

Mendelian Genetics

Contents

	Objectives	1
	Introduction	1
Activity 13.1	Forming Gametes	2
Activity 13.2	Monohybrid Cross	3
Activity 13.3	Dihybrid Cross	4
Activity 13.4	Gene Linkage	5
	Results Section	8

Objectives

- Understand the application of Mendel's laws
- Know the expected ratios of a monohybrid and dihybrid cross
- Be able to recognize and describe phenotypes
- Understand the effects of gene linkage and sex linkage

Introduction

The surest way to determine the inheritance characteristics of a particular trait is to conduct testcrosses between individuals expressing the trait's alternative states. For example, if you wanted to determine how the trait for kernel color in corn is inherited and controlled, you could cross a yellow kernel corn plant with a purple kernel corn plant. These types of experiments were conducted by Gregor Mendel in the 1850's and 60's and have led to the discipline of Mendelian Genetics, that branch of biology concerned with the nature of inheritance.

Mendel found that inheritance of traits followed four laws. In modern terminology these are: 1. individuals possess a pair of alleles for each trait; 2. one allele is dominant, meaning that it is expressed in the heterozygous condition, the other recessive, that is, not expressed in the heterozygous condition; 3. a parent only passes one of their alleles to an offspring (allele chosen at random); and 4. the alleles for different traits are inherited independently of each other.

If these rules hold, in a cross between parent plants (the P generation) that are homozygous yellow kernel corn plants and purple kernel corn plants, one expects the offspring

(the F₁ generation) to have one yellow allele and one purple allele (i.e., heterozygous). As it turns out, purple is dominant to yellow so all of these offspring will be purple in color even though they all contain a yellow allele. If one goes further and crosses these F₁ plants (a heterozygote with a heterozygote), some of the new offspring (the F₂ generation) will get a purple allele from each parent, some F₂ offspring will get a yellow allele from each parent, and some F₂ offspring will get a purple from one and a yellow from the other parent. The appearance of these offspring will be either purple or yellow.

The following lab simulations allow you to investigate these principles of Mendelian genetics. In the first simulation you'll develop your skills in recognizing the types of gametes an individual can produce. The second simulation investigates the outcome of a monohybrid cross (following a single characteristic), in the third simulation you'll investigate a dihybrid cross.

Finally in the fourth simulation you'll be able to explore the effects of gene linkage and sex linkage on the ratio of offspring phenotypes.

Activity 13.1 Forming Gametes

One of the problems students frequently have when first learning and applying genetic principles is recognizing the possible types of gametes which can be created by an individual of a given genotype. The principles to remember here are that the gametes are haploid and that they only receive one of each type of parental chromosome. In the first Mendelian Genetics simulation you will gain experience in creating gametes from various parental genotypes.

Across the top center of the screen for this simulation is a representation of the parental chromosomes. Initially represented are four pairs of chromosomes, three autosome pairs and one sex chromosome pair.

