Acknowledgments

RN.com acknowledges the valuable contributions of...

...Nadine Salmon, RN, BSN, IBCLC. Nadine is the Education Support Specialist for RN.com. She earned her BSN from the University of the Witwatersrand, Johannesburg, South Africa. She worked as a midwife in Labor and Delivery, an RN in Postpartum units and Antenatal units, before moving to the United Kingdom, where she worked as a Medical Surgical Nurse. After coming to the US in 1997, Nadine worked in obstetrics and became a Board Certified Lactation Consultant. Nadine was the Clinical Pre Placement Manager for the International Nurse Staffing division before joining RN.com. When not writing courses and other educational materials, Nadine is currently pursuing her master’s degree in Nursing Education.

... Lori Constantine MSN, RN, C-FNP, original author of RN.com’s Assessment Series:Hematological Anatomy, Physiology and Assessment.

Purpose and Objectives

The focus of this hematological anatomy, physiology, and assessment course is to teach the learner about the structures and functions of the hematological system and its associated assessment.

Understanding the fundamental structures and functions of the hematologic system will allow the healthcare professional to intervene effectively when a patient experiences a hematological disorder.

After successful completion of this course, you will be able to:
1. Discuss the functions of the hematological systems.
2. Describe the physiology of the hematological system.
3. Discuss how to assess the oxygen carrying capacity of blood.
4. Determine how to assess the immunity status of your patients.
5. Identify how to assess the blood’s clotting ability.

IMPORTANT INFORMATION

RN.com strives to keep its content fair and unbiased.
The author has no conflicts of interest to disclose.
The planners of the educational activity have no conflicts of interest to disclose.
(Conflict of Interest Definition: Circumstances create a conflict of interest when an individual has an opportunity to affect Education content about products or services of a commercial interest with which he/she has a financial relationship.)
There is no commercial support being used for this course.
Participants are advised that the accredited status of RN.com does not imply endorsement by the provider or ANCC of any products/therapeutics mentioned in this course.
The information in the course is for educational purposes only.
There is no “off label” usage of drugs or products discussed in this course.
Introduction
The anatomy, physiology, and functions of the hematopoietic system are all involved in the production of blood.

Hematologic activities, such as red blood cell formation and the clotting cascade, require a complex series of events to allow good health and homeostasis.

Without leukocytes to protect us, our bodies could succumb to disease and infection.

As a healthcare professional, a basic understanding of hematological functions is important in providing appropriate patient care.

Components of Blood

- White Blood Cells
  6-9000/mm³

- Platelets
  200-400,000/mm³

- Red Blood Cells
  4-5 Million/mm³
**Glossary**

**Anemia:** A deficiency of red blood cells or of hemoglobin in the blood, resulting in pallor and weariness.

**Clotting Cascade:** A sequence of events culminating in the formation of a blood clot.

**Erythrocytes:** Red blood cells

**Erythropoieten:** Is a hormone that stimulates the production of red blood cells by stem cells in bone marrow.

**Ferritin:** Is a protein that binds to iron.

**Hematocrit:** Is a measure of the total percentage of blood volume that is composed of red blood cells.

**Hemoglobin:** Is a protein-iron compound in red blood cells that carries oxygen from the lungs to the rest of the body.

**Hematopoiesis:** Is the continuous, regulated formation of blood cells.

**Hematology:** Is the science of blood and blood forming tissues.

**Hypoxia:** Refers to low oxygen-carrying capacity of the blood.

**Hypoxemia:** An abnormally low concentration of oxygen in the blood.

**Leukocytes:** White blood cells

**Petichiae:** Pinpoint flat round red spots under the skin surface caused by bleeding into the skin.

**Reticulocytes:** Immature red blood cells.

**Transferrin:** A protein that transports iron in blood.

**Hematopoietic System**

Hematology is the science of blood and blood forming tissues. It includes both cellular and non-cellular blood components.

