Synthetic Blood: Paternity Test

TEACHER’S MANUAL
AND STUDENT GUIDE

CAROLINA
World-Class Support for Science & Math
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*Photocopy the Student Guide as needed for use in your classroom.
Synthetic Blood: Paternity Test

Overview
In this exercise, students perform a simplified paternity test based on the inheritance of human blood groups.

Objectives
Students will
- perform standard tests used for blood type identification.
- understand the importance of blood type identification and its uses.
- interpret test results and draw conclusions.
- demonstrate understanding of Mendelian genetics.
- use prior knowledge to solve a problem.

Content Standards
This kit is designed for high school students and freshman college students and addresses the following National Science Education Standards:

Grades 9–12

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Life Science
- The cell
- Matter, energy, and organization in living systems

Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

Time Requirements
The activities can be done in one 45-minute period.
**Materials**

The materials furnished are sufficient for a class of 30 students.

*Included in the kit:*

- mother’s synthetic blood (B–)
- child’s synthetic blood (AB+)
- 3 possible fathers’ synthetic blood (A–, B–, AB+)
- synthetic anti-A serum
- synthetic anti-B serum
- synthetic anti-Rh (D) serum
- blood typing slides
- mixing sticks (blue, yellow, white)
- Teacher’s Manual and reproducible Student Guide

*Needed, but not supplied:*

- paper towels for cleaning the blood typing slides

**Safety**

Ensure that students understand and adhere to safe laboratory practices when performing any activity in the classroom or lab. Demonstrate the protocol for correctly using the instruments and materials necessary to complete the activities, and emphasize the importance of proper usage. Use personal protective equipment such as safety glasses or goggles, gloves, and aprons when appropriate. Model proper laboratory safety practices for your students and require them to adhere to all laboratory safety rules.

The materials in this kit can be discarded after use. There are no biological materials in the synthetic blood or synthetic antisera that would cause any health hazard when discarded.

**Background**

In an actual paternity test, many other blood factors would be tested in addition to the ABO and Rh factors used in this kit; however, the basic principles would remain the same. When sufficient factors are tested, practically all nonfathers can be excluded, and the relative chance of paternity can be established with a high degree of accuracy. A knowledgeable attorney will seldom seek a trial when a paternity test strongly implicates his client. An important social consequence is that the father must now join the mother in providing for their child.

It will aid the students’ understanding if they are familiar with the Fluid Mosaic Model of the cell membrane. The cell membrane of red blood cells, like that of other cells, has molecules that project from its surface. Some of these molecules function somewhat as identification badges. They allow the immune system to recognize the cell as a normal component of an individual’s body. If red blood cells from another person are introduced into the bloodstream, they may have surface molecules that are different. These molecules, which are recognized as foreign to the body, are called antigens. The immune system attacks these antigens, attempting to destroy them and the cells that carry them.
The ABO blood groups result from the presence or absence of two antigens, A and B, on the surface of the red blood cells. The immune system produces an antibody in the plasma for the antigen not present. Usually, it is necessary for exposure to an antigen to occur before antibodies are produced; however, in this instance the antibodies are already present. Type A blood has the A antigen on its red blood cells and anti-B antibodies in the plasma. Type B blood has the B antigen on its red blood cells and anti-A antibodies in the plasma. Type AB blood has both A and B antigens on the red blood cells and no antibodies in the plasma. Finally, Type O blood has neither A nor B antigens on the red blood cells, and there are both A and B antibodies in the plasma.

These ABO blood groups (or more properly, the A and B antigens) are inherited. There are three alleles: $I^A$, $I^B$, and $i$ (also designated $I^O$). In introductory activities such as this one, the gene designation $I$ is commonly omitted and the alleles are written as $A$, $B$, and $O$.

When present, the alleles $I^A$ and $I^B$ are always expressed in the phenotype, which means that $I^A$ and $I^B$ are codominant. Both $I^A$ and $I^B$ alleles are dominant to $i$. The O phenotype always indicates that the genotype is homozygous. The A and B phenotypes may be homozygous or heterozygous, and the AB phenotype is always heterozygous. The relationships of blood group, genotype, antigen, and antibody of the ABO system are summarized in the table below. Because they are inherited, knowledge of these blood groups can be useful in cases of disputed parentage.

