

# UNIT 3

## Body Fluids and Blood

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### 1. Body Fluids

◆ **Definition:**

Body fluids are the **liquid components** within the body that help maintain **homeostasis** by transporting nutrients, gases, waste products, and regulating body temperature.

◆ **Types of Body Fluids:**

1. **Intracellular Fluid (ICF):**

- Fluid **inside the cells**
- Makes up about **2/3 of total body fluid**
- Rich in **potassium ( $K^+$ ), magnesium ( $Mg^{2+}$ ), and phosphate ( $PO_4^{3-}$ )**

2. **Extracellular Fluid (ECF):**

- Fluid **outside the cells**
- Comprises **1/3 of total body fluid**
- Subdivided into:
  - **Plasma** – fluid portion of blood
  - **Interstitial Fluid** – fluid between cells
  - **Lymph, cerebrospinal fluid (CSF), synovial fluid, aqueous humor** etc.

◆ **Functions:**

- Transport nutrients and gases
- Remove metabolic waste
- Maintain pH, temperature, and fluid balance
- Facilitate communication between cells via signaling molecules

### Composition of Blood

Blood is a **specialized connective tissue** that plays a vital role in transportation, regulation, and protection in the body.

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◆ **Total Volume:**

- **Average adult has 5–6 liters of blood**

- **pH:** 7.35–7.45 (slightly alkaline)
  - **Temperature:** ~38°C
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◆ **Main Components:**

Blood consists of two major parts:

1. **Plasma** (liquid matrix) – 55%
  2. **Formed Elements** (cellular components) – 45%
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**1. Plasma (55%)**

Plasma is the **straw-colored liquid** portion of blood.

◆ **Composition of Plasma:**

**Component Percentage/Function**

<b>Water</b>	~92%; solvent for nutrients, gases, and waste
<b>Proteins</b>	~7%; maintain osmotic pressure, immunity, and clotting
– Albumin	Maintains oncotic pressure, transports substances
– Globulins	Immunity (antibodies), transport lipids
– Fibrinogen	Involved in blood clotting
<b>Solutes (1%)</b>	Nutrients (glucose, amino acids), electrolytes ( $\text{Na}^+$ , $\text{K}^+$ , $\text{Cl}^-$ ), enzymes, hormones, waste products like urea and creatinine

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**2. Formed Elements (45%)**

These are the **cellular components** of blood:

◆ **A. Red Blood Cells (RBCs / Erythrocytes)**

- Biconcave, anucleate cells
- Count: ~4.5–6 million/ $\text{mm}^3$
- Contain **hemoglobin** for  $\text{O}_2$  and  $\text{CO}_2$  transport
- Life span: ~120 days
- Produced in **red bone marrow**

◆ **B. White Blood Cells (WBCs / Leukocytes)**

- Nucleated and colorless
- Count: 4000–11,000/mm<sup>3</sup>
- Function: Defense and immunity

**Types of WBCs:**

**1. Granulocytes:**

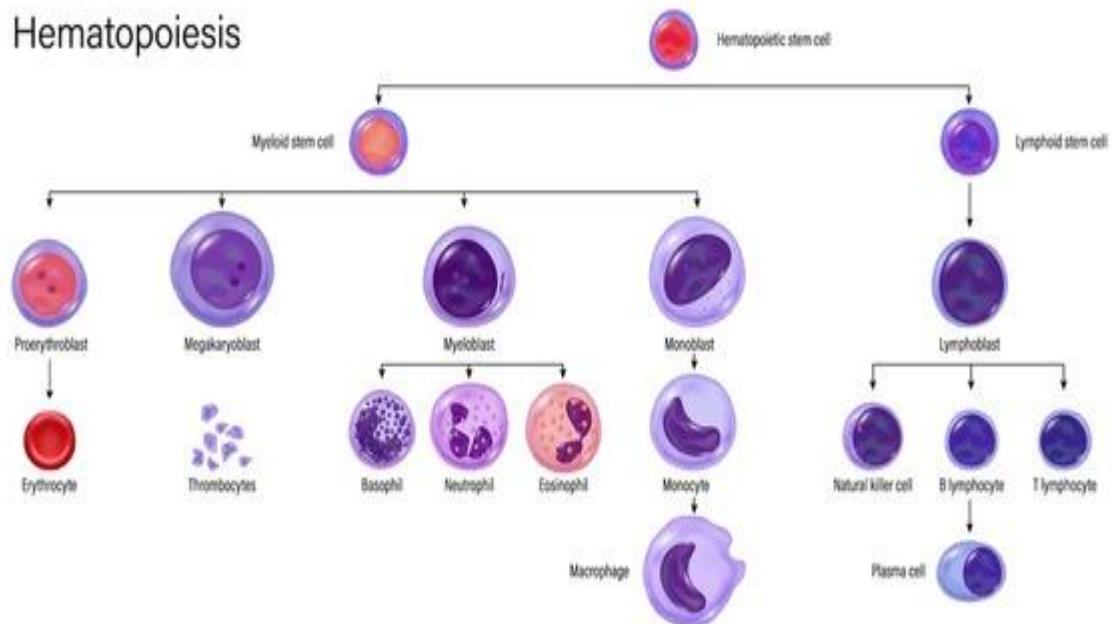
- Neutrophils (60–70%) – Phagocytosis
- Eosinophils (2–4%) – Allergic reactions, parasite defense
- Basophils (0.5–1%) – Release histamine in inflammation

