Were the babies switched? – The Genetics of Blood Types[1]

Two couples had babies on the same day in the same hospital.

- Denise and Earnest had a girl, Tonya.
- Danielle and Michael had twins, a boy, Michael, Jr., and a girl, Michelle.

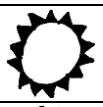
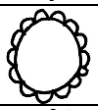
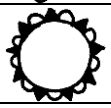

Tonya


Michael Jr.


Michelle

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

The Genetics of Blood Types – Preparing to Interpret the Results of the Blood Type Tests
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 the surface of his or her red blood cells 
type **B** blood	type B carbohydrate molecules on the surface of his or her red blood cells 
type **AB** blood	both type A and type B carbohydrate molecules on the surface of his or her red blood cells 
type **O** blood	neither type A nor type B carbohydrate molecules on the surface of his or her red blood cells 

These four different blood types result from three different alleles of a single gene. Each allele of this gene gives the instructions for making a different version of a protein enzyme that can put carbohydrate molecules on the surface of red blood cells.

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

*The E in each allele name stands for enzyme.

1. Genes only give the instructions for making proteins. So, how do different alleles of the blood type gene result in different carbohydrates on the surface of red blood cells?

Each person has two copies of the blood type gene. One copy was inherited from his/her mother and the other copy was inherited from his/her father. This table shows some of the possible genotypes and the effects of each genotype.

Genotype	Cells of a person with this genotype make:	Blood Type
E^AE^A	the version of the enzyme that puts type A carbohydrate molecules on the surface of red blood cells.	**A**
ee	the inactive protein that does not put either type A or type B carbohydrate molecules on the surface of red blood cells.	**O**
E^Ae	both the version of the enzyme that puts type A carbohydrate molecules on the surface of red blood cells and the inactive protein	**A**

2a. In a person with the E^Ae genotype, which allele is dominant? E^A ___ or **e** ___
2b. Explain your reasoning.

3. For each genotype in the table below, indicate whether the person's cells would make each type of enzyme and which blood type would result.

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
E^BE^B	type A yes ___ no ___; type B yes ___ no ___;	
E^Be	type A yes ___ no ___; type B yes ___ no ___;	
E^AE^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.

4a. In the above table, circle the blood type that provides clear evidence of codominance.
4b. Explain your reasoning.

5a. A mother with the E^Ae genotype makes eggs with either the ___ or the ___ allele.
5b. A father with the E^AE^B genotype makes sperm with either the ___ or the ___ allele.

6a. Draw a Punnett square for this mother and father.

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

Notice that parents can have a child who has:

- the same blood type as one of the parents
- a different blood type that neither parent has.

Testing Blood Types

7a. Our bodies can make **antibodies** against the type A or type B carbohydrate molecules on the surface of red blood cells. Each specific type of antibody binds to a specific type of molecule.

- Anti-A antibodies bind to type A carbohydrates, but not to type B carbohydrates.
- Anti-B antibodies bind to type ___ carbohydrates, but not to type ___ carbohydrates.

When antibodies bind to the carbohydrates on red blood cells, this causes the red blood cells to clump together.

7b. To prepare to interpret the blood type tests, fill in this chart.

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

Procedure

- Your group should get a blood-typing tray or other testing surface, and label two spots (A and B) for each person in the table below.
- Go to the station for each person and put three drops of the person's blood on each spot for that person.
- For each person, put three drops of anti-A antibody solution on the blood in the A spot and put three drops of anti-B antibody solution on the blood in the B spot.
- 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 surface is transparent, put it 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.
- Use the information in the above table to write in the blood type of each person.
- Use the information on the previous page to add the 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 the hospital made a mistake and accidentally switched the baby girls.

8a. Draw a Punnett square for each possible combination of genotypes for Danielle and Michael. Label the blood type for each possible child of this couple.

