Science Learning Packet

BIO B:
Genetics: Inheritance, Part 2 of 2

science learning activities for SPS students during the COVID-19 school closure.

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While Seattle Public Schools endeavors to only post documents optimized for accessibility, due to the nature and complexity of some documents, an accessible version of the document may not be available. In these limited circumstances, the District will provide equally effective alternate access.

Due to the COVID-19 closure, teachers were asked to provide packets of home activities. This is not intended to take the place of regular classroom instruction but will help supplement student learning and provide opportunities for student learning while they are absent from school. Assignments are not required or graded. Because of the unprecedented nature of this health crisis and the District’s swift closure, some home activities may not be accessible.

If you have difficulty accessing the material or have any questions, please contact your student’s teacher.
The goals of *Genetics: Inheritance* are twofold: 1) for students to understand how an organism’s traits are determined by proteins, which in turn are determined by DNA, and 2) to show students how traits are passed between generations.

This unit builds on student’s prior learning in *Genetics: Development*. Students will gather evidence to explain how a trait persists in a family.

**Why should you do this?**
These materials will help you continue your learning at home. The unit addresses content that is not covered in any other high school science course. Goals are listed for each activity to help you track your learning.

*Your teacher will provide information on which item(s) will be submitted, when they are due, and how they will be submitted.*

This unit is designed to address the following Washington State Science Standards (Next Generation Science Standards):

- **Performance Expectations**
  - _LS1-1_: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
  - _LS1-2_: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
  - _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. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]
  - _LS3-2_: Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]
  - _LS3-3_: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

- **Science and Engineering Practices**: Constructing Explanations, Developing and Using Models
- **Crosscutting Concepts**: Systems and System Models, Structure and Function

**What resources do I need?**
This packet, a pencil or pen, and scrap paper. You may find it useful to have a highlighter and markers or colored pencils, but this isn’t required. We recommend that you call a friend to talk through the lessons and/or share your learning with someone in your household.

**What about online resources?**
This packet references several videos and websites that you can access with a phone. If you don’t have internet access on your phone, you may find it helpful to call or text a friend to ask questions. If this is not possible, just skip those suggestions and use the materials in the packet.

**What resources do I have to be successful?**
If you can access Schoology, your teacher may be providing resources on their class webpage. If not, everything you need is in this packet. You can also ask questions of your teacher by sending them an email or contacting them using their usual procedure.

**Timeline:**
This packet will take 5-6 weeks to complete. Below we have provided a suggestion on how you might work through the materials. Your teacher may provide a modified version of this schedule on their Schoology page. Please adjust for you / your family.

**Unit Driving Question**: How does a fatal disease persist in a family?
<table>
<thead>
<tr>
<th>Day</th>
<th>Activities</th>
<th>Extensions (if time allows)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>1.1 Inheritance Initial Model PowerPoint lesson&lt;br&gt;1.1 Inheritance Initial Model Worksheet</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.2 Genetics Review PowerPoint lesson&lt;br&gt;00 Genetics Vocabulary Student Worksheet (first section)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.2 Genetics – Development Self-Assessment worksheet&lt;br&gt;Then:&lt;br&gt;For extra review, watch the video in the “Extensions” section and communicate with your teacher for assistance and/or&lt;br&gt;For a challenge, read 1.1 OPTIONAL Adapted Scientific American SCA NCAA article</td>
<td>Stated Clearly: What is DNA and how does it work?&lt;br&gt;Search for these videos on YouTube</td>
</tr>
<tr>
<td>4</td>
<td>2.1 Protein to Trait PowerPoint lesson&lt;br&gt;2.1 Modeling Proteins in Cells worksheet</td>
<td>2.1 OPTIONAL Serotonin Practice</td>
</tr>
<tr>
<td>5</td>
<td>2.2 Genetics Vocabulary PowerPoint lesson&lt;br&gt;00 Genetics Vocabulary Student Worksheet&lt;br&gt;00 Learning Tracking Tool Inheritance</td>
<td>Stated Clearly: What is a gene?</td>
</tr>
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<td>6</td>
<td>2.2 Practice - Spirit Bears worksheet</td>
<td></td>
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<td>7</td>
<td>2.3 DNA to Protein PowerPoint lesson</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2.3 DNA to Protein Practice worksheet&lt;br&gt;00 Learning Tracking Tool Inheritance</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2.4 Genotype to Phenotype PowerPoint lesson&lt;br&gt;00 Genetics Vocabulary Student Worksheet</td>
<td>Stated Clearly: What is an allele?</td>
</tr>
<tr>
<td>10</td>
<td>Start 2.4 Investigating Genotype to Phenotype – Bioflower Color worksheet</td>
<td>2.4 OPTIONAL Student Questions</td>
</tr>
<tr>
<td>11</td>
<td>Finish 2.4 Investigating Genotype to Phenotype – Bioflower Color worksheet / check work using provided key&lt;br&gt;00 Learning Tracking Tool Inheritance&lt;br&gt;Make an entry in the Discussion provided on your teacher’s Schoology page (if provided)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2.5 Zooming into Sickle Cell</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Catch-up day: Finish anything from above that you haven’t done yet</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2.6 Inheritance Model Revisions Tool&lt;br&gt;00 Learning Tracking Tool Inheritance</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3.1 Chromosomes and Alleles PowerPoint lesson&lt;br&gt;00 Genetics Vocabulary Student Worksheet</td>
<td></td>
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<tr>
<td>16</td>
<td>3.1 Modeling Chromosomes with Chirwibles&lt;br&gt;00 Learning Tracking Tool Inheritance</td>
<td>3.1 OPTIONAL Modeling Chromosomes Review Questions with Chirwibles</td>
</tr>
<tr>
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<td>3.2 Introduction to Meiosis PowerPoint lesson</td>
<td>3.2 OPTIONAL Reproduction and Meiosis Reading</td>
</tr>
<tr>
<td>18</td>
<td>3.3 Meiosis Demo with Chirwibles PowerPoint lesson&lt;br&gt;00 Learning Tracking Tool Inheritance</td>
<td>3.3 OPTIONAL Meiosis Demo Analysis Questions</td>
</tr>
<tr>
<td>19</td>
<td>4.1 Making Gametes&lt;br&gt;4.1 Making Gametes Worksheet</td>
<td>4.1 OPTIONAL Punnett Square Extension - Dihybrid Cross</td>
</tr>
<tr>
<td>20</td>
<td>Make an entry in the Discussion provided on your teacher’s Schoology page (if provided)&lt;br&gt;Catch-up: Finish anything from above that you haven’t done yet</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>4.2 Inheritance Practice PowerPoint lesson&lt;br&gt;Start 4.2 Puppy Practice Problems worksheet</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Finish 4.2 Puppy Practice Problems worksheet&lt;br&gt;00 Learning Tracking Tool Inheritance</td>
<td>Challenge problems on 4.2 Puppy Practice</td>
</tr>
</tbody>
</table>
|   | 5.1 Mutations Reading  
00 Learning Tracking Tool Inheritance | Optional mutations activity:  
5.1 OPTIONAL Mutation Tables  
5.1 OPTIONAL Mutation DNA Sequences  
**Stated Clearly: Point Mutations** |
|---|---|---|
| 23 | 5.2 Explaining Sickle Cell Disease PowerPoint lesson  
5.2 Inheritance Model Revisions Tool  
Start 5.2 Inheritance Final Model | |
| 24 | Finish 5.2 Inheritance Final Model | |
| 25 | 6.1 Explaining Other Examples PowerPoint lesson | |
| 26 | 6.2 Genetics - Inheritance Self-Assessment | |
| 27 | Catch-up day: Finish anything from above that you haven’t done yet | |
How to use this PowerPoint

- Work at your own pace. Your health and your family come first.
- If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
- You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
- Read through the slides one at a time. Take your time to explore the images and any links.
- If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
- When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

3.1 Chromosomes and Alleles

Modeling Chromosomes with “Chirwibbles”

Goals
After reviewing this PowerPoint, you should be able to:

1) Compare and contrast homologous chromosomes.
2) Describe genotypes using the terms “homozygous” and “heterozygous.”
3) Explain how dominant and recessive alleles produce traits (phenotypes).
4) Model “Chirwibble” chromosomes and show how genotype produces phenotype.

Part 1 - Get out your vocabulary sheet and make notes on the next section:
Chromosomes come in PAIRS

Matching chromosomes (homologs or homologous chromosomes): one from your mom (maternal) and other from your dad (paternal).

Chromosomes come in PAIRS

Pink represents chromosomes from mother

Blue represents chromosomes from father

Pairs of chromosomes means you get two versions of each gene

There are actually TWO versions of that chromosome

Chromosomes come in PAIRS!
Homologous pairs have the same genes, but they are not always identical because the alleles can be different.

From Mother

Allele for non-functional Hemoglobin B

From Father

Allele for functional Hemoglobin B

How do the alleles from homologous chromosomes produce the traits we see?

Example: How many RED (functional) alleles are needed to produce a red flower?

<table>
<thead>
<tr>
<th>Chromosome combination</th>
<th>Allele combination</th>
<th>Observed characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>red, red</td>
<td>red, red</td>
<td>RED</td>
</tr>
<tr>
<td>red, blue (or blue, red)</td>
<td>red, blue (or blue, red)</td>
<td>RED</td>
</tr>
<tr>
<td>blue, blue</td>
<td>blue, blue</td>
<td>BLUE</td>
</tr>
</tbody>
</table>

How many RED (functional) alleles are needed to produce a red flower?

1

How many BLUE (nonfunctional) alleles are needed to produce a blue flower?

<table>
<thead>
<tr>
<th>Chromosome combination</th>
<th>Allele combination</th>
<th>Observed characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>red, red</td>
<td>red, red</td>
<td>RED</td>
</tr>
<tr>
<td>red, blue (or blue, red)</td>
<td>red, blue (or blue, red)</td>
<td>RED</td>
</tr>
<tr>
<td>blue, blue</td>
<td>blue, blue</td>
<td>BLUE</td>
</tr>
</tbody>
</table>

How many BLUE (nonfunctional) alleles are needed to produce a blue flower?

