PHLEBOTOMY

** This course provides 2 hrs. of General contact hours for Florida license renewal. **

HUMAN BLOOD COMPOSITION:

Review of Cellular Components

AUTHOR: Deborah L. Buckley, MBA, MT(ASCP)

COURSE CODE:	PH007
CONTACT HOURS:	2
COURSE LEVEL:	Basic
CE BROKER #:	20-584655

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COURSE OBJECTIVES

At the end of this course you will be able to:

1. Recall the composition of Human Blood, discussing the liquid and cellular portions.
2. Briefly describe the Complete Blood Count (CBC) and what blood components it measures.
3. Describe a red blood cell (RBC), listing the causes for increased or decreased values.
4. Describe where white blood cells (WBC) can be found.
5. List the five different types of WBCs and discuss the reasons for increased or decreased values of each.
6. Describe the purpose of Platelets, listing the causes for increased or decreased values.

RIGHTSHOLDER:

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HUMAN BLOOD COMPOSITION: REVIEW OF CELLULAR COMPONENETS
Categories: Phlebotomy/General | **Contact Hours:** 2 | **Course Code:** PH007

1.) Red blood cells (RBCs) are also known as _____.

- **A.** granulocytes
- **B.** macrophages
- **C.** erythrocytes

2.) A low RBC count is known as _____.

- **A.** leukemia
- **B.** anemia
- **C.** thrombocytopenia

3.) There are _____ types of White Blood Cells (WBCs).

- **A.** two
- **B.** five
- **C.** seven

4.) Fever, chills, and sweats are signs of a low WBC.

- **A.** True
- **B.** False

5.) A(n) _____ is the most abundant type of WBC normally seen in the bloodstream of healthy patients.

- **A.** eosinophil
- **B.** monocyte
- **C.** neutrophil

6.) An increased eosinophil count can be seen in asthma.

- **A.** True
- **B.** False

7.) Lymphocytes are part of the Adaptive Immune System in the human body, helping to create antibodies against specific pathogens that the body is exposed to.

A. True
B. False

8.) When a Monocyte moves from the bloodstream into the tissues, it becomes a cell known as a _____.

A. T cell
B. macrophage
C. lymphocyte

9.) When a vessel is damaged, platelets circulate to the injury site then go through several steps to form a clot.

A. True
B. False

******END OF QUIZ******

ABOUT THE AUTHOR

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Prior to joining the management team at 4CEUINC, Deborah was the Laboratory Manager at a privately owned Medical Lab in South Florida. In addition to her management experience, she also brings experience as a generalist in the laboratory, specializing in Microbiology and Hematology, and has taught Microbiology at a community college during her 30+ years in the laboratory industry.

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HUMAN BLOOD

Human blood is the fluid that transports oxygen and nutrients to the cells throughout the body, while transporting metabolic waste away from those same cells. In addition to cells and plasma, blood naturally contains many other constituents including antibodies, electrolytes, hormones, proteins, nutrients, oxygen, etc. It is circulated throughout the body by the pumping action of the heart with oxygenated blood running through arteries to deliver oxygen and other nutrients, while venous blood carries carbon dioxide and other metabolic waste products, to the liver, lungs, and kidneys for elimination.

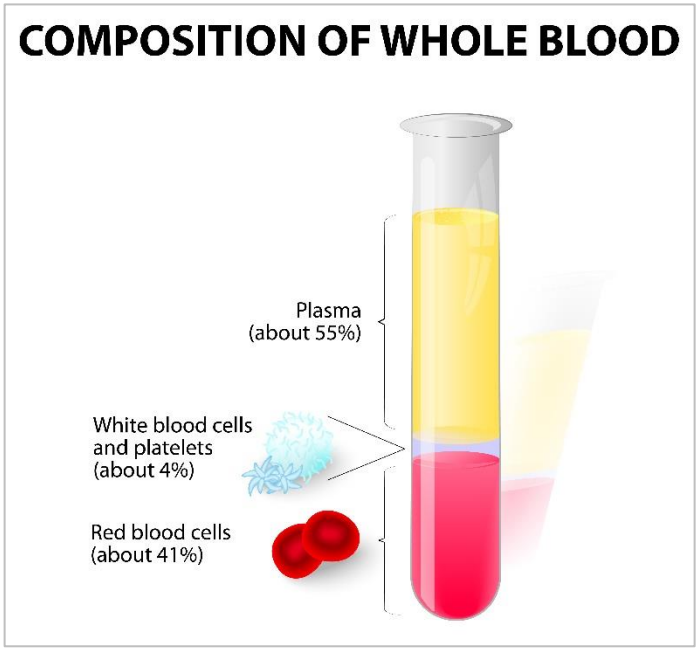
The amount of blood volume in the human body varies, however on average adults typically have approximately 5 liters (~1.3 gallons) of blood, while a child with a body weight of 80 pounds will have approximately half the amount of blood as an average adult. Overall several factors determine the total volume an individual has, including age, sex, size, overall health status, and even altitude. As a general rule, men tend to have more blood volume than women of comparable size and weight. Blood makes up approximately 7-8% of a patient's body weight and has a small pH range of 7.35-7.45.

