The average adult’s body has 8 to 10 pints of blood. Loss of more than 2 pints at any one time leads to a serious condition.

**BLOOD COMPOSITION**

Blood is made up of plasma, the liquid portion of blood without its cellular elements. Serum is the name given to plasma after a blood clot is formed: serum = plasma - (fibrinogen + prothrombin). Blood also contains cellular elements, including erythrocytes or red blood cells (RBCs), leukocytes or white blood cells (WBCs), and thrombocytes (platelets). Figure 12-1.

**BLOOD PLASMA**

Plasma is a straw-colored, complex liquid, comprising about 55% of the blood volume and containing the following six substances in solution:

1. Water—Water makes up about 92% of the total volume of plasma. This percentage is maintained by the kidneys and by water intake and output.

2. Plasma proteins—These three proteins are the most abundant of those found in plasma: fibrinogen, serum albumin, and serum globulin.
   a. Fibrinogen is necessary for blood clotting. Without fibrinogen, the slightest cut or wound would bleed profusely. It is synthesized in the liver.
   b. Albumin is the most abundant of all the plasma proteins. A product of the liver, albumin helps to maintain the blood’s osmotic pressure and volume. It provides the “pulsating” needed to hold and pull water from the tissue fluid back into the blood vessels. Normally, plasma proteins do not pass through the capillary walls, as their molecules are relatively large. They are colloidal substances; they can give up, or take up, water-soluble substances, thus regulating the osmotic pressure within the blood vessels.
   c. Globulin is formed not only in the liver, but also in the lymphatic system (discussed in Chapter 15). Gamma globulin has been fractionated (separated) from globulin. This portion helps in the synthesis of antibodies, which destroy or render harmless various...
Red blood cells (RBCs), or erythrocytes, are biconcave, disc-shaped cells. They are curved on both sides, with a thin center and thicker margins. When viewed from above, they appear to have a doughnut shape, as seen in Figure 12-1.

**Hemoglobin**

Erythrocytes contain a red pigment (coloring agent) called hemoglobin, which provides its characteristic color. Hemoglobin is made of a protein molecule called globin and an iron compound called heme. A single blood cell contains several million molecules of hemoglobin. Hemoglobin is vital to the function of the red blood cell, helping it to transport oxygen to the tissues and store carbon dioxide away from the tissues. Normal hemoglobin count for men is 14 to 16 g and for women is 12 to 16 g per 100 cc.

**Function**

In the capillaries of the lung, erythrocytes pick up oxygen from the inspired air. The oxygen chemically combines with the hemoglobin, forming the compound oxyhemoglobin. The oxyhemoglobin-laden erythrocytes circulate to the capillaries of tissues. Here oxygen is released to the tissues. The carbon dioxide that is formed in the cells is picked up by the plasma as a bicarbonate. The red blood cells circulate back to the lungs to give up the carbon dioxide and absorb more oxygen. Arteries carry blood away from the heart and veins carry blood toward the heart, but there are exceptions. Blood cells that travel in the arteries (except for pulmonary arteries) carry oxyhemoglobin, which gives blood its bright red color. Blood cells in the veins (except for pulmonary veins) contain carbon monoxide-hemoglobin, which is responsible for the dark, reddish-blue color characteristic of venous blood.

Carbon monoxide (CO) poisoning is a serious and sometimes fatal condition. Carbon monoxide is an odorless gas present in the exhaust of gasoline engines. Carbon monoxide rapidly combines with hemoglobin, and binds to the same site on the hemoglobin molecule as oxygen and crowds oxygen out. The cells are deprived of their oxygen supply. Symptoms may include headache, dizziness, drowsiness, and unconsciousness. Death may occur in severe cases of carbon monoxide poisoning. It is important to remember that carbon monoxide gas is odorless. Carbon monoxide is also present in the flue gases of furnaces and gas or oil-fired space heaters. Damaged or improperly installed furnaces and heaters, as well as plugged or defective chimneys and vents, can bring carbon monoxide into the home. Always be certain to allow for proper ventilation of home and work areas. Never allow a car to run in an unventilated garage. Commercial carbon monoxide detectors are available for home use.