2
The combination of alleles determines the observed trait (characteristics)

Chromosome combination
- RED allele
- BLUE allele

Allele combination
- red, red
- red, blue (or blue, red)
- blue, blue

Observed characteristic
- RED
- RED
- BLUE

Homozygous – the two alleles are the same
- RR and rr are homozygous genotypes

Heterozygous – the two alleles are different
- Rr is a heterozygous genotype

Dominant and recessive alleles

Only one allele is needed for the phenotype to be seen.
- Scientists call this a DOMINANT allele

Two alleles are needed for the phenotype to be seen.
- Scientists call this a RECESSIVE allele
  (two alleles required to observe the trait)

Representing Alleles

Use CAPITAL letters to represent DOMINANT allele
- R

Use lowercase letters to represent recessive allele
- r

NOTE! They are BOTH the letter R! Usually use the first letter of the word that represents the dominant trait.
The combination of alleles determines the observed trait (characteristics).

Chromosome combination

<table>
<thead>
<tr>
<th>Chromosome combination</th>
<th>Allele combination</th>
<th>Observed characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>RR</td>
<td>RED</td>
</tr>
<tr>
<td>Rr (or rR)</td>
<td>Rr</td>
<td>RED</td>
</tr>
<tr>
<td>rr</td>
<td>rr</td>
<td>BLUE</td>
</tr>
</tbody>
</table>

Part 2 - Modeling Chromosomes with Chirwibbles

Meet a Chirwibble

Chirwibbles have 6 chromosomes, or 3 pairs of chromosomes. On those chromosomes are genes for different traits. Each Chirwibble has 2 alleles for each trait. Example of one pair:

Chirwibbles have 6 chromosomes, or 3 pairs

Chirwibbles

Green fur

Yellow fur

Curly fur

Straight fur

Big eyes

Small eyes

Long legs

Short legs

Triangle Nose

Round Nose

Curly fur

Short lashes

Green fur

Yellow fur

Curly fur

Short legs

Long lashes

Big eyes

Small eyes

Long legs

Short legs
Modeling Chromosomes Steps:

1. **Part A: Constructing Chromosomes** – You will create 3 pairs of chromosomes, a total of 6 chromosomes.
2. **Part B: Labeling Genes** – Determine which alleles come from each parent and label your chromosomes.
3. **Part C: Reviewing DNA Replication** – Use the chromosomes you set aside to model DNA replication.
4. **Part D: Analysis** – Complete the table to identify the genotype and phenotype of your Chirwibble.
5. Save your chromosomes for our next activity.

Watch this video for a demo of modeling chromosomes:


Check Your Understanding

1) Compare and contrast homologous chromosomes.
2) Describe genotypes using the terms “homozygous” and “heterozygous.”
3) Explain how dominant and recessive alleles produce traits (phenotypes).
4) Model “Chirwibble” chromosomes and show how genotype produces phenotype.

What’s Next?

1) Complete the “Modeling Chromosomes with Chirwibbles” activity, if you haven’t already.
2) Consider answering the “OPTIONAL Modeling Chromosomes Review Questions with Chirwibbles.”
3) Make an entry in your Learning Tracking Tool titled, “Chromosomes and Alleles.”
Modeling Chromosomes with Chirwibbles

Introduction: To further understand the relationship between chromosomes, DNA, genes, proteins, and traits, this activity will model the structure of the chromosomes of one individual. We will also identify the similarities and differences between homologous chromosomes.

We will use a make-believe organism for this activity: the Chirwibble. Chirwibbles have 6 chromosomes, or 3 pairs of chromosomes. On those chromosomes are genes for different traits. Each Chirwibble has 2 alleles for each trait.

Part A: Constructing Chromosomes
1. Working in a group of four, obtain 2 pieces of different colored paper.
   Construct 6 chromosomes using the figure to the right as a guide.
   a. Cut one of the pieces of paper down the middle length-wise. Then, cut each half again length-wise. You should now have four thin strips of paper.
   b. Take two of the long strips and cut them width-wise about 2/3 of the way from the top.
   c. You now have six chromosomes: two long, two medium and two short.
   d. Repeat steps a – c with the other piece (color) of paper.
   e. You should now have six pairs of chromosomes: two long pairs, two medium, and two short (of different colors).
   f. SET ½ of your strips aside (1 long, 1 medium, 1 short of EACH color) for part C – keep these safe to use later in the activity.

Part B: Labeling Genes
2. Label your two long chromosomes (these should be different colors) with gene alleles by doing the following:
   a. Each different gene will be labeled with a different letter (either uppercase or lowercase)
   b. You will need to label both long chromosomes (one of each color)
   c. There are two alleles for each gene. You will determine which allele (dominant or recessive) is present on each chromosome by flipping a coin.
     i. Toss your coin first for fur color of the Chirwibble. If your coin is “Heads” then label the gene with the symbol for the dominant allele that is a capital letter – G (green fur). If the coin is “Tails” then label the gene with the symbol for the recessive allele that is lower case – g (yellow fur).
     ii. Perform an independent coin toss for EACH maternal and paternal chromosome. They might have different alleles!
     iii. Repeat the coin toss for the ear lobe trait using the letter F now instead of G.

Location of Genes:
3. Genotypes of Maternal and Paternal Chromosomes. Refer to Table 1 to write down the paternal and maternal alleles for your chromosomes.
Label your medium and small chromosomes using the same method and the information in Table 1 (trait/gene symbol). The labeling of genes in this activity reflects the system used by scientists. The uppercase letter represents the dominant allele; the lowercase letter represents the recessive allele. An allele is a different form or variant of a gene for a specific trait. A dominant allele only needs one allele present in an individual to observe the trait. A recessive allele needs two copies of the allele to observe the trait in the individual.

**Table 1:**

<table>
<thead>
<tr>
<th>Chromosome 1 (Long)</th>
<th>Allele</th>
<th>Trait</th>
<th>Allele</th>
<th>Trait</th>
<th>Your genotype: Maternal (color 1)</th>
<th>Your genotype: Paternal (color 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G</td>
<td>Green</td>
<td>g</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Curly fur</td>
<td>f</td>
<td>Straight fur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromosome 2 (medium)</td>
<td>B</td>
<td>Big Eyes</td>
<td>b</td>
<td>Small eyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>Long eye lashes</td>
<td>e</td>
<td>Short eye lashes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromosome 3 (short)</td>
<td>N</td>
<td>Round nose</td>
<td>n</td>
<td>Triangle nose</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>Long legs</td>
<td>l</td>
<td>Short legs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Part C: Reviewing DNA Replication**

4. Take the other ½ of your strips (1 long, 1 medium, 1 short of each color) that you had in Part A and add gene labels to match those of the other six chromosomes.

5. Form a replicated chromosome by joining two identical chromosome in the middle to make an “X”. The point of attachment is called the centromere. (you can use tape to hold them together)

**Part D: Analysis**

6. Determine the genotype and phenotype of your Chirwibble by completing Table 2.

7. On a piece of scrap paper draw a picture of your Chirwibble.

**Table 2: Genotype and Phenotype of Traits**

<table>
<thead>
<tr>
<th>Genotype from example (below)</th>
<th>Phenotype from example (below)</th>
<th>Genotype of individual with your model chromosomes</th>
<th>Phenotype of individual with your model chromosomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fur Color (green/yellow)</td>
<td>Ex. Gg</td>
<td>Ex. Green</td>
<td></td>
</tr>
<tr>
<td>Fur Type (curly/straight)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye Size (big/small)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyelash Length (long/short)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose Shape (round/triangle)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Length (long/short)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example Chromosomes:
Modeling Chromosomes – Review Questions
1. Which color paper will represent your maternal chromosomes? Which color represents paternal chromosomes?
2. Using Table 1, list the maternal and paternal alleles present for each gene (trait).
3. Why do the labels in the model use different letters of the alphabet?
4. What is the significance of the uppercase letters? Of the lowercase letters?
5. Explain why the chromosomes of the same length have the same gene labels.
6. Using your model, explain the relationship between genes, chromosomes, DNA and proteins. Use examples of traits from your model to support your explanation.
7. In at least two sentences, explain how Part C models DNA replication.
8. Explain why you placed identical gene and allele labels on the replicated chromosomes as you placed on the original chromosomes.
9. Draw a complete set of your model chromosomes on your paper. Label the following parts: allele(s), gene(s), maternal chromosomes(s), paternal chromosome(s), and replicated and unreplicated chromosomes.
10. Draw Table 2 on your paper and complete the table based on the example chromosome set and your own model chromosome set.
11. Why might alleles for a given gene be different on homologous chromosomes?
12. In at least two sentences explain how an organism’s genotype determines its phenotype.
Modeling Chromosomes – Review Questions

1. Which color paper will represent your maternal chromosomes? Which color represents paternal chromosomes?
   Students select colors for maternal/paternal chromosomes, check to be sure they are different color from one another.

2. Using Table 1, list the maternal and paternal alleles present for each gene (trait).
   Students will list all alleles on ONE color of chromosomes. For the chromosomes below in #9:
   Maternal: gf, be, nl
   Paternal: Gf, Be, NL

3. Why do the labels in the model use different letters of the alphabet?
   Each letter represents a different gene.

4. What is the significance of the uppercase letters? Of the lowercase letters?
   Uppercase letters represent dominant gene version/allele while the lowercase letters represent a recessive gene version/allele.

5. Explain why the chromosomes of the same length have the same gene labels.
   Chromosomes of the same length are homologous, they will always have the same genes (gen labels) but they may not always
   be identical because they may have different gene versions or alleles.

6. Using your model, explain the relationship between genes, chromosomes, DNA and proteins. Use examples of traits from your
   model to support your explanation.
   The model is a chromosome which is coiled up DNA. Segments of DNA is a gene that code for a specific protein. Example:
   Chromosome two has a gene for eye size. The DNA will either code to make small eyes or big eyes, two different versions.

7. In at least two sentences, explain how Part C models DNA replication.
   DNA replication is when the unreplicated chromosome replicates to make a copy of itself. In part C we added a second half of
   our paper strip which modeled DNA replication.

8. Explain why you placed identical gene and allele labels on the replicated chromosomes as you placed on the original
   chromosomes.
   We placed identical gene and allele labels on the replicated chromosomes because they are exact copies of each other so they
   must have the same gene and allele labels.

9. Draw a complete set of your model chromosomes on your paper. Label the following parts: allele(s), gene(s), maternal
   chromosomes(s), paternal chromosome(s), and replicated and unreplicated chromosomes.

10. Draw Table 2 on your paper and complete the table based on the example chromosome set and your own model chromosome
    set.