COMPOSITION OF BLOOD

Blood consists of two main components:

- Plasma
- Cells

FIGURE 1:



PLASMA

As Figure 1 shows, plasma makes up approximately 55% of the blood volume in a healthy adult. Plasma is the liquid portion of the blood that the cells are suspended in. It typically has a pale yellow color, although various disease states can change the appearance.

CELLS

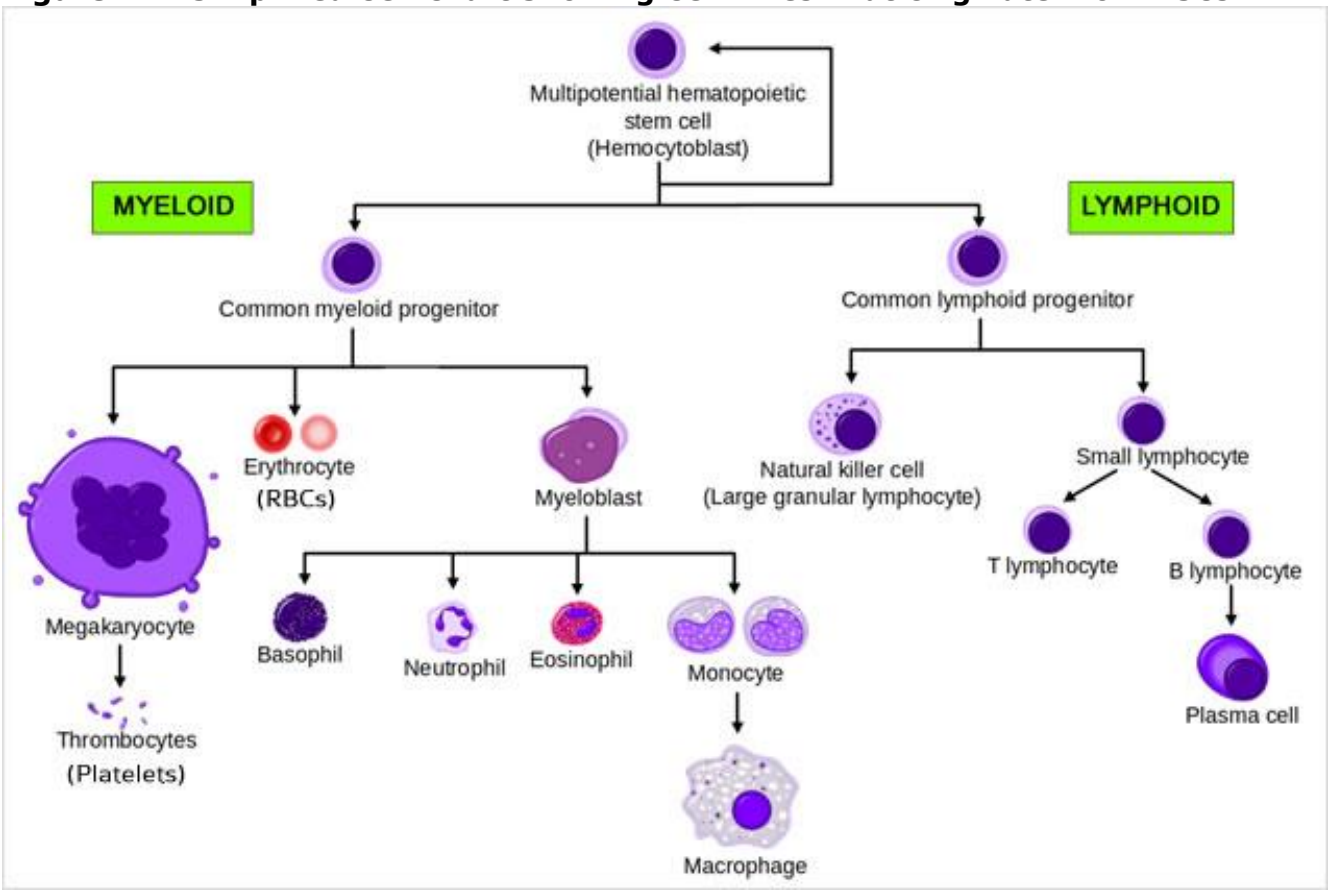
Red cells, White cells, and platelets – found circulating in the blood - are all produced in the bone marrow. Figure 2 (below) shows the steps those blood cells go through while maturing.