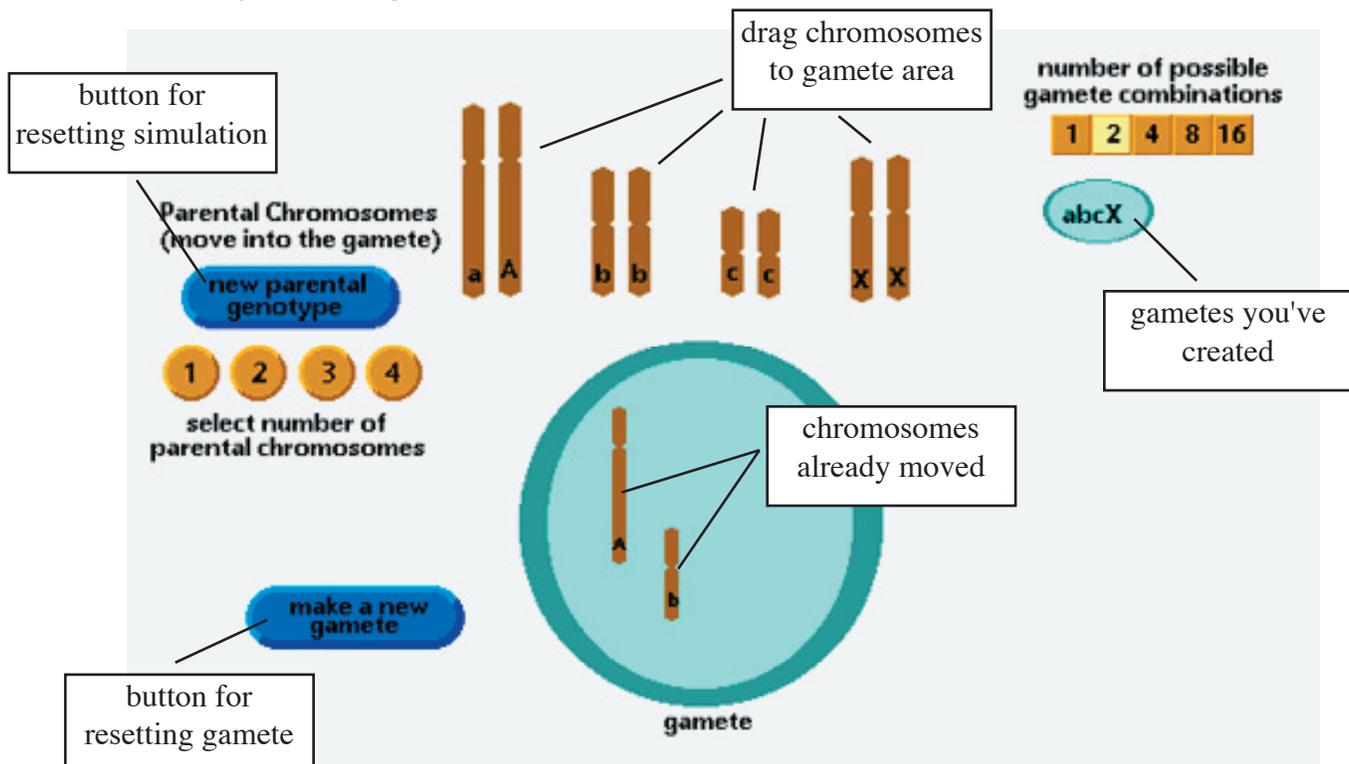
On each chromosome is a letter representing a gene allele carried on that chromosome. The number of parental chromosomes can be changed between one and four pairs by clicking on the appropriate yellow button to the left of the chromosomes. You can change the parental genotype,

keeping the same number of chromosomes, by clicking on the blue button to the left of the chromosomes.

In the center of the screen is the 'gamete cell' into which you are going to place the appropriate chromosomes to create a gamete. When a gamete has been properly filled with the appropriate chromosomes it will appear on the right side of the screen with its genotype displayed. If you attempt to place a chromosome into the gamete which does not belong or if the gamete's genotype has already been created a warning message will appear over the gamete.

Once a new, correct gamete has been created, you can continue to create another gamete by clicking on the 'New Gamete' button. To help you know how many different types of gametes are possible for a particular parental genotype, the number of possible combination will be highlighted in the upper right of the screen.

Simulation for Forming Gametes



Activity 13.2 Monohybrid Cross

Activity

Select the number of parental chromosomes to work with to two. Move the parental chromosomes into the gamete by clicking on the chromosome and while holding the mouse button down, drag the chromosome into the gamete space. Then release the mouse button. If the chromosome belongs, the chromosome will 'pop' into the gamete. Repeat this procedure until you have created a correct gamete. Create all of the possible gametes for the given parental genotype. Record the parental genotype and the genotypes of the gametes in the Results Section.

Repeat this experiment at least two more times with different parental genotypes. At least one time select to work with all four parental chromosome pairs. Record your results in the spaces provided in the Results Section.