11. Why might alleles for a given gene be different on homologous chromosomes?
    The alleles on the homologous chromosomes may be different because they came from different people one homologous
    chromosome came from mom, one came from dad. They may be the same and they may be different.

12. In at least two sentences explain how an organism’s genotype determines its phenotype.
    The genotype is the two alleles that an organism has for the trait, one that came from mom, the other from dad.
    The phenotype is the how the combination of the alleles are expressed, an observed trait.
How to use this PowerPoint

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Goals
After reviewing this PowerPoint, you should be able to:
1) Describe how DNA is inherited from parents to offspring in sexual reproduction.
2) Compare and contrast meiosis and mitosis.
3) Explain why siblings don’t look the same (unless they are identical twins).

3.2 Introduction to Meiosis
How do you inherit DNA?

We learned in the last activity that chromosomes come in pairs, and that one comes from the biological mother and one from the biological father.
This means parents pass on HALF of their chromosomes to their offspring in the sperm or egg.

But how are sperm and eggs formed?

Sperm and eggs are formed in a new kind of cell division called MEIOSIS.

Meiosis is two cell divisions that divides homologous chromosomes to produce cells with half the number of chromosomes.

Meiosis vs. Mitosis

Watch this video: [https://www.youtube.com/watch?v=D1_-mQ5_F20](https://www.youtube.com/watch?v=D1_-mQ5_F20)

- An individual produces a variety of sperm or egg cells (gametes)
- In sexual reproduction the egg from the biological mother combines with the sperm from the biological father to form a fertilized egg (zygote)

Why don’t siblings look the same?

(unless they are identical twins)
Meiosis produces a variety of gametes

Different homologous pairs separate ( assort) independent of each other

Homologous chromosomes can recombine = exchanging genetic info between chromosomes

Recombination or “crossing over” leads to the formation of allele combinations in the offspring that are different from either parent

Sexual reproduction increases variation

Which sperm will fuse with an egg? Fertilization is random!

Check out this video to see how a single sperm fuses with an egg to form a zygote – the single cell that will become a complex, multicellular organism.

https://www.youtube.com/watch?v=_5OvgQW6FG4 (especially time 4:00 on to see how the chromosomes from sperm and egg join to make the zygote)
Check out this video that shows the steps in meiosis:

(watch time 0-1:49)
https://www.youtube.com/watch?v=nMEyeKQClql

Check Your Understanding
1) Describe how DNA is inherited from parents to offspring in sexual reproduction.
2) Compare and contrast meiosis and mitosis.
3) Explain why siblings don’t look the same (unless they are identical twins).

What’s Next?
Consider reading “OPTIONAL Reproduction and Meiosis Reading” to learn more and clarify your understanding of meiosis.
Lesson 3.2: Introduction to Meiosis

1. **Review:** Explain how you inherit your DNA. What do you inherit from your biological mother? What do you inherit from your biological father?

2. **Prediction:** How much of their genetic information does each parent pass on to an offspring? *(circle one)*

   - All
   - Half
   - None
   - Some

   Explain your prediction:

3. **Define** meiosis in your own words. Be certain to include the following terms: homologous chromosomes, sperm, egg, parent cell.

4. **Compare and contrast:**
   While watching the Mitosis vs. Meiosis Video identify similarities and differences between these two types of cell division.

<table>
<thead>
<tr>
<th>similarities:</th>
<th>differences:</th>
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</table>

5. Gametes are the cells used in reproduction.
   a. What type of gamete is produced by biological males?
   b. What type of gamete is produced by biological females?

6. **Explain** what is (or might be) different about the gametes inherited by biological siblings (who are not identical twins)?

7. Meiosis leads to the variation in a species. **Summarize** three ways that meiosis leads to variation:
   a. Independent assortment:
   b. Recombination/crossing over:
   c. Fertilization:

8. After watching the video about the steps of meiosis, **summarize** the process of meiosis in your own words.
Reproduction and Meiosis

All Cells Come From Other Cells
While the production of new cells results in growth and repair within organisms, cell division also has an essential role in the reproduction of entire organisms. Some organisms reproduce by simple cell division, in which a single cell or group of cells each duplicates its genetic material and then splits into two new genetically identical cells. This process, which is known as asexual reproduction, produces offspring that inherit all of their genetic material from a single parent. Bacteria and many other single-celled organisms frequently reproduce this way. In contrast, when two parents are involved in the production of offspring, the process is called sexual reproduction. In sexual reproduction, genetic material from two parents combine, producing offspring that are genetically different from either parent.

Sex Cells are Special
In order to reproduce sexually, specialized sex cells such as the sperm and egg are produced. These sex cells are called gametes. Gametes contain half as many chromosomes as the rest of the cells in the organism’s body. For example, in humans the cells of the body contain 46 chromosomes that can be arranged as 23 pairs. Cells with two copies of each chromosome are known as diploid cells. In contrast, the gametes (egg and sperm) only contain one set of 23 chromosomes, and known as haploid cells because they have a single copy of each chromosome. Because the egg and sperm both contain a single set of chromosomes, when they unite in a process known as fertilization, a new individual known as a zygote is formed. This combination of two sets of chromosomes results in a diploid cell (and an offspring) with a complete set of 23 homologous chromosome pairs.

Meiosis Produces Gametes
Sexual reproduction depends on a process called meiosis. Meiosis is a special type of cell division that produces four cells (gametes), each with a single set of chromosomes. Before meiosis, a cell contains a maternal copy (from female parent) and a paternal copy (from male parent) of each of the 23 human chromosomes. Together, the maternal and paternal copies of a single chromosome are called a homologous pair, or homologues. The DNA in homologous chromosomes contains the same genes at the same locations in the chromosome, but may have different alleles. Therefore homologous chromosomes have nearly identical nucleotide sequences, but not exactly. Meiosis separates homologues into different gametes. Accordingly, these different gametes can have different combinations of alleles. The combination of alleles in a cell is known as the genotype. The genotype of the individual serves as the instructions for the proteins produced, leading to the observable traits, or phenotype, of the organism.

The Stages of Meiosis
The stages of meiosis are highly similar to mitosis and make use of the same cell machinery, but a number of key differences reduce the chromosomes from a diploid set to a haploid set. While mitosis has a single cell division, meiosis uses two cell divisions. In the first division, homologues separate. In the second division, the two new cells divide again, and at this division the sister chromatids separate from each other into two newer cells. At the end of meiosis, there are four new cells (gametes), each of which has a total of 23 chromosomes.
1. **Interphase** – Before meiosis begins, preparations for cell division occur that are nearly identical to those before mitosis. Proteins are produced that are needed to perform the two cell divisions of meiosis and chromosomes replicate with sister chromatids remaining paired at the centromeres.

2. **Meiosis I – The Homologous Chromosomes Separate**
   Meiosis I follows a similar process as mitosis. However, during prophase I as chromosomes condense, homologous chromosomes line up and pair so that four versions of the chromosome (each a sister chromatid) come together. In illustrations of this process, the different colors of homologues show that one chromosome was originally inherited from the male parent and the other from the female parent. Once the homologues have paired, the sister chromatids of adjacent homologous chromosomes exchange some DNA in a process called **crossing over**. After crossing over, meiosis continues and each pair of homologous chromosomes is lined up in the center of the cell. The homologous chromosomes are then pulled to opposite ends of the cell randomly. As a result, the pairs of sister chromatids present in the new nuclei that form at the end of meiosis I are a mix of both maternal and paternal sister chromatids. After Meiosis I, the sister chromatids are still attached at the centromere.

3. **Meiosis II – The Sister Chromatids Separate**
   In a process identical to mitosis, meiosis II separates sister chromatids into separate new cells. What is different from mitosis is there is no round of DNA replication between meiosis I and meiosis II since chromosomes are already arranged in sister chromatid pairs held together at their centromere. Meiosis is completed after new nuclei are formed and the cytoplasm is divided, creating four haploid daughter cells, each with just one set of 23 individual chromosomes (in humans).

**Meiosis Increases Genetic Variation**
There are four ways that meiosis increases the genetic variation in a population. First, when homologous chromosomes are separated at anaphase I, maternal and paternal homologues separate to each side of the cell randomly. For example, for chromosome 1, the maternal homologue may go to the “top” spindle pole, while the paternal homologue travels to the opposite. However, this may not be the case for other homologous pairs, and the paternal homologue may be separated to the “top.” In humans, this means there are $2^{23}$ combinations of maternal and paternal chromosomes possible during meiosis. Secondly, **crossing over**, the exchange of DNA between homologues, (during prophase I) significantly increases genetic variation because it leads to new combinations of alleles. Therefore, this forms chromatids that have some alleles from each parent. Third, genetic variation is also increased by mutation during gamete formation. When a mutation in DNA occurs in a body cell (a non-gamete), the mutation is not passed on to offspring. However, when a mutation occurs in a gamete (or in the production of a gamete), that mutation can be inherited if the gamete is successfully involved in reproduction. Lastly, variation occurs because when sperm fertilize an egg, this fertilization is random. There is a random chance that any of millions of possible sperm, each with a unique combination of alleles (genotype) is the first to fertilize the available egg.
How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
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• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals
After reviewing this PowerPoint, you should be able to:

1) Describe the process of meiosis including the two rounds of cell division.
2) Describe recombination / crossing over of homologous chromosomes.
3) Describe the gametes formed in meiosis including the number of cells formed and the number of chromosomes they contain.

3.3 Meiosis Demo with Chirwibbles

Follow along with this demo using Chirwibble chromosomes:
https://www.youtube.com/watch?v=He8VTUw7NL4&feature=youtu.be
Practice: Can you put these images in order?

Check Your Understanding
1) Describe the process of meiosis including the two rounds of cell division.
2) Describe recombination / crossing over of homologous chromosomes.
3) Describe the gametes formed in meiosis including the number of cells formed and the number of chromosomes they contain.

What’s Next?
1) Consider completing “OPTIONAL Meiosis Demo Analysis Questions.”
2) Make an entry in your Learning Tracking Tool titled, “3.2 and 3.3 Meiosis.”
Fertilization

After gametes are formed, the next step is fertilization. Choose two of your gametes at random. (Note: Typically these gametes would come from two different parents.)