This blood cell maturation process, known as hematopoiesis, starts with a pluripotent stem cell. Pluripotent stem cells have the potential to develop into multiple different cell lines, as shown in Figure 2. By definition, Pluripotent breaks down to mean:

- "Pluri" = many or multiple
- "Potent" = potential

The pluripotent stem cells that are found in the bone marrow are known as hematopoietic stem cells (HSC) and give rise to extremely large numbers of "daughter cells" formed from that original stem cell. HSCs typically represent 1 cell for every 10,000 cells found in the bone marrow. In adults, HSCs are found in the bone marrow of the pelvis, femur, and sternum, and in newborns are found in the umbilical cord blood. HSCs can also be found in very small numbers in the peripheral, circulating bloodstream.

Figure 2: Simplified Cell Chart Showing Cell Lines That Originate From HSCs



As the cells mature, they start to form different "categories" or cell lines (aka - lineage). In some cases, these cell lines branch off multiple times before becoming the mature blood cell that found in the peripheral circulation, which are the cells that are observed and counted in a Complete Blood Count (CBC). Initially as cells are formed from the pluripotent stem cell, they are categorized into either "myeloid" or "lymphoid" cells lines. Figure 2 shows a simplified graphic of the cells that are included in those two categories. It should be noted that each one of the cells pictured in that graphic have already gone through several maturation steps before becoming the mature cells that are released into the blood stream.

Blood cells can normally be found in three areas of the body:

- Bone marrow - where cells are formed and mature
- Peripheral (circulating) blood *
- Tissues - found during injury & other disease states

COMPLETE BLOOD COUNT

In the laboratory, the Complete Blood Count measures the cells in the peripheral bloodstream. The Complete Blood Count is referred to as a CBC and is one of the most commonly ordered tests. It's used as a broad screening tool, providing information on the patient's general health status. Although it's routinely ordered during a patient's annual wellness exam, it's also used to diagnose and monitor various disease states, such as anemia, leukemia, infections, bleeding disorders, etc.

CBC SPECIMEN

Blood is collected in a lavender top EDTA tube, which is gently inverted 5-10 times immediately after collection to prevent clotting. The specimen should remain at room temperature during transport and the testing process. It should be noted that on rare occasions it may be necessary to collect a Sodium Citrate or Sodium Heparin tube when pseudo (false) platelet clumping occurs in a patient's specimen. This occurs in <1% of the population whose platelets react to the EDTA inside the blood tube causing the platelets to stick together and giving a falsely negative platelet count. *Check with your procedure manual or the CBC analyzer's manufacturer to determine which alternate specimen is acceptable to run on the analyzer at your lab.

Since specimen integrity is important to producing a reliable patient result, CBC specimens may be rejected and a redraw requested if the specimen is compromised in any way. Causes for rejection may include:

- Clotted specimen
- Hemolysis
- Overfilled or under-filled specimen tube
- Incorrect specimen tube
- Tube contaminated or diluted with IV fluid. This can occur if blood is draw above an active IV site or when the IV has not been turned off long enough for the fluid to clear from the vein prior to venipuncture.
- Incorrect specimen temperature (ie - frozen)

Other rejection criteria may apply, however, these are the most common causes.