Blood is composed of two elements:

- A liquid component known as plasma
- The solid components, which are mainly erythrocytes, leukocytes, and thrombocytes

The solid components of blood are formed by hematopoiesis, which is the continuous, regulated formation of blood cells.

**There are three primary functions of hematopoiesis:**

1. Oxygen delivery
2. Hemostasis
3. Host defense

**Hematological activities occur in many organs of the body and have the potential for multiple forms of pathology.**
Hematopoiesis
Hematopoiesis occurs in the bone marrow. The degree and location of bone marrow activity varies depending on the age and health status of the patient.

Within the bone marrow, there is a pluripotent stem cell. This stem cell is the “Mother Cell” or the originator of all blood cells. It has the ability to self-renew and create progenitor stem cell lines. They are naturally limited in number.

By reviewing the chart, you can see that all cells come from the stem cell. An attack on the stem cell can theoretically affect all cells similarly.

A disease or agent that impacts erythroblasts could impact all the cell type in that “line,” but not those in a different “line.”
Erythrocytes
Erythrocytes, or red blood cells (RBCs), originate from a stem cell.

Vitamin B12, folic acid, iron, and copper are essential in the formation of erythrocytes.

Erythropoietin is a hormone released by the kidneys in response to hypoxemia, which stimulates the bone marrow to produce red blood cells.

Typically, red blood cells live approximately 120 days. When the red blood cells become old and damaged, the liver, spleen, and bone marrow cleanse them from the blood.

Increases or decreases in the red blood cell count indicate an abnormality.

Please note that laboratory values given in this course are reference ranges only, as values vary at different laboratories.

Normal RBC Range:

Males
4.6-6.3 X10^6/mm^3

Females
4.2 -5.4 X10^6/mm^3

Reticulocytes
When released from the bone marrow, red blood cells are slightly immature and are known as reticulocytes.

Reticulocytes mature into red blood cells within a few days.

The number of reticulocytes in the blood indicates the amount of bone marrow activity.

Low reticulocyte counts may be due to vitamin deficiency, liver cirrhosis, or radiation therapy.

Normal Reticulocyte Range:

0.5-2.5% of RBCs

Hemoglobin
Hemoglobin is a protein-iron compound in red blood cells that carries oxygen from the lungs to the rest of the body.

Hemoglobin is a laboratory value used to evaluate the oxygen-carrying capacity of the blood.

Low levels of hemoglobin in the blood represent anemia.
One unit of packed red blood cells generally equals one whole number increase in the hemoglobin value.

For example:
If a patient’s hemoglobin is 7.0 g/dl, and one unit of packed red blood cells is administered, the patient’s hemoglobin should come up to 8.0 g/dl.

Normal Hemoglobin Range:

**Males**
12.4-14.9 g/dL

**Females**
11.7-13.8 g/dL

**Hematocrit**
Hematocrit is a measure of the total percentage of blood volume that is composed of red blood cells.

It is also known as the packed cell volume (PCV).

Low levels of hematocrit may indicate:

- Anemia
- Blood loss
- A disease process such as cancer

High levels of hematocrit may be due to:

- Dehydration
- Blood disorders

Normal Hematocrit Range:

**Males**
40-54%

**Females**
36-48%

**Iron**
Iron is necessary for the formation of hemoglobin, an essential part of the red blood cell.

Iron is absorbed from the small intestine into the blood and binds with a protein called transferrin.

Transferrin transports iron to the bone marrow, where it is used to make hemoglobin.
Lower than normal iron levels may be related to:

- Inadequate iron intake
- Inadequate iron absorption
- Chronic blood loss.

High levels of iron can be due to:

- Blood disorders
- Hepatitis B
- Vitamin deficiency
- Iron poisoning

Normal Iron Range:

50-150 mcg/dL

**Total Iron Binding Capacity**
The amount of iron that can still bind with transferrin (to be transported to bone marrow to make hemoglobin) is known as the total iron binding capacity or TIBC.

