Teacher Preparation Notes for Using Blood Tests to Identify Babies and Criminals

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Students learn the genetics and immunobiology of the ABO blood type system and use simple chemicals and logical reasoning to solve a murder mystery and to determine whether two babies were switched in the hospital. This activity introduces students to the concept of codominance. If you would like to introduce the additional concept of incomplete dominance and the difference between codominance vs. incomplete dominance, you can replace question 10 on page 5 of the Student Handout with the more extended analysis of the genetics of skin color shown on the last two pages of these Teacher Preparation Notes.

As background for the first section of this activity, students should be familiar with basic concepts of genetics (e.g. as presented in pages 1-3 of "Genetics", available at http://serendip.brynmawr.edu/sci_edu/waldron/#genetics). If you would prefer to present the concepts of codominance and incomplete dominance in a discussion activity, you can use "Were the babies switched?", which is available as an episode of "Soap Opera Genetics – Genetics to Resolve Family Arguments" (http://serendip.brynmawr.edu/exchange/bioactivities/SoapOperaGenetics). A possible substitute for the murder mystery in the second section of the Student Handout is "Ernie's Exit – Forensic Science Blood Typing Lab Activity" (go to http://sciencespot.net/ and search for Ernie's Exit).

Teaching Points

- There are four blood types in the ABO system: A, B, AB, and O. These blood types refer to the presence or absence of two different versions of a carbohydrate molecule (A and B) on the surface of red blood cells.
- Both A and B are antigens which stimulate the formation of antibodies. Anti-A antibodies react specifically with A antigens on the surface of red blood cells, and anti-B antibodies react specifically with B antigens.
- Antibodies are special proteins that travel in the blood, react with antigens, and help our bodies to destroy viruses or bacteria that have infected our bodies.
- Normally, your body does not make antibodies against antigens which are part of your own body. If you have Type A blood, you have A antigens on the surface of your red blood cells and anti-B antibodies, but not anti-A antibodies, in your blood plasma. Etc.
- A blood transfusion can harm a person if the donated red blood cells have antigens that react with antibodies in the person's blood. Only specific matching blood types can be safely used for a blood transfusion.
- Genes code for proteins which influence a person's characteristics. The ABO blood type gene codes for an enzyme that can attach carbohydrates to the surface of red blood cells. There are three alleles of this blood type gene: the $\mathbf{I^A}$ allele codes for a version of the enzyme that attaches the A antigen, the $\mathbf{I^B}$ allele codes for a version of the enzyme that attaches the B antigen, and the ***i*** allele codes for an inactive protein that does not attach either antigen.
- Each person inherits one allele of this gene from his/her mother and a second allele from his/her father. Both alleles code for the production of proteins in red blood cell precursors. In a heterozygous person, the ***i*** allele is recessive relative to the $\mathbf{I^A}$ or $\mathbf{I^B}$ alleles since, even when there is only one copy of the $\mathbf{I^A}$ or $\mathbf{I^B}$ allele in each cell, this allele can code for enough enzyme to result in Type A or Type B blood, respectively.
- Codominance refers to inheritance in which two alleles of the gene each have a different observable effect on the phenotype of the heterozygous individual. The $\mathbf{I^A}$ and $\mathbf{I^B}$ alleles

[1] These Teacher Preparation Notes, the related Student Handout, and multiple additional activities are available at http://serendip.brynmawr.edu/sci_edu/waldron, with additional activities available at http://serendip.brynmawr.edu/exchange/bioactivities.

are codominant, since a person who has the $I^A I^B$ genotype will have Type AB blood (since both alleles are active, resulting in the production of both the version of the enzyme that attaches the A antigen to the surface of red blood cells and the version of the enzyme that attaches the B antigen).

Equipment and Supplies:

- Synthetic blood of all four blood types (A, B, AB, and O)
- Synthetic A and B anti-serum
- Drop-controlled bottles or small bottles with droppers or pipets (8 per class)
- Microscope slides or plates for mixing blood and antibodies (6 per group)
- Toothpicks for mixing blood and anti-serum on plates (6 per group)
- Containers such as 20 oz. soda or water bottle to use as a trash so the students can throw away their disposables immediately after use to avoid contamination (1 per group)

All of the simulated blood kits listed below contain a drop bottle of each of the four types of blood, at least two types of anti-sera (A and B), mixing plates (usually enough for 5-6 groups to work at once), and toothpicks. We have used the Carolina and NeoSci kits. The Carolina B reaction is easier to see than the NeoSci B reaction but you get about 5mL of each blood and anti-sera with the Carolina kit and 30mL of each with the NeoSci kit.