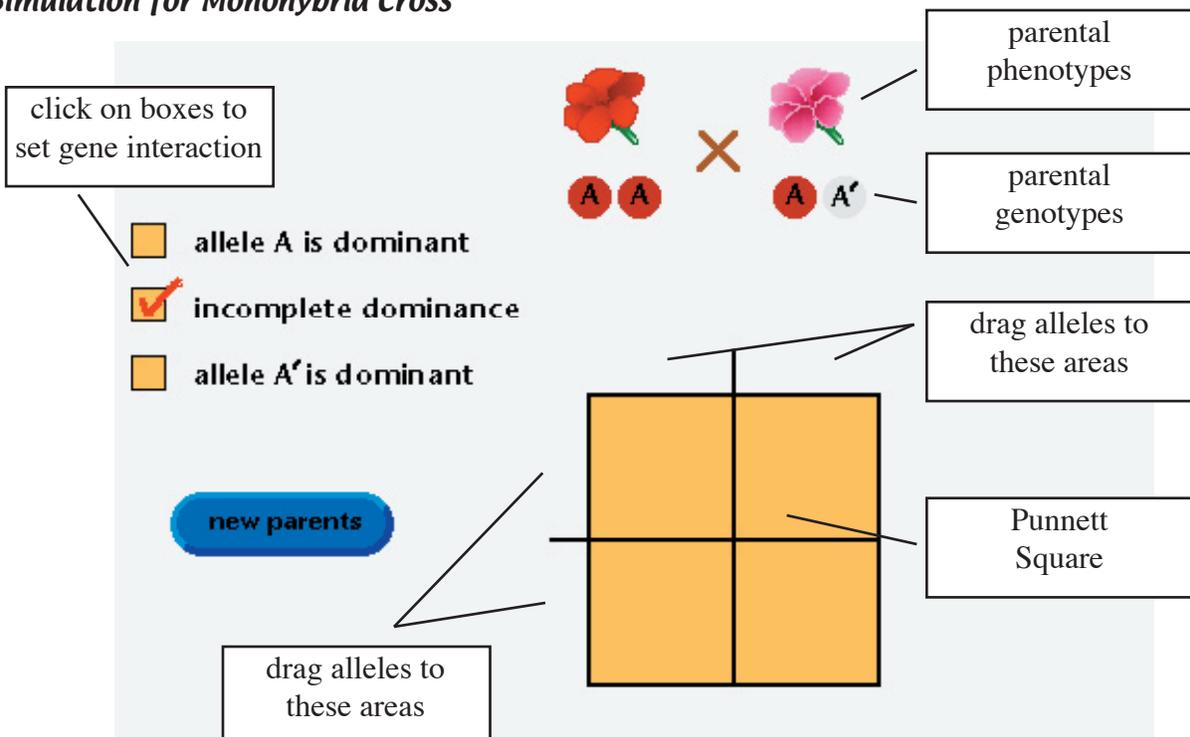
There is a handy tool to determine the proportion of each type of offspring. This is called a Punnett square.

Basically you place the gametes of one parent across the top of the square and the gametes of the other parent along the side. A line is drawn between the two gametes of each parent through the square. Each smaller square inside the larger square represents an offspring. The gametes each parent donates to that offspring are determined by their row and column.

Then you can simply count the different types of offspring to determine their proportion. This simulation will provide you some practice utilizing the Punnett square to derive possible offspring combination from a given parental cross.

At the top of the screen is a representation of the parents giving their genotypes, the alleles represented by A and A', and their phenotypes, flower color. In this simulation the allele A codes for red colored flowers and the allele A' codes

Simulation for Monohybrid Cross



Activity 13.3 Dihybrid Cross

for white flowers. To the left are three boxes which you can click on to change how the alleles interact. The upper box makes allele A dominant over allele A'. The lower box makes allele A' dominant over allele A. The middle box makes the two allele incompletely dominant. The blue button under these boxes can be clicked on to produce a new parental cross. In the center of the screen is the Punnett square which you will fill to see the potential offspring from the cross.