Think of your TIBC as the total amount of people that can get on a bus. The iron is the people and the bus is transferrin.

When your serum iron levels increase, your TIBC level will decrease, as the ability to bind the high levels of circulating iron is impaired.

When serum iron levels decrease, TIBC increases, as the ability to bind circulating iron is increased.

Normal Total Iron Binding Capacity:

250-410 /dl

**Ferritin**

Normal Ferritin Range:

**Males:**
20 - 300 ng/mL

**Females:**
20 - 120 ng/mL

Ferritin is a protein that binds to iron. Most of the iron stored in the body is attached to ferritin.

Ferritin is found in the liver, spleen, and bone marrow. Only a small amount is found in the blood.

Like the TIBC, the amount of ferritin in the blood may help indicate the amount of iron stored in the body.
Leukocytes
Leukocytes, or white blood cells, help to protect the body from bacteria and infection.

They are typically classified as either:

- Granular leukocytes: Includes neutrophils, eosinophils and basophils
- Non-granular leukocytes: Includes lymphocytes, monocytes, and plasma cells.

In a healthy individual, the total WBC count increases in response to infection or trauma.

Individuals that are immunosuppressed often have a low WBC count and are much more susceptible to infection.

*The WBC count is expressed as the number of leukocytes per micro liter of blood.*

**Normal Leukocyte Range:**

5,000 - 10,000 / microlitre
Granular Leukocytes: Neutrophils
Neutrophils are granular leukocytes that function to kill bacteria. Neutrophils act by destroy the ability of bacteria to reproduce, and they destroy bacteria's ability to produce endotoxins.

Neutrophils also release enzymes and substances that affect other cells functions.

An increased number of neutrophils may indicate an acute infection.

**Normal Neutrophil**

**Range:** 40 - 70 %

Granular Leukocytes: Neutrophil Bands
Neutrophil's primal cell type is bands. Bands are adolescent neutrophils, and it is abnormal to have elevated bands in the blood stream. Neutrophils increase in number when an acute bacterial infection is present.

Historically, lab reports were hand-written, and elevated neutrophil bands were recorded on the left. Today, the presence of elevated neutrophil bands indicates the presence of an inflammatory process and the term "shift to the left" means that the bands have increased, indicating an infection in progress.

**Normal Neutrophil Band**

**Range:** 0-8 %

Granular Leukocytes: Eosinophils and Basophils
Eosinophils

Eosinophils are responsible for fighting parasites, and are increased in allergic or autoimmune disorders. For example, eosinophils increase when a patient has hives due to allergic reaction.

**Normal Eosinophil Range:** 0-7%

**Normal Basophil Range:** 0-1 %

Basophils

Basophils make up a small portion of the white blood cell count. Basophils release histamine, heparin, and have a role in the body's immune response.
Non-Granular Leukocytes: Lymphocytes and Monocytes

Lymphocytes

Lymphocytes mature in the lymph nodes. They live approximately 100-300 days.

The total lymphocyte count represents total T and B lymphocytes. T lymphocytes are killer cells, and instruct B lymphocytes to produce antibodies.

Lymphocytes increase in viral illnesses, such as measles, mumps, chicken pox, influenza, viral hepatitis, mononucleosis, and in acute transplant rejection.

Monocytes

Monocytes are phagocytic cells. They ingest cellular debris at the area of infection or inflammation.

They increase after several days of active infection or inflammation. Activated monocytes recognize a number of micro-organisms and will engulf and destroy them.

Normal Monocyte
Range: 0-12%

Normal Lymphocyte
Range: 16 -46 %
Plasma
Plasma is a straw-colored, clear liquid that is ninety percent water. It is essential for the transport of blood components.

In addition to water, plasma also contains dissolved electrolytes responsible for membrane excitability, and plasma proteins that maintain the osmotic distribution of fluid and substances capable of buffering pH changes (Smeltzer, Bare, Hinkle & Cheever, 2009).

