

# Genetics - Dihybrid Cross

## Teacher's Guide

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### 1.0 Summary

*Dihybrid Cross* is the ninth core *Genetics* activity. This activity is comprised of two sections. This activity is designed to be completed in one class period of 45-50 minutes.

### 2.0 Learning Goals

**Driving Question:** What is the likelihood that two traits will be inherited together?

The Dihybrid Cross activity focuses on the inheritance patterns for two traits at a time, and the differences that occur when the genes for those traits are parts of the same chromosome or parts of different chromosomes.

#### Learning Goals

- Students will learn that offspring inherit entire chromosomes from their parents.
- Students will recognize that if two genes are parts of the same chromosome, they will inherit them together.
- Students will recognize that if two genes are parts of different chromosomes, they will inherit them independently.
- Students will distinguish the difference in inheritance patterns between two characteristics that are parts of one chromosome and two characteristics that are determined by genes that are parts of different chromosomes.
- Students will utilize the principles of probability to predict the outcome of genetic crosses for two traits.
- Students will utilize the principles of probability to explain genetic crosses involving more than one trait.
  - Students will use Punnett Square and Pedigree Charts to examine patterns of heredity.

#### Additional Teacher Background

In *Dihybrid Cross*, students will apply the information that they have acquired in the previous *BioLogica* core activities to complete activities of probability, segregation, and independent assortment. To appreciate fully the two laws of Mendelian genetics modeled in this activity, students should have basic comprehension of related terms and concepts.

Students should already have a firm grasp of Mendel's first law; the Law of Segregation of Alternate Factors, for single trait crosses, if the *BioLogica* activities were completed sequentially. This activity will reinforce those concepts and it will demonstrate Mendel's second law, the Law of Independent Assortment, for multiple trait crosses.

What we have learned since Mendel's studies is that his "Laws" have several exceptions. For example; there are eight known interactions between alleles that can form a phenotype. Incomplete and co- dominance, multiple alleles and polygenic traits as well as environmental influences are instances of these exceptions. In addition, we now know that genes are segments of chromosomes. Therefore, multiple traits assort independently if they are part of different chromosomes. However, different genes that are parts of the same chromosome are linked and will not, in the absence of crossing over, assort independently.

### 3.0 Standards Alignment

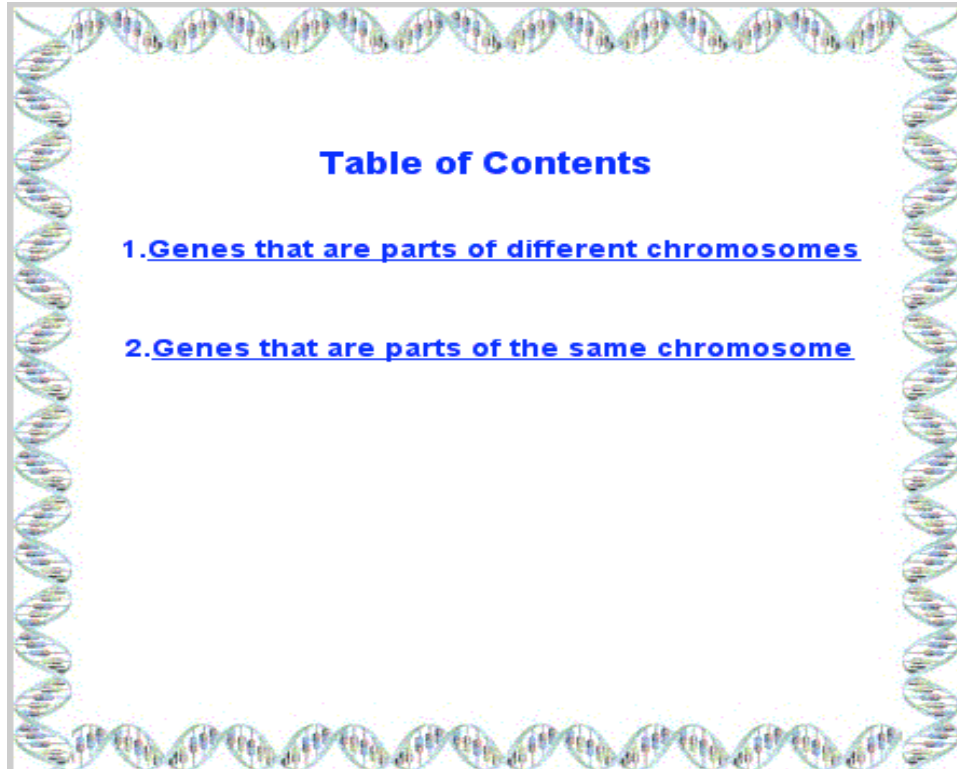
#### Alignment to National Math and Science Standards (NCTM or NSES)

| Objective  | Standards   |
|--|---|
| <p><b>Students will be able to determine whether the genes for 2 traits are parts of the same or different chromosomes through breeding experiments and pedigree analysis.</b></p> | <p>Students will use representations to model and interpret physical, social, and mathematical phenomena.</p>   |
| <p><b>Students will extend their understanding of probability to the inheritance of two traits.</b></p>  | <p>Mathematical tools and models guide and improve the posing of questions, gathering of data, constructing explanations and communicating results.</p> |