<table>
<thead>
<tr>
<th>Blood Group (Phenotype)</th>
<th>Blood Group (Genotype)</th>
<th>Red Cell Antigen</th>
<th>Serum Antibody</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$I^A/I^A$ or $I^A/i$</td>
<td>A</td>
<td>anti-B</td>
</tr>
<tr>
<td>B</td>
<td>$I^B/I^B$ or $I^B/i$</td>
<td>B</td>
<td>anti-A</td>
</tr>
<tr>
<td>AB</td>
<td>$I^A/I^B$</td>
<td>A and B</td>
<td>neither</td>
</tr>
<tr>
<td>O</td>
<td>$i/i$</td>
<td>neither</td>
<td>anti-A and anti-B</td>
</tr>
</tbody>
</table>

Another important antigen found on the surface of blood cells is the Rh factor, named for the Rhesus monkey in which it was first discovered. Blood containing this antigen is said to be Rh positive (Rh+); blood lacking this antigen is said to be Rh negative (Rh−). The production of an Rh antibody requires exposure to the antigen.

In this activity, inheritance of the Rh factor is considered to be through a single pair of alleles at the $D$ locus and to involve simple dominance and recessiveness. The actual situation is more complex, but as long as we restrict our discussion to inheritance of Rh+ and Rh− blood groups, the complications can be ignored.
Preparation

1. Make a copy of the Student Guide for each student.

2. Set up five workstations, one for each synthetic blood sample to be tested (June, Andrea, and the three possible fathers). Equip each station with the synthetic blood sample to be tested, and synthetic anti-A, anti-B, and anti-D (also known as anti-Rh) sera. Also, provide a blood typing slide and 15 mixing sticks, 5 of each color (blue, yellow, and white) for each student.

Procedure

Note: As written, during the exercise each student types each sample of synthetic blood. Alternatively, students could work in teams of 5, with each team member assigned to test just one synthetic blood sample. Team members would then pool their results. This method will allow use of the kit by multiple classes of 30 students.

1. Distribute one copy of the Student Guide to each student. Review the objectives and materials used in the activity. Although there are no biological materials in the synthetic blood or synthetic antisera that would cause any health hazard, you may wish to discuss (and/or implement) relevant safety protocols for working with real blood.

2. Have students go to each workstation in turn, and follow the Student Guide instructions to test each synthetic blood sample. Assign each student an initial blood sample to test, and have students rotate through the stations so that not everyone tries to test the same sample at the same time.

3. Have students record in the data table whether agglutination occurred for each sample when mixed with each anti-serum, and use this information to determine the blood group for each sample.

4. Check to be certain that students clean their blood typing slides after each test. Be certain that all mixing sticks are discarded after each test. Note that it takes a bit longer to get a positive Rh test than it takes for a positive A or B test result. This is also true of blood typing with real blood, and is a common source of error.

5. After they have typed each synthetic blood sample, have the students compare their results. If a student has a result that differs from that obtained by the rest of the class, discuss what may have happened to cause that result. Possibilities include the following:

   • the sample was contaminated
   • the sample was not sufficiently mixed
   • not enough time elapsed before the reaction was viewed
   • the wrong anti-serum was placed in the well
   • the wrong blood sample was placed in the well
Answers to Questions in the Student Guide

Data Table

<table>
<thead>
<tr>
<th>Mother (June)</th>
<th>Child (Andrea)</th>
<th>Possible Fathers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>#1</td>
</tr>
<tr>
<td>Anti-A</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Anti-B</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Anti-Rh</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

Blood Group Determination

<table>
<thead>
<tr>
<th>Mother (June)</th>
<th>Child (Andrea)</th>
<th>Possible Fathers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>#1</td>
</tr>
<tr>
<td>ABO group</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Rh (D) group</td>
<td>Rh−</td>
<td>Rh−</td>
</tr>
</tbody>
</table>

Note: If students have trouble determining genotype from their data, have them construct Punnett squares.

1. As shown by your tests, baby Andrea is group AB, with alleles A/B. What allele did Andrea receive from her mother June?
   Andrea received the B allele from her mother June.

2. What allele must have come to Andrea from her father?
   The A allele Andrea inherited must have come from her father.

3. Which of the possible fathers, if any, is genetically excluded by your ABO data from being Andrea’s father?
   Number 2 is excluded, because he does not have the A allele.

4. The dominant allele D must be present for a person to be Rh+. An Rh+ person is either D/d or D/D. An Rh− person is d/d, homozygous recessive.

   a. What are June's alleles for the Rh factor?
      June’s alleles for the Rh factor are d/d.

   b. As shown by your tests, baby Andrea is Rh+. What alleles does Andrea have for the Rh factor?
      Baby Andrea has the alleles d/D for the Rh factor.

   c. What Rh allele must have come to Andrea from her father?
      Andrea’s D allele must have come from her father.
5. Which of the possible father or fathers are genetically excluded by Rh factor data from being Andrea’s father?

Number 1 and Number 2 are excluded by Rh factor data from being Andrea’s father.

6. Which possible father is a good candidate for paying child support for Andrea?

Number 3 is a good candidate.

