Soap Opera Genetics
– Genetics to Resolve Family Arguments¹

I. How could our baby be an albino?
Tiffany and Joe have just had a baby and are very surprised to learn that their baby is albino with very pale skin and hair color. Tiffany’s sister has come to see the new baby, so Joe goes out to talk with his sister Vicky.

Did Tiffany have an affair?
Joe is very angry. He tells Vicky, "I think Tiffany had an affair with Frank! He’s the only albino we know. Obviously, Tiffany and I aren’t albino, so Frank must be the father."

1. Luckily, Vicky remembers her high school biology, so she explains, “Two parents with normal skin and hair color can have an albino baby, if they are heterozygous and carry a recessive allele for albinism.” She draws a Punnett Square to show this. Draw the Punnett Square. Use A for the dominant allele that results in normal skin and hair color and a for the recessive allele that can result in very pale skin and hair color.

2. Joe is still mad and he doesn't understand Vicky’s explanation. He says "You aren't even speaking English! What does heterozygous mean? What's a recessive allele? And what's the connection between alleles and skin color?" Answer his questions.

3. Once Joe understands this much, he asks for a better explanation of the Punnett square. Draw a new, more complete Punnett Square that includes the genotypes of both parents, labels to indicate which symbols represent the genetic makeup of eggs, sperm, or zygotes, thin arrows (→) to represent meiosis, and fat arrows (⇒) to represent an example of fertilization.

¹ By Ingrid Waldron, Department of Biology, University of Pennsylvania, 2017. Teachers are encouraged to copy this Student Handout for classroom use. A Word file (which can be used to prepare a modified version if desired), Teacher Notes with learning goals, instructional suggestions, and background biology are available at http://serendip.brynmawr.edu/exchange/bioactivities/SoapOperaGenetics.
4. Joe says "Okay, I'm beginning to understand, but what are zygotes? What's the connection between the zygotes in the Punnett square and our baby?" Answer Joe's questions.

Why aren't more babies albino?
By now, Joe has calmed down and he is getting interested. He asks Vicky "If that's how it works, it seems as though a quarter of all babies should be albino. How come there are hardly any albino babies?"

5. What explanation should Vicky give to answer this question?

Joe is starting to feel guilty for getting so mad. He says "Geez, I feel like a jerk. I should have known that Tiffany would never cheat on me." Vicky responds, "That's okay. You were upset. Let's just forget about it."

Will Tiffany and Joe's next baby be albino?
Two years later, Tiffany is pregnant again, and she and Joe are discussing whether their second baby will be albino. Tiffany thinks the baby probably will be albino, but Joe remembers Vicky's explanation, and he tells Tiffany, "No, our second baby can't be albino because only one out of every four of our children should be albino. We already have one albino child, so our next three children should not be albino."

6a. Is Joe right? Explain why or why not.

6b. What is the probability that Tiffany and Joe's second baby will be albino?

6c. How do you know?
II. Were the babies switched?

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.

<table>
<thead>
<tr>
<th>A Person With:</th>
<th>Has:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A blood</td>
<td>Type A carbohydrate molecules on his or her red blood cells</td>
</tr>
<tr>
<td>Type B blood</td>
<td>Type B carbohydrate molecules on his or her red blood cells</td>
</tr>
<tr>
<td>Type AB blood</td>
<td>Both type A and type B carbohydrate molecules on his or her red blood cells</td>
</tr>
<tr>
<td>Type O blood</td>
<td>Neither type A nor type B carbohydrate molecules on his or her red blood cells</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Allele</th>
<th>Gives the directions for making a version of the enzyme that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>I^A</td>
<td>puts type A carbohydrate molecules on the surface of red blood cells</td>
</tr>
<tr>
<td>I^B</td>
<td>puts type B carbohydrate molecules on the surface of red blood cells</td>
</tr>
<tr>
<td>i</td>
<td>is inactive; doesn't put either type A or type B carbohydrate molecule on the surface of red blood cells</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>This person's cells make:</th>
<th>Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>I^A I^A</td>
<td>the version of the enzyme that puts type A carbohydrate molecules on the surface of red blood cells.</td>
<td></td>
</tr>
<tr>
<td>i i</td>
<td>the inactive protein that doesn’t put either type A or type B carbohydrate molecules on the surface of red blood cells.</td>
<td></td>
</tr>
<tr>
<td>I^A i</td>
<td>both the version of the enzyme that puts type A carbohydrate molecules on the surface of red blood cells and the inactive protein A</td>
<td></td>
</tr>
</tbody>
</table>

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?

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Will this person's cells make the version of the enzyme needed to put this carbohydrate on the surface of his/her red blood cells?</th>
<th>Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>I^B I^B</td>
<td>Type A ___ yes ___ no; Type B ___ yes ___ no</td>
<td></td>
</tr>
<tr>
<td>I^B i</td>
<td>Type A ___ yes ___ no; Type B ___ yes ___ no</td>
<td></td>
</tr>
<tr>
<td>I^A I^B</td>
<td>Type A ___ yes ___ no; Type B ___ yes ___ no</td>
<td>AB</td>
</tr>
</tbody>
</table>

**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.

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**Were the babies switched?**

This figure shows the blood types of the families if the hospital did not make a mistake.

This figure shows the blood types of the families if the baby girls were accidentally switched.

5a. Write the possible genotypes for each parent and baby in the left-hand box.

5b. Draw a Punnett square for Michael and Danielle. What blood types could their children have?  

5c. Draw a Punnett Square to show how Earnest and Denise could have a child with type O blood.

6. Who are Tonja's parents? How do you know?
Why do the twins look so different?
Now, Danielle wants to know how her twins could look so different, with Michelle having light skin and Michael Jr. having dark 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.

7. 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, we will consider two alleles of one of the genes for skin color. Notice that, for this gene, a heterozygous individual has an intermediate phenotype, halfway between the two homozygous individuals.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype (skin color)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB</td>
<td>dark brown</td>
</tr>
<tr>
<td>Bb</td>
<td>light brown</td>
</tr>
<tr>
<td>bb</td>
<td>tan</td>
</tr>
</tbody>
</table>

When the phenotype of a heterozygous individual is intermediate between the phenotypes of the two different types of homozygous individual, this is called incomplete dominance.

8a. Explain how incomplete dominance differs from a dominant-recessive pair of alleles. (Hint: Think about the phenotypes of heterozygous individuals.)

8b. Explain how incomplete dominance differs from co-dominance.

9. The parents, Michael and Danielle, both have light brown skin and the Bb genotype. Draw a Punnett square 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. The wide variety of skin colors results from:

- the multiple alleles of the multiple genes that influence skin color and
- environmental effects.

This flowchart summarizes the genetic and environmental influences on skin color.

This flowchart is based on the following scientific findings.

A. Different skin colors result from differences in the types and amounts of the pigment melanin in skin cells.

B. Several different proteins influence the production and processing of melanin molecules in skin cells. Each of these proteins is coded for by a different gene. Different alleles of these genes result in different types and amounts of melanin in skin cells.

C. Exposure to sunlight can change the activity of genes that influence skin color and increase the amount of melanin in skin cells.

10. Use the letter for each scientific finding to label the part of the flowchart that represents this scientific finding.

11. This information indicates that the chart on the previous page is oversimplified. Multiple factors influence skin color, so two people who both have the Bb genotype can have different skin colors. For example, Hernando and Leo both have the Bb genotype, but Hernando’s skin is darker than Leo’s. Explain two possible reasons why Hernando and Leo have different skin colors.
III. I don't want to have any daughters who are colorblind like me!

Awilda and Frank at Breakfast
Awilda: Are you sure you want to wear that new shirt to work today? A green and red shirt like that would be better for Christmas, not for St. Patrick's Day.
Frank: Oh no! Not again! I really thought this shirt was just different shades of green. Where's the red?

At Dinner That Night
Frank: We should try to find a way to make sure we only have sons, no daughters. I don't want to have any daughters who might be colorblind like me. Color blindness would be a big problem for a girl.
Awilda: Remember, the doctor said that he doesn't think that any of our children will be colorblind.
Frank: I don't see how he can be so sure about that. I'm colorblind, so some of our children should be colorblind like me.
Awilda: The doctor said that, since no one in my family was colorblind, I almost certainly do not have the allele for colorblindness, so none of our children will be colorblind.
Frank: That doesn't make any sense. Neither of my parents is colorblind, but I'm colorblind. I think that our children will be more likely to be colorblind since they will have a colorblind father.

Answer these questions to help Awilda explain to Frank why none of their children will be colorblind.

1a. What are the genotypes of Frank and Awilda? (Since the allele for color blindness is located on the X chromosome, use the symbol $X_{cb}$ for an X chromosome with the recessive allele for color blindness and $X_N$ for an X chromosome with the dominant allele for normal color vision. The Y chromosome does not have this gene, so it is represented by $Y$.)

Frank _______  Awilda _______

1b. Draw a Punnett square for this couple and their children.

1c. Explain why none of their children will be colorblind.
Frank: Okay, I guess I don't have to worry about any of our children being colorblind, but what about our grandchildren? Couldn't some of them be colorblind, especially our granddaughters?

Awilda: Well, some of our grandchildren could be colorblind, but I've heard that boys are more likely than girls to be colorblind.

Frank: I disagree. Girls have more X chromosomes than boys, so girls should be more likely to be colorblind.

Answer the following questions to explain why Awilda and Frank’s grandsons are more likely than their granddaughters to be colorblind.

2a. What are the possible genotypes for Awilda and Frank's children?
   Awilda and Frank's sons _______  Awilda and Frank's daughters _______

2b. Draw a Punnett square for each couple in the chart below. In each Punnett Square, circle each boy and use arrows to indicate any colorblind offspring.

<table>
<thead>
<tr>
<th>Punnett square if one of Awilda and Frank's daughters marries a man who is colorblind</th>
<th>Punnett square if one of Awilda and Frank's daughters marries a man who is not colorblind</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2c. Explain why Awilda and Frank's grandsons are more likely than their granddaughters to be colorblind.

3. Explain why having two X chromosomes decreases a woman’s risk of color blindness, instead of increasing her risk.

4. Remember that Frank is colorblind, but neither of his parents are colorblind. Which Punnett square shows how two parents who are not colorblind could have a colorblind son?