## 4.0 Activity Sections

This activity is comprised of two sections: *Genes that are parts different chromosomes* and, *Genes that are parts of the same chromosome*. Students should use the notebook tool to keep track of useful information as they proceed through the screens. It may be helpful to print a copy of the Dragon Genome Chart for reference.

### 4.1 Table of Contents



### 4.2 Genes that are part of different chromosomes

Students review monohybrid predictions and probabilities and pedigrees for wings and horns. Then they are guided through the same procedures for dihybrid inheritance of the two traits together.

- Step 1: Review genotypes in Punnett Squares and in Pedigrees.
- Step 2: Complete the Punnett Square for Wings.
- Step 3: Complete the Pedigree Chart for wings and horns.
- Step 4: View the dragon offspring and count the number of dragons with the phenotypes for both traits.
- Step 5: Practice Punnett squares for multiple traits, simplify the Punnett Squares for Dihybrid traits whenever possible.
- Step 6: Complete the Quiz.
- Step 7: Summarize the process.

**Duncan**

**Darlene**

Here are two dragons, Darlene and Duncan. Notice that they both have fancy tails. They met at the Calling-all-Dragons festival. Now they're happily married and want to have children. Other than their tails, they are phenotypically quite different. For instance, Darlene has wings, but Duncan does not have wings. What are the chances they'll have babies with wings, they wonder.

Look at their chromosomes and enter both their genotypes in the notepad. Complete the Punnett square for Wings and then let Darlene and Duncan know your predictions.

Complete Punnett Square

Complete a Punnett Square for Wings.

Wings  No Wings  Single Wings

Number of Offspring: 40

|        | wings | no wings |
|--------|-------|----------|
| Cross1 | 19    | 21       |

That's about half, which is what you predicted from the Punnett square. Keep in mind that if you flip a coin 40 times, you'll usually get **close** to half heads and half tails, but not exactly 20 of each.

Probability of wings is 50%

Horns Number of Offspring: 40

No Horns  2 Horns

|        | wings | no wings |
|--------|-------|----------|
| Cross1 | 19    | 21       |

That's about half, which is what you predicted from the Punnett square. Keep in mind that if you flip a coin 40 times, you'll usually get **close** to half heads and half tails, but not exactly 20 of each.

|        | horns | no horns |
|--------|-------|----------|
| Cross1 | 29    | 11       |

Probability of horns is 50%

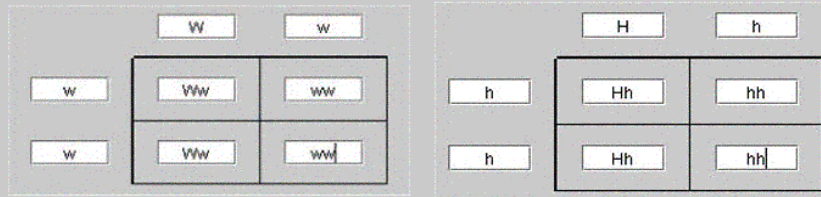
These are the same dragon offspring you were looking at in pedigree. How many of them have both horns and wings?

3. Scroll through all the dragons and count how many of them have both horns and wings. Choose the answer closest to your count.

- About 5 (which equals 1/8) of the dragons have both horns and wings
- About 10 (or 1/4) of the dragons have both horns and wings
- About 15 out of 40 (which equals 3/8) of the dragons have both horns and wings
- About 20 (or 1/2) of the dragons have both horns and wings
- About 25 out of 40 (or 5/8) of the dragons have both horns and wings
- About 30 (or 3/4) of the dragons have both horns and wings
- About 35 out of 40 (or 7/8) of the dragons have both horns and wings
- All of the dragons have both horns and wings

**Submit Answer**

Students scroll through the offspring created in the pedigree and count the number of dragons that have both horns and wings.

