Were the babies switched? – The Genetics of Blood Types[i]

Two couples had babies on the same day in the same hospital. Denise and Earnest had a girl, Tonja. Danielle and Michael had twins, a boy, Michael, Jr., and a girl, Michelle.

Danielle was convinced that there had been a mix-up and she had the wrong baby girl. Tonja and Michael Jr. looked more like twins since they both had darker skin, while Michelle had lighter skin. Danielle insisted that both families have blood type tests to check whether there had been a mix-up.

The Genetics of Blood Types

Each person has one of the blood types shown in this chart. Your blood type is determined by whether your red blood cells have type A and/or type B carbohydrate molecules on the surface.

A Person With:	**Has:**
Type A blood	Type A carbohydrate molecules on his or her red blood cells
Type B blood	Type B carbohydrate molecules on his or her red blood cells
Type AB blood	Both type A and type B carbohydrate molecules on his or her red blood cells
Type O blood	Neither type A nor type B carbohydrate molecules on his or her red blood cells

These four different blood types result from different alleles of a single gene in the DNA. These alleles give the directions for making different versions of a protein enzyme that puts different types of carbohydrate molecules on the surface of red blood cells.

Allele	**Gives the directions for making a version of the enzyme that:**
I^A	puts type A carbohydrate molecules on the surface of red blood cells
I^B	puts type B carbohydrate molecules on the surface of red blood cells
i	is inactive; doesn't put either type of carbohydrate molecule on the surface of red blood cells

1. Each person has two copies of this gene, one inherited from his/her mother and the other inherited from his/her father. Complete the following table to relate genotypes to blood types.

Genotype	**This person's cells make:**	**Blood Type**
$I^A I^A$	the version of the enzyme that puts type A carbohydrate molecules on the surface of red blood cells.	
i i	the inactive protein that doesn't put either type A or type B carbohydrate molecules on the surface of red blood cells.	
I^A ***i***	both the version of the enzyme that puts type A carbohydrate molecules on the surface of red blood cells and the inactive protein	**A**

2. In a person with the I^A ***i*** genotype, which allele is dominant, I^A or ***i***? Explain your reasoning.

3. For the genotypes listed below, which type(s) of enzyme would this person's cells make? What blood type would the person have?

Genotype	Will this person's cells make the version of the enzyme that puts this carbohydrate on the surface of his/her red blood cells?	Blood Type
$I^B I^B$	Type A __ yes __ no; Type B __ yes __ no	
$I^B i$	Type A __ yes __ no; Type B __ yes __ no	
$I^A I^B$	Type A __ yes __ no; Type B __ yes __ no	**AB**

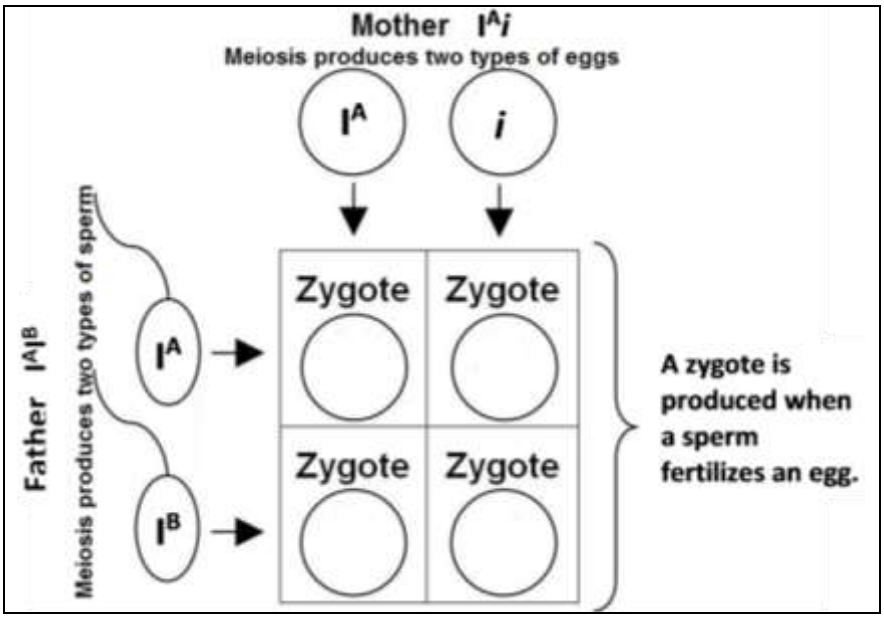
Codominance refers to inheritance in which two alleles of a gene each have a different observable effect on the phenotype of a heterozygous individual. Thus, in codominance, neither allele is recessive — both alleles are dominant.