Extension Activities

The following questions can be used to check for student understanding of the ABO and Rh blood groups and their importance. A suggested answer to each question is provided.

1. Give the phenotype (blood type) for each of the following genotypes.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>I^A/I^A</td>
<td>A</td>
</tr>
<tr>
<td>I^B/I^B</td>
<td>B</td>
</tr>
<tr>
<td>I^A/i</td>
<td>A</td>
</tr>
<tr>
<td>I^B/i</td>
<td>B</td>
</tr>
<tr>
<td>I^A/I^B</td>
<td>AB</td>
</tr>
<tr>
<td>i/i</td>
<td>O</td>
</tr>
</tbody>
</table>

2. Jane is blood type A and her husband is blood type B. Jane is puzzled because their daughter is type O. Explain how the daughter inherited a blood type that neither of her parents has.

Jane and her husband are heterozygous for their blood type. Both carry the recessive allele for type O blood. Their daughter has inherited the recessive allele from each parent and expresses the recessive phenotype of O blood group.

3. (Continued from Question 2) If Jane and her husband were both type AB, could they have a type O daughter? Explain your answer.

No, they could not have a type O daughter. The parents would both have the genotype I^A/i^B and therefore could not pass on the recessive allele i.

4. An archeologist discovers an unopened tomb in Egypt. Inside she finds the mummies of two adults and two children. Inscriptions identify the two adults as the Chief Scribe and his wife. The inscriptions describe how their son and his best friend drowned in the Nile river when their boat overturned. The mummies are so well preserved that lab technicians can type the blood of the four individuals. Both adults are type B. Child 1 is type A. Child 2 is type B. Which child is not the son? How do you know?

Child 1 is not the son. Neither parent possessed the allele for type A blood.
5. **(Continued from Question 4)** On the basis of blood type, you know that one of the children could not have been the son of the two adults. Does this prove that the other child is their son?

   No. Type B blood is (and was) a common blood type. The blood type evidence is consistent with Child 2 being an offspring of the two adults. Some students may correctly assert that the blood types combined with the inscriptions strongly support Child 2 as being an offspring of the adults. Perceptive students may notice that the gender of the children is not given. What if Child 2 is a girl?

6. Jim is blood type A and his mother is blood type O. What is the blood type of Jim's father?

   Jim's father's blood type is either A or AB.

7. **(Continued from Question 6)** Jim has a sister who is blood type O. What does this make their father's blood type?

   A

8. **(Continued from questions 6 and 7)** Is their father's genotype \( I^A/I^A \) or \( I^A/i \)? Explain your answer.

   Their father's genotype is \( I^A/i \). The father has type A blood. The sister is \( i/i \) and must have received one of the recessive alleles from her father. This would make his genotype \( I^A/i \).

9. After graduating from High School, Amanda decides to join the Navy. She knows that her father's blood type is A and her mother's is O. Amanda's blood is typed as part of her physical exam, and she is blood type B. Amanda returns home and asks her parents if she is adopted. Why would Amanda ask this?

   The allele for type B blood is always expressed, and neither parent carries the allele for B. Amanda’s parents could not have produced a child of blood type B.

10. A baby is kidnapped from a couple's home. The parents of the kidnapped child have blood types A and B. As the detective on the case, you identify two suspects with a baby that matches the age and gender of the missing child. The suspects claim that the baby is theirs. From their driver's licenses you learn that their blood types are A and AB. You type the baby's blood, and it is type O. Can the suspects be the biological parents of the baby, and if not, could this be the kidnapped child? Explain your answers.

    The baby had to receive the recessive allele for type O blood from both of its parents. The type AB suspect does not have the recessive allele. The suspects cannot be the baby's biological parents. The parents of the kidnapped baby could be heterozygous for A and B blood types. If so, they could have a type O child. They could be the biological parents of the baby, so this could be (but is not definitively) the kidnapped child.
Resources

Printed Materials


Web Sites

At the time of this printing, the Web sites given below were active. You may wish to perform an independent search for similar sites.

Blood Groups and Red Cell Antigens. Public domain and © individual copyright holders.

This extensive Web site is supported by the National Center for Biotechnology Information, the U.S. National Library of Medicine, and the National Institutes of Health. This Web page provides links to a wealth of information, including a discussion of blood groups other than ABO and Rh.


Blood Groups, Blood Typing, and Blood Transfusions. ©Nobel Web AB.

This Web site provides access to information about the ABO and Rh blood types, their discovery, and medical implications.

http://nobelprize.org/educational_games/medicine/landsteiner/readmore.html


In the educational section of the official American Red Cross Web site, this page presents information about blood types and blood donation. Links to a great deal of additional information are accessible from this page and the Home page.

http://www.givelife2.org/aboutblood/bloodtypes.asp

Related Products

Following is a list of related items available from Carolina Biological Supply Company. For more information, please refer to the most recent Carolina™ Science catalog, call toll free 800-334-5551, or visit our Web site at www.carolina.com.