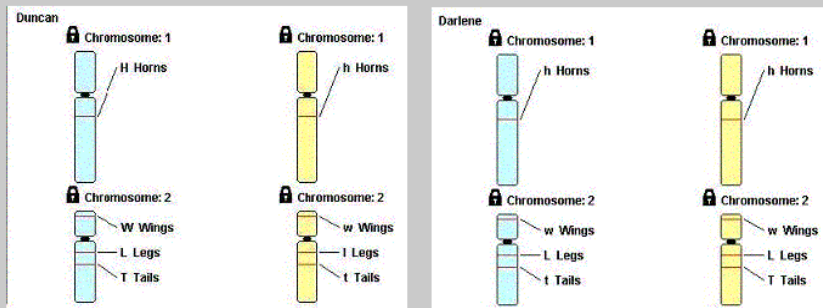


Mathematically speaking, the probability that two events, in this case the occurrence of two particular traits, will both occur is the product of the probabilities of the two separate events occurring, **if the events are unrelated.**

In other words, to predict the likelihood that a dragon will inherit both horns and wings, you multiply the probability that it will have horns times the probability that it will have wings ( $1/2 \times 1/2 = 1/4$ ).



### Probability of simultaneous unrelated events



This only works because the genes are parts of different chromosomes.

Look at the dragons' chromosomes. Notice that the Horns gene is part of Chromosome 1 while the Wings gene is part of Chromosome 2. Since you cannot predict which one of each chromosome pair will end up in which gamete during meiosis, we say that the chromosomes are assorted independently: each chromosome goes its own way. This is called Independent Assortment ([Mendel's](#) second law).



### Explanation of Independent Assortment

| Results          | horns<br>wings | horns<br>no wings | no horns<br>wings | no horns<br>no wings |
|------------------|----------------|-------------------|-------------------|----------------------|
| <b>Cross1</b>    | <b>6</b>       | <b>13</b>         | <b>12</b>         | <b>9</b>             |
| <b>Predicted</b> | <b>10</b>      | <b>10</b>         | <b>10</b>         | <b>10</b>            |

The table above shows the results of Cross1 and the predicted results. The results may or may not agree with the predictions. Geneticists would use statistics to test the agreement, but you don't need to.



### Discussion of predictions vs. data

Students are then guided through the reasoning required to determine parental genotypes for Horns and Tails and then the phenotypes of their offspring, beginning with the genotypes and possible crosses through Punnett Squares and mathematical calculation of the probabilities.

You're right!

Frieda's genotype is HHtt and Michael's genotype is HhTt.

Since Frieda will always contribute an H allele, the probability of their having an offspring with horns is 1.

Since Frieda will always contribute a t allele and Michael will contribute a T allele 1/2 the time and a t allele 1/2 the time, the probability of their having an offspring with a fancy tail is 1/2 and the probability of their having an offspring with a plain tail is 1/2.

So the probability that Frieda and Michael produce a baby with:

- horns and a fancy tail is  $1 \times 1/2 = 1/2$ ,
- horns and a plain tail is  $1 \times 1/2 = 1/2$ ,
- no horns and a fancy tail is  $0 \times 1/2 = 0$ ,
- no horns and a plain tail is  $0 \times 1/2 = 0$ .



### Results for horns and fancy tails

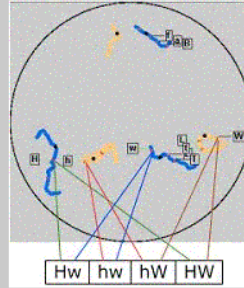
The next section takes them through the same process but with an emphasis on the role of meiosis and independent assortment in producing possible combinations of alleles.

Remember, chromosomes are assorted independently during meiosis.

Since Duncan is heterozygous for both Horns and Wings, he could pass on an H allele. That H allele could end up in a gamete with either a W or w allele.

Or Duncan could pass on an h allele which could end up in a gamete with either a W or w allele.

This results in the 4 combinations shown in the diagram.



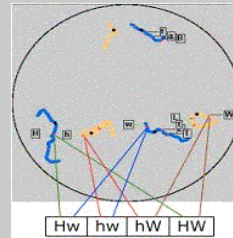
### Possible combinations

However, you can't get all four combinations in any single meiosis.

For Duncan, any single meiosis produces either 2 HW and 2 hw gametes OR 2 Hw and 2 hW gametes.

But when you combine the results of many meioses, half the time you'll get 2 HW and 2 hw gametes and half the time you'll get 2 Hw and 2 hW gametes.

This results in four equally likely gamete genotypes for Duncan (HW, Hw, hW, hw) which we place at the top of a four-by-four Punnett square.