COMPONENTS OF THE CBC

The CBC measures three main cell types and different parameters for each:

- Red blood cells
  - Total RBC count
  - Hemoglobin, Hematocrit, and RBC Indices (measure of size, shape, etc)

- White blood cells (WBCs)
  - Total WBC count
  - WBC differential – automated or manually visualizing a blood smear.
    - Identifies and quantitates each of the 5 WBC cell types

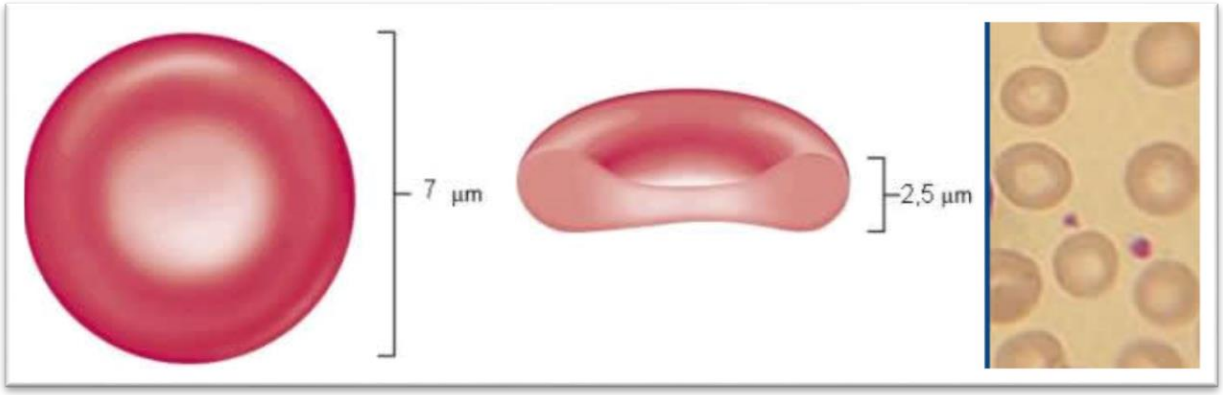
- Platelets
  - Total platelet count
  - Platelet indices

RED BLOOD CELLS

RBC is an abbreviation for "Red Blood Cell", also known as an erythrocyte. Of the three main cell categories, RBCs are the most numerous blood cell and function in the body by transporting oxygen to the cells and tissues, while transporting carbon dioxide to the lungs for removal.

The classic red color of RBCs is from the iron content of the hemoglobin contained within each cell. Each hemoglobin molecule carries four heme groups, which makes up about 1/3 of the total cell volume and is responsible for transporting 98% of the oxygen within the body.

Unlike other cells, RBCs do not have a nucleus and appear as round, indented discs as shown below. The concave central area appears pale, while the rest of the cell appears as a reddish-brown color under a microscope. Their biconcave shape allows them flexibility to bend and fold while flowing smoothly through even the smallest blood vessels.



Average Size: 7 µm (micrometers) in diameter and approximately 2.5 µm in height

Average Lifespan: It takes approximately 7 days for a red blood cell to mature from a stem cell to an erythrocyte in the peripheral blood. Healthy RBCs have an average lifespan of 120 days. Once they die, they're removed from the circulation by the spleen, while their iron content is recycled and used in new RBCs that are formed in the bone marrow.

TOTAL RBC COUNT

The total RBC count measures how many red blood cells a person has in their peripheral circulation. As noted above, these cells are responsible for transporting oxygen in the body, so it's important to have a normal count to feel healthy.

NORMAL TOTAL RBC COUNTS: measured in microliters

Adult Male:	4.7-6.1 X 10^6 / µl
Adult Female:	4.2-5.4 X 10^6 / µl
Newborns:	4.8-7.1 X 10^6 / µl
2-8 weeks old:	4.0-6.0 X 10^6 / µl
2-12 months:	3.5-5.4 X 10^6 / µl
1-18 years:	4.0-5.5 X 10^6 / µl

- Normal values may vary slightly from lab to lab depending on the analyzer.