**Erythrocytosis**

Erythrocytosis, or the manufacture of red blood cells, occurs in the red bone marrow of essentially all bones, until adolescence. In the fetus, red blood cells are also produced by the spleen and liver. As one grows older, the red marrow of the long bones is replaced by fat marrow; erythrocytes are thereafter formed only in the spleen and flat bones.

Erythrocytes come from stem cells in the red bone marrow called hemocytoblasts (see Figure 12-1). As the hemocytoblast matures into an erythrocyte, it loses its nucleus and cytoplasmic organelles. The hemocytoblast also becomes smaller, gains hemoglobin, develops a biconcave shape, and enters into the bloodstream. To aid in erythrocytosis, vitamin B12, folate acid, copper, cobalt, iron, and proteins are needed.

Since erythrocytes are encased (contain no nucleus), they live only about 120 days. Destruction occurs as the cells age, rendering them more vulnerable to rupturing. They are broken down by the spleen and liver. Hemoglobin breaks down into globin and heme; the iron content of heme is used to make new red blood cells. The normal count of red blood cells ranges from 4.5 to 6.2 million/μl venous blood for men and 4.2 to 5.4 million/μl venous blood for women.

**Hemolysis**

A rupture or bursting of the red blood cell (erythrocyte) is called hemolysis. This sometimes
occurs as a result of a blood transfusion reaction or other disease processes.

**WHITE BLOOD CELLS**

White blood cells (WBCs) are called leukocytes. They are larger than the erythrocytes and granular (with grain appearance) or agranular (no grain appearance). Leukocytes are manufactured in both red bone marrow and lymphatic tissue. Leukocytes are the body’s natural defense against injury and disease.

**Types of Leukocytes**

Leukocytes are classified into two major groups of cells: the granulocytes (granular leukocytes) and the agranulocytes (agranular leukocytes). This classification is due to the presence of cytoplasmic granules, nuclear structure, and reactions to stains such as Wright’s stain. In the laboratory, stains are applied to blood smears so that formed elements may be easily identified. Granulocytes are made in red bone marrow from cells called myelocytes. Granulocytes are destroyed as they age and as a result of participating in bactericidal destruction. The lifespan of white blood cells is variable, but most granulocytes live only a few days.

There are three types of granulocytes: neutrophils, eosinophils, and basophils. Neutrophils, also called polymorphonuclear neutrophils, phagocyte bacteria with lysosomal enzymes. Phagocytosis is a process that surrounds, engulfs, and digests harmful bacterial. Eosinophils phagocytize the remains of antibody-antigen reactions. They also increase in great numbers in allergic conditions, malaria, and in wound infections. Basophils perform phagocytosis, and their count increases during chronic inflammation and during the healing from an infection. Basophils produce histamine, a vasodilator, and heparin, an anticoagulant.

Agranulocytes are divided into lymphocytes and monocytes. Lymphocytes are further subdi
divided into B-lymphocytes and T-lymphocytes from the thymus gland. Still others are formed by the lymph nodes and spleen. Their lifespan ranges from a few days to several years. They basically help the body by synthesizing and releasing antibody molecules and by protecting against the formation of cancer cells.

Monocytes are formed in bone marrow and the spleen. They assist in phagocytosis, and are able to leave the bloodstream to attach themselves to tissues; here they become tissue macrophages, or histiocytes. During an inflammation, histiocytes help to wall off and isolate the infected area.

The aforementioned types of leukocytes (basophils, neutrophils, eosinophils, and monocytes) that can perform phagocytosis are called phagocytes. Unlike erythrocytes, they can move through the intercellular spaces of the capillary wall into neighboring tissue. This process is known as diapedesis.

A normal leukocyte count averages from 3,500 to 9,000/μl.

To summarize, leukocytes help protect the body against infection and injury. This is achieved through (1) phagocytosis and destruction of bacteria, (2) synthesis of antibody molecules, (3) "cleaning up" of cellular remnants at the site of inflammation, and (4) the walling off of the infected area. See Tables 12-2 and 12-3.

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**INFLAMMATION**

If living tissue is damaged in any way the body usually responds to the damage by either neutralizing or eliminating the cause of the damage. When this happens, the damaged body part goes through an inflammation process. Inflammation occurs when tissues are subjected to chemical or physical trauma (cut or burn). Injury by pathogenic (disease-causing) microorganisms such as bacteria, fungi, protozoa, and viruses also can cause inflammation.