1. Record one gamete’s genotype (alleles). This is the set of 6 letters from above: ___ ___ ___ ___ ___ ___

2. Record the other gamete’s genotype: ___ ___ ___ ___ ___ ___

3. What is the genotype and phenotype of the resulting offspring? Draw the Chirwibble using the circle below.

Additional analysis

4. Why aren’t all the gametes the same?

5. If all the offspring came from genetically identical parents, would all the offspring be identical? Explain.

6. A disorder like down syndrome occurs when a replicated chromosome doesn’t separate during the second cell division of meiosis (see image below). How many chromosomes would a Chirwibble have if one pair of chromosomes didn’t split at this point?
How to use this PowerPoint

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• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals

After reviewing this PowerPoint, you should be able to:
1) Show how gametes are formed in meiosis.
2) Given the genotype of the parent, predict the possible gametes produced.
3) Use a egg-sperm chart (Punnett square) to predict all the possible genotypes and phenotypes in the offspring from two parents.

4.1 Making Gametes

Meiosis and Punnett Squares

After Meiosis...

The gametes will have:

HALF the total chromosomes
HALF the alleles
SAME NUMBER of genes

You need to pass on every gene you have, but only one copy of each gene = ONE allele
Simplifying meiosis and gamete formation...

Meiosis gives half the gametes one allele and half the gametes get the other allele.

So, half get R and half get r.

Check your work.

What are the possible combinations of sperm and eggs?

Making Gametes Worksheet

Complete the front side of the worksheet. Use what you learned about meiosis to help fill in the steps.
Possible Combinations

Mother (Rr)  

Father (Rr)  

R = red  

r = blue  

= non-functional

Egg-sperm charts (Punnett squares) organize all possible offspring combinations from two parents

Mother (Rr)  

Father (Rr)  

Egg-sperm charts give the **probability** of offspring genotypes and phenotypes possible from two parents

<table>
<thead>
<tr>
<th>Genotype probabilities</th>
<th>Phenotype probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% RR</td>
<td>75% red</td>
</tr>
<tr>
<td>50% Rr</td>
<td>25% blue</td>
</tr>
<tr>
<td>25% rr</td>
<td></td>
</tr>
</tbody>
</table>

Now you practice

Complete the second page of the Making Gametes Worksheet.
Check Your Understanding

1) Show how gametes are formed in meiosis.
2) Given the genotype of the parent, predict the possible gametes produced.
3) Use a egg-sperm chart (Punnett square) to predict all the possible genotypes and phenotypes in the offspring from two parents.

What’s Next?
1) Complete the “4.1 Making Gametes Worksheet.”
2) Challenge: Try the “OPTIONAL Punnett Square Extension – Dihybrid Cross.”
Making Gametes

1. Making Gametes – Single Trait Cross
In this activity we will model how alleles are separated into gametes, increasing the variation that exists in a population. Use the following images to diagram the phases of meiosis that the given cell would go through to make four gametes. Remember that while the parent cell contains two copies of the genetic information, each gamete contains only a single copy.

- Use Figure 1 to show how gametes are formed by meiosis from a given parent cell. Draw the appropriate chromosomes and alleles in each cell. Identify the genotype of each of the gametes produced.

- Draw the phases of meiosis that a cell with one G and one g allele would go through during meiosis.

Figure 1:

Green Fur allele: G
Yellow Fur allele: g

Parent Cell
(Interphase)
Genotype: __________

Prophase I:
(Replication?)

Metaphase I:
(How do chromosomes line up?)

Gamete Genotype: ______
Gamete Genotype: ______
Gamete Genotype: ______
Gamete Genotype: ______
2. Predicting the Variation in Offspring

In this activity we will use the possible gametes an individual can produce to predict the outcome of the mating (cross) with another individual. Using a Punnett square, we can predict the possible genotypes and phenotypes of the offspring. Remember that each individual has two alleles for each gene, while a gamete only has a single allele for each gene.

- Identify the possible gametes that can be formed by individuals, each with a G and g allele for the fur color gene.
- Use the gametes to complete a Punnett Square

**Figure 2:**

![Punnett Square Diagram]

**Figure 3:**

- Create a Punnett Square
- Enter the possible gametes from one parent at the top of the Punnett square
- Enter the possible gametes of the other parent along the left side of the Punnett square
- Fill alleles down, or across, complete the Punnett square
- The new combinations of alleles in the Punnett square represent possible offspring produced by the cross.

Possible offspring genotypes and how many of each genotype in the Punnett square:

Possible offspring phenotypes and how many of each phenotype in the Punnett square:
Genetic Inheritance in Meiosis – Single Trait Crosses

1. Making Gametes – Single Trait Cross
In this activity we will model how alleles are separated into gametes, increasing the variation that exists in a population. Use the following images to diagram the phases of meiosis that the given cell would go through to make four gametes. Remember that while the parent cell contains two copies of the genetic information, each gamete contains only a single copy.

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- Draw the phases of meiosis that a cell with one G and one g allele would go through during meiosis.

Figure 1:

Green Fur allele: G
Yellow Fur allele: g

Parent Cell (Interphase)
Genotype: Gg

Prophase I: (Replication?)
or crossing over may occur

Metaphase I: (How do chromosomes line up?)

Metaphase II: (How do chromosomes line up?)

Gamete Genotype: G
Gamete Genotype: g
Gamete Genotype: G
Gamete Genotype: g
2. Predicting the Variation in Offspring

In this activity we will use the possible gametes an individual can produce to predict the outcome of the mating (cross) with another individual. Using a Punnett square, we can predict the possible genotypes and phenotypes of the offspring. Remember that each individual has two alleles for each gene, while a gamete only has a single allele for each gene.

- Identify the possible gametes that can be formed by individuals, each with a G and g allele for the fur color gene.
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Figure 2:

Figure 3:

- Create a Punnett Square
- Enter the possible gametes from one parent at the top of the Punnett square
- Enter the possible gametes of the other parent along the left side of the Punnett square
- Fill alleles down, or across, complete the Punnett square
- The new combinations of alleles in the Punnett square represent possible offspring produced by the cross.

Possible offspring genotypes and how many of each genotype in the Punnett square:

\[ GG, Gg (2), gg \]

Possible offspring phenotypes and how many of each phenotype in the Punnett square:

"green fur (3) or yellow fur (1)

Gg/Gg"
Genetic Inheritance in Meiosis – Dihybrid Crosses

1. Making Gametes
In this activity we will model how alleles are separated into gametes and assist in generating the variation that exists in organisms. For each example, use the following images to diagram the phases of meiosis that the given cell would go through to make four gametes. Remember that while the parent set contains two copies of the genetic information, each gamete only contains a single copy.

- Use the diagrams provided to show how gametes would be formed by the process of meiosis from the parent cell. Draw the appropriate chromosomes and alleles in each cell. Identify the genotype of each of the gametes produced.
- Draw the phases of meiosis that a cell with one functional and one nonfunctional allele for Cystic Fibrosis Transmembrane Regulator protein channels (CFTR), and one functional allele and one nonfunctional allele for the TSR receptor would go through during meiosis. These genes are on different chromosomes.

Parent Cell (Interphase – Before DNA replication)

Prophase I: (After DNA replication)

Metaphase I: (How do chromosomes line up?)

Metaphase II: (How do chromosomes line up?)

Gamete Genotype: ________
Gamete Genotype: ________
Gamete Genotype: ________
Gamete Genotype: ________

Functional CFTR allele: F
Nonfunctional CFTR allele: f

Functional TSR receptor allele: R
Nonfunctional TSR receptor allele: r
2. Predicting the Variation in Offspring
In this activity we will use the possible gametes an individual can produce to predict the outcome of the mating (cross) with another individual. An egg-sperm chart (Punnett square) will allow us to predict the possible genotypes and phenotypes of the offspring. Remember that each individual has two alleles for each gene, while a gamete only a single allele for each gene.

- Identify the possible gametes that can be formed by individuals, each with a functional and a nonfunctional allele for the CFTR gene and for the TSR receptor. Place the genotype for the parents and possible gamete genotypes in the circles. (Hint: Consider the gametes from Part 1)

- Create a Punnett Square
- Enter the possible gametes from one parent at the top of the Punnett square
- Enter the possible gametes of the other parent along the left side of the Punnett square
- Fill alleles down, or across, complete the Punnett square
- The new combinations of alleles in the Punnett square represent possible offspring produced by the cross.
- Make a key to help identify possible offspring genotypes and phenotypes

Possible offspring genotypes and how many of each genotype in the Punnett square:

Possible offspring phenotypes (traits we see) and how many of each phenotype in the Punnett square:
Genetic Inheritance in Meiosis – Dihybrid Crosses

1. Making Gametes
In this activity we will model how alleles are separated into gametes and assist in generating the variation that exists in organisms. For each example, use the following images to diagram the phases of meiosis that the given cell would go through to make four gametes. Remember that while the parent set contains two copies of the genetic information, each gamete only contains a single copy.

- Use the diagrams provided to show how gametes would be formed by the process of meiosis from the parent cell. Draw the appropriate chromosomes and alleles in each cell. Identify the genotype of each of the gametes produced.
- Draw the phases of meiosis that a cell with one functional and one nonfunctional allele for Cystic Fibrosis Transmembrane Regulator protein channels (CFTR), and one functional allele and one nonfunctional allele for the TSR receptor would go through during meiosis. These genes are on different chromosomes.

**Functional CFTR allele:** F
**Nonfunctional CFTR allele:** f

**Functional TSR receptor allele:** R
**Nonfunctional TSR receptor allele:** r

Parent Cell (Interphase – Before DNA replication)

Prophase I: (After DNA replication) then homologous pair up/crossing over occurs

Metaphase I: (How do chromosomes line up?)

Gamete Genotype: FR
Gamete Genotype: Ff
Gamete Genotype: Ff
Gamete Genotype: Fr
Gamete Genotype: fr
2. Predicting the Variation in Offspring

In this activity we will use the possible gametes an individual can produce to predict the outcome of the mating (cross) with another individual. Then, a Punnett square, we will allow us to predict the possible genotypes and phenotypes of the offspring. Remember that each individual has two alleles for each gene, while a gamete only a single allele for each gene.