LOW RBC COUNT

A low RBC count is known as anemia and occurs when there is a decrease of more than 10% of the normal expected value. Low RBC counts can be caused by many factors and disease states including:

- Blood loss – Chronic or hemorrhage
- Dietary deficiencies – iron, vitamin B12, or folate
- Medical conditions – kidney failure, spleen injury, sepsis, tumor, leukemia, etc.
- Hemolysis – autoimmune, G6PD deficiency, or spherocytosis
- Medications – chloramphenicol, chemotherapy, quinidine, etc.
- Transient or benign conditions – pregnancy or dehydration

Signs and Symptoms of Low RBC Count

- Dizziness
- Shortness of breath
- Pallor (pale skin)
- Other symptoms may also be present if the anemia is caused by another disease.

Treatment of Anemia: The specific treatment of the anemia depends on the underlying cause, but can include blood transfusion of packed RBCs, supplementation of iron, B12, or folate, discontinuation of medications causing the anemia, or erythropoietin injection to stimulate RBC production.

ELEVATED RBC COUNT

An elevated RBC count is known as polycythemia and there are 3 types including primary, secondary, and relative. Elevated RBC counts can be hereditary, caused by a reduced amount of plasma, high altitudes, smoking, etc.

Signs and Symptoms of an Elevated RBC Count

- Headache
- Dizziness
- Severe itching – seen with polycythemia vera
- Abnormally enlarged spleen and/or liver
- Possible blood clot formation (thrombosis)
- Possible high blood pressure

Treatment of Elevated RBC Count: When treatment is necessary, a "therapeutic phlebotomy" is typically performed. The volume of blood taken will depend on the severity of the polycythemia and is usually directed by the ordering physician. When therapeutic

phlebotomies don't work or can't be routinely performed, medications, such as bisulfan or hydroxurea, may be administered reduce the production of RBCs.

WHITE BLOOD CELLS

WBC is an abbreviation for "White Blood Cell", also referred to as a leukocyte. WBCs are cells of the immune system that help with protecting the body against pathogens, such as bacteria, yeasts, viruses, and parasites. WBCs also play a role in allergies and inflammation.

White blood cells can be found in the bone marrow, bloodstream, and can also migrate to the tissues when needed during bouts of allergy, inflammation, or infection. All WBCs start out in the bone marrow from a stem cell and mature through either the Myeloid pathway or the Lymphoid pathway as noted in Figure 2.

There are five types of WBCs pictured below, which can be classified as either "granulocytic" or "non-granulocytic". Granulocytic cells have granules in their cytoplasm and include neutrophils, eosinophils, and basophils, while non-granulocytic cells have no granules in their cytoplasm and include monocytes and lymphocytes.

TOTAL WBC

The total WBC count measures how many white blood cells a person has circulating in their blood. As noted above, these cells are responsible for protecting the body against any invading pathogens, so changes outside the normal range can indicate various disease states.

NORMAL TOTAL WBC COUNTS: measured below in microliters

Adults:	4.5-10.5 X 10^3 / µl	(4,500-10,500/mm^3)
Newborns:	9.0-30.0 X 10^3 / µl	(9,000-30,000/mm^3)
6 mo-2 yrs:	6.0-17.5 X 10^3 / µl	(6,000-17,500/mm^3)
Up to 6 yrs:	5.0-14.5 X 10^3 / µl	(mean 8,500/mm^3)
6-16 years:	4.5-13.5 X 10^3 / µl	(mean 8,100/mm^3)

- Normal values may vary slightly from lab to lab depending on the analyzer.
- Can be reported in 10^3 microliters, 10^9 liters, or mm^3.

LOW WBC COUNT

A low WBC count is known as leukopenia and is recognized typically when the WBC count goes below 2,000/mm^3. Low WBC counts can occur from many different factors, including:

- Cancer – especially when it originates in the bone marrow
- Bone marrow deficiency, failure, or infiltration
- Chemotherapy
- Radiation exposure or radiation treatment for cancer
- Autoimmune illness – Lupus, rheumatoid arthritis, Crohn's disease, etc.
- Certain infections including, TB, HIV, Mononucleosis, Lyme disease, etc.
- Severe bacterial infections, including sepsis
- Certain medications including antibiotics, high blood pressure medications, seizure medications, histamine-2 blockers, etc.

