon dioxide is carried as bicarbonate ions in solution form in the plasma.

Control of RBC formation: Normally, the rate of production and rate of destruction of RBCs is balanced. The stimulus for more production is lack of oxygen supply to the cells of the body. This may occur either because of excessive loss (menstruation) or destruction of RBCs or when oxygen tension is low as at high altitudes (Flowchart 3.2).

Graveyard for RBCs: Spleen is the chief graveyard for RBCs after their lifespan is over.

Flowchart 3.2: Control of erythropoiesis: a negative feedback mechanism

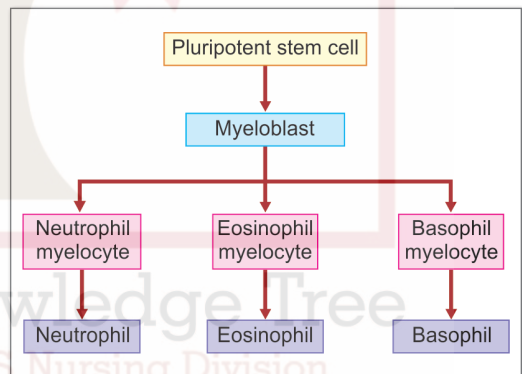


White Blood Cells (WBCs)

The WBCs are large cells, with nuclei, granules and no hemoglobin. Hence these are called white blood cells. There are two types of white blood cells:

1. **Granulocytes** or polymorphonuclear leukocytes: Depending upon the color of granules, these are further classified as (Flowchart 3.3 and Fig. 3.3):
 - a. Neutrophils
 - b. Eosinophils
 - c. Basophils.
2. **Agranulocytes:** These cells do not contain any granules and are of two type (Flowchart 3.4 and Fig. 3.4):
 - a. Monocytes
 - b. Lymphocytes, which are:
 - i. "T" lymphocytes
 - ii. "B" lymphocytes

Flowchart 3.3: Stages of formation of granulocytes



Granulocytes

These cells develop from pluripotent stem cell the myeloblast which matures into three types of myelocytes (Flowchart 3.3). The nuclei of granular series of cells is multilobed and their granules take up specific stains and the cells are named accordingly (Fig. 3.3).

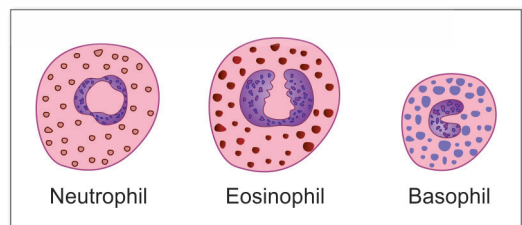


Figure 3.3: Granulocytes (granular leukocytes)

Neutrophils: These cells form line of defence for the body. These protect the body against infecting bacteria. The bacteria enter the body to infect a particular tissue. The damaging cells produce **chemotaxins**. These **chemotaxins** attract the neutrophils to the site of infection, where these reach by amoeboid movements through the capillary wall. At the site of infection, WBCs engulf the bacteria, kill them by the enzymes contained in the granules and then phagocytose the dead bacteria.

The neutrophils are increased in:

- Any inflammatory reaction.
- Leukemia (blood cancer).
- Bacterial infections.

Eosinophils: These cells are especially adapted to fight and kill the worms/parasites/allergic conditions. The eosinophils are found to be high in allergic conditions like asthma, allergic rhinitis, and in various skin allergies.

Basophils: These cells contain large blue granules. Their granules contain heparin which is an anticoagulant and histamine which is an inflammatory agent.

The contents of granules of basophils are released in response to an allergen, helping to fight out and remove the allergen thus protecting the body.

The mast cell is similar to basophil. It releases the contents of its granules as soon as allergen binds to the cell membrane in an attempt to destroy the allergen.

Agranulocytes

The agranulocytes contain a large nucleus and as the name indicates, no granules. These make up 25–50% of WBCs. The agranulocytes are of two types (Fig. 3.4):

1. Lymphocytes
2. Monocytes

Lymphocytes: These are small cells with relatively single large nucleus (Fig. 3.4). These are present in large numbers in lymph nodes, lymph nodules and spleen. These cells originate in bone marrow and reach thymus or lymph nodes. In these tissues the lymphocytes get “activated”, after which these are usually able to deal effectively with the foreign proteins or antigens. There are two types of lymphocytes:

1. **T lymphocytes:** These lymphocytes are processed in the thymus gland situated between the sternum bone and the heart. The hormone **thymosin**, produced by thymus causes the programming and maturation of lymphocytes, so that one set of “T” lymphocytes recognize one type of antigen only. These leave thymus gland to circulate in blood. The “T” cells provide **cell-mediated immunity**.

