Rieder - Genetics
Worksheet 7: Epistasis in *Ursa gummi*
Begun 10/24/17 in class, due 10/26/17 at the beginning of class

Name: ____

I consulted/worked with: ____

This exercise was (circle all that apply):

Stupid Fun Too easy Too difficult Educational

Other: ___________________________ Helpful Not helpful

I will not accept late homework. Special exceptions will be made **only** in the event of illness or if you contact me at least 24 hours ahead of when the assignment is due (at my discretion).

POINTS: / 50

Adapted from: Moore (2009) “Gummi bear genetics: an exercise in understanding epistasis,” based on Baker and Thomas (1998) “Gummy Bear Genetics.”

What is Epistasis?

Mendel’s **dihybrid crosses** with peas resulted in the predicted phenotypic ratio of 9:3:3:1, where the ‘9’ represents double dominant phenotype, the ‘3’s’ represents one dominant and one recessive phenotype, and the ‘1’ represents both recessive phenotypes. This represents a cross between two doubly **heterozygous** individuals (AaBb x AaBb), where the A/a and B/b **loci** are on different chromosomes. The genes that Mendel studied did not affect each other (luck, yet again!).

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

In **epistasis**, one gene interferes with the expression of a different gene. What results is a **change** in the phenotypic ratios in the dihybrid offspring. Today you will explore epistatic genes in the delicious new species *Ursa gummi.*

Below, assume all A/a and B/b **loci** are on different chromosomes.

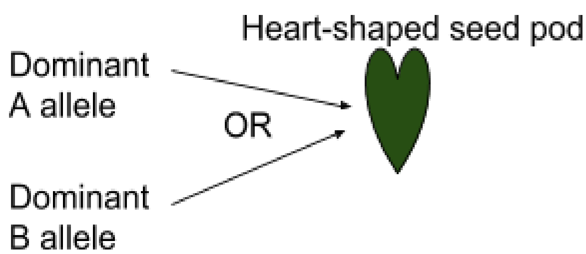
Exercise 1: Predicting Phenotypes in Epistasis

Your fame as a geneticist has reached the ears of the president. He has asked you take on the task of breeding an *Ursa gummi* army to protect the country. These delectable soldiers need to have specific characteristics to be good soldiers and you must determine how these traits are inherited and be able to make predictions of potential offspring.

I. Duplicate Dominant Epistasis

When a dominant allele at either of two **loci** can *mask* the expression of recessive alleles at the other locus, it is known as **duplicate dominant epistasis**.

Fruit shape in shepherd's purse is an example of duplicate dominant epistasis. This weed has two genes that code for the shape of the seed capsule. The dominant allele of both genes codes for triangular/heart-shaped seed pod. Only plants that are homozygous recessive for both genes have seed capsules that are slender or ovoid in shape.



Your first assignment is to predict the phenotypic ratios that accompany two genes that code for the same phenotype.

In *Ursa gummi*, two different genes (A/a and B/b) control the same trait, with **dominant** alleles (A and B) coding for *susceptibility to melt* at relatively low temperatures. The **recessive** alleles (a and b) code for resistance to melting.

It is important that *Ursa gummi* soldiers *do not melt* in the heat of battle!

1. Below, fill out the phenotype (melting or resistance to melting) for each genotype (4 pts).

Genotype: **Phenotype:**

AABB ______________________

AaBB ______________________

aaBB ______________________

aaBb ______________________

AABb ______________________

AAbb ______________________

AaBb ______________________

Aabb ______________________

aabb ______________________

2. What is the **phenotypic ratio** of the 16 offspring produced from a cross between melting *Ursa gummi* who have a family history resistance (hint: This means that the parents are heterozygous AaBb)? You may use one of the dihybrid punnett squares at the end of this worksheet to help you. How many *U. gummi* offspring from this cross will be (4 pts):

Resistant to melting? ______________________________/16

Susceptible to melting? ____________________________/16

II. Duplicate Recessive Epistasis

When recessive alleles at either of the two **loci** *mask* a dominant allele at the other locus, it is called **duplicate recessive epistasis**. This can occur when genes participate in the same pathway.

Snail shell color is as an example of duplicate recessive epistasis. In snails with **albinism**, a recessive allele blocks the formation of the necessary compound that a second protein uses to make pigment. Pigmented snails have dominant alleles present at both loci. A homozygous recessive genotype at either locus blocks production of pigment, resulting in albinism.

Dominant A allele ⟶ Compound A $\xrightarrow[\text{B allele}]{\text{Dominant}}$ Pigment B

In *Ursa gummi*, the final trait that is necessary is heroic behavior. To become heroic, an *Ursa gummi* must be ***<u>BOTH</u>*** educated (A) and brave (B), traits encoded by **dominant** alleles.