When a WBC count falls to 500/mm3 or below, it's considered critical and special precautions need to be taken. Often this is seen with patients on chemotherapy or organ transplantation, although there can be other medical causes. These patients need to take extra precautions if they're among the normal population, such as wearing a mask, not shaking hands, avoiding pets, etc. When the patient is in the hospital, they will be placed in strict isolation, sometimes referred to as "reverse isolation" in order to protect them from infections that others may expose them to.

Signs of Low WBC Count

Although the signs below are not caused directly by a low WBC count, it is a contributing factor when the patient's frail immune system predisposes them to increased infections. Many of these signs or symptoms indicate an infection or infectious process taking place. This is not an all-inclusive list:

- Fever, chills, or sweats
- Severe nausea and vomiting
- Weakness or low blood pressure – can be caused by severe infection or sepsis
- Cough or shortness of breath
- Skin rash or blisters
- Redness, swelling, heat, or drainage at any injection site, IV site, incision, or cut
- Burning and frequency during urination
- An increased frequency of infections

Treatment of Leukopenia: The specific treatment of leukopenia depends on the underlying cause, but can include stopping a medication that's causing the problem,

treating the disease contributing to the low WBC count, delaying radiation treatments until the WBC count rises, treating infections such as TB or HIV, etc.
In addition, there are also medications, such as Neulasta, that help increase a WBC count when it's too low and are commonly given during chemotherapy treatment. Neulasta, a biologic response modifier, is also known as a granulocyte colony stimulating factor (G-CSF) and is responsible for the increased production of WBCs in the bone marrow.

It should be noted that Zinc, Vitamin C, Vitamin D, Selenium, and probiotics also play a role in stimulating the immune system aiding in the production of WBCs.

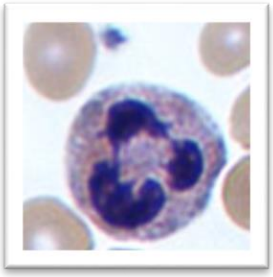
ELEVATED WBC COUNT

An elevated WBC count is known as Leukocytosis and typically represents a value over 10,000/mm^3. Leukocytosis may be caused by a number of factors, including:

- Infection
- Leukemia
- Trauma
- Severe mental or physical stress
- Tissue damage (ie: burns) or necrosis
- Inflammation
- Cigarette smoking
- Certain medications – Epinephrine, heparin, lithium, beta adrenergic agonists (ie: buterol), corticosteroids (note: steroids may decrease the WBC during severe sepsis), allopurinol, etc.
- Pregnancy can sometimes cause a slight elevation in the WBC count during the final month.

LET'S TAKE A CLOSER LOOK AT THE 5 TYPES OF WBCS:

NEUTROPHILS



A neutrophil is a type of white blood cell known as a granulocyte. It is the most abundant type of WBC normally seen in the bloodstream of healthy patients. Neutrophils are among the first cells to respond to a bacterial infection and are an important part of the innate immune system. Although neutrophils normally circulate in the blood stream, they can be signaled to move into the tissues by bacteria. Neutrophils help fight infection by releasing granules from inside the

cell to help immobilize and kill any invading bacteria. This process of ingesting the bacteria is known as phagocytosis.

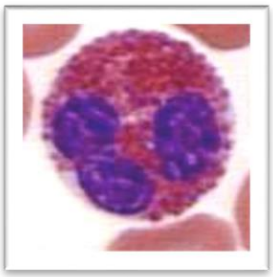
Decreased Neutrophil Count

A low neutrophil count is known as neutropenia and occurs when the actual count dips below the normal expected value. Low neutrophil counts can be caused by many factors and disease states including decreased production, nutritional deficiency, increased destruction, certain medications, bone marrow failure, etc.

Increased Neutrophil Count

An increased neutrophil count is known as neutrophilia. Although neutrophilia is the hallmark of a bacterial infection, high neutrophil counts can be caused by many factors and disease states including fungal infection, tissue injury (burns, trauma, etc.), severe stress, Myelocytic Leukemia, certain medications, etc.

EOSINOPHILS



An eosinophil is a type of white blood cell known as a granulocyte and is the 2nd least common cell (only behind Basophils) found in the bloodstream. Visually it is very distinctive under the microscope with bright red granules. Although the eosinophil can be found in the circulation, it is primarily a tissue-dwelling cell and tends to migrate mainly to the lungs, gastrointestinal tract, and skin.