The characteristic symptoms of inflammation are redness, local heat, swelling, and pain. This is due to irritation by bacterial toxins, to increased blood flow to congestion of blood vessels, and to the collection of blood plasma in the surrounding tissues (edema) Figure 12-2. Histamine released from the basophil and other chemical substances increase blood flow to the injured area as well as increasing capillary permeability. Thus, large amounts of blood plasma and fibrinogen enter the damaged area. The damaged area is walled off as a result of the clotting action of fibrinogen on the damaged tissue and macrophage action. Neutrophils move very quickly to the damaged area. The neutrophils move through the capillary walls by diapedesis and begin phagocytosis of the pathogenic microorganisms. Macrophages also participate in phagocytosis.

In most inflammations, a cream-colored liquid called pus forms. Pus is a combination of dead tissue, dead and living bacteria, dead leukocytes, and blood plasma. If the damaged area is below the epidermis, an abscess (pus filled cavity) forms. If it is on the skin or a mucosal surface, it is called an ulcer. In many inflammations, chemical substances called pyrogens are formed, which are circulated to the hypothalamus. In the hypothalamus, the pyrogens affect the temperature control center, which raises the body’s temperature causing fever or pyrexia.

In inflammation, there is an increased production of neutrophils by bone marrow. If the white blood cell count exceeds 10,000 cells/μl, a condition called leukocytosis exists. Following healing, the leukocyte count returns to normal. Sometimes a decrease in the number of white blood cells occurs. This is called leukopenia.
important to note that prothrombin and fibrino-
gen are plasma proteins manufactured in the
liver; therefore, serious liver disease may interfere
with the blood clotting process.

Clotting Time. The time it takes for blood to clot
is known as its clotting time. The clotting time
for humans is from 5 to 15 minutes. This informa-
tion is quite useful prior to surgery.

**Blood Types**

There are four major groups or types of blood: A,
B, AB, and O. Blood type is inherited from one's
parents. It is determined by the presence—or ab-
ence—of the blood protein called agglutinogen or
antigen, on the surface of the red blood cell. People
with type A blood have the A antigen on their
red blood cells; type B blood has the type B
antigen; type AB has both A and B antigen; and
type O has neither of the antigens.

There is a protein present in the plasma
known as agglutinin or antibody. An individ-
ual with type A blood has antibodies in the blood
plasma. Type B blood possesses antibodies; type
O contains both A and B antibodies; and type AB
contains no antibodies.

Knowledge of one’s correct type is impor-
tant in cases of blood transfusions and surgery. A
test known as type and crossmatch is done before
receiving a blood transfusion. This determines the
compatibility of the blood of the recipient and donor. Antibodies
react with the antigens of the same type, causing
the red blood cells to clump together. The clump-
ing of blood, a process known as agglutination
blocks the blood vessels, impeding circulation; this
can cause death.

By way of an example, if a person with type
A blood needs a transfusion, he or she must receive
A blood. Should the person receive type B blood,
the B antigen of the type B blood would cause
the B antibodies of the person's type A blood
to react. The reaction could either be positive (+)
and negative (−) or vice versa, depending on the
recipient's blood type. Type O blood is consid-
ered the universal donor, because it has no antigens
for A or B blood and no antibodies for the Rh
factor. Type AB is considered the univer-
sal recipient, because it has both A and B
antigens and the Rh antigen. See Table 12-4 for
blood type crossmatches.

**RH Factor**

Human red blood cells, in addition to containing
antigens A and B, also contain the Rh antigen. We
know it as the Rh factor because it was first
found in the Rh blood type. The Rh factor is found on
the surface of red blood cells. People possessing the
Rh factor are said to be Rh positive (Rh+). Those
without the Rh factor are Rh negative (Rh−).

About 85% of North Americans are Rh posi-
tive and 15% are Rh negative. If an Rh negative
individual receives a transfusion of Rh positive
blood, he or she will develop antibodies to the Rh
antigen. These antibodies take 2 weeks to develop. Generally
there is no problem with the first transfusion; but
if a second transfusion of Rh positive blood is
given, the accumulated Rh antibodies will damage
the blood cells and cause death. Both Rh type
and Rh factor must be taken into account for safe
and successful transfusions.