Activity

Select the "allele A is dominant" condition. If you would like to select different parents, click on the new parents button. When ready, begin to fill the Punnett square by clicking on one of the parental alleles and while holding the mouse button down, drag the allele to one of the spaces just outside the square's left side or top. Place the allele by releasing the mouse button. If the allele is positioned properly the allele will click into place and alleles will be moved into place in the locations representing possible offspring within the square. Repeat this procedure to place all four alleles from the two parents along the top and left sides of the square. The two alleles from the same parent must be placed on the same side. As the offspring genotypes are completed their phenotypes will bloom. In the Results Section, record the parent's phenotype and genotype and complete the Punnett square provided.

Change the condition to "incomplete dominance" and repeat the experiment, recording your results in the Results Section. Then change to the "allele A' is dominant" condition and repeat. Note how changing the type of allele interaction alters the phenotypic ratios in the offspring.

A dihybrid cross follows the inheritance of two separate traits at once. If Mendelian laws are followed and the traits are inherited independently, from a cross of two heterozygous parents we expect to see offspring in the ratio of 9 with both dominant traits to 3 with one dominant and the other recessive to 3 with the first recessive and the second dominant to 1 with both recessive traits.

In this simulation the two traits observed are the color of peas (yellow and green) and the texture of the peas (smooth and wrinkled). You are asked to first create the gametes from the parents and then to place the gametes into a Punnett square to observe the possible types of offspring.

On the first screen the phenotypes and genotypes of the parents to be crossed are displayed. A button to the left allows you to change the parents to a different combination.

Across the bottom of the screen are four gamete genotypes. These represent all possible combinations of alleles for these two traits. Depending on the parent genotypes, you may not use all of these gametes.

In the middle of the screen are two circles. It is within these spaces that you will place the possible gametes for each parent. For each parent, click and drag the appropriate gametes from the bottom row into a parent's circle. If the gamete belongs it will snap into place.

When all possible gametes are selected for both parents, each circle will contain four gametes (some may have the same genotype). A button will appear to take you to the next step, completing the Punnett square.

On the second screen of the simulation, the gametes you just created will be displayed across the top of the screen and along the left side. A Punnett square is located in the middle of the screen. Drag the gametes into an appropriate position for the Punnett square. When placed, the gametes will snap into place and the alleles from that gamete will be placed into each cell of the row or column. As the genotype of the offspring are completed their phenotype appears.

Activity 13.4 Gene Linkage

Activity

Select the type of parental cross you would like to follow. Record the parental phenotypes and genotypes in the Results Section. For each parent, select the appropriate gametes. Record these in the space provided in the Results Section.

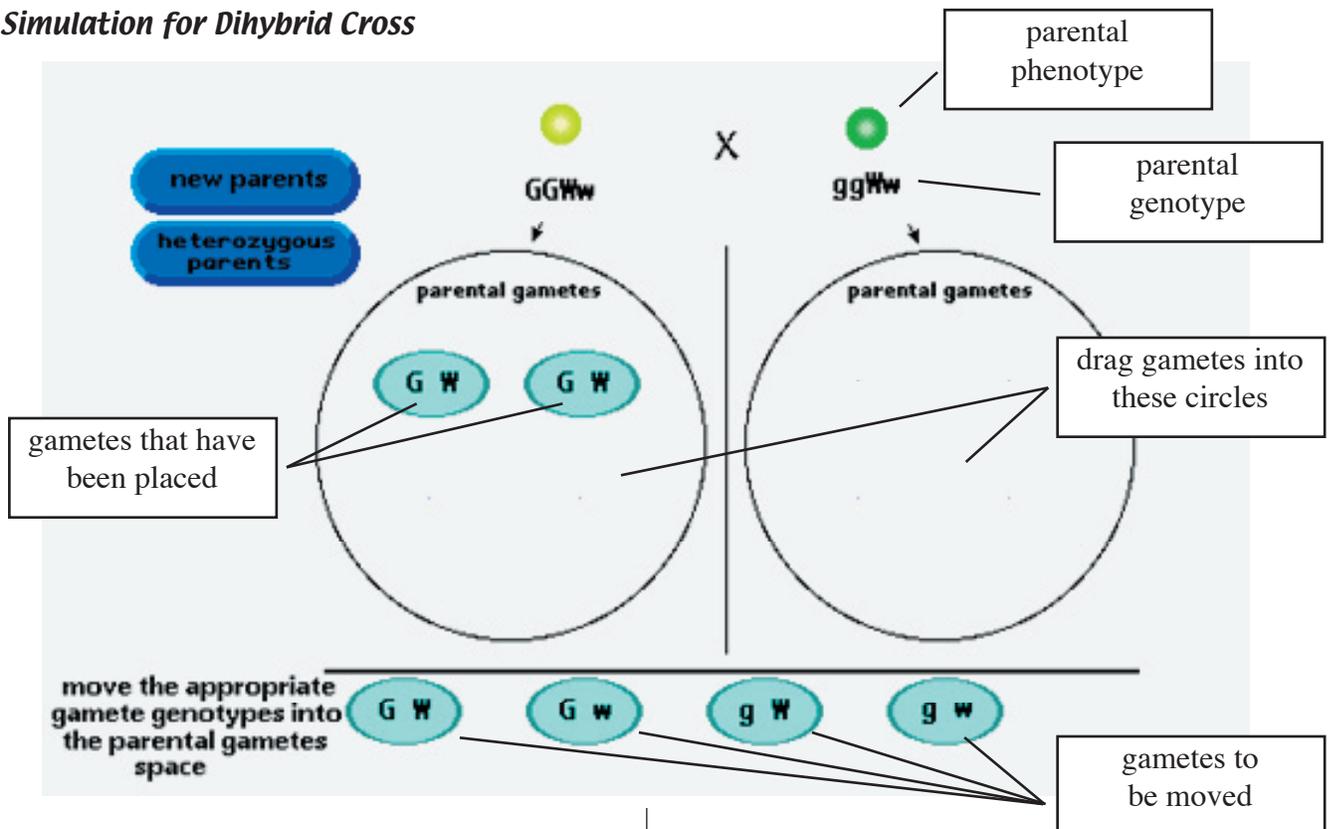
Go to the second screen of the simulation and move the gametes into position to complete the Punnett square. Record your results by filling in the spaces of the Punnett square in the Results Section.

The last simulation for Mendelian genetics investigates the effects of gene linkage and sex linkage on the proportions of offspring phenotypes. In this simulation you will be following two traits in flies, eye color and wing type. For eye color, it is known that green eyes are dominant to yellow eyes. For wing type, it is known that full sized wings are dominant to withered wings.

Activity

In the first screen of this simulation you must place the genes for eye color and wing type on the fly's chromosomes. In other words, you determine the locus for these two traits. Click and drag the gene (green piece of DNA) for eye color on to one of chromosomes 1 through 3. When placed it will pop onto the chromosome and appear as a green band. Then click and drag the gene (red piece of DNA) for wing type and place it on a different chromosome 1 through 3. These gene loci can be moved after the genes have been placed on the chromosomes if desired.

Simulation for Dihybrid Cross



Once the loci for the genes have been set, mark the location of these loci in the spot provided in the Results Section. Click on the button in the upper right to set the parental phenotypes.

On this screen you must set the phenotypes of the parents to be crossed. Click on the eye color and wing type below the male to set the male's phenotype. Set the female's phenotype so that it's traits are opposite that of the male. The phenotypes can be changed anytime while on this screen. Record the phenotypes of each parent in the space provided in the Results Section. Click on the button in the upper right to breed the parents.

