Teacher Notes for
Soap Opera Genetics – Genetics to Resolve Family Arguments

This analysis and discussion activity contains three "soap opera" episodes that contribute to student understanding of the principles of inheritance and the relevance of genetics to everyday life. In the first episode, students explain the relevant biology to answer the probing questions of a skeptical father who wants to know how his baby could be albino when neither he nor his wife are albino. The second episode, "Were the babies switched?" covers the concepts of codominance, incomplete dominance, polygenic inheritance, and the combined effects of genes and the environment on phenotypic characteristics. In the third episode, students analyze sex-linked inheritance. Each episode can be used separately or with other episodes, depending on your teaching goals.

As background for this activity, students should have a basic understanding of:
- dominant and recessive alleles, with heterozygous individuals having the same phenotype as homozygous dominant individuals
- how meiosis and fertilization result in inheritance and how these processes are summarized in Punnett squares.

To provide this background you may want to use the first three pages of our "Genetics" activity or the first four pages of "Genetics Supplement" (both available at http://serendip.brynmawr.edu/sci_edu/waldron/#genetics).

Learning Goals Related to National Standards
In accord with the Next Generation Science Standards and A Framework for K-12 Science Education:
- Students will gain understanding of several Disciplinary Core Ideas:
  - LS1.A: Structure and Function – "All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins."
  - LS3.A: Inheritance of Traits – "The instructions for forming species' characteristics are carried in DNA."
  - LS3.B: Variation of Traits – In sexual reproduction, meiosis can create new genetic combinations and thus more genetic variation. Environmental factors also affect expression of traits.
- Students will engage in several Scientific Practices:
  - constructing explanations
  - engaging in argument from evidence
  - using models.
- This activity provides the opportunity to discuss the Crosscutting Concepts, "Patterns" and "Systems and system models".
- This activity helps to prepare students for the Performance Expectations
  - HS-LS3-1, "Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring."

1 By Ingrid Waldron, Department of Biology, University of Pennsylvania, 2017. These Teacher Notes and the related Student Handout are available at http://serendip.brynmawr.edu/exchange/bioactivities/SoapOperaGenetics.


3 http://www.nap.edu/catalog.php?record_id=13165
• HS-LS3-2, "Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis…"
• HS-LS3-3, "Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population."

This activity will also help students meet Common Core English Language Arts Standards for Science and Technical Subjects, including "write arguments focused on discipline-specific content".  

Additional, more specific learning goals for each section are presented below.

**General Instructional Suggestions**
To maximize student learning, we recommend that you have your students complete groups of related questions in the Student Handout individually or in pairs and then have a class discussion for each group of related questions. In each discussion, you can probe student thinking and help them to develop a sound understanding of the concepts and information covered before moving on to the next part of the activity.

The PDF of the Student Handout shows the correct format; please check this if you use the Word document to make revisions.

If you would like to have a key with the answers to the questions in the Student Handout, please send a message to iwaldron@sas.upenn.edu. The following paragraphs provide additional instructional suggestions and background information – some for inclusion in your class discussions and some to provide you with relevant background that may be useful for your understanding and/or for responding to student questions.

**Episode I. How could our baby be an albino?**

**Learning Goals**
• Students will understand how **meiosis and fertilization** provide the basis for inheritance of genes.
• Students will understand how to interpret **Punnett squares**, including prediction of the genotypes of offspring and determination of phenotypes based on understanding recessive and dominant alleles.
• Students will understand the **limitations** of Punnett square predictions, including that:
  • Punnett square predictions are limited to couples with the specified genotypes. To predict the population prevalence of phenotypes you need to know the population prevalence of genotypes.
  • Random variation in which sperm fertilizes which egg means that the genotype of each sibling is independent of the genotype of any previous siblings. As a result, the distribution of genotypes of siblings in an individual family often deviates from Punnett square predictions.

**Suggestions for Implementation and Biology Background**
If your students have completed the recommended introductory part of the "Genetics" or "Genetics Supplement" activity (http://serendip.brynmawr.edu/sci_edu/waldron/#genetics), then this first "Soap Opera Genetics" episode can be used for review and assessment. You can enhance student learning and retention of important concepts and vocabulary by having your students complete this episode using active recall (without referring to previous notes or

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4 From http://www.corestandards.org/
Questions 1-4 engage students in explaining Punnett squares to Joe. This approach follows the principle that one way to develop better understanding of a concept is to try to teach it to someone else. These questions assume that two heterozygous parents have had a child with a different phenotype. The possibility that the different phenotype of the child could be due to a new mutation is not discussed since that would be very rare.

Recessive alleles often code for a non-functional protein, while dominant alleles often code for a functional protein. The single dominant allele in a heterozygous individual can code for enough functional protein to produce the same phenotype as observed in an individual who is homozygous for the dominant allele. For example, the allele for albinism is recessive and the normal allele is dominant because the allele for albinism codes for a defective enzyme for producing melanin and the normal allele codes for the functioning enzyme (tyrosinase), and even when there is only one copy of the normal allele, this allele codes for enough functioning enzyme to produce enough melanin to prevent albinism.