The first step to produce a heroic *Ursa gummi* is to educate it. The second step to becoming heroic is to be brave; a *U. gummi* must apply its education to operate complicated equipment, such as a motorcycle, and to ride off into battle. <u>One can not produce a heroic *Ursa gummi* from an uneducated OR cowardly *Ursa gummi.*</u>

3. Heroic *Ursa gummi* make good soldiers. Below, fill out the phenotypes (educated, uneducated; brave, cowardly) for each genotype (4 pts).

Remember that educated + brave = HEROIC!

AABB ____________________

AaBB ____________________

aaBB ____________________

aaBb ____________________

AABb ____________________

AAbb ____________________

AaBb ____________________

Aabb ____________________

aabb ____________________

4. What is the **phenotypic ratio** of the 16 offspring produced from a cross between two heroic *Ursa gummi* that have a family history of cowardice and both educated and uneducated family members (AaBb)? You may use one of the dihybrid punnett squares at the end of the worksheet to help you. How many *U. gummi* offspring from this cross will be (4 pts):

Educated but cowardly? ____________________________________/16

Uneducated but brave? ____________________________________/16

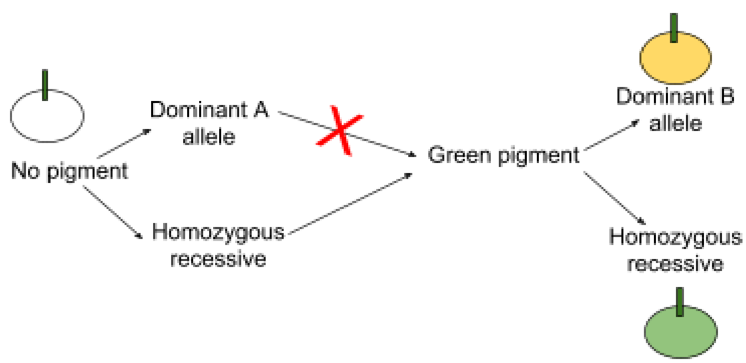
Educated AND brave = HEROIC? ____________________________/16

Uneducated AND cowardly? ___________________________1/16

III. Dominant Epistasis

When a dominant allele at one **locus** can *mask* the alleles--whether dominant or recessive--at another locus, it is known as **dominant epistasis.**

In squash, fruit color is the result of a multi-step pathway that exhibits dominant epistasis. In the first step, a dominant allele at the first locus *inhibits* the production of pigment. Plants that have the dominant allele are white, while plants that are homozygous for the recessive allele will produce green fruit. A second locus codes for a second pigment that must use the green pigment produced by the first locus. Plants with a dominant allele at the second locus produce a yellow pigment, while plants that are homozygous recessive at the second locus do not produce new pigment and remain green.



In *Ursa gummi*, a single, **dominant** allele (A) *inhibits* the ability to hold and use a spear. The spearless *Ursa gummi*, caused by the **homozygous recessive** state at the A/a locus, holds a balloon instead.

Of course, an *Ursa gummi* who can hold a spear will make a good soldier, but it should use it only ceremonially, behavior controlled by the **dominant** allele (B) at another locus. It is important to monitor and control any violent behavior, which is caused by the **homozygous recessive** state at the B/b locus.

5. Below, fill out the phenotypes (balloon-holding, spear + ceremonial, spear + violent) for each genotype (4 pts):

AABB ______________________

AaBB ______________________

aaBB ______________________

aaBb ______________________

AABb ______________________

AAbb ______________________

AaBb ______________________

Aabb ______________________

aabb ______________________

6. Using the Punnett square of a **dihybrid cross**, determine the **phenotypic ratio** of the 16 offspring produced from a cross between two non-violent, balloon holding *Ursa gummi* who have had a family history of both spear holding and violence (AaBb). You may use one of the dihybrid punnett squares at the end of the worksheet to help you. How many *U. gummi* offspring from this cross will be (4 pts):

Balloon-holding? ____________________________________/16

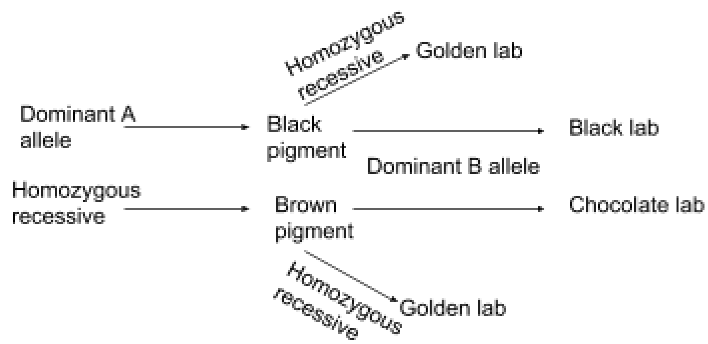
Ceremonial use of a spear? ____________________________________/16

Violent use of a spear? ____________________________/16

IV. Recessive Epistasis

When recessive alleles at one **locus** *mask* the expression of both alleles (dominant and/or recessive) alleles at another locus, it is known as **recessive epistasis.**

In Labrador retrievers, coat color can be masked by the recessive allele of a gene for pigment deposition and the dog will be a golden labrador, regardless of the pigment alleles present. A second gene codes for color, with the dominant allele for black pigment and the recessive allele for brown (chocolate) pigment.