8b. Could Danielle and Michael be the parents of Baby girl 1? yes ___ no ___

8c. Could Danielle and Michael be the parents of Baby girl 2? yes ___ no ___

9a. Draw a Punnett square for each possible combination of genotypes for Denise and Earnest. Label the blood type for each possible child of this couple.

9b. Could Denise and Earnest be the parents of Baby girl 1? yes ___ no ___

9c. Could Denise and Earnest be the parents of Baby girl 2? yes ___ no ___

10a. The hospital said that:

- Danielle and Michael were the parents of Baby girl 1, and
- Denise and Earnest were the parents of Baby girl 2.

Did the hospital make a mistake? yes ___ no ___

10b. How do you know?

Why do the twins look so different?
Now, Danielle wants to know how her twins could look so different, with Michael Jr. having dark skin and Michelle having light skin. First, Danielle needs to understand that there are two types of twins. Identical twins have exactly the same genes, since identical twins originate when a developing embryo splits into two embryos.

11. How do you know that Michelle and Michael Jr. are not identical twins?

Michelle and Michael Jr. are fraternal twins, the result of two different eggs, each fertilized by a different sperm. These different eggs and sperm had different alleles of the genes that influence skin color. So, Michelle and Michael Jr. inherited different alleles of these genes.

To begin to understand how Michelle could have light skin and her twin brother, Michael Jr., could have dark skin, consider the **T** and **t** alleles of one of the genes that influence skin color.

Notice that the heterozygous **Tt** individual has an intermediate phenotype, halfway between the two homozygous individuals (**TT** and **tt**)**.** This is an example of incomplete dominance**.**

Genotype	**Phenotype** (skin color)
TT	dark brown
Tt	light brown
tt	tan

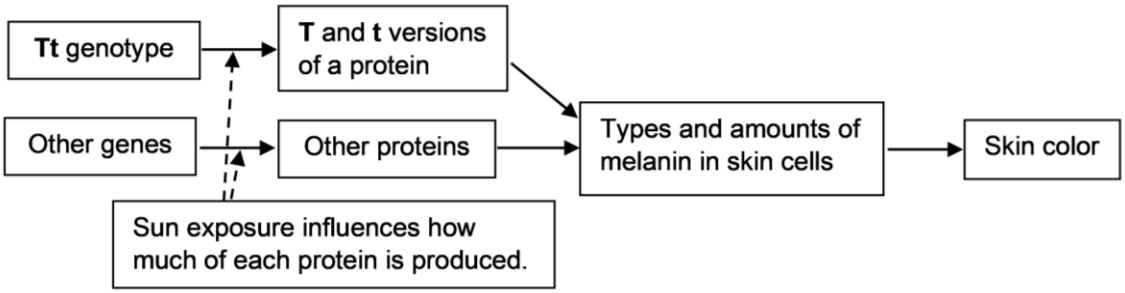
Incomplete dominance occurs when the phenotype of a heterozygous individual is intermediate between the phenotypes of the two different types of homozygous individual.

12. Match each item in the list on the left with the best match from the list on the right.

If the phenotype of a heterozygous individual:	**then the type of dominance is:**
· is intermediate between the phenotypes of the two different types of homozygous individuals, ___ · is the same as the phenotype of an individual who is homozygous for the dominant allele, ___ · shows distinct observable effects of both alleles, ___	a. a dominant-recessive pair of alleles b. codominance c. incomplete dominance

13. The parents, Michael and Danielle, both have the **Tt** genotype and light brown skin. Draw a Punnett square for this couple, and explain how these parents could have two babies with different color skin – one dark brown and the other tan.

Obviously, people have many different skin colors, not just dark brown, light brown, or tan. These varied skin colors result from the effects of multiple alleles of multiple genes, plus environmental factors such as sun exposure. This flowchart summarizes how multiple genetic and environmental factors influence skin color.



14. This information indicates that the table on the top of this page is oversimplified. Since multiple genetic and environmental factors influence skin color, two people who both have the **Tt** genotype can have different skin colors. Give two possible reasons why one person with the **Tt** genotype could have darker skin than another person with the same genotype.