The same problem arises when an Rh negative
mother is pregnant with an Rh positive fetus. The
mother’s blood can develop anti-Rh antibodies to
the fetus’s Rh antigens. The first-born child will
normally survive with no harmful effects; however, sub-
sequent pregnancies will be affected, because the
mother’s accumulated anti-Rh antibodies will
make the baby’s red blood cells. If the condition is
left untreated, the baby will usually be born with
the condition known as erythroblastosis fetalis (he-
monic disease of newborn). This condition is rare
today because of the use of the drug RHOGAM,
which is a special preparation of immune globulin.
RHOGAM is given to the Rh negative (Rh−) mother
within 72 hours after delivery of each baby. Some
doctors also give this drug during the last trimester
of pregnancy. The antibodies in the RHOGAM will
destroy any Rh positive (Rh+) cells of the baby’s
which may have entered the mother’s bloodstream;
therefore, the mother’s immune system will not be
stimulated to produce antibodies.

**Blood Noms**

Tests have been devised to use physiological
blood norms in diagnosing and following the course
of certain diseases. Some of these norms are listed
in Table 12-5.

Patients who are taking anticoagulant med-
ications to prolong the clotting time of their blood
must have prothrombin time (PT) and a partial
thromboplastin time (PTT) done frequently. The
dosage of their medication is based on their clot-
ting times.

**Sedimentation rate** is the time required
for erythrocytes to settle to the bottom of an
upright tube at room temperature. An elevated
sedimentation rate indicates whether disease is
present and is valuable in observing the progress
of inflammatory conditions.

**Disorders of the Blood**

Anemia is a deficiency in the number and/or per-
centage of red blood cells and the amount of he-
moglobin in the blood. Anemia results from a large
or chronic loss of blood (hemorrhage) which de-
creases the number of erythrocytes. Extreme ery-
throcyte destruction and malfunction of the
hemoglobin of red blood cells also causes this con-
dition. Because these conditions always cause
some hemoglobin deficiency, there is never enough
oxygen transported to the cells for cellular oxida-
tion. Consequently, not enough energy is being re-
leased. Anemia is characterized by varying degrees
of dyspnea, pallor, palpitation, and fatigue.

Iron-deficiency anemia is a condition that
often occurs in women, children, and adolescents.
It is caused by a deficiency of adequate amounts of
iron in the diet. This leads to insufficient hemoglo-
in synthesis in the red blood cells. The condition is
easily alleviated by ingestion of iron supple-
ments and green, leafy vegetables that contain the
mineral iron.

Pernicious anemia is a form of anemia caused by a
deficiency of vitamin B12 and/or lack of the
intrinsic factor. Pernicious anemia is seen in asso-
ciation with some autoimmune endocrine dis-
eses. The intrinsic factor produced by the stom-
ach mucosa is necessary for the absorption and
utilization of vitamin B12. Vitamin B12 and folic
acid are necessary for the development of mature
red blood cells. Symptoms such as dyspnea, pallor,
and fatigue are present as well as specific neuro-
logic changes. Treatment for pernicious anemia
involves injections of vitamin B12.

Aplastic anemia is a disease caused by the
suppression of the bone marrow. Suppression can
be caused by chemical agents, certain drugs, or
radiation therapy. In this condition, bone marrow
does not produce enough red blood cells and white
blood cells. Treatment consists of removal of the
toxic substances or discontinuing the drugs and
radiation. In severe cases, a bone marrow transplun
may be performed.

Sickle cell anemia is a chronic blood dis-
 ease inherited from both parents. The disease

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**Table 12-4** Blood Type Crossmatches

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DONOR'S BLOOD TYPE</th>
<th>MUST BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, A-+, O</td>
<td>+, -</td>
</tr>
<tr>
<td>B</td>
<td>B, B+, O-</td>
<td>+, -</td>
</tr>
<tr>
<td>AB</td>
<td>A, B, O</td>
<td>+, -</td>
</tr>
<tr>
<td>O</td>
<td>A, B, AB, O</td>
<td>+, -</td>
</tr>
</tbody>
</table>