4. Which of the genotypes listed above results in a blood type that provides clear evidence of codominance? Explain your reasoning.

This expanded version of a Punnett square shows how meiosis and fertilization result in the inheritance of genes.

5. Complete this chart to show the genetic makeup of each zygote produced by fertilization.

A baby develops from a zygote by repeated rounds of mitosis, so each cell in a baby's body has the same genetic makeup as the zygote. This is the genotype of the child.



6a. Draw a Punnett square in the usual format for this same mother and father.

6b. Write in the blood type for each parent and each child.

Notice that meiosis and fertilization can produce:

- children who have the same blood type as one of their parents
- children who have a different blood type than either parent.

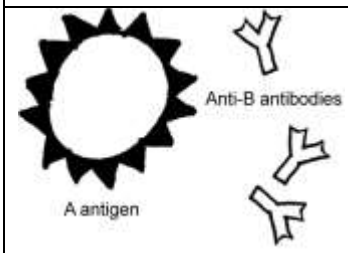
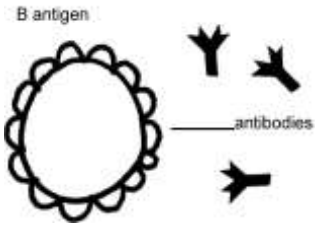
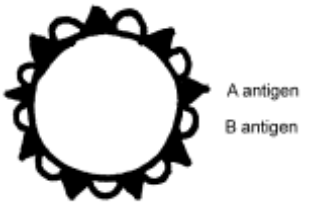
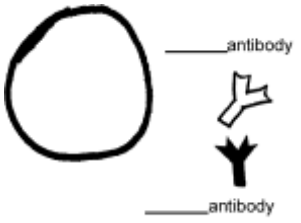
Using Immune Responses to Test Blood Types

Our bodies can make **antibodies** against **antigens** such as the type A and type B carbohydrate molecules on the surface of red blood cells. Each specific type of antibody binds to a specific antigen. For example, anti-B antibodies in the blood bind to type B antigens, but not to type A antigens.

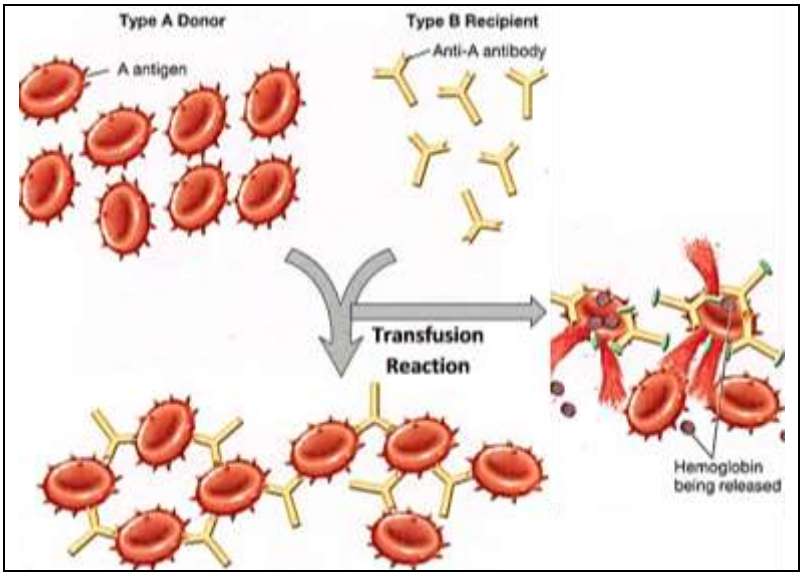
When an antibody binds with an antigen on the surface of a cell, this can result in damage to the cell. Fortunately, your body generally does *not* make antibodies against any antigens that are part of your body.

