Mendelian Genetics Part 4: Dihybrid Cross **Name** _____

Terms and Explanations
Explain the following terms and concepts, using both a diagram and an explanation in sentences or statements:

Monohybrid cross –

Meiosis –

Crossing over -

Mendel's Law of Segregation –

Mendel's Law of Independent Assortment -

Dihybrid Cross

A dihybrid cross is used to study 2 different traits on 2 different chromosomes. Follow the same five step process for Monohybrid crosses but there are 4 times as many possibilities for the offspring. *NOTE: Dihybrid cross Punnett squares and statistics work ONLY when the traits are not linked, that is, on different chromosomes.*

Example:

A pea plant is heterozygous for both height and seed color. It is crossed with another plant heterozygous for both traits. What are the possible phenotypes and genotypes of offspring they can produce?

Each plant has the following alleles: Tt for height and Y*y* for seed color, so the genotype is TtY*y*.

TtY*y* X TtY*y*

To arrange the alleles on a Punnet square, consider all possible combinations of alleles for gametes from each parent. The gamete, and thus the offspring, could receive alleles for tall and yellow (TY), tall and green (T*y*), dwarf and yellow (tY), or dwarf and green (t*y*). Both parents have the same known genotype, so the allele combinations are the same for each parent.

	TY	Ty	tY	ty
TY	TTYY	TTYy	TtYY	TtYy
Ty	TTYy	TTyy	TtYy	Ttyy
tY	TtYY	TtYy	ttYY	ttYy
ty	TtYy	Ttyy	ttYy	ttyy

Label each box with Tall or dwarf, and Yellow or green. What is the phenotypic ratio?

1. In pea plants, the round seed allele is dominant over the wrinkled seed allele, and the yellow seed allele is dominant over the green seed allele. The genes for seed texture and those for seed color are on different chromosomes. A plant heterozygous for seed texture and seed color is crossed with a plant that is wrinkled and heterozygous for seed color. **R = round, r = wrinkled, Y= yellow, y = green*

    a. List the genotypes of the parents _____ X _____

    b. Construct a Punnett square for this cross.

    c. What is the expected **<u>phenotypic</u>** ratio for the offspring?

2. A female guinea pig is heterozygous for both fur color and coat texture is crossed with a male that has light fur color and is heterozygous for coat texture. What possible offspring can they produce? Dark fur color is dominant (D) and light fur (d) is recessive. Rough coat texture (R) is dominant, while smooth coat (r) is recessive.

a. List the genotypes of the parents _____ X _____

b. Construct a Punnett square for this cross.

c. What is the expected **phenotypic** ratio for the offspring?

3. In humans there is a disease called Phenylketonuria (PKU)which is caused by a recessive allele. People with this allele have a defective enzyme and cannot break down the amino acid phenylalanine. This disease can result in mental retardation or death. Let "**E**" represent the normal enzyme. Also in humans in a condition called galactose intolerance or galactosemia, which is also caused by a recessive allele. Let "**G**" represent the normal allele for galactose digestion. In both diseases, normal dominates over recessive. If two adults were heterozygous for both traits (EeGg), what are the chances of having a child that is completely normal? Has just PKU? Has just galactosemia? Has both diseases?

   a. List the genotypes of the parents _____ X _____

   b. Construct a Punnett square for this cross.

c. What is the expected **phenotypic** ratio for the offspring?

Non-Mendelian Genetics **Name** _____

Part 5: Incomplete Dominance

In Four o'clock flowers the alleles for flower color are both equal therefore neither dominates over the other. We call this condition incomplete dominance and it violates Mendel's principle of dominance. A red four o'clock flower (rr) is crossed with a white flower (ww). Since there is no dominant trait we use two different little letters for the genotype.