- Identify the possible gametes that can be formed by individuals, each with a functional and a nonfunctional allele for the CFTR gene and for the TSR receptor. Place the genotype for the parents and possible gamete genotypes in the circles. *(Hint: Consider the gametes from Part 1)*

- Create a Punnett Square
- Enter the possible gametes from one parent at the top of the Punnett square
- Enter the possible gametes of the other parent along the left side of the Punnett square
- Fill alleles down, or across, complete the Punnett square
- The new combinations of alleles in the Punnett square represent possible offspring produced by the cross.
- Make a key to help identify possible offspring genotypes and phenotypes

Possible offspring genotypes and how many of each genotype in the Punnett square:

<table>
<thead>
<tr>
<th>FR</th>
<th>fr</th>
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<th>FR</th>
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<tbody>
<tr>
<td>FR</td>
<td>FFRR</td>
<td>FfRR</td>
<td>FfRr</td>
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<td>fr</td>
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<tr>
<td>FR</td>
<td>FfRR</td>
<td>Ffrr</td>
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<td>FR</td>
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<tr>
<td>FR</td>
<td>FfRR</td>
<td>Ffrr</td>
<td>FFrr</td>
</tr>
</tbody>
</table>

Possible offspring phenotypes (traits we see) and how many of each phenotype in the Punnett square:

- Functional CFTR/normal
- Functional CFTR/normal
- Functional TSR/roll
- Functional TSR/roll
- Nonfunctional CFTR/cystic fibrosis
- Nonfunctional CFTR/cystic fibrosis
- Nonfunctional TSR/roll
- Nonfunctional TSR/roll
How to use this PowerPoint

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• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

### 4.2 Inheritance Practice

**Goals**

After reviewing this PowerPoint, you should be able to:

1) Identify the genotype and phenotype of an individual given information about the genes.

2) Predict the possible gametes produced by an individual given their genotype and/or phenotype.

3) Use egg-sperm charts (Punnett squares) to predict possible genotypes and phenotypes.

**Warm Up**

Chelizabeth and Chandrew are partners who have had several Chirwibble children together. Below are their chromosomes #1 (only some of the genes are shown).

1. Given the chromosomes of her parents, explain and draw how is it possible that their daughter Chebecca’s chromosomes #1 look like this:

2. Chelizabeth and Chandrew notice that all of their children with curly fur (F) also have a round jaw (J). Explain why this is.
Order of Operations: Genetics Problems

1. Identify the genotypes of the parents
2. Identify the possible gametes each parent can produce (genotype of potential egg or sperm)
3. Complete the egg-sperm chart (Punnett Square)
4. Identify the percentage of each possible offspring genotype
5. Identify the percentage of each possible offspring phenotype

Reviewing Possible Gametes:

- Genotypes: What are the possible gametes?
  - TT
  - Tt
  - aa
  - Bb
  - DdBb

More Practice

1. A dog has the alleles BB for fur color. What is the genotype of the gametes it can produce?
2. A cat is heterozygous for tabby stripes (gene T). What is the genotype of the gametes it can produce?
3. A horse is homozygous recessive for blue eyes (gene E). What is the genotype of the gametes it can produce?
4. A pumpkin has the alleles GG for growing giant pumpkins. It is also heterozygous for color (gene O). What is the genotype of the gametes it can produce?
More Practice

1. Gametes = B or B
2. Gametes = T or t
3. Gametes = e or e
4. Gametes = GO, Go, GO or Go = use FOIL

Check Your Understanding

1) Identify the genotype and phenotype of an individual given information about the genes.
2) Predict the possible gametes produced by an individual given their genotype and/or phenotype.
3) Use egg-sperm charts (Punnett squares) to predict possible genotypes and phenotypes.

What’s Next?

1) Finish the “4.2 Puppy Practice Problems.”
2) Make an entry in your Learning Tracking Tool titled, “Making Gametes and Inheritance.”

Now complete the “4.2 Puppy Practice Problems” worksheet.
Inheritance Practice – Lots of Puppies!

In this activity, we will examine patterns of inheritance in a litter of puppies. The puppies, like all dogs, have a total of 78 chromosomes – this means 39 homologous pairs. We will focus on four different traits that are coded for by four genes on the 7th chromosome of the dogs*. The table to the right shows the genes, traits, and associated alleles we will be investigating.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Dominant allele</th>
<th>Recessive allele</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair length</td>
<td>Short (L)</td>
<td>Long (l)</td>
</tr>
<tr>
<td>Hair texture</td>
<td>Wiry (T)</td>
<td>Silky (t)</td>
</tr>
<tr>
<td>Hair Curliness</td>
<td>Curly (H)</td>
<td>Straight (h)</td>
</tr>
<tr>
<td>Coat Pattern</td>
<td>Spotted (A)</td>
<td>Solid (a)</td>
</tr>
</tbody>
</table>

Part A: Examine the homologous chromosomes of the two parent dogs below. Note that these are the chromosomes of the parent dogs in each body cell. The female is named Ariel while the male is named Bull.

1. Identify the phenotypes of the two parent dogs.

2. Explain how each of the parent dogs pass on one homologous chromosome to each of their puppies.

Part B: Ariel and Bull have a litter of 8 puppies. The dog owners are amazed that all the puppies look the same even though they know each puppy is a result of an independent fertilization event (female dogs often release 6-12 eggs at a time). Assume that all the traits are completely dominant (there is no intermediate trait).

3. What is the genotype of the puppies? Draw the homologous pair of chromosome #7 that one of your puppies inherited.

4. What is the phenotype of the puppies?

5. For which traits are the puppies homozygous? For which traits are the puppies heterozygous?

* These genes and traits are not actually located on dog Chromosome 7 and are simplified for the purpose of this activity.
6. Explain why all the puppies have the same traits as each other.

**Part C:** The dog owners keep one of the puppies and name her Sunny. When Sunny is older, the owners cross her with a friend’s dog named Brisket who has long, straight, silky hair, and has a solid coat pattern (not spotted). Sunny and the neighbor’s dog have eight puppies.

7. What is the genotype of the friend’s dog? Draw the homologous pair of chromosome #7.

8. How many of the puppies do you predict will have curly hair? Use an egg-sperm chart in your answer.

9. How many of the puppies do you predict will have silky hair? Use an egg-sperm chart in your answer.

10. Based on your answer to Question 9, explain how it would still be possible for all the puppies to have silky hair.

**Challenge Question:** The dog owners notice that puppies with silky hair also have a spotted coat. They also notice that puppies with wiry hair have a solid coat pattern. Based on the chromosomes of the mother dog Sunny (Your answer to Question 3), explain why these traits seem to be inherited together.

**Challenge Question:** The dog owners have a second litter of puppies with Sunny and the friend’s dog (Brisket - from Part C). They are amazed to see new variation in their puppies!

One of the puppies has a silky, solid (not spotted) coat. Explain how crossing over during meiosis of the mother dog could have led to this combination of traits. Draw a model of what the mother’s (Sunny’s) homologous chromosomes must have looked like during metaphase I of meiosis to support your answer. Be certain to label the alleles for each gene in your model.
In this activity, we will examine patterns of inheritance in a litter of puppies. The puppies, like all dogs, have a total of 78 chromosomes – this means 39 homologous pairs. We will focus on four different traits that are coded for by four genes on the 7th chromosome of the dogs*. The table to the right shows the genes, traits, and associated alleles we will be investigating.

**Part A:** Examine the homologous chromosomes of the two parent dogs below. Note that these are the chromosomes of the parent dogs in each body cell. The female is named Ariel while the male is named Bull.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Dominant allele</th>
<th>Recessive allele</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair length</td>
<td>Short (L)</td>
<td>Long (l)</td>
</tr>
<tr>
<td>Hair texture</td>
<td>Wiry (T)</td>
<td>Silky (t)</td>
</tr>
<tr>
<td>Hair Curliness</td>
<td>Curly (H)</td>
<td>Straight (h)</td>
</tr>
<tr>
<td>Coat Pattern</td>
<td>Spotted (A)</td>
<td>Solid (a)</td>
</tr>
</tbody>
</table>

1. Identify the phenotypes of the two parent dogs.

   Ariel – short, silky, curly, spotted fur  
   Bull – long, wiry, curly, solid fur

2. Explain how each of the parent dogs pass on one homologous chromosome to each of their puppies.

   During meiosis each dog will produce gametes (sperm or eggs) that contain one of their two chromosomes for Chromosome #7. Their puppy will have one copy of Chromosome #7 from Ariel and one from Bull.

**Part B:** Ariel and Bull have a litter of 8 puppies. The dog owners are amazed that all the puppies look the same even though they know each puppy is a result of an independent fertilization event (female dogs often release 6-12 eggs at a time). Assume that all the traits are completely dominant (there is no intermediate trait).

3. What is the genotype of the puppies? Draw the homologous pair of chromosome #7 that one of your puppies inherited.

   LlTtHHAa

4. What is the phenotype of the puppies?

   Short, wiry, curly, spotted fur

5. For which traits are the puppies homozygous? For which traits are the puppies heterozygous?

   *These genes and traits are not actually located on dog Chromosome 7 and are simplified for the purpose of this activity.*
6. Explain why all the puppies have the same traits as each other.

The puppies all have the same traits because both parent are homozygous for all 4 traits, so they passed on the same alleles to each puppy.

Part C: The dog owners keep one of the puppies and name her Sunny. When Sunny is older, the owners cross her with a friend’s dog named Brisket who has long, straight, silky hair, and has a solid coat pattern (not spotted). Sunny and the neighbor’s dog have eight puppies.

7. What is the genotype of the friend’s dog? Draw the homologous pair of chromosome #7.

8. How many of the puppies do you predict will have curly hair? Use an egg-sperm chart in your answer.

   H | H
---|---
H | H
H | H

All curly

9. How many of the puppies do you predict will have silky hair? Use an egg-sperm chart in your answer.

   t | t
---|---
T | T
T | T
t | t

½ will have silky fur

10. Based on your answer to Question 9, explain how it would still be possible for all the puppies to have silky hair.

Yes, it would still be possible because each parent randomly passes on one of their two chromosomes.

Challenge Question: The dog owners notice that puppies with silky hair also have a spotted coat. They also notice that puppies with wiry hair have a solid coat pattern. Based on the chromosomes of the mother dog Sunny (Your answer to Question 3), explain why these traits seem to be inherited together.

The genes that are closer together on the chromosome are more likely to stay together (not be split apart during crossing over).

Challenge Question: The dog owners have a second litter of puppies with Sunny and the friend’s dog (Brisket - from Part C). They are amazed to see new variation in their puppies!