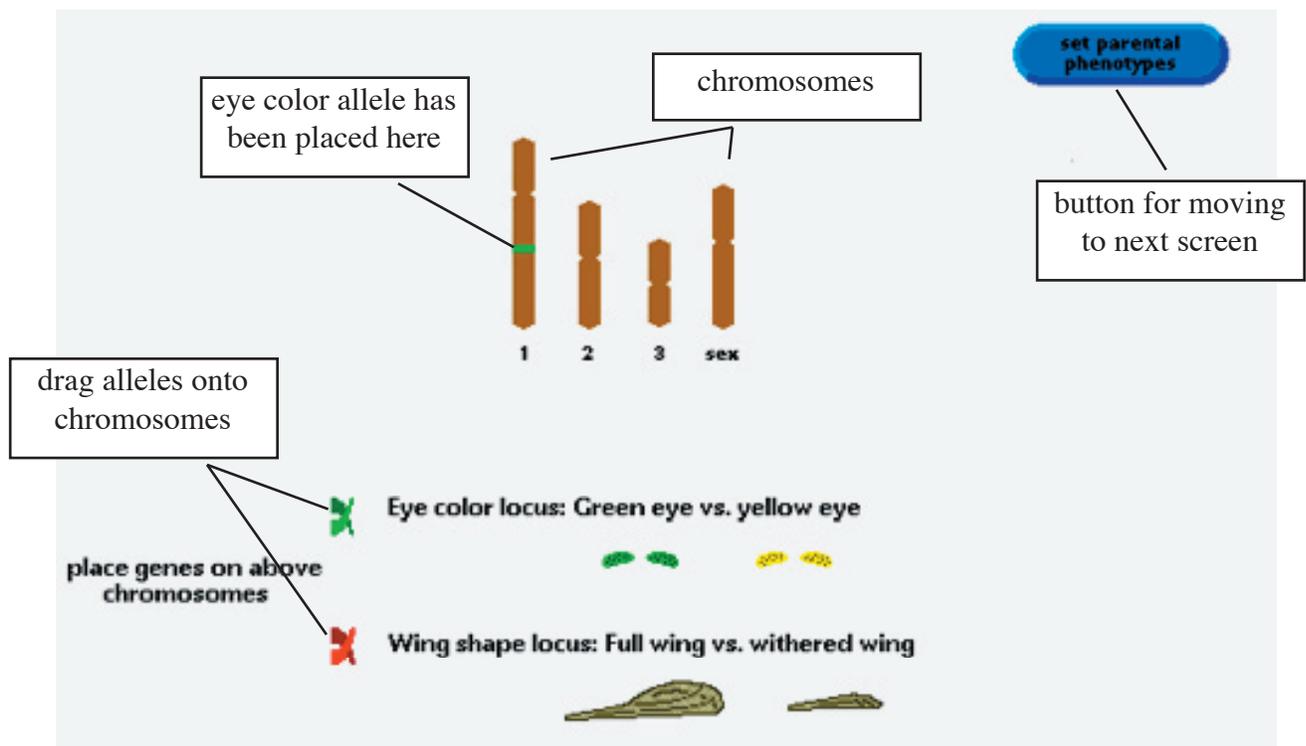
The third screen of this simulation shows all possible combinations of phenotypes for these two traits for both males and females. Below each phenotype is a number indicating the number of offspring observed in the F1 generation. A zero indicates that this phenotypes was not found. Record the number offspring for each phenotype in the

space provided in the Results Section. Is this the expected outcome based on what is known about these traits?

When ready, click on the button in the upper right to breed the F1 offspring and obtain the F2 generation.