The antigen (abnormal body cell, cancer cell) on coming into contact with ‘T’ lymphocytes stimulate the proliferation of these cells. The specialized ‘T’ cells are as follows:

Flowchart 3.4: Stages of formation of agranulocytes

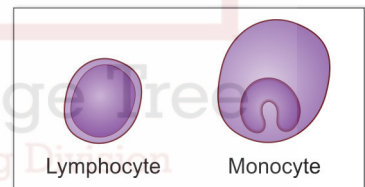
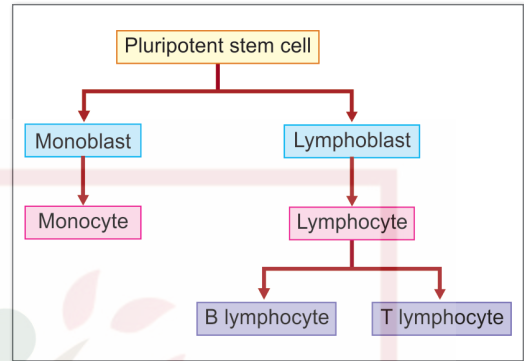


Figure 3.4: Agranulocytes

- a. **Cytotoxic ‘T’ cells:** These ‘T’ cells attach themselves to the target cells carrying antigens. Then these ‘T’ cells release strong toxins, thereby destroying infected cells/cancer cells.
 - b. **Memory ‘T’ cells:** These cells remember the antigen and act fast in any future attack by same antigen.
 - c. **Helper ‘T’ cells:** These cells are important as these help the ‘T’ cells by producing cytokines, i.e., interferons and interleukins. These helper ‘T’ cells help B lymphocytes in producing antibodies.
2. **‘B’ lymphocytes:** The ‘B’ lymphocytes are programmed and processed in the bone marrow. These cells produce antibodies which destroy the antigen. The B lymphocytes also are very specifically matured, so that one set of ‘B’ cells respond to only one type of antigen. So ‘B’ lymphocytes produce antibody mediated immunity or **humoral immunity**.

Humoral Immunity or Antibody Mediated Immunity

‘B’ lymphocytes are mostly in lymph nodes, lymph nodules and in spleen. Once ‘B’ cells recognize the antigen, the ‘B’ cells start to enlarge and multiply, to produce the following two types of cells:

1. **Plasma cells:** These are modified ‘B’ lymphocytes. The specific plasma cells produce antibodies against a specific antigen, which was initially bound to ‘B’ lymphocyte.
2. **Memory ‘B’ cells:** The specific plasma cells remain in the body, with an imprint of the antigen. If the same antigen enters again even after years, these ‘B’ cells get activated and fight out with the antigen.

Normally the lymphocytes recognize the body cells as their own and not ‘foreign’. In auto-immune diseases, the lymphocytes produce antibodies against body cells, leading to disease.

Monocytes: These are large cells with single large nucleus and no granules. Some monocytes remain in blood and act as phagocytes. Others migrate to the tissues and mature as macrophages. **Monocytes and macrophages** produce interleukin I which acts as under:

- a. Increases the production of programmed and activated ‘T’ lymphocytes.
- b. Acts on the hypothalamus, and raises the body temperature especially in bacterial infections. Macrophages act a little later in inflammatory responses. After 24 hours, macrophages collect at the inflamed site, leading to chronic inflammation. The macrophages live longer than neutrophils. The macrophages phagocytose dying or dead tissues, bacteria or antigens.

Macrophages act hand in hand with monocytes of blood and with lymphocytes.

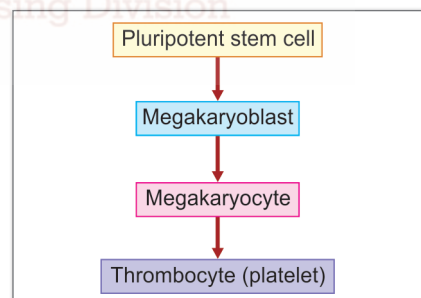
Reticuloendothelial system: This system comprises monocyte-macrophage cells. Macrophages are not only present in blood. These are also found in various tissues such as microglia in brain to phagocytose the dying or dead brain cells, Kupffer’s cells in liver, macrophages in alveolar wall, reticular cells in spleen and lymph nodes.