In the most common form of albinism, the lack of the pigment melanin affects not only skin and hair color, but also the appearance and function of the eyes. Further information about the various forms of albinism (as well as a great deal of information on other aspects of human genetics) is available from OMIM, Online Mendelian Inheritance in Man (www.ncbi.nlm.nih.gov/omim/).

Students may ask questions concerning the distinction between inherited albinism and vitiligo. Albinism results from the inability of the body's cells to produce melanin and affects the whole body. Vitiligo results from the destruction of melanocytes, the cells that produce melanin, and results in light patches in a normally pigmented skin. (Additional information is available at www.nvfi.org.)

Question 5 provides the opportunity to discuss the distinction between the predictions of Punnett squares and population prevalence of alleles and phenotypes. Question 6 provides the opportunity to reinforce student understanding of the independence of each fertilization event, which will help students reconcile the discrepancies between the families they know and the Punnett square predictions.

Episode II. Were the babies switched?

Learning Goals
- Students will understand that genes code for proteins which influence a person's characteristics.
- Students will understand codominance (when both alleles of a gene have different observable effects on the phenotype of a heterozygous individual).
- Students will understand incomplete dominance (when the phenotype of a heterozygous individual is intermediate between the phenotypes of the two different types of homozygous individuals).
- Students will understand that some genes have more than two alleles.
- Students will understand that some characteristics are influenced by multiple genes and environmental factors.
- More practice with Punnett squares
Biology Background and Suggestions for Implementation

If you prefer, you can use a hands-on version of this episode in which students use simple chemicals to simulate blood type tests (available as “Were the babies switched? – The Genetics of Blood Types” at http://serendip.brynmawr.edu/exchange/waldron/bloodtests).

For the ABO blood group:

- The I\textsuperscript{A} allele codes for a version of an enzyme that plays a crucial role in synthesizing glycoprotein and glycolipid molecules that contain the Type A carbohydrate; these glycoproteins and glycolipids are located in the cell membrane of red blood cells, with the carbohydrate on the outer surface of the cell membrane.\textsuperscript{5}
- The I\textsuperscript{B} allele codes for a different version of this enzyme that plays a crucial role in synthesizing glycoproteins and glycolipids with the Type B carbohydrate molecules.
- The i allele codes for an inactive version of the enzyme.

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

Page 3, including question 1, provides the opportunity to reinforce student understanding that:

- genes code for proteins which influence an organism’s characteristics
- genes often have more than two alleles.

In discussing question 2, you should remind students that heterozygous individuals have the same phenotype as an individual who is homozygous for the dominant allele. You will probably also want to point out that recessive alleles often code for a nonfunctional protein. In a heterozygous individual a single dominant allele can code for enough functional protein to result in the same phenotype as the phenotype of the homozygous dominant individual. For example, the i allele is recessive relative to the I\textsuperscript{A} or I\textsuperscript{B} alleles because, in a heterozygous individual, the

\textsuperscript{5} The I or i in the names of these alleles stands for isoagglutinogen, which refers to an antigen that can stimulate the production of antibodies in other members of the same species; these antibodies result in agglutination (clumping) upon exposure to the antigen.
single dominant \(I^A\) or \(I^B\) allele codes for enough functional enzyme to result in the same blood type as observed in a homozygous dominant individual.

This activity helps students to understand the molecular basis for codominance, as well as dominant-recessive alleles. Each cell in the body contains two copies of each gene and typically both alleles are transcribed. Thus, at a molecular level, the alleles of most genes are codominant.\(^6\) For example, the \(I^A I^B\) 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. Therefore, the \(I^A I^B\) genotype results in Type AB blood. This illustrates codominance at the phenotypic level.

The Type A and Type B carbohydrate molecules are called antigens because they can stimulate the body to produce an immune response, including antibodies. Normally, your body does not make antibodies against any molecules that are part of your body. This is useful because antibodies against antigens that are part of your body could trigger harmful reactions.

As would be expected, a person does not make antibodies against the blood type antigens present on their red blood cells. However, a person with type B blood does make anti-A antibodies since gut bacteria have antigens similar to type A antigens, which stimulates the production of anti-A antibodies. If a person with type B blood is given a transfusion of type A blood, the anti-A antibodies will cause the donated type A red blood cells to burst and also to clump, which can block blood vessels. This transfusion reaction can be fatal. To prevent a transfusion reaction, medical personnel test whether a person's blood is compatible with the donated blood before they give a transfusion.

The ABO blood types are the major determinant of which type of blood will cause a transfusion reaction. However, 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/](http://www.ncbi.nlm.nih.gov/books/NBK2264/).

\(^6\) 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. The sickle cell hemoglobin in the red blood cells of a heterozygous person inhibits the reproduction of the malaria parasite in the red blood cells, so the heterozygous person is protected against severe malaria infections.
On page 4 of the Student Handout, students use genetic analysis for blood types to determine whether the babies were switched. 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).