Eosinophils are found in numerous inflammatory reactions, especially allergic disorders and parasitic infections. Once they move to the areas of inflammation they are capable of killing & ingesting microorganisms (especially parasites) and participating in immediate allergic reactions.

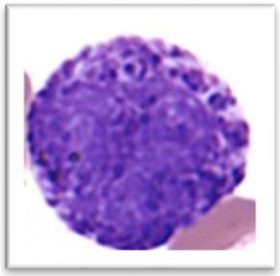
Decreased Eosinophil Counts

A decreased eosinophil count is known as eosinopenia. Because there are so few eosinophils in the blood a decreased count is uncommon and often hard to determine, however, there are a few disease states that have lowered eosinophil production and activity including stress, bone marrow depression, and steroid use.

Increased Eosinophil Counts

An increase in eosinophils is known as eosinophilia and can be seen in a number of conditions and disease states including Asthma, parasitic infections, allergic reactions, Chronic Myelogenous Leukemia, etc.

BASOPHILS



A basophil is a type of white blood cell known as a granulocyte and is the least common cell found in the peripheral blood. Basophils have immunoglobulin (IgE) receptors on their surface membranes that when cross-linked by antigens, result in the release of their granules. Like neutrophils, basophils are found in the peripheral circulation, but when activated by the appropriate chemical signals can move into the tissues where their granules help contribute to the inflammatory or hypersensitivity response typically stimulated by an exposure to allergens or parasites.

The granules inside basophils contain multiple chemicals, each with their own immune task. Those granules include heparin, histamine, platelet activating factor (PAF), interleukin-4, and peroxidase, just to name a few. Those chemicals contribute to immediate hypersensitivity reactions, as well as, prolonged allergic responses capable of triggering smooth muscle contraction, as seen in asthma. The histamine serves as a vasodilator bringing more blood to the area of inflammation. As part of the allergic response, basophils are also known to attract eosinophils to the area, as is seen in both allergic responses and parasitic infections.

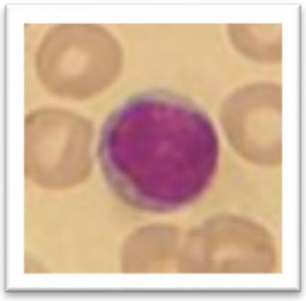
DECREASED BASOPHIL COUNT

A decreased basophil count is known as basopenia. Because there are so few basophils in the blood a decreased count is often hard to determine, however, there are a few disease states that have lowered basophil production and activity including hyperthyroidism, stress, pregnancy, corticosteroids, etc.

INCREASED BASOPHIL COUNT

An increase in basophils is known as basophilia and can be seen in a number of conditions and disease states including viral & parasitic infections, hypothyroidism, leukemia, polycythemia, and inflammatory conditions, such as asthma, IBS, etc.

LYMPHOCYTES



Lymphocytes are a type of non-granulocytic white blood cell. They are the 2nd most populous cell in the bloodstream, only behind neutrophils. Lymphocytes can be found in the blood, the lymph (lymph fluid, lymph vessels, and lymph nodes), and lymphoid organs, such as the thymus, appendix, and spleen. They are part of the Adaptive Immune System in the human body, helping to create antibodies against specific pathogens that the body is exposed to.

There are several types of Lymphocytes produced by the body, including natural killer cells, B cells, T cells, and plasma cells. Each of these cell types have their own function in the immune process, working together along with other cells to resist against infection. Some cell types also have subsets, which again have their own individual functions.

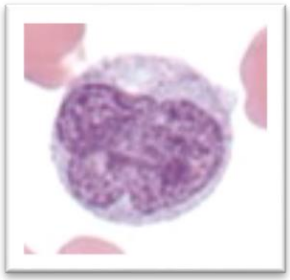
Decreased Lymphocyte Count

A decreased total lymphocyte count is known as either lymphopenia or lymphocytopenia and can be caused by large doses of radiation, chemotherapy, HIV, corticosteroid use, some autoimmune diseases, etc.

Increased Lymphocyte Count

An increase in lymphocytes is known as lymphocytosis and can be seen in a number of conditions and disease states including acute viral infections, some protozoal infections, tuberculosis, Lymphoma, Chronic and Acute Lymphocytic Leukemias.

