Around 1900, Karl Landsteiner discovered that there are at least four different kinds of human blood, determined by the presence or absence of specific agglutinogens (antigens) on the surface of red blood cells (erythrocytes). These antigens have been designated as A and B. Antibodies against antigens A or B begin to build up in the blood plasma shortly after birth, the levels peak at about eight to ten years of age, and the antibodies remain, in declining amounts, throughout the rest of a person’s life. The stimulus for antibody production is not clear; however, it has been proposed that antibody production is initiated by minute amounts of A and B antigens that may enter the body through food, bacteria, or other means. Humans normally produce antibodies against those antigens that are not on their erythrocytes: A person with A antigens has anti-B antibodies; a person with B antigens has anti-A antibodies; a person with neither A nor B antigens has both anti-A and anti-B antibodies; and a person with both A and B antigens has neither anti-A nor anti-B antibodies (Figure 1). Blood type is based on the antigens, not the antibodies, a person possesses.

The four blood groups are types A, B, AB, and O. Blood type O, characterized by the absence of A and B agglutinogens, is the most common in the United States and is found in 45% of the population. Type A is next in frequency, and is found in 39% of the population. The frequencies at which types B and AB occur are 12% and 4% respectively.

**Figure 1**

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Antigens on Erythrocytes (Agglutinogens)</th>
<th>Antibodies in Plasma (Agglutinins)</th>
<th>Can Give Blood To</th>
<th>Can Receive Blood From</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
<td>A, AB</td>
<td>O, A</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
<td>B, AB</td>
<td>O, A</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>Neither Anti-A nor Anti-B</td>
<td>AB</td>
<td>O, A, B, AB</td>
</tr>
<tr>
<td>O</td>
<td>Neither A nor B</td>
<td>Both Anti-A and Anti-B</td>
<td>O, A, B, AB</td>
<td>O</td>
</tr>
</tbody>
</table>
ABO System
Process of Agglutination

There is a simple test performed with antisera containing high levels of anti-A and anti-B agglutinins to determine blood type. Several drops of each kind of antiserum are added to separate samples of blood. If agglutination (clumping) occurs only in the suspension to which the anti-A serum was added, the blood type is A. If agglutination occurs only in the anti-B mixture, the blood type is B. Agglutination in both samples indicates that the blood type is AB. The absence of agglutination in any sample indicates that the blood type is O (Figure 2).

Figure 2
Agglutination Reaction of ABO Blood-Typing Sera

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-A Serum</td>
<td>Anti-B Serum</td>
</tr>
<tr>
<td>Agglutination</td>
<td>No Agglutination</td>
</tr>
<tr>
<td>No Agglutination</td>
<td>Agglutination</td>
</tr>
<tr>
<td>Agglutination</td>
<td>Agglutination</td>
</tr>
<tr>
<td>No Agglutination</td>
<td>No Agglutination</td>
</tr>
</tbody>
</table>

Importance of Blood Typing

As noted in the table above, people can receive transfusions of only certain blood types, depending on the type of blood they have. If incompatible blood types are mixed, erythrocyte destruction, agglutination and other problems can occur. For instance, if a person with type B blood is transfused with blood type A, the recipient's anti-A antibodies will attack the incoming type A erythrocytes. The type A erythrocytes will be agglutinated, and hemoglobin will be released into the plasma. In addition, incoming anti-B antibodies of the type A blood may also attack the type B erythrocytes of the recipient, with similar results. This problem may not be serious, unless a large amount of blood is transfused.

The ABO blood groups and other inherited antigen characteristics of red blood cells are often used in medico-legal situations involving identification of disputed paternity. A comparison of the blood groups of mother, child, and alleged father may exclude the man as a possible parent. Blood typing cannot prove that an individual is the father of a child; it merely indicates whether or not he possibly could be. For example, a child with a blood type of AB, whose mother is type A, could not have a man whose blood type is O as a father.
The Genetics of Blood Types

The human blood types (A, B, AB, and O) are inherited by multiple alleles, which occurs when three or more genes occupy a single locus on a chromosome. Gene $I^A$ codes for the synthesis of antigen (agglutinogen) $A$, gene $I^B$ codes for the production of antigen $B$ on the red blood cells, and gene $i$ does not produce any antigens. The phenotypes listed in the table below are produced by the combinations of the three different alleles: $I^A$, $I^B$, and $i$. When genes $I^B$ and $I^A$ are present in an individual, both are fully expressed. Both $I^A$ and $I^B$ are dominant over $i$ so the genotype of an individual with blood type O must be $ii$ (Figure 3).