The last screen for this simulation shows all possible combinations of phenotypes for males and females in the F2 generation. Below each is the number of these flies observed. Record this data in the space provided in the Results Section. Calculate and record the ratio for these phenotypes within each sex. To do this for the males, find the male phenotype with the smallest nonzero number of individuals. This number will be used in the denominator. The ratio of each phenotype is then calculated by dividing the number of that phenotype observed by this denominator. For example, if the number of males for each phenotype was 200, 78, 86, and 23 respectively, the ratios would be calculated to be $200/23 = 8.7$, $78/23 = 3.4$, $86/23 = 3.7$ and $23/23 = 1$ respectively.

First Simulation Screen for Gene Linkage



If you would like to repeat this experiment with the genes at the same loci but with different parental phenotypes, click on the “Reset Parental Phenotypes” button in the upper right.

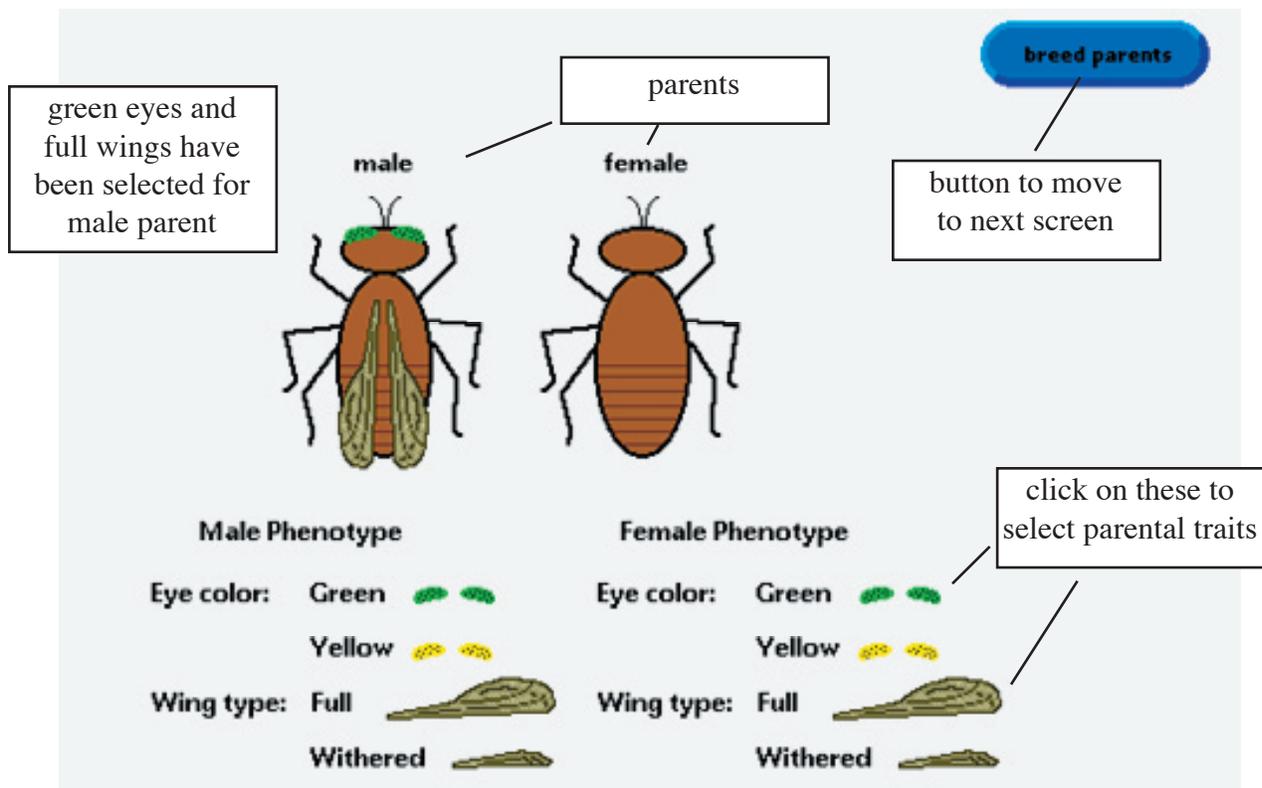
From the screen showing the F2 offspring, click on the “Reset Gene Loci” button in the upper right. This will return you to the screen to set the loci for these genes. This time place both genes on the same non-sex chromosome. Place the gene loci fairly close together. Proceed to the screen to set the parental phenotypes and set the male and female phenotypes to what you selected previously. Breed these flies to observe the F1 offspring. After recording this data in the Results Section, proceed to the screen showing the F2 offspring. Record this data and calculate the phenotypic ratios. How do these compare to the ratios when the genes were located on different chromosomes?