This image depicts the separation of plasma, red blood cells and cellular elements found in a blood sample.

Blood Clotting: Platelets
Platelets are small, colorless cells that have a lifespan of seven to ten days.

They perform three major roles:
1. Decreasing the luminal size of damaged vessels to decrease blood loss.
2. Forming blockages in injured vessels to decrease blood loss.
3. With plasma providing the correct ingredients needed to accelerate blood coagulation.

To truly understand the clotting mechanism of your body, review the clotting cascade table.

Normal Platelet Range:
150,000 – 400,000 / microliter
The Clotting Cascade
The end result of the clotting cascade is:

- Fibrin clots
- Fibrin
- Thrombin

When the clotting cascade is activated, usually due to vessel injury or damage, platelets are one of the first responders. They stick to the damaged vessel and recruit more platelets to the site. This aggregation of platelets forms a temporary plug that safeguards the vessel wall from further bleeding. Simultaneously, additional proteins from the clotting cascade are activated in a specific order that lead to the formation of fibrin.

Fibrin is a very sticky substance and acts as glue at the site, securing the platelet plug.

Finally, the clot must be dissolved in order for normal blood flow to resume following tissue repair. The dissolution of the clot occurs through the action of plasmin, which is a protein responsible for digesting fibrin. Eventually, scar tissue forms completing the healing of the injured vessel (Agruss & Watson, 2010).
Assessment of Clotting
Assessment of clotting requires the nurse to examine the patient’s history, physical exam findings, and review of clotting studies.

When obtaining a patient history, ask about:
- The frequency and ease of bruising
- The presence of bleeding gums, or heavy menstrual periods
- The presence of blood in vomitus, stools, or urine
- The presence of petichiae

When assessing your patients clotting ability, look for signs and symptoms of bleeding such as:
- Bruising
- Low blood pressure with an increased pulse rate (internal bleeding)
- Firm, tender abdomen
- Positive hemacult

Examine the complete blood count and serum clotting factors lab results.
### Review of Clotting Factors

<table>
<thead>
<tr>
<th>Blood Component</th>
<th>Normal Value</th>
<th>Elevated when…(†)</th>
<th>Decreased when…(↓)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platelets</td>
<td>150,000-440,000 cells per microliter</td>
<td>• Thrombocytopenia&lt;br&gt;• Sleep Dysfunction&lt;br&gt;• Dehydration</td>
<td>• Leukemia&lt;br&gt;• Platelet Antibody presence&lt;br&gt;• AIDs&lt;br&gt;• Bone Marrow Suppression</td>
</tr>
<tr>
<td>PT (Prothrombin Time)</td>
<td>10-13 seconds</td>
<td>• Vitamin K Deficiency&lt;br&gt;• Liver Disease&lt;br&gt;• Disseminated Intravascular Coagulation (DIC)&lt;br&gt;• Aspirin Overdose&lt;br&gt;• Anticoagulant Therapy</td>
<td>• Enteritis</td>
</tr>
<tr>
<td>INR</td>
<td>2.0-3.0 for embolism&lt;br&gt;2.5-3.5 for mechanical heart valves</td>
<td>• Same as PT</td>
<td>• Same as PT</td>
</tr>
<tr>
<td>aPTT (activated partial thromboplastin time)</td>
<td>21-45 seconds</td>
<td>• Liver Disease&lt;br&gt;• DIC&lt;br&gt;• Heparin Therapy</td>
<td>• Acute Hemorrhage&lt;br&gt;• Extensive Cancer</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>200-400 mg/dl</td>
<td>• Rheumatoid Arthritis&lt;br&gt;• Hepatitis&lt;br&gt;• Acute Infection</td>
<td>• Liver Disease&lt;br&gt;• DIC&lt;br&gt;• Recent Trauma</td>
</tr>
</tbody>
</table>

### Assessment of The Hematological System

When assessing your patient's hematological system, it is important to ask questions that reveal clues about the oxygen carrying capacity of their blood.