The reticuloendothelial system helps in providing immunity to the body.

Thrombocyte or Platelets

The platelets are 2–4 micron discs which are non-nucleated. These develop from megakaryocytes in bone marrow (Flowchart 3.5). The chief function of platelets is to “stop bleeding” and “promote clotting” of blood. This is possible due to number of substances present in these tiny blood cells.

Flowchart 3.5: Stages of formation of thrombocytes (platelets)



BLOOD CLOTTING

The normal platelet count is 200,000–350,000/mm³. The life span of platelets is 8–11 days. These produce a substance called **thrombopoietin**. The stages of **hemostasis** (stoppage of bleeding) following damage to blood vessel wall are as follows:

- **Vasoconstriction:** At the site of bleeding, the damaged blood vessels get narrowed, due to serotonin released by platelets present at the site of damaged blood vessel. The narrowing of blood vessels reduce the blood flow at the site.
- **Formation of platelet plug:** The platelets adhere to each other and clump at the site of bleeding. The release of adenosine diphosphate (ADP) attracts more platelets and these huge number of platelets form a '**platelet plug**' which acts as a temporary seal at the site of blood vessel wall damage.
- **Blood clotting or coagulation:** Plasma protein prothrombin is converted into thrombin by the **prothrombin activator**. Thrombin converts fibrinogen into fibrin. Fibrin are thread-like pieces, which forms a mesh and hold the blood cells in between them.
Prothrombin activator can be formed by either intrinsic or extrinsic pathway. After some time clot shrinks and serum is squeezed out.
- **Breakdown of the clot (fibrinolysis):** The clot is broken down and healing of wall of injured blood vessel starts. As the clot is slowly removed, the healing process gets started and blood vessel gets new look.

Control of Coagulation

The coagulation is controlled by smoothness of normal blood vessel lining, presence of natural anticoagulants, e.g., heparin which inactivates clotting factors and presence of a special thrombin receptor on the cells lining blood vessels which inactivates thrombin on binding.

BLOOD PRODUCTS AND THEIR USES

Packed Red Blood Cells

Packed red blood cells (PRBCs) are made from a unit of whole blood by centrifugation and removal of most of the plasma. It is generally indicated in patients with a hemoglobin of 7–8 g/dL, a markedly decreased oxygen saturation and/or orthostatic hypotension. There is indication that the patient needs additional oxygen carrying capacity.

Fresh Frozen Plasma

Fresh frozen plasma contains all factors of the soluble coagulation system. It is generally indicated when a patient has multiple factor deficiencies and is bleeding, or for thrombotic thrombocytopenic purpura (TTP). It prolongs prothrombin time, an important indicator for bleeding problems.

Platelets

A single platelet unit is derived from one whole blood unit collected. Platelets are stored at room temperature and cannot be frozen. They must be used in 5 days. It is generally indicated for a platelet count of less than 50,000/μL and there is active bleeding, or if a procedure such as surgery is to be performed.

Cryoprecipitate

It contains a concentrated subset of fresh frozen plasma components including fibrinogen, factor VIII coagulant, vonWillebrand factor, and factor XIII. Cryoprecipitate is used for hypofibrinogenemia and vonWillebrand disease.

BLOOD GROUPS

The blood groups are genetically controlled (Table 3.1). The major grouping is into ABO system, i.e., A, B, AB and O. This depends on two allelic genes. These genes are responsible for the potential to form the antigens known as agglutininogen A and agglutininogen B on the surface of RBC. The same genes control formation of agglutinins α and β in the blood serum. Agglutinin α is responsible for agglutination of those RBCs which carry agglutininogen A and vice versa. But the arrangement is such that if A agglutininogen is present, α agglutinin is absent, instead β agglutinin is present in serum. Similarly if β agglutininogen is present, then α agglutinin is present in serum. So, the serum does not agglutinate its own RBCs.

Before transfusion of blood it is imperative to see blood group named according to agglutininogen, i.e., A or B or AB or O in both the patients and the donor blood (Table 3.1).

Table 3.1: Blood groups

Blood groups	Agglutininogen	Agglutinin	Can receive blood
A	A	β	A and O
B	B	α	B and O
AB	A and B	–	AB, A, B and O
O	–	α, β	O only

Rhesus System

This system is also under the control of genes. This system produces either Rh +ve individuals with antigens and no antibody (85%).

Rh –ve individuals are with neither antigen nor antibody (15%). These individuals can produce antibody if RBCs carrying antigens reach in such a circulation.