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Possible Genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$I^AI^A$</td>
</tr>
<tr>
<td></td>
<td>$I^AI_i$</td>
</tr>
<tr>
<td>B</td>
<td>$I^BI^B$</td>
</tr>
<tr>
<td></td>
<td>$I^BI_i$</td>
</tr>
<tr>
<td>AB</td>
<td>$I^AI^B$</td>
</tr>
<tr>
<td>O</td>
<td>$ii$</td>
</tr>
</tbody>
</table>

Use $I^A$ for antigen $A$, $I^B$ for antigen $B$, and $i$ for no antigens present.
Genes $I^A$ and $I^B$ are dominant over $i$.
AB blood type results when both genes $I^A$ and $I^B$ are present.

Rh System

In the period between 1900 and 1940, a great deal of research was done to discover the presence of other antigens in human red blood cells. In 1940, Landsteiner and Wiener reported that rabbit sera containing antibodies for the red blood cells of the Rhesus monkey would agglutinate the red blood cells of $5\%$ of Caucasians. These antigens, six in all, were designated as the Rh (Rhesus) factor, and they were given the letters $C, c, D, d, E, e$ by Fischer and Race. Of these six antigens, the $D$ factor is found in $85\%$ of Caucasians, $94\%$ of African Americans, and $99\%$ of Asians. An individual who possesses these antigens is designated $Rh^+$; an individual who lacks them is designated $Rh^-$. The genetics of the Rh blood group system is complicated by the fact that more than one antigen can be identified by the presence of a given Rh gene. Initially, the Rh phenotype was thought to be determined by a single pair of alleles. However, there are at least eight alleles for the Rh factor. To simplify matters, consider one allele: $Rh^+$ is dominant over $Rh$; therefore, a person with an $Rh^-/Rh^-$ or $Rh^-/Rh^+$ genotype has $Rh^-$ blood.
The anti-Rh antibodies of the system are not normally present in the plasma, but anti-Rh antibodies can be produced upon exposure and sensitization to Rh antigens. Sensitization can occur when Rh\(^+\) blood is transfused into an Rh\(^-\) recipient, or when an Rh\(^-\) mother carries a fetus who is Rh\(^+\). In the latter case, some of the fetal Rh antigens may enter the mother’s circulation and sensitize her so that she begins to produce anti-Rh antibodies against the fetal antigens. In most cases, sensitization to the Rh antigens takes place toward the end of pregnancy, but because it takes some time to build up the anti-Rh antibodies, the first Rh\(^+\) child carried by a previously unsensitized mother is usually unaffected. However, if an Rh\(^-\) mother, or a mother previously sensitized by a blood transfusion or a previous Rh\(^+\) pregnancy, carries an Rh\(^+\) fetus, maternal anti-Rh antibodies may enter the fetus’ circulation, causing the agglutination and hemolysis of fetal erythrocytes and resulting in a condition known as erythroblastosis fetalis (hemolytic disease of the newborn). To treat an infant in a severe case, the infant’s Rh\(^+\) blood is removed and replaced with Rh\(^-\) blood from an unsensitized donor to reduce the level of anti-Rh antibodies.

**Blood Components**

The formed elements in blood include erythrocytes, or red blood cells (RBCs); various types of leukocytes, or white blood cells (WBCs); and platelets.

Erythrocytes are circular, biconcave disks of 5 to 8 micrometers. Their chief function is to transport oxygen (O\(_2\)) and carbon dioxide (CO\(_2\)). The transport of O\(_2\) and CO\(_2\) depends largely on the hemoglobin present in the erythrocytes. The biconcave shape is also related to the erythrocytes function of transporting gases, in that it provides an increased surface area through which gases can diffuse.