Click on the “Reset Gene Loci” button to reset the location of the genes once again. This time place one gene on chromosome 1 through 3 and place the second gene on the sex chromosome. Proceed to the screen to set the parental phenotypes and set the male and female phenotypes to phenotypes you originally selected. Breed these flies to observe the F1 offspring. After recording this data in the Results Section, proceed to the screen showing the F2 offspring. Record this data and calculate the phenotypic ratios. How does sex linkage effect these ratios?

Do males and females have the same ratios? Click the button to reset the parental phenotypes (this keeps the genes at the same loci). This time set the male parent to the phenotype the female had before and set the female phenotype to what the male had before.

Repeat the breeding to observe the F1 and F2 offspring. Are the results the same?

Second Simulation Screen for Gene Linkage



Results Section

Activity 13.1 Forming Gametes

Record the genotype of the parent and the possible gametes that individual could produce.

Parental Genotype _____

Gamete Genotypes _____

Parental Genotype _____

Gamete Genotypes _____

Parental Genotype _____

Gamete Genotypes _____

Activity 13.2 Monohybrid Cross

When A is dominant:

Parents phenotype _____ X phenotype _____
 genotype _____ genotype _____

Punnett square:

	_____	_____
_____	phenotype ____ genotype ____	phenotype ____ genotype ____
_____	phenotype ____ genotype ____	phenotype ____ genotype ____

With Incomplete Dominance:

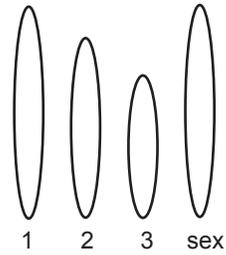
Parents phenotype _____ X phenotype _____
 genotype _____ genotype _____

Punnett square:

	_____	_____
_____	phenotype ____ genotype ____	phenotype ____ genotype ____
_____	phenotype ____ genotype ____	phenotype ____ genotype ____

Activity 13.4 Gene Linkage

Mark the location of the gene loci



Parental
Phenotypes

male
eye phenotype _____

female
eye phenotype _____

wing phenotype _____

wing phenotype _____

F₁ offspring

males	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

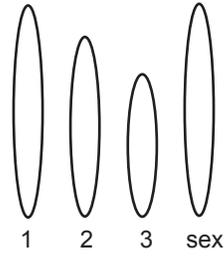
females	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

F₂ offspring

males	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

females	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

Mark the location of the gene loci



Parental
Phenotypes

male
eye phenotype _____

female
eye phenotype _____

wing phenotype _____

wing phenotype _____

F₁ offspring

males	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
	green eyes full wings			green eyes withered wings		

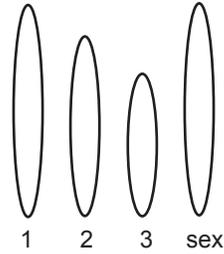
females	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
	green eyes full wings			green eyes withered wings		

F₂ offspring

males	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
	green eyes full wings			green eyes withered wings		

females	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
	green eyes full wings			green eyes withered wings		

Mark the location of the gene loci



Parental
Phenotypes

male
eye phenotype _____
wing phenotype _____

female
eye phenotype _____
wing phenotype _____

F₁ offspring

males	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

females	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

F₂ offspring

males	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			

females	phenotype	number	ratio	phenotype	number	ratio
	yellow eyes full wings			yellow eyes withered wings		
green eyes full wings			green eyes withered wings			