### Possibilities for Duncan's traits explained



Duncan

|  |    |    |    |    |
|--|----|----|----|----|
|  | HW | Hw | hW | hw |
|--|----|----|----|----|

|    |      |      |      |      |
|----|------|------|------|------|
| hw | HhWw | Hhww | hhWw | hhww |
| hw | hHwW | hHww | hhwW | hhww |
| hw | hHwW | hHww | hhwW | hhww |
| hw | hHwW | hHww | hhwW | hhww |

Darlene

Using what you know about completing Punnett squares, fill in the allele combinations for all the offspring represented by the 16 inner boxes. As you copy the parent alleles into the corresponding rows and columns, keep the Horns alleles next to each other, and the Wings alleles next to each other, so you can see them together.

We've filled in the first box for you, so you can see how it's done. Based on the rules you know for Horns and Wings, you will then be able to tell lots about the offspring's phenotypes.

Students complete a 4X4 dihybrid Punnett Square, with the help of the "Show Me" button if desired.

Note: Students can copy and paste from one cell to another once they understand the pattern.

Duncan

|  |    |    |    |    |
|--|----|----|----|----|
|  | HW | Hw | hW | hw |
|--|----|----|----|----|

|    |      |      |      |      |
|----|------|------|------|------|
| hw | HhWw | Hhww | hhWw | hhww |
|----|------|------|------|------|

Darlene

You're right! Even without doing the math, you can see from this simplified Punnett square that 1/4 of the possible offspring would have horns and wings. This is the same result you got by multiplying the probabilities of having horns times having wings.

Simplified dihybrid Punnett Square gives same probability of offspring having both wings and horns as calculated previously with 2 Punnett Squares.

17. Using this Punnett square, what is the probability that Darlene and Duncan will have an offspring with horns and a fancy tail?

0  1/8  1/4  3/8  1/2  5/8  3/4  7/8  1/1

Submit Answer

Students are asked a series of questions about calculating probabilities from Punnett squares. The correct answer to this question is 3/8 of the offspring could have both horns and a fancy tail, which is explained in the next screen.

Time to check your work!

Using the math rule for calculating the probability of two independent events you should have come up with the following equation:  $1/2 \times 3/4 = 3/8$ , since the probability of Darlene and Duncan having an offspring with horns is 1/2 and the probability of them having an offspring with a fancy tail is 3/4.

Using the Punnett square that combines Horns and Tail, you can see that 3 of the 8 possible offspring genotypes would result in the offspring phenotype with horns and a fancy tail.

Explanation of answer

|        |    | Sam  |      |
|--------|----|------|------|
|        |    | Ht   | ht   |
| Karuna | HT | HHTt | HhTt |
|        | Ht | HHtt | Hhtt |

From the simplified Punnett square, you can see that Karuna produces 2 types of gametes -- HT and Ht. This means that her Horns/Tails genotype must be HHTt.

Sam also produces 2 types of gametes -- Ht and ht. This means that his Horns/Tails genotype must be Hhtt.

Since Karuna can contribute only the dominant H allele for Horns to her offspring, all of Karuna and Sam's offspring will have horns (either HH or Hh). So the probability that any of their offspring will have horns is 1-- a statistical certainty.

Because Karuna is heterozygous for Tails (Tt) and Sam is homozygous recessive (tt), approximately 1/2 of their offspring will have fancy tails (Tt) and approximately 1/2 of their offspring will have plain tails (tt).

Since 2 (HHtt and Hh tt) of the 4 offspring genotypes in the simplified Punnett square correspond with the horns/plain-tail phenotype, the Punnett square predicts that approximately 1/2 of Karuna and Sam's offspring will have horns and plain tails.

### Further explanation of Dihybrid traits

|        |   | Sam |    |   |     |
|--------|---|-----|----|---|-----|
|        |   | H   | h  |   |     |
| Karuna | H | HH  | Hh | W | W/w |
|        |   |     |    | w | ww  |

Here are Punnett squares for a cross between Karuna and Sam focusing on Horns and Wings.

25. What is the probability that one of Karuna and Sam's offspring will have horns and wings?

0  
 1/8  
 1/4  
 3/8  
 1/2  
 3/4  
 1/1

26. Show how you calculated that answer.

[Submit Answer](#)

$$1 \times 1/2 = 1/2$$

**Note:** Karuna is homozygous dominant for Horns and Sam is homozygous recessive for Wings.



A 12-question quiz concludes the first section. Students are given their score, followed by an explanation of the answers.

|        |     |    |    |    |
|--------|-----|----|----|----|
|        | Sam |    |    |    |
|        | H   | h  |    | w  |
| Karuna | H   | HH | Hh | W  |
|        |     |    |    | Ww |
|        |     |    |    | w  |
|        |     |    |    | ww |

For Horns and Wings, again all of Karuna and Sam's offspring will have horns because Karuna can contribute only the dominant H allele to her offspring. And as with Tails, Karuna is heterozygous for Wings (Ww) and Sam is homozygous recessive (ww). So approximately 1/2 of their offspring will have no wings (Ww) and approximately 1/2 of their offspring will have wings (ww).