Obtaining a thorough health history will assist you to identify any risk factors that could influence your patient's hematological status.

Assessment of the oxygen carrying capacity of the blood requires the nurse to examine the patient's history, physical exam findings, and the lab results of their complete blood count with differential.

### History & Physical Clues

Ask your patient about the ease in which they perform activities of daily living, to determine if hypoxia is present.

Inquire about fatigue, shortness of breath, or episodes of breathlessness. These assessment findings may clue you in to a potential hematological deficiency.

Common blood-related causes of hypoxia (low oxygen-carrying capacity of the blood) include:

- Low number of circulating red blood cells
• Poor supply of hemoglobin within these red blood cells
• Carbon monoxide poisoning (Smeltzer et al., 2009)

Physical clues that will aid in assessing oxygen carrying capacity include:
• Skin coloration
• Respiratory rate
• Pattern of respiration
• Capillary refill
• Heart rate
• Skin temperature
## Analysis of Blood Components

A complete blood count is often used to augment the history and physical examination. Normal values and conditions associated with altered oxygen-carrying capacity of the blood within the complete blood count with differential are summarized in the table below.

<table>
<thead>
<tr>
<th>Blood Component</th>
<th>Normal Value</th>
<th>Elevated when…(↑)</th>
<th>Decreased when…(↓)</th>
</tr>
</thead>
</table>
| **Red Blood Cell (RBC)**                    | 4.6-6.3 X10⁶ /mm³ (males) 4.2-5.4 X10⁶ /mm³ (females) | • Chronic pulmonary disease  
• Cardiovascular disease  
• High altitude | • Chronic renal failure  
• Bone marrow damage  
• V B12 or folic acid deficiency  
• Hemolysis  
• Hemorrhage  
• Anemia of chronic disease  
(systemic lupus, Rheumatoid, arthritis, infection, bacterial endocarditis, AIDS, Crohn’s disease, some malignancies) |
| **Reticulocyte Count**                      | 0.5-2.5% of RBCs                       | • Anemia  
• Hemorrhage  
• Hemolysis  
• Leukemia  
• Pregnancy | • Bone Marrow Failure  
• Radiation Therapy  
• Chronic Infection  
• Liver Cirrhosis  
• Folic Acid Deficiency |
| **Hemoglobin**                              | 4-18 g/dL (males) 12-16 g/dL (females) | • Polycythemia  
• Dehydration | • Anemia  
• Hypervolemia  
• Bleeding problems  
• Bone Marrow Suppression |
| **Hematocrit**                              | 42-52% (males) 37-57% (females)        | • Polycythemia  
• Dehydration | • Anemia  
• Hypervolemia  
• Bleeding problems  
• Bone Marrow Suppression |
| **Iron**                                    | 50-150 mcg/dL                          | • Hemolysis  
• Hemolytic Anemias | • Dietary Deficiency  
• Excessive Blood Loss  
• Iron Deficiency Anemia |
| **Total Iron Binding Capacity (TIBC)**      | 250-410 mcg/dL                         | • Iron Deficiency Anemia  
• Acute or chronic blood loss  
• Polycythemia  
• Pregnancy | • Hemolytic Anemias  
• GI Cancers  
• Liver Cirrhosis |
| **MCV (Mean Corpuscular Volume)**           | 80-96 mm³ (males) 82-98 mm³ (females)  | • Pernicious Anemia  
• Folate Deficiency  
• Chronic Liver Disease | • Iron Deficiency Anemia  
• Thalassemia  
• Rheumatoid Arthritis  
• Lead Poisoning  
• Malignancy |
| **MCHC (Mean Corpuscular Hemoglobin Concentration)** | 27-33 pg/cell | • Rare | • Iron Deficiency Anemia  
• Thalassemia  
• Lead Poisoning |
| **MCH (Mean)**                               | 31-35 g/dL                             | • Pernicious | • Iron Deficiency Anemia |
Corpuscular Hemoglobin