Step 1: *The genotype of the red flower will be "rr" and the genotype of the white flower is "ww".*

Step 2 and 3: *Complete a Punnett square for this cross.*

	r	r
w	rw	rw
w	rw	rw

Step 4: *All of the offspring will be "rw". So the genotypic ratio is:* **4 : 0 : 0**
rw ww rr

Step 5: *All of the offspring will have one of each allele (rw), so all will be pink.*

14. Predict the offspring when two pink Four o'clock flowers are crossed.

a. Complete a Punnett square for this cross.

b. What is the predicted genotypic ratio for the offspring?

c. What is the predicted phenotypic ratio for the offspring?

15. In humans straight hair (ss) and curly hair (cc) are codominant traits, that result in hybrids who have wavy hair (sc). Cross a curly hair female with a wavy haired male.

a. Complete a Punnett square for this cross.

b. What are the chances of having a curly haired child?

16. In some cats the gene for tail length shows incomplete dominance. Cats with long tails (l) and cats with no tails (n) are homozygous for their respective alleles. Cats with one long tail allele and one no tail allele have short tails. For each of the following construct a Punnett square and give phenotypic and genotype ratios of the offspring.

a) a long tail cat and a cat with no tail

b) a long tail cat and a short tail cat

c) a short tail cat and a cat with no tail

d) two short tail cats.

Codominance

Roan cattle

Part 5: Codominance and Multiple Allele

So far we have studied traits or genes that are coded for by just two alleles. Like in rabbits, there was one allele for brown hair color and one allele for white hair. However, some traits are
coded for by more than two alleles. One of these is blood type in humans. This is a violation of Mendel's Principle of unit characteristics.

*In humans, there are four types of blood; type A, type B, type AB, and type O. The alleles A and B are codominant to each other and the O allele is recessive to both A and B alleles. So a person with the genotype **AA** or **AO** will have **A type** of blood.*

a. What possible genotypes will produce B type of blood? _____

b. What is the only genotype that will produce O type of blood? _____

c. What is the only genotype that will produce AB type of blood? _____

1. You are blood type O and you marry a person with blood type AB. a. Complete a Punnett square for this cross.

   b. List the possible blood types (phenotypes) of your offspring. _____

2. In the 1950's, a young woman sued film star/director Charlie Chaplin for parental support of her illegitimate child. Charlie Chaplin's blood type was already on record as type AB. The mother of the child had type A and her son had type O blood.
   a. Complete a Punnett square for the possible cross of Charlie and the mother
   b. The judge ruled in favor of the mother and ordered Charlie Chaplin to pay child support

costs of the child. Was the judge correct in his decision based on blood typing evidence? Explain why or why not. **refer to any Punnett squares to support your answer.*

3. Suppose a newborn baby was accidentally mixed up in the hospital. In an effort to determine the parents of the baby, the blood types of the baby and two sets of parents were determined.

   Baby 1 had type O Mrs. Brown had type B Mr. Brown had type AB Mrs. Smith had type B Mr. Smith had type B

   a. Draw Punnett squares for each couple (you may need to do more than 1 square/ couple)

   b. To which parents does baby #1 belong? Why? *Hint you may want to refer to your Punnett squares.*

Part 6 SEX LINKED TRAITS

*As many of you know boys are different than girls. In humans sex is determine by the twenty third pair of chromosomes known as "sex chromosomes". If you have two x-shaped **(XX)** chromosomes you are destined to be a female. If you have an x and a Y-shaped **(XY)** chromosomes you are destined to be a male. Since the **X** and **Y** chromosomes carry different information, any genes found on the **X** chromosomes are referred to as **sex-linked genes**. Therefore, women will have two alleles for these genes because they have two **(XX)** chromosomes. On the other hand, men have only one allele for each of these genes because they have only one X chromosome **(XY)**. This is clearly a violation of Mendel's Principle of Unit Characteristics, which implies that you receive one set of alleles from each parent.*

E.g. *In fruit flies, the gene for eye color is carried on the **X** chromosome which is a sex chromosome (sex-linked). The allele for red eyes is dominant over the allele for white eyes.* ***If a white-eyed female fruit fly is mated with a red-eyed male, predict the possible offspring.***