From the individual Punnett squares for Horns and Wings, you can predict the probability that Karuna and Sam will have an offspring with both horns and wings by multiplying the probability that offspring will have horns (1/1) times the probability that offspring will have a plain tail (1/2) which equals 1/2 or  $1/1 \times 1/2 = 1/2$

Now that you've explored how 2 characteristics are inherited when their genes are part of different chromosomes, it's time to investigate what happens when the genes for 2 characteristics are parts of the same chromosome.

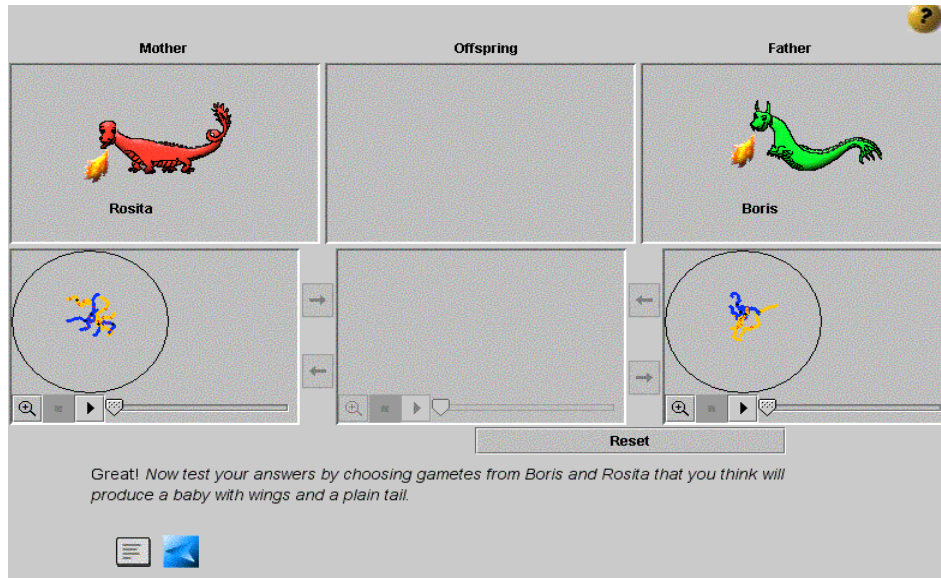
Done

Assessment questions explained.

### 4.3 Genes that are Part of the same Chromosome

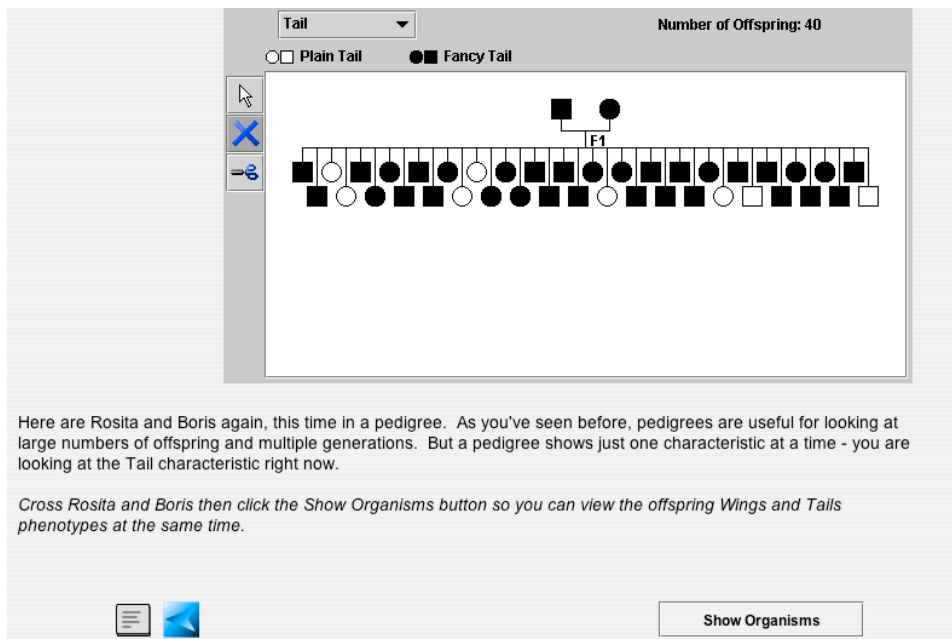
The model of meiosis is used to help students explore inheritance patterns when genes for those characteristics are parts of the same chromosome. Note: While BioLogica has the capability to model crossing over, it is not used in the current set of activities. Students are guided through the reasoning from genotypes to pedigrees.

- Step 1: Run meiosis and then run fertilization
- Step 2: Use the cross tools to show a pedigree chart for Rosa and Boris
- Step 3: Click the Show Organisms button view offspring.
- Step 4: Complete the data table.
- Step 5: Determine the probability of unrelated events, (traits on different chromosomes)
- Step 6: Use your data to answer the questions.
- Step 7: Review key concepts.



Students are challenged to produce a baby with wings and a plain tail. Both are recessive traits.

Note: Students must examine the gametes to select those with the recessive alleles for Wings and Tail.



Here are Rosita and Boris again, this time in a pedigree. As you've seen before, pedigrees are useful for looking at large numbers of offspring and multiple generations. But a pedigree shows just one characteristic at a time - you are looking at the Tail characteristic right now.

Cross Rosita and Boris then click the Show Organisms button so you can view the offspring Wings and Tails phenotypes at the same time.

Students then create lots of offspring in pedigree.

Female

Here's all 40 of Rosita and Boris' offspring. Complete the data tables below by entering offspring counts for each phenotypic category in each table. When tables are complete, click the "Submit" button.

| Rosita & Boris | no wings             | wings                | Rosita & Boris | fancy tail           | plain tail           |
|----------------|----------------------|----------------------|----------------|----------------------|----------------------|
| Cross 1        | <input type="text"/> | <input type="text"/> | Cross 1        | <input type="text"/> | <input type="text"/> |

| Rosita & Boris | no wings & fancy tail | no wings & plain tail | wings & fancy tail   | wings & plain tail   |
|----------------|-----------------------|-----------------------|----------------------|----------------------|
| Cross 1        | <input type="text"/>  | <input type="text"/>  | <input type="text"/> | <input type="text"/> |

Students create data table by scrolling through the offspring and counting the different phenotypes and combinations.

Female

Here's all 40 of Rosita and Boris' offspring. Complete the data tables below by entering offspring counts for each phenotypic category in each table. When tables are complete, click the "Submit" button.

| Rosita & Boris | no wings | wings | Rosita & Boris | fancy tail | plain tail |
|----------------|----------|-------|----------------|------------|------------|
| Cross 1        | 30       | 10    | Cross 1        | 30         | 10         |

| Rosita & Boris | no wings & fancy tail | no wings & plain tail | wings & fancy tail | wings & plain tail |
|----------------|-----------------------|-----------------------|--------------------|--------------------|
| Cross 1        | 30                    | 0                     | 0                  | 10                 |

Completed table looks like this but the numbers may be different, not because students miscount, which they might, but because organisms are generated randomly as they are in nature.

|   |    |    |
|---|----|----|
|   | W  | w  |
| W | WW | Ww |
| w | Ww | ww |

|   |    |    |
|---|----|----|
|   | T  | t  |
| T | TT | Tt |
| t | Tt | tt |

Above are Punnett squares that show crosses with Rosita and Boris for Wings and for Tails. Each predicts that about 1/4 of Rosita and Boris' offspring will have wings (ww) and about 1/4 will have plain tails (tt) which may or may not be consistent with your counts in the tables below.

|  |          |       |
|--|----------|-------|
|  | no wings | wings |
| Rosita & Boris:<br>Cross 1   | 30       | 10    |
| Ratios predicted by<br>Punnett square                                      | 3/4      | 1/4   |
| Number of offspring<br>out of 40 predicted<br>by independent<br>assortment | 30       | 10    |

|  |            |            |
|--|------------|------------|
|  | fancy tail | plain tail |
| Rosita & Boris:<br>Cross 1   | 30         | 10         |
| Ratios predicted by<br>Punnett square                                      | 3/4        | 1/4        |
| Number of offspring<br>out of 40 predicted<br>by independent<br>assortment | 30         | 10         |

The difference between predicted and actual counts of phenotypes is discussed.

|   |                |                |
|---|----------------|----------------|
|   | W              | w              |
| W | WW<br>no wings | Ww<br>no wings |
| w | Ww<br>no wings | ww<br>wings    |

|   |                  |                  |
|---|------------------|------------------|
|   | T                | t                |
| T | TT<br>fancy tail | Tt<br>fancy tail |
| t | Tt<br>fancy tail | tt<br>plain tail |

Applying the notion of independent assortment to Wings and Tails, what predictions would you make about the probability of Rosita and Boris having offspring with different Wings and Tails phenotypic combinations?