- Folic Acid Deficiency Anemia
- Thalassemia

RDW (Red Cell Distribution Width)

- Acquired Anemias

ESR (Erythrocyte Sedimentation Rate)

- Inflammation

<table>
<thead>
<tr>
<th>Blood Component</th>
<th>Normal Value</th>
<th>Elevated when... (↑)</th>
<th>Decreased when... (↓)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Blood Cell</td>
<td>5,000-10,000 cells/microliter</td>
<td>Infection, Trauma, Post op day #1, Leukemias</td>
<td>Immune disorders, HIV, Cancer, Chemotherapy, Bone Marrow Suppression</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>40-70%</td>
<td>Bacterial Infection</td>
<td>Bone Marrow Suppression, Severe Infection/Sepsis</td>
</tr>
<tr>
<td>Bands</td>
<td>0-8%</td>
<td>Acute Bacterial Infection</td>
<td>Severe Infection/Sepsis</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>16-46%</td>
<td>Viral Illness, Rejection of transplant tissue</td>
<td>Bone Marrow Suppression</td>
</tr>
<tr>
<td>Monocytes</td>
<td>0-12%</td>
<td>Several days of active infection</td>
<td></td>
</tr>
<tr>
<td>Eosinophils</td>
<td>0-7%</td>
<td>Allergic disorders, Parasitic infections, Autoimmune disorders</td>
<td></td>
</tr>
<tr>
<td>Basophils</td>
<td>0-1%</td>
<td>Healing Process</td>
<td></td>
</tr>
</tbody>
</table>
Assessment of Immunity: History
Assessment of immunity requires the nurse to examine the patient’s history, physical exam findings, and the white count with differential result.

When assessing your patient’s immunity status be sure to ask about the following:

- Recurrent infections
- Chronic conjunctivitis
- Chronic diarrhea caused by giardia
- Arthritis-like symptoms
- Autoimmune diseases
- Allergies

Recurrent infections, chronic conjunctivitis, and chronic diarrhea (caused by giardia) indicate a possible attack on the immune system or an underactive, low functioning immune system.

Allergies, autoimmune disease, and arthritis like symptoms are disease processes that are related to auto-immunity. When the immune system response is altered and does not recognize the body's cells as being part of the host, these symptoms may occur.

Assessment of Immunity: Physical Clues
Physical clues that will aid in assessing the immunity status of your patient include:

- Inspection of open sores in the mouth
- Signs of chronic inflammation, such as body aches or pains
- Presence of wounds that are not healing in a timely manner

When assessing a patient’s immunity status, the healthcare professional should examine the patient’s white cell count and differential.

Conclusion
A thorough knowledge of hematological anatomy and physiology paired with appropriate assessment techniques is essential in effectively caring for patients, especially those with blood related disorders.

A good understanding of hematological processes will allow you to successfully care for patients with the most minor hematological problems to those experiencing hematological emergencies.
References


At the time this course was constructed all URL’s in the reference list were current and accessible. rn.com. is committed to providing healthcare professionals with the most up to date information available.

© Copyright 2004, AMN Healthcare, Inc.

Please Read: This publication is intended solely for the use of healthcare professionals taking this course, for credit, from RN.com. It is designed to assist healthcare professionals, including nurses, in addressing many issues associated with healthcare. The guidance provided in this publication is general in nature, and is not designed to address any specific situation. This publication in no way absolves facilities of their responsibility for the appropriate orientation of healthcare professionals. Hospitals or other organizations using this publication as a part of their own orientation processes should review the contents of this publication to ensure accuracy and compliance before using this publication. Hospitals and facilities that use this publication agree to defend and indemnify, and shall hold RN.com, including its parent(s), subsidiaries, affiliates, officers/directors, and employees from liability resulting from the use of this publication. The contents of this publication may not be reproduced without written permission from RN.com.