MONOCYTES



Monocytes are a type of white blood cell and are the largest normal cell in the bloodstream (only malignant cells are larger). They play an important role in immune defense, inflammation, and tissue remodeling, which is accomplished through phagocytosis (ingesting dead cells and pathogens), antigen processing, and cytokine production. During tissue damage or inflammation, the monocyte is recruited out of the bloodstream and into that area of the tissue damage where through chemical instruction, they transform into a macrophage.

When a monocyte moves from the bloodstream into the tissues, it becomes a cell known as a macrophage. A Macrophage's role is to ingest infectious organisms causing disease and to trigger the adaptive immune system by recruiting other cells to the area to assist in the destruction of any invading pathogen. They can also perform "housekeeping duties" acting as scavenger cells clearing away cellular debris and recycling dead cells.

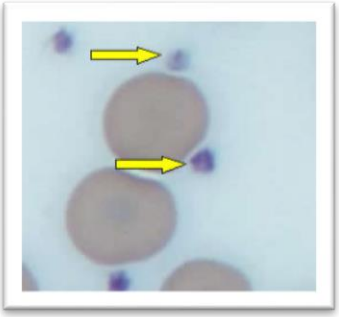
DECREASED MONOCYTE COUNT

A decrease in the number of monocytes is known as monocytopenia and can be seen in anemia and with certain medications.

INCREASED MONOCYTE COUNT

An increase in the number of monocytes is known as monocytosis and can be seen in a number of disease states including chronic inflammation, infections, autoimmune diseases, and malignancies.

PLATELETS



Platelets, also known as thrombocytes, are cells whose main function is to stop bleeding by binding together when a blood vessel is damaged. Circulating platelets are actually cellular fragments from the cytoplasm of a Megakaryocyte, which is normally only found in the bone marrow.

When a vessel is damaged, platelets circulate to the injury site then go through several steps to form a clot:

- Adhesion: Platelets attach to the surface around the injury site
- Activation: Platelets alter their shape to better adhere to the injury site and to one another, they then turn on receptors, and secrete chemical messengers to signal other chemical processes.
- Aggregation: Platelets adhere to one another and the surrounding tissue. The mass is held together with fibrin, forming a 'platelet plug'.

TOTAL PLATELET COUNT

NORMAL PLATELET COUNTS: 150,000 – 400,000 per microliter (μL)

- Normal values may vary slightly from lab to lab depending on the analyzer.

Average Cell Size of Platelet: 1 – 3 μm (micrometers)

Average Lifespan: The average lifespan of a platelet is approximately 10 days.

Common Abbreviation or Nicknames: Platelet is abbreviated as "PLT"

LOW PLATELET COUNT

A low platelet count is known as thrombocytopenia and can be due to either decreased production or increased destruction or usage. Thrombocytopenia has several causes:

Reduced production can be seen in bone marrow failure, leukemia, congenital diseases, etc.

Increased Destruction has immune and non-immune causes. Immune causes include Idiopathic Thrombocytopenia Purpura (ITP), Heparin Induced Thrombocytopenia (ITP), post-transfusion reaction, viral illness, etc, while non-immune causes include hemorrhage, Disseminated Intravascular Coagulation (DIC), medication induced, etc.

Signs and Symptoms of Thrombocytopenia

- Petechiae (pinpoint purple or red spots on skin)
- Easy bruising
- Nosebleeds
- Mild to moderate bleeding (depending on the thrombocytopenia severity)
- Excessive bleeding from superficial wounds

Treatment of Thrombocytopenia

Treatment of thrombocytopenia depends on the cause and the severity. The main goal is to prevent uncontrolled bleeding and/or death and can include stopping a medication that's causing the problem or a platelet transfusion when the platelet count is severely low.

ELEVATED PLATELET COUNT

An elevated platelet count is known as thrombocytosis and can be due to many causes including Chronic Myelogenous Leukemia (CML), spleen removal, surgery, inflammation or infection, acute hemorrhage, cancer, and living at high altitudes.

Signs and Symptoms of Thrombocytosis

Typically there are no symptoms, however, some patients may experience blood clots.

Thrombocytosis Treatment

- Careful observation for asymptomatic patients
- Low dose aspirin for prevention of blood clots
- With essential thrombocythemia (ET) hydroxyurea or anagrelide can be used