**Table 12-5** Blood Tests

<table>
<thead>
<tr>
<th>TEST</th>
<th>NORMAL RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood glucose</td>
<td>70 to 110 mg/dL</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>13.5 to 15.5 g/dL</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>39 to 44%</td>
</tr>
<tr>
<td>Platelet count</td>
<td>150 to 450 x 10^3/µL</td>
</tr>
<tr>
<td>Erythrocytosis</td>
<td>45 to 54 g/dL</td>
</tr>
<tr>
<td>Sedimentation rate</td>
<td>Low</td>
</tr>
</tbody>
</table>
Medical Highlight

Uses for Newborn's Umbilical or Cord Blood

The blood found in the umbilical cord contains the same immunity-producing stem cells found in the bone marrow and is far easier to transplant. While bone marrow transplants require an almost exact match, cord blood stem cells are too young and the brand new donor has not yet developed antibodies that turn against the recipient. At this time, these transplants are highly experimental and have been used mainly in children. Proponents of this treatment say it will give a new chance for life to people with some forms of leukemia, anemia, Hodgkin's disease, and other conditions.

Medical Highlight

Treatment for Sickle Cell Anemia

Scientists continue to work to treat and prolong the life expectancy for someone diagnosed with sickle cell anemia. Following are some of the latest developments.

1. Partial chimerism—This procedure uses a mixture of the patient's bone marrow and a donor's bone marrow to combine and form healthy new blood cells. It allows for a patient's bone marrow not to be destroyed. This type of mixture will allow more people to be eligible for the transplant. Controlled studies will begin in a few months.

2. Cord blood stem cell transplant—Doctors from Emory University's Department of Pediatrics, Hematology-Oncology Bone Marrow Transplant successfully performed the first cord blood stem cell transplant from an unrelated donor. This type of stem cell transplant is an alternative for a patient who does not have family to provide an immunologic match.

3. Gene cell therapy—Scientists have been able to correct sickle cell disease in mice using gene cell therapy. Researchers inject a gene into the mice and that gene stops the red blood cells from sickling.

The Clinical laboratory testing plays a key role in the detection, diagnosis, and treatment of disease. Clinical laboratory personnel obtain, and analyze body fluids, tissue, and cells. Clinical laboratory technicians perform routine tests in a medical laboratory and are able to discriminate and recognize factors that directly affect procedures and results. Clinical lab technicians have either an associate's degree or certification from a hospital or vocational-technical school. They work under the supervision of a medical technologist or physician. Clinical laboratory technologists physically and chemically analyze and culture all body fluids. Knowledge of specimen collection, anatomy and physiology, biochemistry, and laboratory equipment is essential. Education requirement is at least a bachelor's degree.

The American Society of Clinical Pathology is a professional organization that oversees credentialing and education in the medical laboratory profession.

Embolism is a condition where an embolus is carried by the bloodstream until it reaches an artery too small for passage. An embolus is a substance foreign to the bloodstream. It may be a clot, cancer cells, fat, bacterial clumps, a needle, or even a bullet that was lodged in tissue and breaks free.

Thrombosis is the formation of a blood clot in a blood vessel. The blood clot formed is called a thrombus. It is caused by unusually slow blood circulation, changes in the blood or blood vessel walls, immobility, or a decrease in mobility.

Hemiatome is a localized clotted mass of blood found in an organ, tissue, or space. It is caused by an injury, such as a blow, that can cause a blood vessel to rupture.
Hemophilia is a hereditary disease in which the blood clots slowly or abnormally. This causes prolonged bleeding with even minor cuts and bumps. Although sex-linked hemophilia occurs mostly in males, it is transmitted genetically by females to their sons. The person with hemophilia may be treated with the missing clotting factor. The hemophiliac is taught to avoid trauma, if possible, and report promptly any bleeding, no matter how slight.

Thrombocytopenia is a blood disease in which there is a decrease in the number of platelets (thrombocytes). In this condition, blood will not clot properly.

Leukemia is a cancerous or malignant condition in which there is a great increase in the number of white blood cells. The overabundant immature leukocytes replace the erythrocytes, thus interfering with the transport of oxygen to the tissues. They can also hinder the synthesis of new red blood cells from bone marrow. The acute form of the disease, which develops quickly and runs its course rapidly, occurs most often in children and young adults. Treatment today consists of drug therapy, bone marrow transplants, and radiation therapy which has given people with leukemia remissions lasting for several years.