One of the puppies has a silky, solid (not spotted) coat. Explain how crossing over during meiosis of the mother dog could have led to this combination of traits. Draw a model of what the mother’s (Sunny’s) homologous chromosomes must have looked like during metaphase I of meiosis to support your answer. Be certain to label the alleles for each gene in your model.
Sunny's chromosomes

 traded Sections
 crossing over occurs here or between t and A
 l t H A

 Brisket's chromosomes

 after crossing over

 l t H A

 In Metaphase I of meiosis:

 Puppy with silky, solid coat's chromosomes

 from Sunny

 l t H A

 from Brisket

 l t H A

 Genotype: l t t t H h a a g

 Phenotype: silky solid

 KEY
**Mutations Reading**

**What is a mutation?**
A mutation is any change in the DNA nucleotide sequence. When a mutation occurs, a new allele (version) of a gene is formed.

**What causes mutations?**
Some mutations are inherited from your parents. The particular allele for a gene that you inherit may have been the product of a mutation that occurred many generations ago.

New mutations can also occur over the course of a person’s life due to mistakes in cell division or because of environmental factors such as smoking or exposure to UV light. You can reduce your risk for new mutations by avoiding tobacco and alcohol, exercising regular, and getting regular check-ups from your doctor.

**What is the impact of mutations?**
Many mutations have no effect on the person at all. Sometimes mutations are helpful, like when alleles for a gene code for useful versions of proteins. These may increase in the population, as we will see in the Evolution Unit. Other mutations produce alleles that code for non-functional proteins, resulting in negative impacts on individuals.

Mutations have an impact, positive or negative, when the change in the DNA sequence results in a change in the proteins produced in a cell. Recall that genes are sections of the DNA which code for proteins.

**Types of mutations**

- **Point/substitution**
  - A point or substitution is a mutation that exchanges one nitrogenous base for another (i.e., a change in a single nucleotid such as switching an A to a G).

- **Insertion**
  - Insertions are mutations in which extra nucleotides are inserted into a new place in the DNA.

- **Deletion**
  - Deletions are mutations in which a section of DNA is lost, or deleted.

**Effect of mutations on protein structure**

1. A DNA mutation that results in the same amino acid (doesn’t change the protein). This occurs because there are 20 amino acids, but 64 codons. Some codons produce the same amino acids!
2. A mutation that produces a different amino acid. This may change protein folding and shape. This is the case with Sickle Cell Disease.

| DNA sequence: | T A C G G A G A T T C A |
| amino acid sequence: | Met -- Ala -- Leu -- Ser |
| DNA sequence: | T A C C G A G A T T C A |
| amino acid sequence: | Met -- Ala -- Iso -- Ser |
3. A mutation that produces an early “STOP” in the middle of a protein. This shortens the protein and changes its shape. Duchenne muscular dystrophy (DMD) is caused by a nonsense mutation.

Do mutations cause cancer?
Only some mutations cause cancer. Cancer occurs when mutations have affected the genes that control the cell cycle, resulting in uncontrolled cell division. There are many different types of cancer because usually a new mutation has occurred in one location, such as a cell in the lung.

Some people inherit mutations that increase their cancer risk. It is a good idea to talk to your doctor if there is a history of cancer in your family.

So why are the individuals in a population different from one another?
There is variation between individuals for several reasons:
1. Meiosis creates new combinations of alleles that are passed on during reproduction
2. Mutations may occur because of mistakes during DNA replication
3. Mutations caused by environmental factors such as exposure to tobacco and UV light

How much variation exists between people?
About 1 in every 1,000 nucleotides is different between 2 people (0.1% difference means 99.9% identical). We have about 3 billion nucleotides in all, so there are about 3 million nucleotide differences between 2 people. All this amazing variety is the product of mutations that have occurred over millions of years!

Reading Questions:
1. What would cause an individual to have a mutation in the DNA of just one or some of their cells? What would cause an individual to have a mutation in all of their cells?
2. How are DNA mutations related to changes in proteins and traits?
3. Why is there variation between individuals in a population?
Mutations Table

**Directions:** Circle the mutation on the Mutations Worksheet. Fill out the table below.

<table>
<thead>
<tr>
<th>Describe the mutation</th>
<th>Type of mutation: 1. Point/substitution 2. Insertion 3. Deletion</th>
<th>Describe any change in the amino acid sequence Ex. “Tyrosine changed to STOP”</th>
<th>Effect of mutation: 1. No change in protein 2. Different amino acid 3. Early “STOP” resulting in shortened protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex. “In the third codon G changed to T”</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Which types of mutations have the biggest effect on the protein? Explain.

Which types of mutations have the smallest effect on the protein? Explain.
Compare the DNA Sequences

Directions: Circle the difference(s) in the DNA sequence. Then use the DNA to amino acid codon wheel to determine the amino acid sequence. Circle the difference(s) in the DNA sequence.

Original DNA:  ATG  CAA  GGT  CTC  GAA  GGG  ACG  AAA  TAT  CAT  GTA  CCA  CGA  GAT  CTA  TGA

Mutation 1:     ATG  CAA  GGT  CTC  GAA  GGG  ACG  AAA  TAA  CAT  GTA  CCA  CGA  GAT  CTA  TGA

Mutation 2:     ATG  CAA  GGT  CTC  GAA  GGT  ACG  AAA  TAT  CAT  GTA  CCA  CGA  GAT  CTA  TGA

Mutation 3:     ATG  CAA  GGT  CTC  GAA  GGG  ACG  AAA  TAT  CAA  GTA  CCA  CGA  GAT  CTA  TGA

Mutation 4:     ATG  CAA  GGT  CTC  GAA  GGG  ACG  AAA  TAT  CAT  GTA  CCA  CGA  GGA  TCT  ATG  A
**Compare the DNA Sequences – Teacher Key**

**Directions:** Circle the difference(s) in the DNA sequence. Then use the DNA to amino acid codon wheel to determine the amino acid sequence. Circle the difference(s) in the DNA sequence.

**Original DNA:**

<table>
<thead>
<tr>
<th>ATG</th>
<th>CAA</th>
<th>GGT</th>
<th>CTC</th>
<th>GAA</th>
<th>GGG</th>
<th>ACG</th>
<th>AAA</th>
<th>TAT</th>
<th>CAT</th>
<th>GTA</th>
<th>CCA</th>
<th>CGA</th>
<th>GAT</th>
<th>CTA</th>
<th>TGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Met</td>
<td>Gln</td>
<td>Gly</td>
<td>Leu</td>
<td>Glu</td>
<td>Gly</td>
<td>Thr</td>
<td>Lys</td>
<td>Tyr</td>
<td>His</td>
<td>Val</td>
<td>Pro</td>
<td>Arg</td>
<td>Asp</td>
<td>Leu</td>
<td>Stop</td>
</tr>
</tbody>
</table>

**Mutation 1:**

<table>
<thead>
<tr>
<th>ATG</th>
<th>CAA</th>
<th>GGT</th>
<th>CTC</th>
<th>GAA</th>
<th>GGG</th>
<th>ACG</th>
<th>AAA</th>
<th>TAA</th>
<th>CAT</th>
<th>GTA</th>
<th>CCA</th>
<th>CGA</th>
<th>GAT</th>
<th>CTA</th>
<th>TGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Met</td>
<td>Gln</td>
<td>Gly</td>
<td>Leu</td>
<td>Glu</td>
<td>Gly</td>
<td>Thr</td>
<td>Lys</td>
<td>Stop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mutation 2:**

<table>
<thead>
<tr>
<th>ATG</th>
<th>CAA</th>
<th>GGT</th>
<th>CTC</th>
<th>GAA</th>
<th>GGT</th>
<th>ACG</th>
<th>AAA</th>
<th>TAT</th>
<th>CAT</th>
<th>GTA</th>
<th>CCA</th>
<th>CGA</th>
<th>GAT</th>
<th>CTA</th>
<th>TGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Met</td>
<td>Gln</td>
<td>Gly</td>
<td>Leu</td>
<td>Glu</td>
<td>Gly</td>
<td>Thr</td>
<td>Lys</td>
<td>Tyr</td>
<td>His</td>
<td>Val</td>
<td>Pro</td>
<td>Arg</td>
<td>Asp</td>
<td>Leu</td>
<td>Stop</td>
</tr>
</tbody>
</table>

**Mutation 3:**

<table>
<thead>
<tr>
<th>ATG</th>
<th>CAA</th>
<th>GGT</th>
<th>CTC</th>
<th>GAA</th>
<th>GGG</th>
<th>ACG</th>
<th>AAA</th>
<th>TAT</th>
<th>CAA</th>
<th>GTA</th>
<th>CCA</th>
<th>CGA</th>
<th>GAT</th>
<th>CTA</th>
<th>TGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Met</td>
<td>Gln</td>
<td>Gly</td>
<td>Leu</td>
<td>Glu</td>
<td>Gly</td>
<td>Thr</td>
<td>Lys</td>
<td>Tyr</td>
<td>Gln</td>
<td>Val</td>
<td>Pro</td>
<td>Arg</td>
<td>Asp</td>
<td>Leu</td>
<td>Stop</td>
</tr>
</tbody>
</table>

**Mutation 4:**

<table>
<thead>
<tr>
<th>ATG</th>
<th>CAA</th>
<th>GGT</th>
<th>CTC</th>
<th>GAA</th>
<th>GGG</th>
<th>ACG</th>
<th>AAA</th>
<th>TAT</th>
<th>CAT</th>
<th>GTA</th>
<th>CCA</th>
<th>CGA</th>
<th>GAT</th>
<th>CTA</th>
<th>TGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Met</td>
<td>Gln</td>
<td>Gly</td>
<td>Leu</td>
<td>Glu</td>
<td>Gly</td>
<td>Thr</td>
<td>Lys</td>
<td>Tyr</td>
<td>His</td>
<td>Val</td>
<td>Pro</td>
<td>Arg</td>
<td>Gly</td>
<td>Ser</td>
<td>Met</td>
</tr>
</tbody>
</table>
**Mutations Table**

**Directions:** Circle the mutation on the Mutations Worksheet. Fill out the table below.

<table>
<thead>
<tr>
<th>Describe the mutation</th>
<th>Type of mutation:</th>
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<th>Effect of mutation:</th>
</tr>
</thead>
</table>
| Ex. “In the third codon G changed to T” | 1. Point/substitution  
2. Insertion  
3. Deletion | Ex. “Tyrosine changed to STOP” | 1. No change in protein  
2. Different amino acid  
3. Early “STOP” resulting in shortened protein |
| In the 9th codon the last nucleotide was changed from T to A | Point | Tyrosine changed to STOP | Early “STOP” resulting in shortened protein |
| In the 6th codon the third nucleotide was changed from G to T | Point | No change in amino acids | No change in protein |
| In the 10th codon the third nucleotide was changed from T to A | Point | HIS changed to GLN | Different amino acid |
| At the start of the 14th codon an additional G nucleotide was added | Insertion | ASP-LEU-STOP changed to GLY-SER-MET | Multiple amino acid changes |

Which types of mutations have the biggest effect on the protein? Explain.
Frameshift mutations (insertions and deletions can cause a change in every amino acid after the insertion or deletion. When point mutations occur, those that change one of the first two nucleotides tend to cause more changes in amino acids. Those that result in early stops are particularly impactful.