If mother is Rh –ve and father is Rh +ve, Rh +ve fetus is being nurtured, and a few Rh antigen carrying RBCs escape from fetus into maternal bloodstream and are enough to stimulate her to produce antibodies which can come back to the fetus. These antibodies may be less in first pregnancy but can be in great amount in next pregnancy to be able to severely harm the fetus.

Human lymphocytic antigen (HLA) complex is a group of genes which have been identified on chromosome six. These play a major part in the identification of immune responses and foreign cells.

CROSSMATCHING

Crossmatching is a series of tests done to ensure compatibility of blood between the donor and recipient. It is of two types, i.e., major crossmatch and minor crossmatch. Major crossmatching is mandatory especially in a blood bank before releasing blood to a patient. In this, blood cells from donor are combined with patient serum.

Hemoglobin estimation is now usually done using an automated hemoglobin analyzer. Another commonly used method is Sahli's method.

Sahli's Method

Sahli's hemoglobinometer is a manual device that contains a hemoglobin tube, pipette and stirrer as well as a comparator. HCl converts hemoglobin to acid hematin, which is then diluted until the color of the solution matches that of the comparator block (Fig. 3.5).

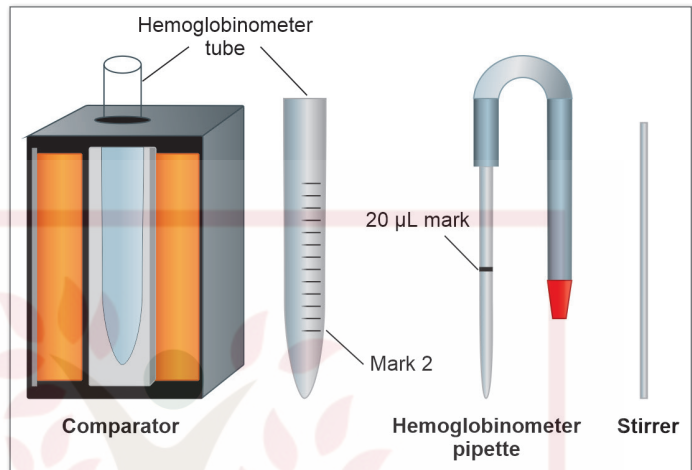


Figure 3.5: Sahli's hemoglobinometer

Clinical Aspects

Anemia

Anemia is a condition where the hemoglobin level is lower than normal. It may be due to:

- Enhanced RBC loss as in hemolytic anemia and in normocytic anemias.
- Decreased RBC manufacture: This occurs mostly due to iron deficiency or megaloblastic anemias due to deficiency of vitamin B₁₂ and/or folic acid.

Hemolytic Anemias

When RBCs are destroyed earlier than their life span of 120 days. These may be:

- **Congenital hemolytic anemia:** This is a genetic disease where Hb is abnormal and RBC are friable. This is of following types:
 - **Sickle cell anemia:** The Hb molecule is abnormal and RBC get sickle shaped. Life span of such RBCs is less.
 - **Thalassaemia:** The protein globin synthesis is less than normal, resulting in decreased Hb synthesis. These RBC are also more friable.
- **Acquired hemolytic anemias:** The reasons are:
 - **Malaria**
 - Chemicals like lead, arsenic compounds in environment.
 - Drugs like sulphonamides, primaquine taken for long periods.
 - X-rays, radioactive isotopes.

Normocytic Anemias

The number of RBCs is less than normal. It is usually due to chronic diseases or after hemorrhage.

Decreased RBC Manufacture

- **Iron deficiency anemia:** This is most prevalent type of anemia in India and is due to lack of iron in food (usually), malabsorption or increased loss of blood. Every one must eat food items containing iron. The anemia is responsible for breathlessness on exertion, palpitations and tachycardia. Daily requirements of iron is 1–3 mg. Children and women require more iron than male adults. Iron deficiency anemia is microcytic (cells smaller than normal) and hypochromic (cells paler than normal).

- **Megaloblastic anemia:** This type of anemia occurs in deficiency of folic acid and/or vitamin B₁₂. Abnormally large RBCs (megaloblasts) are found in blood.
- **Hypoplastic anemia:** This occurs due to depression of bone marrow. It may be due to hepatitis, ionising radiation and cytotoxic drugs.

Polycythemia

When the number of RBCs is more than normal, the condition is known as polycythemia. There is increased viscosity of blood which may lead to clotting within the blood vessels (intravascular clotting).

Leukopenia

When total WBC count is less than 4,000 mm³, the condition is called leukopenia.

Neutropenia

When the neutrophils are abnormally less, the condition is called neutropenia. It may be due to leukemia, bacterial infections, cytotoxic drugs—sulphonamides and some antibiotics. Neutropenia leads to acute and severe infections as the line of defence becomes very weak.

Leukocytosis

When the WBCs are abnormally more the condition is called leukocytosis. If WBCs are more than 11,000 mm³, the condition is leukocytosis. It may occur as a protective response to a variety of diseases, especially infections.

Leukemia

When there is uncontrolled production of premature or mature WBCs the condition is called leukemia. Its reasons may be genetic, chemicals like cytotoxic drugs, ionising radiations.

Leukemias may be acute or chronic

- **Acute leukemia:** There is overproduction of 'blast' cells. It may be acute myeloblastic or lymphoblastic leukemia.
- **Chronic leukemia:** Here the overproduced cells are in the 'myelocyte' stage. This may also be chronic granulocytic or lymphocytic leukemia.

Due to proliferation of WBC precursors in bone marrow there is decreased formation of other blood cells in bone marrow causing anemia, leukopenia and thrombocytopenia.

Thrombocytopenia

This is the condition when platelet count is abnormally low to a level below 150,000/mm³. This may be due to decreased production of platelets or enhanced destruction of platelets. A very common reason of thrombocytopenia is "dengue" fever, caused by a virus and transmitted by Aedes mosquito. Spontaneous bleeding from capillaries occur when platelet count falls below 30,000/mm³.

Deficiency of Vitamin K

Vitamin K is required for synthesis of clotting factors II, VII, IX and X by liver. Deficiency of vitamin K leads to bleeding disorders. It may be due to deficiency of vitamin K in the diet or decreased absorption of vitamin K in the intestines.

Hemophilias

This is a sex-linked bleeding disorder. The female is the carrier and male is the sufferer. If mother is carrier and father is normal, the possibilities are—normal girl, normal boy, carrier girl and hemophilic boy.

The sufferer has bleeding episodes with very mild trauma.

ASSESS YOURSELF

Long Answer Questions

1. Discuss the various functions of blood.
2. Discuss the various stages of hemostasis.

Short Answer Questions

1. Write the functions of plasma proteins.
2. Name the types of hemolytic anemias.

Multiple Choice Questions

1. Blood cells are formed at _____ organ.
 - a. Liver
 - b. Thymus
 - c. Red bone marrow
 - d. Spleen
2. Blood cell which is responsible for coagulation is:
 - a. RBC
 - b. WBC
 - c. Platelet
 - d. Neutrophil
3. The main function of hemoglobin is to:
 - a. Maintain a normal erythrocyte sedimentation rate
 - b. Neutralize any free radicals circulating in the blood
 - c. Bind to oxygen and transport it to the tissues
 - d. Absorb heat generated as a by-product of cell metabolism
4. Life span of RBCs are:
 - a. 30–60 days
 - b. 60–90 days
 - c. 90–120 days
 - d. 120–140 days
5. Fresh frozen plasma contains:
 - a. Plasma proteins and clotting factors
 - b. RBCs
 - c. Platelets
 - d. None of these

Nursing Knowledge Tree
An Initiative by CBS Nursing Division

Answers to Multiple Choice Questions

1. c 2. c 3. c 4. c 5. a

Essentials of

Anatomy & Physiology

for GNM Nursing Students

Salient Features

- Exclusively designed for the GNM nursing students, this edition has been thoroughly revised and updated as per the INC syllabus.
- Anatomy and Physiology as a subject is presented in an integrated manner throughout the book.
- Relevant diagrams and images have been added to supplement the text.
- Simple and easy-to-understand language of this edition helps the students understand the concepts in no time.
- Clinical correlations and applied concepts of anatomy and physiology have been highlighted at the end of each chapter.
- Important histological slides from nursing perspective have been arranged in a separate section along with their three important identification points.
- Chapter wise exercises in the form of *Assess Yourself* are given at the end of each chapter to help the students evaluate their understanding.

What's New in this Edition

- *Nutritional needs during various stages of life* is the newly-added topic in the *Digestive System* chapter.
- At places, various new matters (cell organelles functions, formation of blood, crossmatching, placenta, events of fetal developments, ossification of bones, etc.) have been added keeping the syllabus as well as the students' requirement in mind.
- Clinical aspects have been elaborated in the respective chapters.

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