The number of circulating RBCs is closely related to the blood’s oxygen-carrying capacity. Any changes in the RBC count may be significant. RBC counts are routinely made to diagnose and evaluate the course of various diseases.

Leukocytes range in size from approximately 9 to 25 micrometers and function primarily to control various disease conditions. Leukocytes can move against the current of the bloodstream through amoeboid movement, and pass through the blood vessel walls to enter the tissues. The total WBC count normally varies from 5,000 to 10,000/mm\(^3\). Certain infectious diseases are accompanied by an increase in WBCs. If the number exceeds 10,000/mm\(^3\), the person has an acute infection. If it drops below 5,000/mm\(^3\), the person may have a condition such as measles or chicken pox. The percentage of the different types of leukocytes present in the blood may also change in particular diseases, this number is important for diagnostic purposes and is called a differential count.

**DID YOU KNOW?**

Leukocytes are capable of amoeboid movement and are sometimes called ameobocytes.
OBJECTIVES

- Define agglutinogen and agglutinin
- Perform an actual blood typing procedure
- Observe the antigen/antibody reaction in simulated blood
- Determine the ABO and Rh blood type of four unknown samples
- Prepare a wet mount of simulated blood
- Estimate the number of erythrocytes and leukocytes in normal blood
- Understand requirements for blood transfusions

MATERIALS

MATERIALS NEEDED PER GROUP

4 Blood typing slides
12 Toothpicks
1 Microscope slide
1 Coverslip
Compound microscope (400X magnification)
Marker

SHARED MATERIALS

4 Unknown blood samples:
   Mr. Smith
   Mr. Jones
   Mr. Green
   Ms. Brown
Simulated Anti-A Serum
Simulated Anti-B Serum
Simulated Anti-Rh Serum

PROCEDURE

Although WARD’S Simulated Blood is completely safe, non-biological, and non-toxic, you should wear the proper personal protective equipment to mimic the experience of an actual hematology laboratory.

PART A: ABO and Rh BLOOD TYPING

1. Label each blood typing slide:
   Slide #1: Mr. Smith
   Slide #2: Mr. Jones
   Slide #3: Mr. Green
   Slide #4: Ms. Brown
2. Place three to four drops of Mr. Smith’s blood in each of the A, B, and Rh wells of Slide #1.

3. Place three to four drops of Mr. Jones’s blood in each of the A, B, and Rh wells of Slide #2.

4. Place three to four drops of Mr. Green’s blood in each of the A, B, and Rh wells of Slide #3.

5. Place three to four drops of Ms. Brown’s blood in each of the A, B, and Rh wells of Slide #4.

6. Place three to four drops of the simulated anti-A serum in each A well on the four slides.

7. Place three to four drops of the simulated anti-B serum in each B well on the four slides.

8. Place three to four drops of the simulated anti-Rh serum in each Rh well on the four slides.

9. Obtain three toothpicks per blood typing slide. Stir each well with a separate clean toothpick for 30 seconds. To avoid splattering the simulated blood, do not press too hard on the typing tray.

10. Observe each slide and record your observations in Table 1 of the Analysis section. To confirm agglutination try reading text through the mixed sample. If you cannot read the text, assume you have a positive agglutination reaction.

Agglutination No Agglutination

11. Dispose of all materials according to your teacher’s instructions.

WARD’S Simulated blood is non-biological and nontoxic and may be flushed down the drain.

Be sure to wash and save the blood typing trays and toothpicks for future use.
PART B: Blood Cell Count

1. Thoroughly shake one of the vials of WARD’S Simulated Blood. Add one drop of simulated blood to a microscope slide, and cover with a coverslip. Lower the coverslip slowly to avoid trapping air bubbles on the slide.

2. Examine the slide with the low power (10X). Find an area of the slide with an even distribution of cells.

3. Switch to high power (40X). Refocus and count the number of simulated red blood cells (red spheres) in the field of view. Count the cells in any clump separately. Record the number in Table 2.

4. Count the number of simulated white blood cells (blue spheres). Record the number in Table 2.

5. Repeat the counting procedure with two other fields of view. Record these counts in Table 2.

6. Calculate the average of the three red blood cell counts and the three white blood cell counts. Record the results in Table 2.