RN-202100    Immunodetective BioKit®
RN-699918    ABO/Rh Eldoncard Classroom 30 Kit
RN-700101    Carolina™ ABO-Rh Blood Typing with Synthetic Blood Kit
RN-700113    Carolina™ Forensics Mystery with Synthetic Blood Kit
Synthetic Blood: Paternity Test

Background

Knowledge of the genetics of human blood groups can be used to determine paternity. In this investigation, you will determine the blood groups of the mother (June), her natural daughter (Andrea), and three possible fathers. Use the data to decide who should not and who should pay June child support. Use the following procedure to test the blood samples provided by June, Andrea, and the three possible fathers.

Procedure

1. Using the dropper vial, place a drop of the assigned synthetic blood sample in each well of the blood typing slide. Replace the cap on the dropper vial. To prevent cross-contamination, always replace the cap on one vial before opening another vial.

2. Add a drop of synthetic anti-A serum (blue) to the well labeled A. Replace the cap.

3. Add a drop of synthetic anti-B serum (yellow) to the well labeled B. Replace the cap.

4. Add a drop of synthetic anti-Rh serum (clear) to the well labeled Rh. Replace the cap.

5. Using a different color mixing stick for each well (blue for anti-A, yellow for anti-B, white for anti-Rh), gently stir the synthetic blood and anti-serum drops for 30 seconds. Remember to discard each mixing stick after a single use to avoid contamination of your samples.

6. Carefully examine the thin films of liquid mixture left behind. If a film remains uniform in appearance, there is no agglutination. If the sample appears granular, agglutination has occurred. In the Data Table below, answer “yes” or “no” as to whether agglutination occurred. Be sure to record the data in the correct column.

7. Thoroughly rinse the blood typing slide, and then repeat the procedure for the other synthetic blood samples. Record these results in the data table, also. Be sure to record each set of results in the correct column for each sample.

Data Table

<table>
<thead>
<tr>
<th></th>
<th>Mother (June)</th>
<th>Child (Andrea)</th>
<th>Possible Fathers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anti-A</td>
<td>Anti-B</td>
<td>#1</td>
</tr>
<tr>
<td></td>
<td>Anti-B</td>
<td>Anti-B</td>
<td>#2</td>
</tr>
<tr>
<td></td>
<td>Anti-Rh</td>
<td>Anti-Rh</td>
<td>#3</td>
</tr>
</tbody>
</table>

8. Blood reacting to anti-A is group A. Blood reacting to anti-B is group B. Blood reacting to both anti-A and anti-B is group AB. Blood not reacting to either anti-A or anti-B is group O. Blood reacting to anti-Rh (D) is Rh++; blood not reacting to anti-Rh (D) is Rh−. Use this information to complete the Blood Group Determination table.
Blood Group Determination

| Mother (June) | Child (Andrea) | Possible Fathers
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ABO group</td>
<td></td>
<td>#1</td>
</tr>
<tr>
<td>Rh (D) group</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Duplication of lab tests is important; therefore, compare agglutination results with another student. When you and your partner are satisfied that both tables are accurate and complete, answer the questions below independently.

**Questions**

Each person’s ABO group is controlled by a pair of alleles—one ABO controlling allele from the mother and one from the father. The ABO controlling alleles A, B, and O can pair up six different ways, but they only produce four different ABO blood groups: A, B, AB, and O.

<table>
<thead>
<tr>
<th>ABO Blood Group</th>
<th>Alleles</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O/O</td>
</tr>
<tr>
<td>A</td>
<td>A/A or A/O</td>
</tr>
<tr>
<td>B</td>
<td>B/B or B/O</td>
</tr>
<tr>
<td>AB</td>
<td>A/B</td>
</tr>
</tbody>
</table>

1. As shown by your tests, baby Andrea is group AB, with alleles A/B. What allele did Andrea receive from her mother June?

2. What allele must have come to Andrea from her father?

3. Which of the possible fathers, if any, is genetically excluded by your ABO data from being Andrea’s father?
4. The dominant allele $D$ must be present for a person to be Rh+. An Rh+ person is either $D/d$ or $D/D$. An Rh− person is $d/d$, homozygous recessive.

a. What are June’s alleles for the Rh factor?

b. As shown by your tests, baby Andrea is Rh+. What alleles does Andrea have for the Rh factor?

c. What Rh allele must have come to Andrea from her father?

5. Which of the possible father or fathers are genetically excluded by Rh factor data from being Andrea’s father?

6. Which possible father is a good candidate for paying child support for Andrea?
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