**Question 5** provides the opportunity to discuss:
- how meiosis and fertilization result in new combinations of alleles, so children may have different blood types (and other phenotypic characteristics) than their parents have
- how transmission of genes via meiosis and fertilization result in similarities between offspring and parents. For example, a child can only have type A blood if one or both parents have type A or AB blood (i.e. a child with the I^A allele must have at least one parent with this allele).

Skin color is influenced by multiple genes. For example, one gene that influences skin color codes for the enzyme tyrosinase, a crucial enzyme involved in the synthesis of melanin, the primary pigment in skin and hair. The normal allele codes for functional tyrosinase, and the allele for albinism codes for a defective, non-functional version of this enzyme. The allele for albinism is recessive because, even when there is only one copy of the normal allele, this allele codes for enough functioning enzyme to produce enough melanin to result in normal skin and hair color.

Another important gene that influences skin color 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 (and hair color). (Additional information on this gene is available at https://ghr.nlm.nih.gov/gene/MC1R. Additional information on the complex genetics and molecular biology involved in regulation of skin color is available at http://www.jbc.org/content/282/38/27557.full and http://hmg.oxfordjournals.org/content/18/R1/R9.full.)

In discussing question 8, the following table may be helpful.

<table>
<thead>
<tr>
<th>Type of Dominance</th>
<th>Phenotype of Heterozygous Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant-recessive pair of alleles</td>
<td>Same as phenotype of individual who is homozygous for the dominant allele</td>
</tr>
<tr>
<td>Codominance</td>
<td>Shows different observable phenotypic effects of both alleles; phenotype different from either homozygous individual</td>
</tr>
<tr>
<td>Incomplete dominance^7</td>
<td>Intermediate between phenotypes of the two types of homozygous individual (typically observed for quantitative traits); phenotype different from either homozygous individual</td>
</tr>
</tbody>
</table>

^7 Incomplete dominance can occur when each wild type allele produces a set dose of protein product and the phenotype is proportionate to the amount of protein. The Student Handout uses a capital letter and lowercase letter to indicate the two alleles for a gene with incomplete dominance; you may prefer to use an alternate notation such as b/b’ or B/B’. 
Pages 5-6 of the Student Handout provide the opportunity to reinforce student understanding that individual phenotypic characteristics are often influenced by multiple alleles of multiple genes, as well as environmental factors. Our introductory genetics teaching frequently focuses on inheritance and phenotypic effects of single genes, as illustrated on page 5 of the Student Handout. However, this is only a beginning for understanding the genetics of most traits. For example, as discussed on page 6, a person with a Bb genotype could have lighter or darker skin, depending on whether 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.

During your discussion of question 11, you may want to revisit the previous page of the Student Handout and explain that the genotype/phenotype table and question 9 provide a very simplified introduction to the genetics of skin color.

This figure provides a somewhat more accurate representation of the Punnett square for inheritance of skin color. Even this relatively complex Punnett square is a simplified representation of reality, since it assumes a simple additive model with only two alleles for each gene and incomplete dominance for all of the alleles.

![Punnett Square](https://www.quora.com/How-is-skin-color-determined-in-babies)

**Episode III. I don't want to have any daughters who are colorblind like me!**

**Learning Goals**

- Students will understand sex-linked inheritance (inheritance of recessive alleles on the X chromosome).
- More practice with Punnett squares

**Biology Background and Suggestions for Implementation**

If your students are not familiar with the genetics of sex determination, you can provide a brief explanation or use the mini-activity shown on the last page of these Teacher Preparation Notes.

The X chromosome has multiple important genes, including the genes that code for the protein part of the photoreceptor molecules in the eye that respond to specific colors of light. Defective alleles of these photoreceptor genes code for defective photoreceptor molecules; this can result in
red-green colorblindness. In a heterozygous female, a defective photoreceptor allele is recessive because the normal allele codes for enough normal photoreceptor molecule to result in normal color vision. A student friendly discussion of color vision is available at http://www.thescientist.com/?articles.view/articleNo/41055/title/The-Rainbow-Connection/.

The answers to question 2 support the concept that, in general, sex-linked recessive conditions are much more common in males. You may want to ask your students to carry out a more complete analysis by drawing Punnett squares for the offspring of Awilda and Frank's sons.

**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. Part II recommends learning activities to develop student understanding of these key concepts. These recommended learning activities are aligned with the Next Generation Science Standards.8

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8 Next Generation Science Standards (http://www.nextgenscience.org/next-generation-science-standards)
Mini-activity on the genetics of sex determination that you could use as background for episode III, "I don't want to have any daughters who are colorblind like me!"

**Genetics of Sex Determination**

A crucial gene that stimulates the development of male anatomy is located on the Y chromosome. Therefore,

- a person with an X and a Y chromosome (XY) is male
- a person with two X chromosomes (XX) is female.

1. In this figure, label each cell with the appropriate symbols (X, Y) for the sex chromosomes or chromosome.

2a. Complete this Punnett Square to show the inheritance of the sex chromosomes. Use X and Y to indicate the genetic makeup of the mother’s and father’s gametes and the zygotes.

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2b. Based on this Punnett square, what percent of babies are predicted to be male?