33. The first one is done for you. Using it as an example, select an answer for each of the remaining combinations.

**no wings & fancy tail**     1/16     3/16     9/16     1/1

[since (3/4 no wings) X (3/4 fancy tails) = 9/16]

**no wings & plain tail**     1/16     3/16     9/16     1/1

**wings & fancy tail**     1/16     3/16     9/16     1/1

**wings & plain tail**     1/16     3/16     9/16     1/1

Students calculate what the probabilities would be if wings and tails were inherited independently.

|   | no wings & fancy tail | no wings & plain tail | wings & fancy tail | wings & plain tail |
|---|-----------------------|-----------------------|--------------------|--------------------|
| Rosita & Boris: Cross 1   | 32                    | 0                     | 0                  | 8                  |
| Ratios predicted by independent assortment                        | 9/16                  | 3/16                  | 3/16               | 1/16               |
| Number of offspring out of 40 predicted by independent assortment | about 22              | about 8               | about 8            | about 22           |

Clearly, your observations are not consistent with predictions based on independent assortment. Was Mendel wrong? Or is there a sound biological explanation about why the inheritance of the Wings and Tails genes does not act according to the Law of Independent Assortment?

Keeping in mind that

- during meiosis the chromosomes AND their included genes travel together, and
- fertilization combines chromosomes AND their included genes

34. Explain the differences between predicted and observed Wings and Tail phenotypes among Rosita and Boris' offspring.

☰
Submit Answer

Students are asked to explain why the counts predicted by independent assortment differ from those produced by pedigree.

Mother

Your observations are not consistent with your predictions based on independent assortment because the Wings and Tail genes are part of the same chromosome. So they do not travel through meiosis **independently** of one another the way genes that are parts of different chromosomes do.

*Click the play button, then carefully follow Rosita's Wings and Tail genes as they go through meiosis as parts of the same chromosome.*


☰
▶

Students are asked to observe the action of the Wings and Tail genes as they go through meiosis, demonstrating that they do not sort independently.



|   |    |    |
|---|----|----|
|   | H  | h  |
| h | Hh | hh |
| h | Hh | hh |

|   |    |    |
|---|----|----|
|   | W  | w  |
| w | ww | ww |
| w | ww | ww |



$\frac{1}{2} \times \frac{1}{2}$

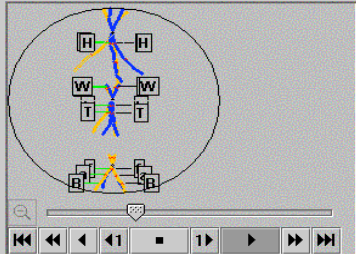
When you determined probabilities for the behavior of chromosomes as they assort independently, you multiplied the probability of offspring inheriting one specific trait (like horns) times the probability of the same offspring inheriting another specific trait (like no wings). You used this to determine the probability that the offspring will inherit **both** traits. In the language of mathematics, these are 'unrelated events'.

Comparison of unrelated events when genes are parts of different chromosomes is contrasted with what happens when genes are parts of the same chromosome and therefore do not assort independently.

But here we have two genes traveling through meiosis as part of the same chromosome. Therefore, how each gene gets from the beginning of meiosis to the end of meiosis is **not** a series of 'unrelated events'. So multiplying their independent probabilities to determine a combined probability is incorrect.

And it's important to understand that treating two genes as independent and creating data tables like the one you created **is exactly what geneticists do** as one way of finding out where different genes are located.

**Father**



|   | no wings & fancy tail | no wings & plain tail | wings & fancy tail | wings & plain tail |
|---|-----------------------|-----------------------|--------------------|--------------------|
| Rosita & Boris: Cross 1   | 32                    | 0                     | 0                  | 8                  |
| Ratios predicted by independent assortment                        | 9/16                  | 3/16                  | 3/16               | 1/16               |
| Number of offspring out of 40 predicted by independent assortment | about 22              | about 8               | about 8            | about 22           |

As you've seen many times already, data and predictions rarely agree **exactly**. This is true in genetics and in other sciences as well. Scientists build imperfect models of the natural world and use them to make predictions about how the world actually works. Then they observe and gather data from the actual world and look at how well their predictions and observations match the data. This gives scientists information about the quality of their models.

Discrepancies between data and predictions are discussed.

Mendel's imperfect model of inheritance wasn't wrong. The chart below shows the general steps of how scientists use models and data on the left and the corresponding steps of your work with the inheritance of Wings and Tail on the right. The general 'steps' are actually part of a repeating cycle.

| In general ...  | In this case ...   |
|---|--|
| 1. Based on observations/data, build a convincing model of the world.   | 1. Mendel did this for you ☺. You are also doing something similar as you learn about genetics and other new things.   |
| 2. Assume that model to be correct when interpreting new data.  | 2. Use Mendelian model of inheritance, particularly independent assortment, to predict possible Wings/Tail phenotypes for Rosita and Boris' offspring. Compare these predictions with the actual Wings/Tail phenotypes of Rosita and Boris' offspring. |
| 3. Decide if the model still basically makes sense with some modifications or if the new data indicate that the model is fundamentally wrong and needs to be replaced with a new model. | 3. Modify Mendel's Law of Independent Assortment so that it applies to genes that are parts of different chromosomes but not to genes that are part of the same chromosome.  |

Reasoning with models is discussed in general and in the context of what students have just done in Dihybrid.