In *Ursa gummi*, the recessive allele (a) for “all work” behavior *masks* both types of play that *Ursa gummi* enjoy—a dominant allele (B) for “play nice” behavior and a recessive allele (b) for “play rough” behavior.

You want an army of *Ursa gummi* soldiers that play rough!

7. Below, fill out the phenotypes (all work, play nice, play rough) for each genotype (4 pts):

AABB ______________________

AaBB ______________________

aaBB ______________________

aaBb ______________________

AABb ______________________

AAbb ______________________

AaBb ______________________

Aabb ______________________

aabb ______________________

8. Using the Punnett square of a **dihybrid cross**, determine what the phenotypic ratio of a cross between Nice playing *Ursa gummi* who have had a family history hard working *Ursa gummi* and *Ursa gummi* who played rough (AaBb). You may use one of the dihybrid punnett squares at the end of the worksheet to help you. How many *U. gummi* offspring from this cross will be (4 pts):

Hard working? ___________________________________/16

Nice playing? ____________________________________/16

Rough playing? __________________________________/16

Exercise 2: Analyzing offspring

You have been given a bag of *Ursa gummi* that were derived from a dihybrid cross. Unfortunately, the laboratory notes of the cross were lost. You need to develop a hypothesis regarding the relationship between genotype and phenotype.

Bag number: ______________________________

9. The colors represent phenotypes. One color represents the phenotype **you** want to be ubiquitous in your *U. gummi* army. The other color(s) are the phenotype(s) you want to breed out (2 pt). You can be creative here!

What is the desired color/phenotype: ________________________/______________________

What is the undesired color(s)/phenotype(s): __________________/______________________

10. What are the phenotypic ratios present in your offspring? Record your observations in the table below (2 pts). Your bags have either two or three colors.

Color/Phenotype	Number of *U. gummi*
Total number in bag:	

11. Convert your **phenotypic ratios** to fractions of 16. Remember that the dihybrid cross, ratios are built upon Mendel's ratio of 9:3:3:1 which can be expressed as fractions (9/16, 3/16, 3/16, and 1/16). To convert, divide the number of *U. gummi* of a certain color by the total number of *U. gummi* in your bag, then multiply by 16. You may have decimals (2 pts).

Color/Phenotype	Number of *U. gummi*
	/16
	/16
	/16

12. Based on what you've learned today, hypothesize a possible **epistatic interaction** that could lead to your observed phenotypic ratio. You may draw out a pathway, if you like, but make sure to *name* a particular type of epistasis you have learned today (3 pts).

13 What is the *expected* phenotypic ratio for the type of epistasis you have chosen (1 pt)?

Chi-square test:

We will now test your hypothesis and determine whether the data you collected support or do not support your hypothesis. Geneticists typically use the **chi-square statistical test** to determine whether experimentally obtained data ("observed") are satisfactory approximation of the expected data ("expected").

In short, this test expresses the difference between expected and observed numbers as a single value, **chi²**. If the difference between observed and expected results is large, a large chi² will tell you your observed is *significantly different* than your expected, which suggests it is time to seek a new hypothesis to explain your data. while a small difference results in a small chi² —hey hypothesis is supported! Chi² values are calculated according to the formula:

$$(\text{Observed Value} - \text{Expected Value})^2 \div (\text{Expected Value})$$

Note: Use the "raw numbers" of the data (from the table in **10** above), and compare these to the raw numbers you expect for the epistasis pattern you've chosen. Do not use probability or ratios or fractions in chi².

You have to convert your *expected* ratios to total numbers of *Ursa gummi*: multiply your expected ratio by the total number of *Ursa gummi* in your bag to obtain your expected values (as in, 9/16 X total number of gummis).

14. Fill out the table below (4 pts):

Characteristic	(Category 1) Observed	(Category 2) Expected
(group 1)		
(group 2)		
(group 3*)		

* Note: not all bags have 3 colors

15. Use the website http://www.socscistatistics.com/tests/chisquare2/Default2.aspx to calculate your chi² statistic. Round decimals to the nearest whole number and choose significance value 0.05**.** What is your chi² statistic (1 pt)?

Does your chi² statistic support your hypothesis about type of epistasis (3 pts)?

Duplicate dominant epistasis:

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Duplicate recessive epistasis:

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Dominant epistasis:

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Recessive epistasis:

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb