Lesson Plan: Wonder Genetics
By: Kyla Rightmer and Darby Feldwinn
Inspired By: *Wonder* by R.J. Palacio

Target Grade: 5th

Teacher Prep Time: 20 min

Lesson Time: 2 hours and 50 minutes (Not including Part 0). (We recommend doing this lesson over 3 days. On Day 1 do Part 1, Day 2 Parts 2 and 3, and Day 3 Part 4.)

- Part 0: *Wonder* Read Aloud or Class Read
  - ~7 hours
- Part 1: Traits
  - 10 min – Beginning Thoughts
  - 50 min - How are Traits Inherited?
- Part 2: Probability of Traits
  - 10 min - Introduction
  - 10 min - Calculating Probabilities
  - 10 min - Punnett Square
- Part 3: Testing Our Model
  - 15 min - Simulation
  - 15 min - Simulation Analysis
- Part 4: Via's and August's Possible Children
  - 15 min - Introduction
  - 25 min - Via's Future Children
  - 10 min - August's Future Children
  - 25 min - Comparing Results to Book

Where This Lesson Fits in:

This lesson is a science extension for the book, *Wonder* by R.J. Palacio. This book should be read to the class or by the class prior to doing this lesson (as long as you are through page 106, you can start the lesson). This lesson prepares students for 6th grade, where they learn about how traits are passed down by both sexual and asexual reproduction (MS-LS3-2).

Lesson Overview:

Students use passages from *Wonder* to determine how a trait (August's deformity) is passed from parents to children. With guidance, they develop a model that explains how and why August got his facial deformity. In addition, the model allows for students to predict the probability that a set of parents, with known alleles, will have a child with the deformity.

Learning Objectives:

- Students will know that each parent gives one allele (piece of genetic information) to their child, and depending on the two alleles the child receives, the child might or might not display the trait.
- Students will be able to make mathematical predictions about the probability of parents passing down a trait to their child.

NGSS:

- **Performance Expectation**
  - MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
    - This lesson is in preparation for the 6th grade PE above.
- **Science and Engineering Practice**
  - #5 Mathematics and Computational Thinking
    - Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.
      - Organize simple data sets to reveal patterns that suggest relationships.
- **Disciplinary Core Idea -** Preparation for the following 6th grade DCIs
  - LS1.B Growth and Development of Organisms
    - Animals engage in behaviors that increase the odds of reproduction. An organism's growth is affected by both genetic and environmental factors.
  - LS3.A Inheritance of Traits
    - Genes chiefly regulate a specific protein, which affect an individual's traits.
  - LS3.B Variation of Traits
    - In sexual reproduction, each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to proteins in or traits of an organism.
- **Cross Cutting Concept**
  - #2 Cause and Effect
    - In grade 3-5, students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause and effect relationship.
- **Common Core State Standard**
  - RI.5.3 Reading: Informational Text (While *Wonder* is not an informational book, the section that we are examining is scientific text and not based on fiction, and thus considered informational text.)
    - Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text. https://www.cde.ca.gov/re/cc/
  - RI.5.8 Reading: Informational Text
    - Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s).

Materials Needed:

- *Wonder* by R.J. Palacio (1 class copy or class set)
- Student worksheet (1 per student + 1 class worksheet)
- Brown paper lunch bag (1 per student)
- Clear marble (1 per student)
- Colored marble (1 per student)
- Analysis table (1 per student)
- Document camera

Teacher Prep:

Part 0:

- Have the book *Wonder* available.

Part 1:

- Printout the worksheet.

Part 3:

- Get simulation bags ready by placing one clear marble and one colored marble in each brown paper lunch bag.

Part 4:

- Print and cut out analysis table.

Lesson Sequence:

* For this activity we recommend that students have a partner to check in with. In Part 3, there is a simulation in which students will have to work with a partner, so it is helpful if they are already sitting next to each other.

Part 0: Wonder	

~7 hours	**Reading**
	• Read *Wonder* by R.J. Palacio aloud to students or have students read the book.
	  ○ As an alternative, students can watch the movie.
	  ○ This lesson can be done after reading through page 106.

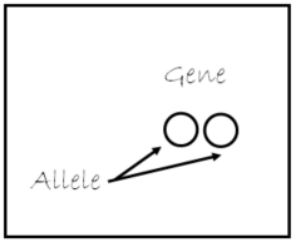
Part 1: Traits	

10 minutes	**Beginning Thoughts**
	• Pass out worksheets to students.
	• Keep one worksheet to be the class worksheet. This will be put under the document camera to record student answers as they complete the activity.
	• Tell students, "A trait is a quality or characteristic of an individual. For example, brown hair or blue eyes."
	• Have students fill in questions 1-3 on their worksheet on their own. Then have them share their answer with a partner. After, have students share their answers with the class. Try to encourage a variety of answers and record some of their responses in the class worksheet.
	  ○ For question 1, make sure that students understand that some traits you can see, like your height, and some you cannot, like your personality.
	  ○ For question 3, students might say that traits are both inherited and come from the environment. If they do, make sure that they understand that some traits (like personality) can be affected by the environment, but there are some traits (like eye color) that are not affected by the environment.

40 minutes	**How are Traits Inherited?** • Read the excerpt from *Wonder* that is given in the worksheet (pages 1 and 2). Remind the class that this part of the text is from Via's perspective. • Ask the class, "Is August's deformity a trait?" ○ ESR: Yes • Record this in the class worksheet for question 4 while students record it on their worksheet. • Tell students, "The book refers to August's condition as a deformity, so this is the term we will use in this activity. However, there is nothing wrong with what August has, and we know he had no control over it. If we all were the same, then the world

would be boring. We are using this term, not out of disrespect, but to keep continuity with the book."

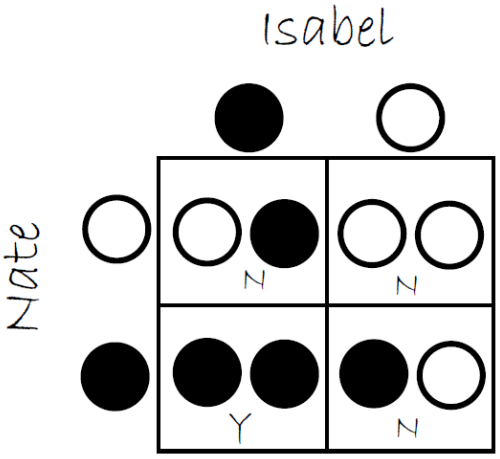
- Have students talk with a partner about how August got his facial deformity. Then, have them share their thoughts with the class and record the class consensus answer for question 5 on the class worksheet while students record it on their own worksheet.
    - If students had brought up that traits come from the environment, ask them, "Did the environment affect August's deformity?"
        - ESR: No.
- In pairs, have students discuss what it means about his parents' genetic makeup if in fact August got his facial deformity from his parents. After allowing them to talk in pairs, have a class discussion. By the end of the discussion, make sure students understand that August's parents must have the genetic information for the facial deformity even though they do not show the deformity. Record this on the class worksheet under question 6 while students record it on their worksheet.
- Read question 7 to the class: "Peoples' genetic material is stored in sections of DNA called genes. Each gene will determine how a specific trait (ex: face freckles) is displayed. Each gene carries two pieces of genetic material. These pieces are known as alleles. Alleles code for the different version of the trait (ex: freckles or no freckles)." Draw a picture of a gene and label the alleles in the gene. Then, guide students to draw the following picture.



- For question 8, tell students, "The trait we will be exploring is August's facial deformity. This trait has two alleles which are the facial deformity or no-facial deformity. We will use a filled-in circle to represent the facial deformity allele and an empty circle to represent the no-facial deformity allele." Fill this in on the class worksheet while students fill it in on their worksheet.
- Have students individually go through and fill out whether each member of August's immediate family shows the deformity in question 9. Then, have students share their answers and record them on the class worksheet. As a class, work together to determine what alleles must be in the genes of each member of August's immediate family. Make sure by the end of the discussion that students understand that a person will only show the facial deformity if they get two alleles for the facial deformity. If they get one allele for the deformity and one for no deformity, then they will not have the deformity, but carry the genetic information for the deformity. In addition, make sure that they understand that there are two possible allele combinations for Via.
- Have students discuss with a partner about where August's two alleles came from and what this mean about how genetic information is passed down from parents to children. Then have them share their thoughts with the class. Make sure students understand that August got one allele each from of his parents (question 9) and this is what happens for all traits (question 10). Record these on the class worksheet while students record them on their own worksheet.
- Read question 12 to students: "A recess is a small space created by building part of the wall farther back from the rest." Have them identify the recessed door and circle

	it on their worksheet while you circle it in the class worksheet. Ask students, "If I stood in both doorways, what doorway would it be harder to see me in?" o ESR: It would be harder to see you in the recessed doorway. • Have students discuss in pairs why they think that August's facial deformity is called a recessive trait. Then, have them share their thoughts with the class and record the class consensus answer in the class worksheet while students copy it into their worksheets. • Read the excerpt from *Wonder* that is given in the worksheet on page 3. Discuss as a class if the description matches the model of inheritance that the class has been developing (question 14). Then, write the class consensus answer in the class worksheet while students write it on their worksheet. o If students are struggling with this because Via said that she is a carrier, ask students, "Did Via provide any evidence/data that she is a carrier?" Make sure students realize that Via never said that she was tested so we are not sure if anyone confirmed that she is a carrier and according to the model that was developed it is possible for her not to be a carrier. • As a class, go over what you learned about heredity from Part 1. The review should include the following: o People have genes, which have two alleles. o Alleles are the version of the trait. o It is possible to carry an allele but not show it. o Each parent passes down one allele to their children.
Part 2: The Probability of Traits	
10 minutes	**Introduction** • Ask students, "What did we learn last time about how traits are passed down?" o ESR: People have at least two alleles per trait. People can carry an allele for a trait, but not exhibit the trait. Parents pass down one allele each to their children. • Summarize student answers in question 15 on the class worksheet while students copy this onto their worksheet. • Have students tell you what they already know about Isabel, Nate, August, and Via's genes, and fill out the table in question 16 on the class worksheet while students fill it in on their worksheet. o Make sure that students understand that if a person has one allele for the facial deformity and one allele for no facial deformity, it does not matter if they put the carrier allele in for allele 1 or allele 2 (e.g.: genetically, ◯● and ● ◯ are the same thing).
10 minutes	**Calculating Probabilities** • Have students work with partners to try to fill in the table for question 16. • Have students share the possible alleles that children of Isabel and Nate could have, and state whether or not those alleles would result in the child showing the facial deformity. Record these on the class worksheet. o There is an extra row in this table that will not be filled out. Students should understand that there are only four options. • As a class, determine the fraction of future children of Nate and Isabel that are predicted to show the deformity. Then, fill in the response on the class worksheet while students fill it in on their worksheet.

10 minutes	**Punnett Square** • Tell students, "Geneticists do exactly what we just did to calculate the fraction of children that they expect will have a certain trait given the traits of the parents, but they use a box to help with their calculations." • Show students how to make the box and put the traits that the parents have on the outside of the box. Remind students that it does not matter if they write Isabel's and Nate's traits as ◯● or ●◯ because they are genetically equivalent. • Then, show students how to fill in the center of the box. • In each square of the box write a "Y" if the child would show the deformity and a "N" if the child would not show the deformity. • Use the box to calculate the fraction of future children that would be expected to have the deformity or not have the deformity. • Have students confirm that this agrees with their results from question 17. • Tell students, "What we just made is known as a Punnett square." Fill this in on the class worksheet while students copy it onto their worksheet.
Part 3: Testing Our Model	
15 minutes	**Simulation** • Tell students, "We will now check our model to see how accurate it is. In partners, you will decide who is Isabel, and who is Nate. You will each get a bag that contains two marbles. These marbles represent alleles and the bag represents the gene. The colored marbles represent the allele for the facial deformity and the clear marbles represent the allele for no facial deformity. Since Nate and Isabel are carriers but do not show the deformity, there is one of each marble in the bags. If a colored marble is pulled from the bag, then the allele for the facial deformity is passed down to the child. If a clear marble is pulled from the bag, then the allele for no facial deformity is passed down to the child. During the simulation you each will pull out a marble from your bag. You will fill your results out in the table for question 19 on page 5. You will then use the alleles to determine if the child will show the deformity or not." After you have explained this to students, have one student model with you what they will do and fill in the top row of the table in the class worksheet. • As a class, fill out question 18 with the expected fraction, equivalent fraction (out of 12), and the predicted number of children the simulation will give on the class worksheet while students fill it in on their worksheet. • Pass out the bags with marbles and have students complete the simulation, question 20. Then, have students fill in question 21 and 22 to help them analyze their data from the simulation.
15 minutes	**Simulation Analysis** • Have groups report out the fraction of their children that had the deformity and that did not have the deformity. Only record unique fractions in the table for question 23 in the class worksheet, and have students write these on their own worksheets. • Have a class discussion about why everyone did not get the exact same probabilities and why these do not (all) match exactly with the predicted model. Fill in questions 24-26 as a class. Make sure by the end of the conversation, students know that the model only gives predicted fractions and the actual number of children could deviate from these fractions. The more children parents have (the more trials of the simulation that you do), the closer the values should be to the fractions in the model.

	○ To help students understand why having more data gets fractions that are closer to the predicted values, ask students, "Who is the first child that Isabel and Nate had?" (ESR: Via) "After having Via what was the fraction of children that had the deformity?" (ESR: $\frac{0}{1}$). Point out that this is far from the $\frac{1}{4}$ predicted from the model. Ask students, "What was the fraction of children that Isabel and Nate had with the deformity once August was born?" (ESR: $\frac{0}{2}$). Tell them that this is as far off as when there was one child and explain their data which had many more children in it was much closer to the predicted value of $\frac{0}{4}$.
Part 4: Via's Possible Children	
5 minutes	**Introduction** • Have students share what they did and learned the previous day. Ask students, "How are traits passed down, and can we predict the likelihood that a child will have a given trait?" ○ ESR: Parents pass down one allele each to their child. If we know the alleles of the parents, we can use a Punnett square to determine all possible combinations of the alleles that can be passed down. This allows us to determine the fraction of their children we would expect to show the trait. • If Punnett squares have not been brought up already, make sure to review them. Redraw the Punnett square for Isabel and Nate, including writing "N" and "Y" for if the child would or would not have the facial deformity. Also make sure that students understand that if the child does not show the deformity they still could be a carrier of the deformity and this happens when they get the same alleles as Nate and Isabel. In addition, review the fraction of the children that would have the deformity and how to get a percentage from the fraction. For Nate and Isabel $\frac{1}{4}$ (25%) of their children would show the deformity, $\frac{2}{4}$ (50%) of their children would be carriers, and $\frac{1}{4}$ (25%) of their children would not be carriers of the allele for the deformity at all.  • Ask students, "Are the percentages that we just calculated guaranteed?" ○ ESR: No, when people actually have a child the percentages could differ. The more children that are in the study, the closer the percentage would be to the predicted percentage. • Pass out an analysis table to each student.

	• Tell students, "We will be calculating the chance that Via's and August's children will be born with the facial deformity, using all possible allele combinations for their future partners. This is the same thing that Via did in the book. While I read this section to you I want you to box the partners that Via is talking about and underline the probabilities that Via comes up with." • Read the excerpt from *Wonder,* page 7 of the worksheet, aloud to the class. Students should follow along on their worksheets. Pause after each paragraph and ask what students have boxed and underlined. Then, record these on the class worksheet. In addition, have students fill in their analysis table, discussing each match that Via considered. After paragraph 2, the following should be filled out in the analysis table:

Pullman Family Member	Partner	(From Book) % of Children having the Deformity	(From Book) % of Children that are Carriers	(From Book) % of Children that are Not Carriers	(From Math) % of Children having the Deformity	(From Math) % of Children that are Carriers	(From Math) % of Children that are Not Carriers
Via	Carrier	25%	50%	25%			
August	Non Carrier	0%	100%	0%			
August	Carrier	25%	50%	25%			

- When you get to paragraph 4 and read "countless doctors have drawn tic-tac-toe grids for my parents over the years," stop and ask students, "What is Via talking about?"
  - ESR: Punnett squares.
- When you get to paragraph 4 and read "they can forecast the odds, but they can't guarantee them," stop and ask students, "Why is Via saying this?"
  - ESR: Just like our simulations, we did not get the exact predicted numbers.

10 minutes	**Via's Future Children** • Direct students to page 8 of their worksheets. Tell them, "We will be creating Punnett squares to show the different possibilities for Via's children. We will use those Punnett squares to calculate the chances, based on Via's possible future partners." • Ask students, "What do we know about Via's genetic makeup?" ○ ESR: She might or might not be a carrier. • Tell students, "Because we do not know Via's genetic makeup, we will complete two sets of Punnett squares, one for if she is a carrier, and one for if she is not a carrier. " • Do the first Punnett square as a class (Via being a carrier and having a child with a person who does not carry the trait). Remind students that the parent's alleles go on the outside of the square and the children's alleles are in the middle. If the allele is for the deformity we will represent it with a black circle and if the allele is not for the deformity we will represent it with a white circle. On the class worksheet, fill in the first Punnett square, including putting "Y" in the box of the alleles that would cause the child to show the deformity and an "N" in the box of the alleles that would not cause the child to not show the deformity. Then have students copy this into their worksheets. • Fill in the fraction and percentage of Via and her partner having a child with the deformity, being a carrier but not showing the deformity, and of not being a carrier in the class worksheet while students copy this onto their worksheets.

	• Ask students, "How many of the four boxes represent a child that would have the deformity?"
	  ○ ESR: 0.
	  ○ Fill in the top fraction and percentage line to the right to show that $\frac{0}{4}$ chance of having the deformity, which equals 0%.
	• Repeat the process for having a child who is a carrier but does not show the deformity, and for a child who is not a carrier.
	• Then, go through and fill in the parent alleles for the other two Punnett squares on that page.
	• Have students work with a partner to fill out the next two Punnett squares and calculate the fraction and percent of children who will have each set of alleles. While students are doing this, fill in the Punnett squares on the class worksheet so that students will be able to check their work. Do not put the class worksheet under the document camera until the majority of students are finished. Have students tell you what fraction and percentage of children will have each set of alleles, and record this on the class worksheet.
	• Have students turn to page 9 and tell students, "We will now repeat the process but we will assume that Via is <u>not</u> a carrier."
	• As a class fill in all of the parent alleles.
	• Have students work with a partner to fill out the Punnett squares and calculate the fraction and percent of children that will have each set of alleles. While students are doing this, fill in the Punnett squares on the class worksheet so that students will be able to check their work. Do not put the class worksheet under the document camera until the majority of students are finished. Have students tell you what fraction and percentage of children will have each set of alleles, and record this on the class worksheet.

15 minutes	**August's Future Children** • Direct students to page 10 in their worksheet. Tell them, "We will be creating Punnett squares to show the different possibilities for August's children." • As a class fill in all of the parent alleles. • Have students work with a partner to fill out the Punnett squares and calculate the fraction and percent of children that will have each set of alleles. While students are doing this, fill in the Punnett squares on the class worksheet so that students will be able to check their work. Do not put the class worksheet under the document camera until the majority of students are finished. Have students tell you what fraction and percentage of children will have each set of alleles, and record this on the class worksheet.

20 minutes	**Comparing Results to Book**
	• Have students get their analysis table out and tell them, "We will now use our Punnett squares to see if the fiction writing in the book is accurate or not."
	• Have students find the Punnett square that describes Via having a child with a partner that is a carrier and then have them fill in the table. Ask students, "Does this data match our math?"
	  ○ ESR: Yes, as long as Via is a carrier.
	• Have students find the Punnett square that describes August having a child with a partner that is not a carrier and then have them fill in the table. Ask students, "Does this data match our math?"
	  ○ ESR: Yes
	• Have students find the Punnett square that describes August having a child with a

	partner that is a carrier and then have them fill in the table. Ask students, "Does this data match our math?" o ESR: No • Ask students, "What is not in agreement?" o ESR: August's children will have a 50% chance of showing the deformity where the book said it would be 25%. In addition, none of August's children will <u>not</u> be a carrier and the book said this number would be 25%. • Have students circle the numbers that are not in agreement. • Have students tape the analysis table into the worksheet. • Have students individually use this information to fill in questions 31-33. Then, have them share their answers with their partner. Afterwards, have them share their answers with the class and put the class consensus answers on the class worksheet. • Have students individually fill in question 34. Then, invite them to share their answers with the class. o For this question there are two answers. In both cases Via needs to be a carrier. But she could have had a child with a person that showed the deformity or had a child with a person that is only a carrier. Make sure that students understand both of these cases by the end of the discussion. In addition, make sure that they understand Via would be more likely to have a child with a deformity if her partner showed the deformity. • Ask students, "What did the *Wonder* book teach us about traits?" o ESR: Parents pass down traits to their children. You can carry a trait and not physically display that trait. This is known as a recessive trait. If you know the genetic information that the parents carry, you can predict the probability of traits in their children. These predictions are just probabilities and the actual percentages can deviate from the predicted values.

Example Student Work:

Name: Kyle

Wonder Genetics

Part 1: Traits

A trait is a quality or characteristic of an individual. Example: brown hair or blue eyes.

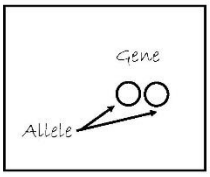
1. Another example of a trait is: Attached or detached ear lobes.
2. Where do people get their traits from? People get their traits from their parents or from the environment.
3. What do you notice about traits of people within one family? Kids look similar to but not exactly like both their parents and their siblings.

Read the following excerpt from *Wonder*, on pages 103-104. This passage is from the perspective of Via.

> Both sides of Dad's family were Jews from Russia and Poland. Poppa's grandparents fled the pogroms and ended up in NYC at the turn of the century. Tata's parents fled the Nazis and ended up in Argentina in the forties. Poppa and Tata met at a dance on the Lower East Side while she was in town visiting a cousin. They got married, moved to Bayside, and had Dad and Uncle Ben.
>
> Mom's side of the family is from Brazil. Except for her mother, my beautiful Grans, and her dad, Agosto, who died before I was born, the rest of Mom's family—all her glamorous aunts, uncles, and cousins—still live in Alto Leblon, a ritzy suburb south of Rio. Grans and Agosto moved to Boston in the early sixties, and had Mom and Aunt Kate, who's married to Uncle Porter.
>
> Mom and Dad met at Brown University and have been together ever since. Isabel and Nate: like two peas in a pod. They moved to New York right after college, had me a few years later, then moved to a brick townhouse in North River Heights, the hippie-stroller capital of upper Manhattan, when I was about a year old.
>
> Not one person in the exotic mix of my family gene pool has ever shown any obvious signs of having what August has. I've pored over grainy sepia pictures of long-dead relatives in babushkas; black-and-white snapshots of distant cousins in crisp white linen suits, soldiers in uniform, ladies with beehive hairdos; Polaroids of bell-bottomed teenagers and long-haired hippies, and not once have I been able to detect even the slightest trace of August's face in their faces. Not a one. But after August was born, my parents underwent genetic counseling. They were told that August had

> what seemed to be a "previously unknown type of mandibulofacial dysostosis caused by an autosomal recessive mutation in the TCOF1 gene, which is located on chromosome 5, complicated by a hemifacial microsomia characteristic of OAV spectrum." Sometimes these mutations occur during pregnancy. Sometimes they're inherited from one parent carrying the dominant gene. Sometimes they're caused by the interaction of many genes, possibly in combination with environmental factors. This is called multifactorial inheritance.

4. Is August's facial deformity a trait? (Yes) No
5. Where did August get his facial deformity from? It came from his parents.
6. What does this mean about the genetic material his parents have? His parents must have the genetic information for the facial deformity even though they do not show it.
7. Peoples' genetic material is stored in sections of DNA called **genes**. Each gene will determine how a specific trait (ex: face freckles) is displayed. Each gene carries two pieces of genetic material. These pieces are known as **alleles**. Alleles code for the different version of the trait (ex: freckles or no freckles). Draw a picture of a gene and label the alleles in the gene.



8. We will be exploring the gene that is responsible for August's facial deformity (trait = facial deformity). What are the versions of the trait (the alleles) and what will you use to represent these versions? Facial Deformity ● No Facial Deformity ○

9. If August has the deformity, draw what his, his parent's, and Via's genes could be.

Parents: (Generation 1)	Isabel Shows Deformity: No Gene: ●○	Nate Shows Deformity: No Gene: ●○
Children: (Generation 2)	August Shows Deformity: Yes Gene: ●●	Via Shows Deformity: No Gene: ○○ ●○

10. Who did August get his alleles for his deformity from? One from his mother and one from his father.
11. In general, how are alleles inherited? You get one from your mother and one from your father.
12. A recess is a small space created by building part of the wall farther back from the rest. Circle the door that is recessed.

13. Why do you think August's facial deformity is called a recessive trait? Because the allele for the deformity is not as strong/important as the allele not for not the deformity and you will only see the facial deformity if you get both alleles for the deformity.

Read the following excerpt from *Wonder*, on page 104. This passage is from the perspective of Via.

> In August's case, the doctors were able to identify one of the "single nucleotide deletion mutations" that made war on his face. The weird thing is, though you'd never know it from looking at them: both my parents carry that mutant gene. And I carry it, too.

14. Do your answers in question 9 agree with this statement from the book? My answers agrees with what the book says for the parents but for Via she is not necessarily a carrier depending on what she inherited from her parents.

Part 2: Probability of Traits

As a class we want to understand what causes changes in the frequency of inherited traits and be able to predict the frequency in which the condition will occur.

15. What are the key parts of describing how traits are passed down?
    - People have two alleles per gene.
    - One trait is seen while another can be hidden.
    - Parents pass down one allele each to their children.
16. What do we know about the genes that each member of August's family carries that are associated with his facial deformity?

	Allele 1	Allele 2	Shows the Trait		Allele 1	Allele 2	Shows the Trait
Isabel	●	○	No	August	●	●	Yes
	○	●		Via	○	○	No
Nate	●	○	No		●	○	
	○	●			○	●	

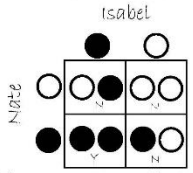
17. If Isabel and Nate were to have another baby, what is the probability that they would have a baby with a facial deformity?

Possible Combinations of Alleles in Children

Possibility	Allele From Isabel	Allele From Nate	Child Will Show the Trait
1	●	●	Yes
2	●	○	No
3	○	●	No
4	○	○	No
5			

This would cause the child to have a 1/4 chance of having the **deformity** and a 3/4 chance of **not having the deformity**.

18. Draw another way to show the possible combinations of alleles in their children.



This would cause the child to have a 1/4 chance of having the deformity and a 3/4 chance of not having the deformity.

Do these results agree with question 16? Yes No

This is known as a Punnett Square

Part 3: Testing Our Model

In partners, you will simulate possible children that Isabel and Nate could have. Decide who will be Isabel and Nate.

Isabel: Darby Nate: Kyla

Each bag represents a gene. Inside the bag are the two alleles the parent possesses. Reach into your bag and pull out one allele while your partner does the same. These alleles will form the gene of your child. Determine if the gene would cause the child to show the facial deformity or not. Do this process 12 times and fill in the table for each child.

19. Our Model (use question 18 to fill out the table):

Appearance	Fraction	Equivalent Fraction (out of 12)	Number of Children we Predict we will get in the Simulation
Deformity	1/4	3/12	3
No Deformity	3/4	9/12	9

20. Data Table

Child	Allele From Isabel	Allele From Nate	Child Shows the Trait
1	○	○	No
2	●	●	Yes
3	○	●	No
4	●	●	Yes
5	○	○	No
6	●	●	Yes

Child	Allele From Isabel	Allele From Nate	Child Shows the Trait
7	●	○	No
8	○	●	No
9	○	●	No
10	○	○	No
11	○	●	No
12	●	●	Yes

21. Fill in the table with your simulation results.

Appearance	Number of Children from Simulation	Fraction (out of 12)	Number of Children we Predicted Simulation Would Give (from question 18)
Deformity	4	4/12	3
No Deformity	8	8/12	9

22. Does your data exactly match the predicted data? Yes (No)

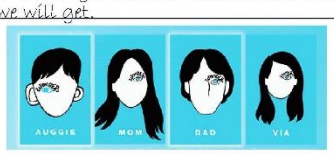
23. Fractions that other groups recorded:

Fraction Having	Fraction Not
4/12	8/12
3/12	9/12
2/12	10/12
5/12	7/12

24. Does everyone's data exactly match the predicted data? Yes (No)

25. Is the data that the class gathered close to the predicted data? (Yes) No

26. Does the model have limitations and when is it most accurate? The numbers that we get from our model are just probabilities not certainties. The larger the data set, the closer to the predicted numbers we will get.



Part 4: Via's and August's Possible Children

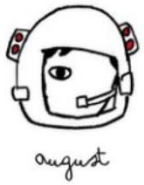
Read this excerpt from *Wonder*, on pages 105-106. This passage is from the perspective of Via. In the passage, box information about the partners that is discussed and underline information about the probabilities that is discussed.

If I have children, there's a one-in-two chance that I will pass on the defective gene to them. That doesn't mean they'll look like August, but they'll carry the gene that got double-dosed in August and helped make him the way he is. If I marry someone who has the same defective gene, there's a one-in-two chance that our kids will carry the gene and look totally normal, a one- in-four chance that our kids will not carry the gene at all, and a one-in-four chance that our kids will look like August.

If August has children with someone who doesn't have a trace of the gene, there's a 100 percent probability that their kids will inherit the gene, but a zero percent chance that their kids will have a double dose of it, like August. Which means they'll carry the gene no matter what, but they could look totally normal. If he marries someone who has the gene, their kids will have the same odds as my kids.

This only explains the part of August that's explainable. There's that other part of his genetic makeup that's not inherited but just incredibly bad luck.

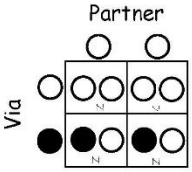
Countless doctors have drawn little tic-tac-toe grids for my parents over the years to try to explain the genetic lottery to them. Geneticists use these Punnett squares to determine inheritance, recessive and dominant genes, probabilities and chance. But for all they know, there's more they don't know. They can try to forecast the odds, but they can't guarantee them. They use terms like "germline mosaicism," "chromosome rearrangement," or "delayed mutation" to explain why their science is not an exact science. I actually like how doctors talk. I like the sound of science. I like how words you don't understand explain things you can't understand. There are countless people under words like "germline mosaicism," "chromosome rearrangement," or "delayed mutation." Countless babies who'll never be born, like mine.



Use the boxes below to create Punnett squares showing the different possibilities for Via's and August's children. If we know the alleles that Via and August carry as well as the alleles their partners carry, we can make predictions of their children's chances of having the facial deformity, being a carrier, or not carrying the allele at all. These chances can also be converted into percentages.

27. Via's future children if she is **a carrier**.

What would be the effect caused by Via having a child with a partner who is **not a carrier**?

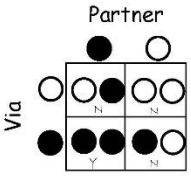


0/4 chance of **having the deformity**, which equates to 0 %.

2/4 chance of not having the deformity but **being a carrier**, which equates to 50 %.

2/4 chance of not having the deformity and **not being a carrier**, which equates to 50 %.

What would be the effect caused by Via having a child with a partner who is **a carrier**?

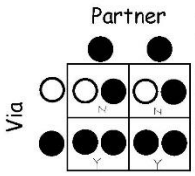


1/4 chance of **having the deformity**, which equates to 25 %.

2/4 chance of not having the deformity but **being a carrier**, which equates to 50 %.

1/4 chance of not having the deformity and **not being a carrier**, which equates to 25 %.

What would be the effect caused by Via having a child with a partner who **shows the deformity**?



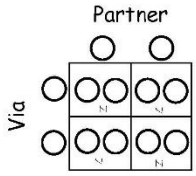
2/4 chance of **having the deformity**, which equates to 50 %.

2/4 chance of not having the deformity but **being a carrier**, which equates to 50 %.

0/4 chance of not having the deformity and **not being a carrier**, which equates to 0 %.

28. Via's future children if she is **not a carrier**.

What would be the effect caused by Via having a child with a partner who is **not a carrier**?

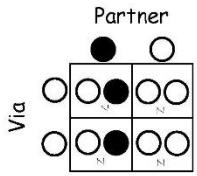


0/4 chance of **having the deformity**, which equates to 0 %.

0/4 chance of not having the deformity but **being a carrier**, which equates to 0 %.

4/4 chance of not having the deformity and **not being a carrier**, which equates to 100 %.

What would be the effect caused by Via having a child with a partner who is **a carrier**?

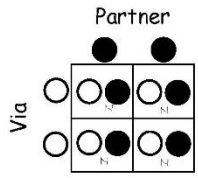


0/4 chance of **having the deformity**, which equates to 0 %.

2/4 chance of not having the deformity but **being a carrier**, which equates to 50 %.

2/4 chance of not having the deformity and **not being a carrier**, which equates to 50 %.

What would be the effect caused by Via having a child with a partner who **shows the deformity**?



0/4 chance of **having the deformity**, which equates to 0 %.

4/4 chance of not having the deformity but **being a carrier**, which equates to 100 %.

0/4 chance of not having the deformity and **not being a carrier**, which equates to 0 %.

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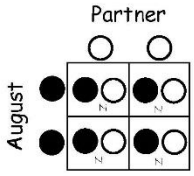
29. August's future children.

What would be the effect caused by August having a child with a partner who is **not a carrier**?

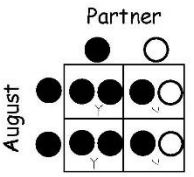


0/4 chance of **having the deformity**, which equates to 0 %.

4/4 chance of not having the deformity but **being a carrier**, which equates to 100 %.

0/4 chance of not having the deformity and **not being a carrier**, which equates to 0 %.

What would be the effect caused by August having a child with a partner who is **a carrier**?

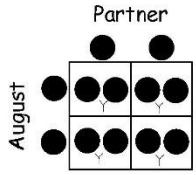


2/4 chance of **having the deformity**, which equates to 50 %.

2/4 chance of not having the deformity but **being a carrier**, which equates to 50 %.

0/4 chance of not having the deformity and **not being a carrier**, which equates to 0 %.

What is the predicted effect if August has a child with a partner who **shows the deformity**?



4/4 chance of **having the deformity**, which equates to 100 %.

0/4 chance of not having the deformity but **being a carrier**, which equates to 0 %.

0/4 chance of not having the deformity and **not being a carrier**, which equates to 0 %.

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30. Tape the data table below and circle any disagreements between the book and your math:

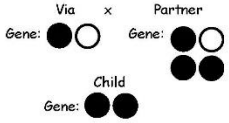
Pullman Family Member	Partner	(From Book) % of Children having the Deformity	(From Book) % of Children that are Carriers	(From Book) % of Children that are Not	(From Math) % of Children having the Deformity	(From Math) % of Children that are Carriers	(From Math) % of Children that are Not
Via	Carrier	25%	50%	25%	25%	50%	25%
August	Non	0%	100%	0%	0%	100%	0%
August	Carrier	(25%)	50%	(25%)	(50%)	50%	(0%)

31. Does your math match the math in the book? Yes (No)

32. Who were the partners when the math matched? Via (carrier) x carrier
August x non Carrier

33. Who were the partners when the math did not match? August x Carrier
For this case, the book said there was a 25% chance that their child would show the deformity.
but I think the probability is 50%.
The book also said there was a 25% chance that their child would not carry the allele.
but I think the probability is 0%.

34. If Via has a child with the deformity, what combination of alleles in her and her partner caused this effect?



Via would have to be a carrier. Her partner could be a carrier or show the deformity. It would be more likely if her partner showed the deformity.

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