Let's take a look at meiosis in Boris to understand independent assortment and gene location more fully and to think about what this means in terms of dihybrid offspring probabilities.

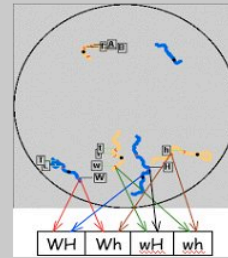
Remember, **chromosomes** are assorted independently during meiosis.

Since Boris is heterozygous for Horns (part of Chromosome1), he could pass on an H or h allele.

Since he is also heterozygous for Wings (part of Chromosome2),

- his H allele could end up in a gamete with either a W or w allele and
- his h allele could end up in a gamete with either a W or w allele.

The results of many of Boris' germ-line cells going through meiosis are the 4 combinations shown in the diagram.

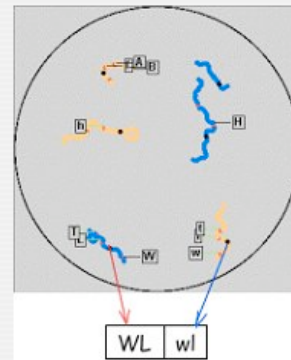


Independent assortment for Horns and Wings genes are contrasted with assortment of Wings and Legs genes that are parts of the same chromosome.

Remember that it's the **chromosomes, not the genes**, that assort independently.

Although Boris is heterozygous for Wings and Legs, he can only pass on Wings and Legs allele combinations as they occur in each of his Chromosome2s.

This results in just two combinations as shown in the diagram.



|    |      |      |
|----|------|------|
|    | WL   | wl   |
| WL | WWLL | WwLl |
| wL | wWLL | wwLl |

Here's a correctly filled in Punnett square.

38. Using the Punnett square above, determine the probability of Rosita and Boris having offspring with different Wings and Legs phenotypic combinations.

- no wings & no legs  0  1/4  1/2  3/4  1/1
- no wings & 2 legs  0  1/4  1/2  3/4  1/1
- no wings & 4 legs  0  1/4  1/2  3/4  1/1
- wings & no legs  0  1/4  1/2  3/4  1/1
- wings & 2 legs  0  1/4  1/2  3/4  1/1
- wings & 4 legs  0  1/4  1/2  3/4  1/1

You're right! About 1/2 of Rosita and Boris' offspring would have no wings and 4 legs (WWLL and wWLL). About 1/4 would have no wings and 2 legs (WwLl). And about 1/4 would have wings and 2 legs (wWlL).

Students are asked to reason through the probabilities of possible phenotypic combinations for the offspring of Rosita and Boris.

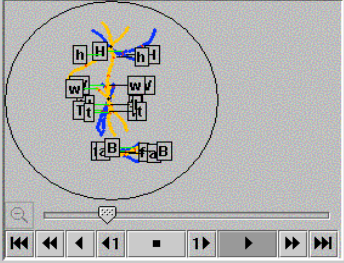
A series of quiz questions exercise and assess students' ability to reason about dihybrid.

To summarize...

If two genes are part of the same chromosome, they are inherited together.  
If two genes are parts of different chromosomes, they are inherited independently.

Remember how the chromosomes sort out during meiosis? The offspring don't just inherit particular alleles from their parents - they inherit whole chromosomes. So if an offspring gets a particular allele for some gene from its mother, it also gets the alleles for the other genes that are part of **that** chromosome. The same is true of the chromosomes offspring inherit from their fathers.

Throughout your work with dihybrid inheritance and other concepts in BioLogica, you have been working with an incomplete, simplified model of meiosis as a way to help you build your own model and ultimately a more sophisticated understanding of genetics. When learning about complex things, like meiosis, it's useful and easier to build simple but incomplete models first and then add missing pieces and more complex details, such as crossing-over, as your learning continues.



Done

Summary of dihybrid inheritance

## 5.0 Student Reports

Your students' work with Dihybrid is logged and viewable on the MAC Project Web Portal at <http://mac.concord.org>. For each student, you can view a report containing questions and answers.

Students have now completed the core instructional activities of BioLogica and are ready for *Invisible Dragons*, an assessment activity that requires that students figure out the genotypes of invisible parents from the phenotypes of their offspring.

Other optional activities include *Scales*, which guides students through reasoning about a previously unknown trait and *Plates*. Plates gives students a chance to explore an unknown trait with less guidance.