Septicemia describes the presence of pathogenic (disease-producing) organisms or toxins in the blood.

**Medical Terminology**
- without blood
- without clotting
- process of clotting
- process of blood clotting
- swelling
- presence of swelling
- plug
- condition of plug or blockage
- red cell
- red blood cell
- formation of red blood cell
- blood
- tumor or swelling
- swelling that contains blood
- white blood cell
- clear blood cell

**Select the letter of the choice that best completes the statement.**

1. Blood of the universal donor is:
   a. type B-
   b. type A-
   c. type AB+
   d. type O-

2. Blood of the universal recipient is:
   a. type B+
   b. type A+
   c. type AB+
   d. type O+

3. Negative Rh blood is found in:
   a. 5% of the population
   b. 10% of the population
   c. 15% of the population
   d. 20% of the population

4. The leukocytes that phagocytize bacteria with lysosomal enzymes are the:
   a. eosinophils
   b. basophils
   c. neutrophils
   d. monocytes

5. The prothrombin in the blood-clotting process is dependent upon:
   a. vitamin A
   b. vitamin K
   c. vitamin D
   d. vitamin P
6. Which of the following is not a blood cell?
   a. erythrocyte
   b. leucocyte
   c. osteocyte
   d. monocyte

7. Erythrocytes contain all but one of the following elements:
   a. Rb factor
   b. leukocytes
   c. hemoglobin
   d. globin and heme

8. What characteristic is not true of normal thrombocytes?
   a. They average 4,500 for each cubic millimeter of blood
   b. They are also called platelets
   c. They are plate-shaped cells
   d. They initiate the blood-clotting process

9. The normal leucocyte cell:
   a. can only be produced in the lymphatic tissue
   b. goes to the infection site to engulf and destroy microorganisms
   c. is too large to move through the intercellular spaces of the capillary wall
   d. exists in numbers which amount to an average of 12,000 cells per cubic millimeter of blood

10. The blood-clotting process:
    a. requires a normal platelet count which is 5,000 to 9,000 for each cubic millimeter of blood
    b. is delayed by the rupture of platelets which produces thromboplastin
    c. occurs in less time with persons having type O blood
    d. requires vitamin K for the synthesis of prothrombin

**COMPLETION**

Briefly answer the following questions.

1. Name the three major types of blood cells.

2. What name is given to the straw-colored liquid portion of the blood?

3. What five proteins are contained in the blood and what are their functions?

4. Describe the process of blood clot formation.

**APPLYING THEORY TO PRACTICE**

1. You hear that your friend has been in a car accident and needs a blood transfusion; you want to donate blood. You friend has type O+ blood and you have A+ blood. Can your blood be given to your friend? Explain the reason for your answer.

2. Why is blood considered the "gift of life"?

3. A patient comes to the doctor's office. She is pregnant and states she is Rh negative and her husband is Rh positive. She has heard that there may be a problem with the baby. Explain to her about the Rh factor and how this situation is treated today.

4. In the hospital you are caring for a 6-year-old girl with leukemia. The mother asks what she did that caused the disease. What will be your response?

5. You are employed as a medical technologist. A patient comes to the lab and requires a complete blood count and sedimentation rate. The patient asks you to explain these tests and their purpose.

**CASE STUDY**

John, age 24, is involved in an automobile accident. Ken, a paramedic, arrives on the scene and does emergency first aid. John has multiple lacerations on his hand and arms; the laceration on his right arm is bleeding profusely. Ken applies a pressure bandage and notes that John's blood pressure is 90/60. Ken starts an intravenous line and transports John to the hospital. The ER doctor examines John and notes he also has contusions near his liver. The doctor has the med tech draw blood for a CBC and to type and crossmatch for blood.

1. A severe loss of blood may lead to what condition?

2. Name the blood components and their function.

3. What is a normal blood count for John?

4. Why is the ER doctor concerned about possible liver damage? How does liver damage relate to the blood?

5. Describe the role of a med tech.

6. Explain typing and crossmatching.

7. It is determined that John has type A positive blood. Can John receive blood from Ken who is O negative?