7. Multiply the average number of red and white blood cells by the dilution factor to determine the number of red and white blood cells per cubic millimeter. Record each value in Table 2.

8. Dispose of all materials according to your teacher’s instructions.

WARD’S Simulated blood is non-biological and non-toxic and may be flushed down the drain.
WARD’S
Simulated ABO and Rh
Blood Typing Lab Activity

Name: __________________________
Group: __________________________
Date: __________________________

## ANALYSIS

### Table 1

<table>
<thead>
<tr>
<th>Slide #</th>
<th>Name</th>
<th>Anti-A Serum</th>
<th>Anti-B Serum</th>
<th>Anti-Rh Serum</th>
<th>Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Mr. Smith</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>Mr. Jones</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>Mr. Green</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>Ms. Brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Blood Cell Type</th>
<th>Cell Count</th>
<th>Total # of Cells</th>
<th>Avg. # Cells or Total/3</th>
<th>Dilution Factor</th>
<th>Total # Blood Cells per mm³ or Avg. # Cells x Dilution Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red (Red)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>150,000</td>
<td></td>
</tr>
<tr>
<td>White (Blue)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5,000</td>
<td></td>
</tr>
</tbody>
</table>
WARD’S
Simulated ABO and Rh
Blood Typing Lab Activity

Name: ___________________________
Group: ___________________________
Date: ___________________________

ASSESSMENT

1. a. Choose one of the following patients:
   Mr. Smith    Mr. Jones
   Mr. Green    Ms. Brown

   Record his/her name here: ______________________

   b. Using the information shown in Figure 1 on blood type and the data recorded in Table 1, what agglutinogens are present on the patient’s RBCs? __________________

   c. What ABO agglutinin(s) is/are found in this patient’s plasma? __________________

   d. What is this patient’s blood type? _________________

   e. If this patient needed a transfusion, what blood type(s) could this patient safely receive? __________

   f. What blood type(s) could safely receive this patient’s blood? ________________

2. Below is a diagram representing the blood type analysis of a new patient (patient X). From the information obtained from the slide, fill out the medical technologist’s report.

   Medical Technologist’s Report
   Patient Name: ___
   ABO Type: ___
   Rh Type: ___
   Med Tech Name: ___________________
3. Using a Venn diagram, compare and contrast agglutinogens and agglutinins. In your diagram, show at least two similarities and two differences.

4. Pretend you went with your class on a medical career field trip to a local hospital. One of the stops on the visit was to the hospital’s blood lab. The medical technologist at this stop gave a demonstration of how blood types are determined. Your job is to write a paragraph for the school newspaper on the visit to the blood lab, summarizing what you’ve learned about how ABO/Rh blood groups are determined. Write a paragraph and include the title.

5. List at least three situations where blood typing could be used.


   b. Describe the sequence of events that result in this condition.

   c. What might be some benefits if the medical profession developed a shot or vaccination that could desensitize an Rh+ situation?
7. You are a type A erythrocyte placing an ad in the personals and you are seeking a compatible mate for a long lasting transfusion. Create an ad to be submitted to the newspaper. The newspaper charges $0.25 per word and the ad can cost no more than $10.

8. Another important diagnostic tool used by medical technologists is determining a patient’s blood cell count, for both red blood cells (erythrocytes) and white blood cells (leukocytes). When this procedure is performed, one technique used is to take multiple samples and calculate the average. This method of multiple sampling is a standard procedure in scientific and medical investigations. Discuss why this method is important in blood typing.

9. Each year thousands of people contract blood borne diseases. What could be done in a clinical blood lab to minimize the risk of obtaining or spreading a blood borne disease?

10. The flowchart below represents a short history of the study of blood and blood typing. The area marked “????” represents possibilities for the next important new discovery in blood and blood typing. In a short paragraph, identify what you think may be the next important breakthrough, milestone or discovery in the study of blood and blood diseases and explain why.

Landsteiner and Weiner

↓

Fisher and Race

↓

Clark

↓

Hunt

↓

????