7. Do you think that a person with type A blood makes __ anti-A antibodies or __ anti-B antibodies? Explain your reasoning.

8. Fill in the blanks in this chart.

If you have type A blood, you have:	If you have type B blood, you have:	If you have type AB blood, you have:	If you have type O blood, you have:
• type A antigens on the surface of your red blood cells and • _____ antibodies in your blood.	• type B antigens on the surface of your red blood cells and • _____ antibodies in your blood.	• both type ___ and type ___ antigens on the surface of your red blood cells and • neither anti-A nor anti-B antibodies in your blood.	• neither type of antigen on the surface of your red blood cells and • both _____ and _____ antibodies in your blood.
			

If you are given a blood transfusion that does not match your blood type, antibodies in your blood can react with the antigens on the donated red blood cells and cause them to burst and/or clump together and block blood vessels. This type of transfusion reaction can be fatal. To prevent this from happening, doctors test whether donated blood is compatible with a person's blood before they give a blood transfusion.



9. Explain how a type A blood transfusion could be fatal for a person with type B blood.

10. If a blood sample has antigens that match the antibodies, this will result in clumping. To test the blood type of each parent and each baby, you will:

- mix one sample of his/her blood with anti-A antibodies to test whether his/her blood has the type ____ antigen
- mix a second sample of his/her blood with anti-B antibodies to test whether his/her blood has the type ____ antigen.

11. To prepare to interpret the blood type tests, fill in the following chart.

Blood type	**Will this blood type clump if mixed with**	
	anti-A antibody?	**anti-B antibody?**
A		
B		
AB		
O		

Procedure

- Your group will need a blood-typing tray or other testing surface for each person listed below.
- Go to the station for each person and:
  - Put three drops of the person's blood on the location to test for the type A antigen and put three drops on the location to test for the type B antigen.
  - Put three drops of anti-A antibody solution on the appropriate blood sample and put three drops of anti-B antibody solution on the other blood sample.
- Return to your seat and mix each blood sample and antibody solution with a clean toothpick. Discard each toothpick after you have used it.
- If your testing surfaces are transparent, put them on a white background so you can more easily see whether there is a clumping reaction. For each person, record the results of both tests in the table below.
- Write in the blood type and possible genotypes of each person.

Results

	Reacts with anti-A antibody (Yes or No)	**Reacts with anti-B antibody (Yes or No)**	**Blood type (A, B, AB, O)**	**Possible genotype or genotypes**
Danielle (mother of twins)				
Michael (father of twins)				
Denise (mother of daughter)				
Earnest (father of daughter)				
Michael Jr. (boy twin)				
Baby girl 1 (girl twin, according to hospital)				
Baby girl 2 (daughter of Denise and Earnest, according to hospital)				

Interpretation

Now, you will use the results of your blood tests to evaluate whether Danielle and Michael's baby girl was switched with Denise and Earnest's baby girl.

12a. Draw Punnett squares for each possible combination of genotypes for Danielle and Michael. Write in the blood type for each genotype to show the possible blood types for Danielle and Michael's children.

12b. Draw Punnett squares for each possible combination of genotypes for Denise and Earnest. Write in the blood type for each genotype to show the possible blood types for Denise and Earnest's children.

12c. Who are the parents of each baby girl? How do you know?

12d. Were the babies switched?

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[i] By Drs. Jennifer Doherty and Ingrid Waldron, Dept Biology, Univ Pennsylvania, © 2017. An alternative version of the Student Handout with more genetics and less immunobiology, together with Teacher Preparation Notes with background information and instructional suggestions, are available at http://serendip.brynmawr.edu/exchange/waldron/bloodtests.