**2. Agranulocytes:**

- Lymphocytes (20–25%) – T and B cells for immune response
- Monocytes (3–8%) – Become macrophages and perform phagocytosis

**◆ C. Platelets (Thrombocytes)**

- Small, disc-shaped cell fragments
- Count: 150,000–400,000/mm<sup>3</sup>
- Life span: 7–10 days
- Function: Blood clotting (hemostasis)



## Formation of Hemoglobin

### ◆ What is Hemoglobin?

Hemoglobin is a **complex protein** in RBCs that transports oxygen.

### ◆ Structure:

- **Globin** – 4 polypeptide chains (2 alpha + 2 beta in adults)
- **Heme** – Each chain has a **heme group** containing **iron ( $Fe^{2+}$ )** which binds  $O_2$

### ◆ Synthesis:

1. **Occurs in developing erythroblasts** in bone marrow

2. **Raw materials required:**

- Iron (Fe)
- Amino acids (for globin chains)
- Vitamin B12 and folic acid (for DNA synthesis)
- Vitamin C (enhances iron absorption)

### ◆ Regulation:

- Controlled by **oxygen demand**
- Hypoxia (low oxygen) stimulates **erythropoietin** from kidneys → increases RBC and hemoglobin production

## Hemopoiesis (Haematopoiesis)

◆ **Definition:** Hemopoiesis is the **process of blood cell formation**. It occurs in the **red bone marrow** of adults (mainly flat bones: sternum, ribs, pelvis).

### ◆ Types:

1. **Erythropoiesis** – formation of RBCs  
Stimulated by **erythropoietin** (hormone from kidney)
2. **Leukopoiesis** – formation of WBCs  
Influenced by **interleukins and colony-stimulating factors (CSFs)**
3. **Thrombopoiesis** – formation of platelets  
Stimulated by **thrombopoietin** (from liver)

### Sites of Hemopoiesis:

Stage	Primary Site
Embryo (1st trimester)	Yolk sac
Fetus (2nd–3rd trimester)	Liver and spleen
After birth	Red bone marrow

## Anemia

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### ◆ Definition:

Anemia is a condition characterized by a **decrease in the number of red blood cells (RBCs)** or the **amount of hemoglobin** in the blood, resulting in **reduced oxygen-carrying capacity** of blood.

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### ◆ Normal Hemoglobin Levels:

#### Gender Normal Hemoglobin (Hb)

Men 13–17 g/dL

Women 12–15 g/dL

Anemia is diagnosed when Hb falls **below these levels**.

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### ◆ Causes of Anemia:

Anemia can occur due to:

1. **Decreased RBC production** (deficiency of iron, B12, folate)
  2. **Increased RBC destruction** (hemolytic anemia)
  3. **Blood loss** (injury, menstruation, gastrointestinal bleeding)
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### ◆ Types of Anemia:

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#### 1. Iron Deficiency Anemia

- **Cause:** Inadequate iron intake or absorption, chronic blood loss
  - **Features:** Small (microcytic), pale (hypochromic) RBCs
  - **Symptoms:** Fatigue, pallor, brittle nails, pica (craving for clay/ice)
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#### 2. Megaloblastic Anemia

- **Cause:** Deficiency of **vitamin B12 or folic acid**
  - **Features:** Large, immature RBCs (megaloblasts), fewer in number
  - **Symptoms:** Fatigue, glossitis, neurological symptoms (in B12 deficiency)
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#### 3. Hemolytic Anemia

- **Cause:** Premature destruction of RBCs
  - **Types:**
    - **Inherited:** Sickle cell anemia, thalassemia
    - **Acquired:** Autoimmune disorders, infections
  - **Features:** Increased bilirubin → jaundice
  - **Symptoms:** Fatigue, enlarged spleen, dark urine
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#### 4. Aplastic Anemia

- **Cause:** Failure of bone marrow to produce blood cells
  - **Causes:** Radiation, chemotherapy, autoimmune disease
  - **Features:** Pancytopenia (low RBCs, WBCs, platelets)
  - **Symptoms:** Weakness, infections, bleeding tendency
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#### 5. Sickle Cell Anemia

- **Cause:** Genetic mutation → abnormal hemoglobin (HbS)
  - **Effect:** RBCs become sickle-shaped → block capillaries
  - **Symptoms:** Pain episodes, anemia, organ damage
  - **Diagnosis:** Hemoglobin electrophoresis
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#### 6. Thalassemia

- **Cause:** Genetic defect in globin chain synthesis
  - **Types:** Alpha or Beta thalassemia
  - **Features:** Microcytic anemia, bone deformities
  - **Treatment:** Blood transfusions, iron chelation, bone marrow transplant
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#### ◆ General Symptoms of Anemia:

- Fatigue and weakness
- Pale skin and mucous membranes
- Shortness of breath
- Dizziness or fainting
- Cold hands and feet

- Rapid heart rate
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◆ **Diagnosis of Anemia:**

- **Complete Blood Count (CBC)** – Hb, RBC count, hematocrit
  - **Peripheral blood smear** – Cell shape and size
  - **Serum iron, ferritin, vitamin B12, folate levels**
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◆ **Treatment:**

- **Iron supplements** – For iron deficiency
  - **Vitamin B12/folate** – For megaloblastic anemia
  - **Blood transfusions** – Severe anemia or thalassemia
  - **Bone marrow transplant** – Aplastic anemia, severe thalassemia
  - **Treat underlying cause** – e.g., control bleeding, stop offending drugs
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◆ **Prevention:**

- Balanced diet rich in iron, B12, folic acid
- Iron supplements during pregnancy
- Treat underlying diseases (e.g., parasitic infections)

## Mechanisms of Coagulation

Coagulation is the process by which **blood forms a clot** to stop bleeding from damaged blood vessels. It is a complex **cascade of biochemical reactions** involving clotting factors, calcium ions, and enzymes that ultimately form a fibrin clot.

### Phases of Coagulation

1. **Vascular Phase (Vasoconstriction)**
  - Immediate response to blood vessel injury
  - Smooth muscle in the vessel wall contracts (vasoconstriction) to reduce blood loss
2. **Platelet Phase (Platelet Plug Formation)**
  - Platelets adhere to exposed collagen at the injury site
  - Platelets become activated and release chemicals (ADP, serotonin, thromboxane A2)
  - Platelets stick to each other forming a temporary platelet plug

### 3. Coagulation Phase (Clotting Cascade)

- Involves **13 clotting factors** (I to XIII, excluding VI)
- Factors are mostly plasma proteins synthesized in the **liver** (some require **vitamin K**)

#### Coagulation Pathways

There are **three pathways** that lead to clot formation:

##### a) Intrinsic Pathway

- Triggered by **internal damage to the blood vessel**
- Begins when **Factor XII** is activated by contact with collagen
- Slower but more complete pathway
- Sequence: XII → XI → IX → VIII → X

##### b) Extrinsic Pathway

- Triggered by **external trauma** that exposes blood to tissue factor (TF or Factor III)
- Rapid and short pathway
- Tissue factor + Factor VII → activates Factor X

##### c) Common Pathway

- Both intrinsic and extrinsic pathways activate **Factor X**
- Factor X + Factor V + Ca<sup>2+</sup> → activates **Prothrombin (Factor II)** to **Thrombin**
- Thrombin converts **Fibrinogen (Factor I)** to **Fibrin**
- Fibrin strands form a **stable mesh/clot**

#### Clot Retraction and Repair

- After clot formation, **platelets contract** to shrink the clot and pull damaged tissue edges together
- Fibroblasts and endothelial cells repair the vessel wall

#### Fibrinolysis (Clot Removal)

- After healing, the clot is removed by the enzyme **plasmin**
- Plasmin is formed from plasminogen activated by **tissue plasminogen activator (tPA)**

## Important Factors and Their Functions

Factor	Name	Function
I	Fibrinogen	Converted to fibrin
II	Prothrombin	Converted to thrombin
III	Tissue Factor (TF)	Initiates extrinsic pathway
IV	Calcium ions ( $\text{Ca}^{2+}$ )	Cofactor in multiple steps
V, VIII	Labile and anti-hemophilic A	Cofactors in common/intrinsic path
X	Stuart-Prower factor	Start of common pathway
XIII	Fibrin-stabilizing factor	Crosslinks fibrin mesh

## Role of Vitamin K

- Required for synthesis of factors **II, VII, IX, X**
- Deficiency can lead to bleeding disorders

## Clinical Relevance

- Hemophilia A:** Deficiency of Factor VIII
- Hemophilia B:** Deficiency of Factor IX
- Anticoagulants:** Heparin (inhibits thrombin), Warfarin (inhibits vitamin K)

## Blood Grouping

**Blood grouping** is the classification of blood based on the presence or absence of **antigens** on the surface of **red blood cells (RBCs)**. The most important systems used for blood typing are the **ABO system** and the **Rh factor system**.

### ABO Blood Group System

- Discovered by **Karl Landsteiner** in 1901.
- Based on the presence or absence of **A and B antigens** on the RBC surface and **anti-A and anti-B antibodies** in the plasma.

Blood Group	Antigens on RBCs	Antibodies in Plasma
A	A	Anti-B
B	B	Anti-A
AB	A and B	None
O	None	Anti-A and Anti-B

- Universal Donor:** Group O (especially O<sup>-</sup>)
- Universal Recipient:** Group AB (especially AB<sup>+</sup>)

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## Rh Factor

- Another antigen on RBCs, named after the **Rhesus monkey**.
- Individuals **with Rh antigen** are **Rh positive (Rh<sup>+</sup>)**
- Those **without it** are **Rh negative (Rh<sup>-</sup>)**

## Rh Compatibility

- If an **Rh<sup>-</sup> person receives Rh<sup>+</sup> blood**, the immune system produces **anti-Rh antibodies**.
  - First exposure is usually harmless, but second exposure can be dangerous.
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## Erythroblastosis Fetalis (Hemolytic Disease of the Newborn)

- Occurs when an **Rh<sup>-</sup> mother carries an Rh<sup>+</sup> fetus** (from an Rh<sup>+</sup> father)
  - Mother's immune system forms **anti-Rh antibodies** after exposure during the first pregnancy
  - In subsequent Rh<sup>+</sup> pregnancies, these antibodies **cross the placenta and destroy fetal RBCs**
  - Prevented by giving **Rh immunoglobulin (Rho(D) immune globulin)** to the mother after the first delivery
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## Blood Transfusion

**Blood transfusion** is the process of transferring blood or its components (RBCs, plasma, platelets) from one person (donor) to another (recipient).

### Significance

- Used to treat **severe anemia, trauma, surgeries, clotting disorders**
- Ensures proper oxygen delivery and volume maintenance

### Cross-Matching

- Before transfusion, **cross-matching** is done to ensure compatibility between donor and recipient blood
- Avoids transfusion reactions

### Incompatible Transfusion Reaction

- Antibodies in recipient's plasma attack donor RBCs
  - Leads to **agglutination, hemolysis, kidney damage, fever, chills, shock, and even death**
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## **Disorders of Blood**

### **1. Anemia**

- Decrease in RBC count or hemoglobin (explained previously)

### **2. Leukemia**

- **Cancer of white blood cells**
- Uncontrolled proliferation of abnormal WBCs
- Symptoms: Frequent infections, fatigue, anemia, bleeding
- Types: Acute or chronic, myeloid or lymphoid

### **3. Thrombocytopenia**

- Low platelet count
- Causes: Viral infections, bone marrow failure, autoimmune conditions
- Symptoms: Easy bruising, bleeding gums, prolonged bleeding

### **4. Hemophilia**

- Genetic disorder due to deficiency of clotting factors
- Hemophilia A: Deficiency of Factor VIII
- Hemophilia B: Deficiency of Factor IX
- Only affects males (X-linked inheritance)
- Symptoms: Spontaneous bleeding, joint pain, excessive bleeding after injury

### **5. Polycythemia**

- Increased RBC count
- Primary (bone marrow disease) or secondary (high altitude, tumors)
- Symptoms: Increased blood viscosity, hypertension, clot risk

### **6. Septicemia (Blood Poisoning)**

- Presence of pathogenic organisms or their toxins in the blood
- Causes fever, chills, rapid heart rate, organ damage
- Life-threatening if untreated

## **Lymphatic System**

The **lymphatic system** is a part of the **circulatory and immune system**. It plays a major role in maintaining **fluid balance**, **filtering pathogens**, and **producing immune responses**.

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## **Lymphatic Organs and Tissues**

Lymphatic organs and tissues are classified into two main types:

### **1. Primary Lymphatic Organs**

These are sites where **lymphocytes are produced and mature**.

#### **a) Bone Marrow**

- Found in long bones (femur, humerus) and flat bones (sternum, pelvis)
- Produces all blood cells including **lymphocytes**
- **B lymphocytes** mature here

#### **b) Thymus**

- Located in the upper thorax behind the sternum
  - Site for **T lymphocyte maturation**
  - Active in children; shrinks after puberty
  - Contains **T cells**, epithelial cells, macrophages
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### **2. Secondary Lymphatic Organs and Tissues**

These are the sites where **immune responses are initiated and lymphocytes are activated**.

#### **a) Lymph Nodes**

- Small bean-shaped structures located along lymphatic vessels
- Filter lymph and trap pathogens
- Contain **B cells, T cells, and macrophages**
- Swell during infection due to lymphocyte proliferation

#### **b) Spleen**

- Largest lymphatic organ, located in the upper left abdomen
- Filters blood, not lymph
- Removes old or damaged RBCs
- Stores platelets and iron
- Contains **white pulp** (lymphatic tissue) and **red pulp** (RBC storage and phagocytosis)

#### **c) Mucosa-Associated Lymphoid Tissue (MALT)**

- Lymphoid tissues associated with mucosal surfaces
- Protect against inhaled or ingested pathogens
- Found in respiratory, digestive, urinary, and reproductive tracts
- Includes **tonsils, Peyer's patches (in ileum), and appendix**

### **Examples of MALT components:**

- **Tonsils:** Protect respiratory passages
    - Palatine, pharyngeal (adenoids), lingual
  - **Peyer's Patches:** Clusters of lymphoid tissue in the small intestine
  - **Appendix:** Lymphoid tissue in the large intestine, helps in gut immunity
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### **Functions of Lymphatic Organs**

- **Bone marrow:** Lymphocyte production and B-cell maturation
- **Thymus:** T-cell maturation
- **Lymph nodes:** Filter lymph and activate immune response
- **Spleen:** Filter blood, store platelets, remove damaged cells
- **MALT:** Protect mucosal surfaces from pathogens

### **Lymphatic Vessels**

The **lymphatic vessels** are a network of tubes that carry **lymph** (a clear fluid rich in white blood cells) back toward the heart.

#### **Structure**

- Begin as **lymphatic capillaries** in tissues
- Merge to form **larger lymphatic vessels**, similar to veins but thinner and with **more valves**
- Ultimately drain into the **venous system** via large ducts

#### **Types of Lymphatic Vessels**

##### **1. Lymphatic Capillaries**

- Microscopic, blind-ended tubes
- Present in most tissues except the CNS, bone marrow, and avascular tissues
- Have **flap-like endothelial valves** allowing unidirectional lymph flow

##### **2. Larger Lymphatic Vessels**

- Formed by merging capillaries
- Pass through **lymph nodes**
- Contain **valves** to prevent backflow
- Accompanied by arteries and veins

##### **3. Lymphatic Ducts**

- **Thoracic duct** (left lymphatic duct):

- Drains lymph from the **entire body** except right upper quadrant
  - Empties into the **left subclavian vein**
  - **Right lymphatic duct:**
    - Drains lymph from **right arm, right side of head, and right thorax**
    - Empties into the **right subclavian vein**
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## Lymph Circulation

### 1. Formation of Lymph

- Plasma leaks from blood capillaries into tissues as **interstitial fluid**
- About 85% returns directly to the blood; the rest enters **lymphatic capillaries**, becoming **lymph**

### 2. Lymph Flow

- Capillaries → Vessels → Lymph Nodes → Larger Trunks → Lymphatic Ducts → Subclavian Veins

### 3. Mechanism of Lymph Flow

- No central pump like the heart
- Flow is maintained by:
  - **Skeletal muscle contractions**
  - **Respiratory movements**
  - **Valves** to prevent backflow
  - **Smooth muscle contractions** in vessel walls

### 4. Lymph Nodes

- Act as filters to trap pathogens before lymph returns to the bloodstream
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## Functions of the Lymphatic System

### 1. Return of Interstitial Fluid

- Returns excess fluid and proteins from tissues to the bloodstream
- Prevents **tissue swelling (edema)**

### 2. Absorption of Fats

- In the **small intestine**, specialized lymphatic capillaries called **lacteals** absorb **dietary fats** and fat-soluble vitamins
- Forms a milky fluid called **chyle**

### **3. Immune Defense**

- Lymph carries antigens to **lymph nodes**, where **B and T lymphocytes** respond
- **Lymph nodes, spleen, and MALT** act as immune filters

### **4. Transport of White Blood Cells**

- Lymph transports **lymphocytes** and other immune cells to areas of infection or inflammation

### **5. Removal of Cellular Debris**

- Helps remove dead cells, waste, and foreign particles