Website	Catalog Number	Description	Price
www.carolina.com	700101	ABO-Rh Blood Typing with Synthetic Blood Kit	$37.75
	700102	Refill	$20.50
www.neosci.com	E2-20-2953	The Frequency of Blood Types Using Neo/BLOOD	Call for prices
	E2-20-2955	Refill	
www.wardsci.com	360022	Simulated ABO Blood Typing Lab Activity	$35.60
	360035	Refill	$20.30

If you have insufficient budget for these kits, you can adapt the instructions to use food coloring, milk, vinegar and water provided on pages 1-3 of "Teachers' Talking Science – Blood Typing, available at http://www.sciencefriday.com/blogs/11/16/2010/blood-typing.html. However, you should be aware that you will have to designate different antisera for each sample in order to get the desired results.

Preparation for Crime Investigation

As each kit above only comes with 6 drop controlled bottles (2 for anti-sera and 4 for blood) if you only purchased one kit you need to come up with 2 more drop bottles or containers with pipets so you can have a labeled bottle for each suspect (an easy way to do this is to buy a full kit and a refill).

Before class you should label a bottle for each of the blood samples the students must analyze. The chart on the next page illustrates one possible assignment of blood types to each name. If you teach multiple lab sections, you can vary the blood type in the sample from the shower door and/or from the individuals involved, in order to maintain some suspense and variety. To minimize the ambiguity of interpretation, the blood type on the shower door should match the blood type of only one of the potential culprits and should not match the victim's blood type.

One possibility is as follows.

Suspects	Blood type (A, B, AB, O)
Shamari Davis – Victim	**B**
Daleesha Jones—Co-worker	**A**
Harvey Willis—Janitor	**B**
Mike Reed—Client	**O**
Steve O'Hare—Boss	**AB**
Blood on shower door	**AB**

During class you can either 1) pass around a box containing each of the 8 bottles to each group's table as they reach the hands-on portion of the activity or 2) set up a station somewhere in your classroom where the students can come test their blood. After the initial dropping of blood and anti-sera onto plates it takes students a while to mix and read the reactions, so option 1 may be better if you have a large class.

Background for Discussion of Blood Types, Codominance, and Skin Color

For the ABO blood group:

- $\mathbf{I^A}$ codes for an enzyme that plays a crucial role in synthesizing glycoproteins and glycolipids with the Type A carbohydrate molecules; these glycoproteins and glycolipids are located in the cell membrane of red blood cells.
- $\mathbf{I^B}$ codes for an enzyme that plays a crucial role in synthesizing glycoproteins and glycolipids with the Type B carbohydrate molecules.
- ***i*** codes for an inactive protein. (The most common versions of this allele have an early single nucleotide deletion which results in a premature stop codon that codes for a protein only one third as long as the active enzyme.)

The function of the carbohydrate molecules is unknown. People who have neither Type A nor Type B carbohydrates (blood type O) are as healthy as people who have these carbohydrates. Different blood types are correlated with certain illnesses and vary in frequency in different ethnic groups, but the reasons are unknown.

Questions 4-6 provide the opportunity to reinforce student understanding that each cell in the body contains two copies of each gene and often both alleles are active. Recessive alleles often code for a nonfunctional protein, and in a heterozygous individual the dominant allele codes for enough functional protein to result in the same phenotype as the homozygous dominant individual. Thus, the ***i*** allele is recessive relative to $\mathbf{I^A}$ or $\mathbf{I^B}$. The $\mathbf{I^A\ I^B}$ genotype results in the production of both the version of the enzyme that puts Type A carbohydrate molecules on red blood cells and the version of the enzyme that puts Type B carbohydrate molecules on red blood cells, so the $\mathbf{I^A\ I^B}$ genotype results in Type AB blood. This provides the molecular basis for understanding codominance.

At a molecular level, the alleles of most genes are codominant. For example, a person who is heterozygous for the allele for normal hemoglobin and sickle cell hemoglobin has both types of hemoglobin in their red blood cells. Due to the normal hemoglobin in the red blood cells of a heterozygous person, the hemoglobin molecules almost never clump into rods that distort the shape of the red blood cells, so the heterozygous person almost never develops the symptoms of sickle cell anemia. Due to the sickle cell hemoglobin in the red blood cells of a heterozygous person, the reproduction of the malaria parasite in the red blood cells is inhibited, so the heterozygous person is protected against severe malaria infections.

The determination of blood type is more complex than the ABO blood types discussed in this activity. For additional information on other blood group antigens and blood types see http://www.ncbi.nlm.nih.gov/books/NBK2264/.

Modern methods use DNA testing to determine biological relatedness; these results are much more definitive than testing blood types (http://en.wikipedia.org/wiki/Parental_testing).

Skin color is influenced by multiple genes. For example, the gene for the enzyme tyrosinase codes for an enzyme that plays a crucial role in the production of melanin; some alleles of this gene are responsible for most cases of albinism. Another important gene is the MC1R gene which codes for the melanocortin receptor; when alpha melanocyte stimulating hormone binds to normal melanocortin receptor this stimulates melanocytes to produce melanin. More than 80 alleles of the MC1R gene have been identified, resulting in various levels of function of the melanocortin receptor and correspondingly varied skin tones. Heterozygotes for these alleles have intermediate skin color, between the lighter and darker homozygotes (called incomplete dominance or a dosage effect). The multiple alleles and the effects of incomplete dominance result in multiple different phenotypes for skin color (as well as multiple different phenotypes for sun sensitivity, freckling, and hair color). (Additional information is available at ghr.nlm.nih.gov/genes/MC1R.) In addition, environmental factors such as sun exposure influence skin color.

If you incorporate in the Student Handout the extended analysis of the genetics of skin color provided on the last two pages of these Teacher Notes, the following table may be helpful for your discussion of questions 11 and 12.

Type of Dominance	**Phenotype of Heterozygous Individual**
Dominant-recessive pair of alleles	Same as phenotype of individual who is homozygous for the dominant allele
Codominance	Shows different observable phenotypic effects of both alleles; phenotype different from either homozygous individual
Incomplete dominance	Intermediate between phenotypes of the two types of homozygous individual (typically observed for quantitative traits); phenotype different from either homozygous individual

Question 14 provides the opportunity to reinforce understanding that individual phenotypic characteristics are often influenced by multiple genes and environmental factors. Introductory genetics teaching frequently focuses on inheritance and phenotypic effects of single genes, but this is only a beginning for understanding the genetics of most traits. For example, a person with a **Bb** genotype could have dark brown skin if he or she:

- has developed a tan as a result of sun exposure or tanning booth use
- has alleles for other genes that contribute to darker skin color.

Additional Activities

"Genetics – Major Concepts and Learning Activities"
(http://serendip.brynmawr.edu/exchange/bioactivities/GeneticsConcepts)
This overview summarizes important genetic concepts and provides links to suggested learning activities. Part I provides an outline of key concepts needed to understand how genes are transmitted from parents to offspring and how genes influence phenotypic characteristics and a learning activity to develop student understanding of these key concepts. Part II presents learning activities that support the Next Generation Science Standards, including Disciplinary Core Ideas related to inheritance and variation of traits and Scientific Practices.

Why do the twins look so different?

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

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

Michelle and Michael Jr. are fraternal twins, the result of two separate eggs, each fertilized by a different sperm. Michelle and Michael Jr. inherited different alleles of the genes for skin color because the egg and sperm that formed the zygote that developed into Michelle carried different alleles of the genes for skin color than the egg and sperm that formed the zygote that developed into Michael Jr.

To understand how one of the twins could have light skin and the other dark skin, we will consider two alleles of one of the genes for skin color.

Genotype	**Phenotype** (skin color)
BB	dark brown
Bb	light brown
bb	tan

Notice that for this gene a heterozygous individual has an intermediate phenotype, halfway between the two homozygous individuals. This is called **incomplete dominance**.

11. Explain how incomplete dominance differs from a dominant-recessive pair of alleles. (Hint: Think about the phenotypes of heterozygous individuals.)

12. Explain how incomplete dominance differs from co-dominance.

13. The parents, Michael and Danielle, both have light brown skin and **Bb** genotype. Draw a Punnett square to show 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. The reasons for all these different skin colors include:

- Multiple genes influence skin color.
- For at least one of these genes, there are multiple different alleles that have different effects on skin color.
- Skin color is also influenced by the amount of exposure to the sun.

14. The relationships between genotype and phenotype are not as simple as shown in the chart on the previous page. For example, one person with **Bb** genotype may have light brown skin, but another person with **Bb** genotype may have dark brown skin. Based on the above information, explain how this could happen.