Which types of mutations have the smallest effect on the protein? Explain.
Point mutations that do not cause a change in the amino acid coded for (silent mutations).
How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
• You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
• Read through the slides one at a time. Take your time to explore the images and any links.
• If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

5.2 Explaining Sickle Cell Disease
How does a fatal disease persist in a family?

Goals
After reviewing this PowerPoint, you should be able to:

1) Compare individuals with Sickle Cell Disease, Sickle Cell Trait, and normal red blood cells at the organism, cellular, and molecular scales.
2) Explain how genotype determines phenotype.
3) Describe the inheritance of genetic traits in a family.

How is it determined if a person has Sickle Cell Disease or Trait (carrier)?

- Normal Blood Cells
  - No problem!

- Sickle Cell Trait
  - 1 in 13 African American Births
  - Usually no symptoms

- Sickle Cell Disease
  - 1 in 365 African American Births
  - Can kill if not treated
Homologous pairs have the same genes, but they are not always identical because the alleles can be different.

How would two different alleles for hemoglobin come to exist? (review Lesson 5.1)

If an individual has sickle cell disease or trait, how did they come to have the non-functional allele(s)? (review Lessons 3 and 4)

How would two different alleles for hemoglobin come to exist?

From Mother
Allele for non-functional Hemoglobin B

From Father
Allele for functional Hemoglobin B

How would two different alleles for hemoglobin come to exist?

From Mother
Allele for non-functional Hemoglobin B

From Father
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How would two different alleles for hemoglobin come to exist?

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Practice
Determine the genotypes of individuals with these phenotypes:

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Normal Cells</th>
<th>Sickle Cell Trait</th>
<th>SC Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromosomes (sketch)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genotype</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With Sickle Cell Disease scientists often represent the alleles as A and S.
Practice
Determine the genotypes of individuals with these phenotypes:

<table>
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</table>

We could also think about it as $+$ for functional and $-$ for non-functional.

Determine the genotypes of individuals with these phenotypes:

We could also think about it as $+$ for functional and $-$ for non-functional.

This brings us back to our driving question:
How does a fatal disease persist in a family?

Complete your final model:
- Fill out the Model Revisions Tool to plan for your final model.
- Use pictures and written explanations to clearly show your ideas
- Answer the Genetics Three Questions for individuals with and without Sickle Cell Disease

Check Your Understanding
1) Compare individuals with Sickle Cell Disease, Sickle Cell Trait, and normal red blood cells at the organism, cellular, and molecular scales.
2) Explain how genotype determines phenotype.
3) Describe the inheritance of genetic traits in a family.

What’s Next?
1. Complete the Model Revisions Tool.
2. Complete your final model. You will need to submit this to your teacher.
How Does a Fatal Disease Persist in a Family? Model Revisions

Changes:
- Identify **TWO** changes you made and *explain why* you made those changes (revisions, additions, etc).
- Explain which evidence(s) support your argument. At least one evidence should be at the atomic-molecular scale.
- Identify the scientific principle(s) that support your argument – this is the reasoning.

<table>
<thead>
<tr>
<th>Part of your Argument</th>
<th>Explanation why…</th>
<th>Evidence(s)</th>
<th>Supporting Scientific Principle(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Things you kept the same:
- Identify **TWO** parts of your argument that you did NOT change and *explain why* you did not change those parts.
- Explain which evidence(s) support your argument. At least one evidence should be at the atomic-molecular scale.
- Identify the scientific principle(s) that support your argument – this is the reasoning.

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<th>Explanation why…</th>
<th>Evidence(s)</th>
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</tr>
</tbody>
</table>
Final Model: How does a fatal disease persist in a family? Use pictures and words to explain.

Think of this as a step-by-step explanation of how and why a fatal disease persists in a family. Explain what happens at each scale:

- Use the zoom-ins to show what you think is happening at the cellular and atomic-molecular scales
- Explain how information and instructions are passed between generations
- Show how DNA and proteins are involved in the trait(s)

Grandma’s Cell:
Trait: ____________________

Mother’s Cell:
Trait: ____________________

Child 1’s Cell:
Trait: ____________________

Grandpa’s Cell:
Trait: ____________________

Father’s Cell:
Trait: ____________________

Child 3’s Cell:
Trait: ____________________
Complete the table below to answer the Genetics Three Questions for individuals with different traits.
Use scientific vocabulary to describe the processes that take place at each scale.

**Individual Without Sickle Cell Disease**

<table>
<thead>
<tr>
<th>Organism Scale Question:</th>
<th>Individual with Sickle Cell Disease (⭐)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the observable trait?</td>
<td>Organism Scale Question:</td>
</tr>
<tr>
<td>________________________</td>
<td>1. What is the observable trait?</td>
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<table>
<thead>
<tr>
<th>Cellular Scale Question:</th>
<th>Individual with Sickle Cell Disease (⭐)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is going on inside the cell to produce the observable trait?</td>
<td>Cellular Scale Question:</td>
</tr>
<tr>
<td>________________________</td>
<td>1. What is going on inside the cell to produce the observable trait?</td>
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<table>
<thead>
<tr>
<th>Molecular Scale Question:</th>
<th>Individual with Sickle Cell Disease (⭐)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where is DNA coming from?</td>
<td>Molecular Scale Question:</td>
</tr>
<tr>
<td>________________________</td>
<td>1. Where is DNA coming from?</td>
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<tr>
<td>2. How are DNA and proteins involved in the trait?</td>
<td>2. How are DNA and proteins involved in the trait?</td>
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</table>

**Please note:** Your final model will be submitted on Schoology. You MAY discuss ideas with other students, but you may NOT SHARE any writing or pictures with peers. You also CANNOT copy material from a source like the internet or a book. Plagiarism is monitored and will result in a grade of zero, and possible disciplinary consequences.
### Genetics: Inheritance Final Model and Explanation Grading Checklist

<table>
<thead>
<tr>
<th>Pedigree diagram</th>
<th>Checklist</th>
<th>Score</th>
</tr>
</thead>
</table>
|                  | □ Shows DNA and proteins in correct locations  
|                  | □ Accurately shows information being passed down from one generation to another  
|                  | Uses zoom-ins or detail in the cell drawings to show what’s happening to the produce the trait at the:  
|                  | □ cellular scale (cell shape)  
|                  | □ atomic-molecular scale (how DNA/proteins are involved)                                                                                                                                                | 4     |
|                  | □ Accurately identifies the observable trait(s)                                                                                                                                                           | 1     |
|                  | □ Uses accurate scientific vocabulary to describe what is happening inside cells  
|                  | □ Accurately describes how the observable trait is produced                                                                                                                                               | 2     |
|                  | □ Uses accurate scientific vocabulary to explain how DNA is inherited from one generation to another                                                                                                                                                               | 1     |
|                  | □ DNA is involved in producing the trait  
|                  | □ Proteins are involved in producing the trait                                                                                                                                                           | 1     |
|                  | □ Work is submitted to Schoology following teacher’s instructions  
|                  | □ Pedigree diagram is neat and easy to see  
|                  | □ Written explanation is typed or neatly written with correct grammar and spelling                                                                                                                      | 3     |

**TOTAL:** 19

Notes/Comments:
Explaining Other Examples

In humans, the ability to taste PTC is dominant to the inability to taste PTC (Gene T). The ability to roll one’s tongue is dominant to inability to roll one’s tongue (Gene R). Gene T and Gene R are located on two different chromosomes.

**Part 1:** Use the model to show how meiosis leads to variation in traits in a family.

**Biological Mother**  
Genotype: TtRr

**Biological Father**  
Genotype: TtRr

Explain what is happening in each step of the model.

- **Explain:** _______________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- **Explain:** _______________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- **Explain:** _______________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- **Explain:** _______________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- **Explain:** _______________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________

Explain how the biological mother could produce gametes with a different genotype from your model above. Assume it is the same biological mother with the same TtRr genotype.

- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
- __________________________________________________________________________________
Part 2: Assume the two biological parents in Part 1 have children. Use the model to show how one egg and one sperm create a child that may have a different genotype than either biological parent. Draw the DNA and proteins present in the cell of child (assume the proteins are expressed in this cell).

Part 3: Explain the probability of the two parents have children who can taste PTC or roll their tongues.

PTC (Gene T): Make an egg-sperm chart (Punnett Square) showing the possible genotypes of the children:

What is the probability of the children being able to taste PTC?

Tongue Rolling (Gene R): Make an egg-sperm chart showing the possible genotypes of the children:

What is the probability of the children being able to roll their tongue?
Explain: During meiosis, the cell has unreplicated chromosomes. To prepare for cell division, the DNA is replicated. Mitotic cell division, homologous chromosomes pair up and crossing over may occur.

Explain: In the first cell division (meiosis I), homologous chromosomes are divided into separate cells. The separate chromosomes are still replicated. In meiosis II, separate chromosomes will divide into unreplicated chromosomes.

Explain: After meiosis, gametes (sperm and eggs) are formed. Each gamete will receive half the number of chromosomes of the parent cell. In fertilization, sperm and egg will fuse together to form the offspring (zygote).

Key:
- $T$ or $t$: Tasting PTC (Gene $T$)
- $R$ or $r$: Red-green color blindness (Gene $R$)

Explain: In humans, the ability to taste PTC is dominant to the inability to taste PTC (Gene $t$). The ability to roll one's tongue is dominant to inability to roll one's tongue (Gene $R$). Gene $T$ and Gene $R$ are located on two different chromosomes.

Part 1: Use the model to show how meiosis leads to variation in traits in a family.

Explain: How the biological mother could produce gametes with a different genotype from your model above. Assume it is the same biological mother with the same $TtRr$ genotype.

4 possible gametes

The biological mother's homologous chromosomes may or may not separate. The separate chromosomes may or may not line up separately. So there are three.

Crossing over with respect to independent assortment.

The separate chromosomes $T$ vs. $t$ will line up separately. So there are three.
3:1 or 75% to 25%

What is the probability of the child being tall or roll their tongue?

<table>
<thead>
<tr>
<th>R</th>
<th>r</th>
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<tbody>
<tr>
<td>R</td>
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</tbody>
</table>

Tongue Rolling (gene A): Make an EEG-cmap chart showing the possible genotypes of the children.

- R produces all functional rolling protein.
- r produces all nonfunctional rolling protein.

So the tongue cannot be rolled.

Explain how the two siblings have different traits. Include a discussion of DNA and proteins in your explanation.

Part 2: Explain the probability of the two parents having children who can taste PI or roll their tongues.

The DNA and proteins present in the cell of the child (assuming the parents are express in this cell)

Part 3: Assume the two biological parents can have a second child that is different from the first. Draw the model to show how the two biological parents can have a second child that is different from the first.

Protein Key: 
- R: Rolling protein
- r: Non-rolling protein
- El: EEG-cmap

Name: ____________________

Period: ____________________
Genetics: Inheritance Self-Assessment

Reflect on the standards addressed in the Genetics: Inheritance unit. Check which box describes your current understanding:

- 4 I know this well enough to teach it to someone.
- 3 I can do this with almost no mistakes.
- 2 I can do much of this, but I have questions.
- 1 I can do this, but only with help.
- 0 I can’t do this, even with help.

**Inheritance Unpacked Standards**

<table>
<thead>
<tr>
<th>Description</th>
<th>Rating (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can describe how a complex organism is organized by: the same type of cells that make tissues (differentiated cells), tissues that make organs, and organs that comprise parts of an organ system.</td>
<td></td>
</tr>
<tr>
<td>I can describe how organ systems work together to maintain a complex organism.</td>
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<tr>
<td>I can describe how systems of specialized cells within organisms help them live.</td>
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<tr>
<td>I can explain how traits are determined by the activity of proteins.</td>
<td></td>
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<tr>
<td>I can explain how the structure of a protein determines its function.</td>
<td></td>
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<tr>
<td>I can explain how protein structure is determined by the order of nucleotides in DNA. (Protein structure is based on amino acid sequence, which is determined by nucleotide sequence in the DNA.)</td>
<td></td>
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<tr>
<td>I can explain that genes are regions on DNA that code for proteins.</td>
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<tr>
<td>I can explain that when a gene is turned on, that protein is made. When a gene is turned off, that protein is not made.</td>
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<tr>
<td>I can describe meiosis as a cell division process that makes genetically distinct gametes which are also different from the parent cell.</td>
<td></td>
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<tr>
<td>I can describe how genetic variation occurs in 3 ways: recombination (crossing over) and the independent assortment of chromosomes during meiosis, mutations during DNA replication, and mutations from environmental factors.</td>
<td></td>
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<tr>
<td>I can explain how the mutations that happen in gametes are the only heritable mutations.</td>
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<tr>
<td>I can describe how sexual reproduction occurs through the fusion of a random egg and a random sperm.</td>
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<tr>
<td>I can explain that the variation and distribution of traits observed in a population depends on both genetic and environmental factors (will be covered more in Evolution – it’s okay if you don’t fully understand this one yet).</td>
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</tbody>
</table>

Notes / Comments:
Genetics Vocabulary KEY

Add in Lesson 1.2:

1. What is DNA? What are chromosomes?

   DNA monomer of a chromosome, made up of 4 different nucleotides (Guanine, Cytosine, Adenine and Guanine). Contains the genetic material, the code to build a protein. DNA coils up into a polymer called a chromosome.

2. Draw and label an unreplicated chromosome and a replicated chromosome.

   ![Unreplicated and Replicated Chromosome Diagram]

Add in Lesson 2.2:

3. Label a gene in the picture below. A gene is the instructions for making a ______ protein _____________________.

   ![Gene Diagram]
Add in Lesson 2.4:

4. What is an **allele**? Label the alleles in the picture below.

An allele is a different version of a gene – it has a slightly different nucleotide sequence (W vs. w)

5. What makes a protein **functional vs. non-functional**? Draw an example.

A protein is functional if it has the correct shape to perform its function. A protein is non-functional if it has a different shape so it is not able to form its function. Example:

- Functional (has correct shape)
- Non-functional (has incorrect shape)

6. Use the picture below to explain the difference between **genotype** and **phenotype**. *Hint: ___genotype_____ determines ___phenotype_____.

**Phenotype** – the observed (or measurable) trait of an organism that relates to one gene

**Genotype** – the two alleles that an organism has for a trait = the combination of alleles
Add in Lesson 3.1:

7. What are **homologous chromosomes**? How are they the same and how are they different? Explain using the picture.

   **Homologous pairs** have the same *genes*, but they are **not** always identical because the *alleles* can be different.

   In the picture you can see there are two alleles for each chromosome, an “A” allele and a “B” allele. However, they are not the same because the left chromosome has a big B and the right chromosome has a little b. They B might be a gene for a specific trait but there are two versions of the trait.

8. Define and give examples of **homozygous** vs. **heterozygous**. Hint: The person with the two chromosomes show in Question 7 is homozygous for gene _A_ and heterozygous for gene _B_.

   **Homozygous** – the two alleles are the same, RR and rr are homozygous genotypes

   **Heterozygous** – the two alleles are different, Rr is a heterozygous genotype

9. Define and give examples of **dominant** vs. **recessive alleles**.

   Dominant alleles are represented with a uppercase letter – B or R, rececessive alleles are represented with a lowercase letter, b or r.
# KEY Learning Tracking Tool for Genetics - Inheritance: How does a fatal disease persist in a family?

<table>
<thead>
<tr>
<th>Lesson</th>
<th>What did we do? What did we figure out?</th>
<th>How can our learning be used to explain the phenomenon?</th>
<th>Self-Assess: Where am I with my understanding of the phenomenon?</th>
<th>What questions do I have?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 and 2.2 Protein to Trait and Genetics Vocabulary</td>
<td>Proteins in cells produce the traits we see. Some proteins are functional while others are nonfunctional (or less/differently functional). For example, a functional protein might act as an enzyme that changes a colorless molecule into a pigment molecule that produces tan skin or color in a flower.</td>
<td>Students MIGHT say: People with different traits have different proteins or protein functionality. For example, some people have skin that tans easily, while others burn easily.</td>
<td>(Example: Ready to explain, starting to get it, need more information)</td>
<td>Many options! Example: How are proteins related to DNA?</td>
</tr>
<tr>
<td>2.3 DNA to Protein</td>
<td>A person’s DNA contains instructions for making proteins. Each set of three nucleotide bases codes for one amino acid, and these amino acids link together in order to build a protein. A change in the DNA sequence could change the protein it codes for.</td>
<td>Students MIGHT say: People with different traits have different DNA. These DNA differences code for different protein, and the proteins produce the traits we see.</td>
<td></td>
<td>Many options! Example: What DNA differences result in different traits?</td>
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<tr>
<td>Section</td>
<td>Description</td>
<td>Example</td>
<td>Question</td>
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<tr>
<td>2.4 Genotype to Phenotype</td>
<td>A gene is a section of DNA that codes for one protein. Different versions of genes are called alleles – they have small differences in the nucleotide sequence and may produce slightly different proteins. Genotype describes what’s in a person’s DNA while phenotype is the traits we see. Genotype determines phenotype. Students MIGHT say: People with different traits (phenotypes) have different DNA (genotypes). The DNA is instructions for making proteins, and the proteins determine the traits we see.</td>
<td>Many options! Example: How does this relate to Sickle Cell Disease?</td>
<td></td>
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<tr>
<td>2.5 Zooming into Sickle Cell</td>
<td>Sickle Cell Disease results from a different allele for hemoglobin – S instead of the usual A. The S allele codes for a different protein with a shape that forms chains when linked to other proteins. These chains cause the sickle or crescent shape of the red blood cells. Students MIGHT say: Individuals with Sickle Cell Disease have different DNA, proteins, and observed traits.</td>
<td>Many options! Example: How is SCD inherited?</td>
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</tr>
<tr>
<td>3.1 Chromosomes and Alleles</td>
<td>Humans have two copies of every chromosome, one that comes from the biological mother and one from the biological father. These are called homologous chromosomes. Individuals may have the same or different alleles for a gene on their homologous chromosomes, making them homozygous (same alleles) or heterozygous (different alleles). Some alleles are dominant, meaning you only need one copy to see the trait, and some are recessive, meaning two copies are required to see the trait. Students MIGHT say: Humans inherit one copy of each chromosome from their biological mother and one from their biological father. That means of the 46 chromosomes, 23 come from mom and 23 come from dad.</td>
<td>Many options! Example: How are the chromosomes inherited?</td>
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<tr>
<td>3.2 and 3.3 Meiosis</td>
<td>A person’s 46 chromosomes are inherited from their biological mother and father through sperm and eggs. Sperm and egg cells carry 23 chromosomes, one copy of each type of chromosome. Sperm and egg cells are formed through meiosis, a special type of cell division. Sperm and egg combine in fertilization.</td>
<td>Students MIGHT say: Sperm and egg cells are formed during meiosis and combine in fertilization to form the offspring.</td>
<td>Many options! Example: How can we predict the traits that parents will pass on to their offspring?</td>
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<tr>
<td>4.1 and 4.2 Making Gametes and Inheritance</td>
<td>There is a 50/50 chance of a parent passing on either of their two copies of a chromosome to their offspring in the sperm or eggs. We can predict the possible genotypes of the offspring of two parents using an egg-sperm chart.</td>
<td>Students MIGHT say: There is a 50/50 chance of a parent who carries one S allele passing on that allele to their offspring. A parent who has SCD will pass on an S allele to their offspring.</td>
<td>Many options! Example: Where do different alleles come from?</td>
<td></td>
</tr>
<tr>
<td>5.1 Mutations</td>
<td>Mutations are changes in the DNA sequence. Mutations occur during DNA replication or as a result of environmental factors such as UV (sun) and exposure to tobacco smoke.</td>
<td>Students MIGHT say: New alleles like the S allele that results in SCD come about because of mutations in the DNA sequence.</td>
<td>Many options! Example: Why would mutated alleles stick around in the population?</td>
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</tbody>
</table>