Step 1: *Since the female has white eyes, she must be* ***"X^rX^r".*** *The male is red-eyed and because he has only one X chromosome, he has only one allele for eye color. His eyes are red so he must be* ***RY.*** *means he only has one allele for eye color, so he must be* ***"X^RY".*** *Since the allele "R" is present on the X chromosome only, and there is no other allele for eye color because the male other sex chromosome is a Y chromosome.*

Step 2: *For sex-linked traits we need to list the genotype in a different fashion. We must identify the individual as being male or female according to their sex chromosomes. Females are XX, and males are XY. Sex-linked traits are only found on the X chromosome, therefore the letters are placed as superscripts (above) the X chromosome. Therefore the genotype for the female fly is X^rX^r and the male is X^RY. You can use shorthand notation rr x RY, but sometimes this can be*

confusing.

Step 3: *The Punnett square for the parent flies are shown below.*

	X^R	Y
X^r	X^RX^r	$X^r Y$
X^r	X^RX^r	$X^r Y$

Step 4: *The genotypic ratio is* 1 X^RX^r : 1 $X^r Y$

Step 5: *The individual* $\mathbf{X^R X^r}$ *will be a female because she has two* **X** *chromosomes.* ***She will have red eyes because she has*** Rr. *The individual with* $\mathbf{X^r}$ Y *will be a male because he has the* **X** *and* **Y** *chromosomes. He will have white eyes because he has only one allele and it is* "r". *So from this cross you would expect all of the females to have red eyes and all of the males to have white eyes.*

1. Hemophilia is a sex-linked trait. A person with hemophilia is lacking certain proteins that are necessary for normal blood clotting. Hemophilia is caused by a recessive allele so use "N" for normal and "n" for hemophilia. Since hemophilia is sex-linked, remember a woman will have two alleles (NN or Nn or nn) but a man will have only one allele (N or n). A woman who is heterozygous (a carrier) for hemophilia marries a normal man:

   a. What are the genotypes of the parents?

   b. Make a Punnett square for the above cross.

   c. What is the probability that a male offspring will have hemophilia? _____

   d. What is the probability of having a hemophiliac female offspring? _____

2. Can a color blind female have a son that has normal vision? Color blindness is caused by a sex-linked recessive allele. **use N = normal vision and n = color blind*

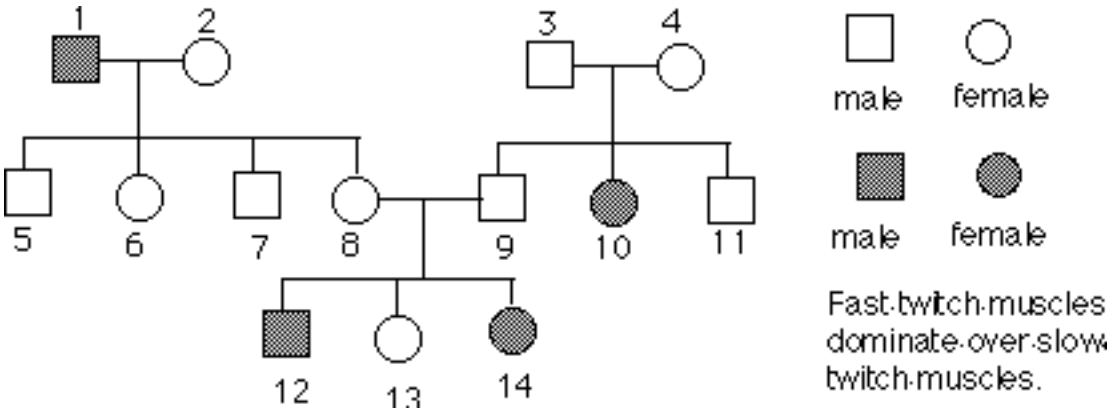
3. Baldness is a sex-linked trait. What parental genotypes could produce a bald woman? ***use H = normal hair, and h = bald*

Part 9:

Part 10: Pedigree Charts:

In genetics, traits can be traced over several generations similar to a family tree. This family tree is called a Pedigree chart. Pedigree charts are useful in gathering background genetic information that can be used for medical reasons. Horse race enthusiasts also rely heavily on pedigree charts to predict a horse's success. sWhen interpreting pedigree charts remember square are male and circles are females

1. Use the below pedigree chart to answer the following three questions. Muscle type is not a sex linked characteristic.



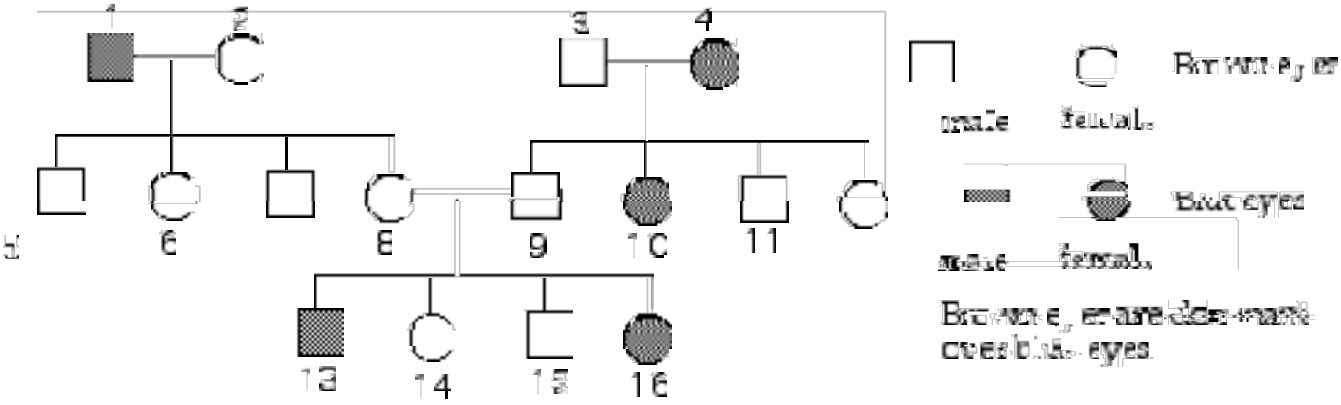
a. Place the genotypes of each individual below its symbol.

b. What is the genotype of individual #3 and 4?.

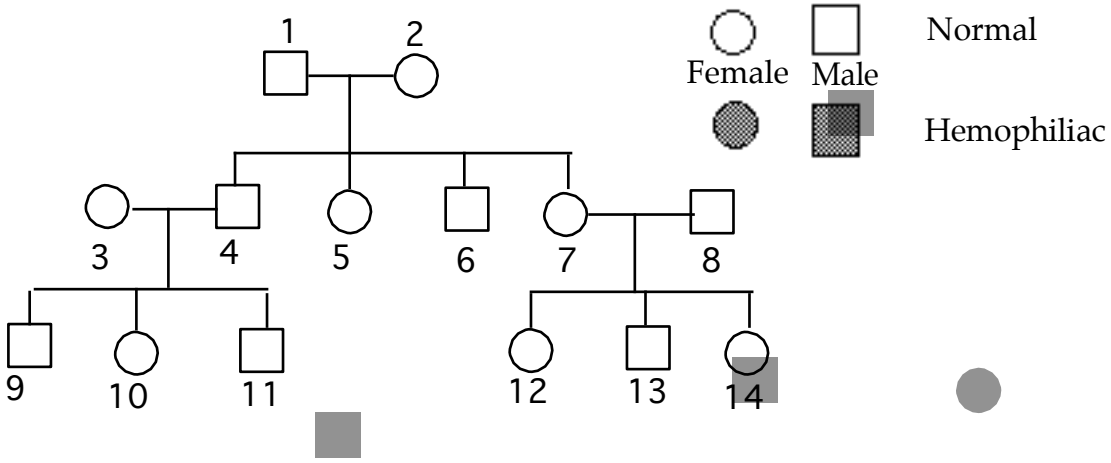
c. Can either individual #8 or 9 be homozygous?

d. Explain the family relationship that #12 has with #2.

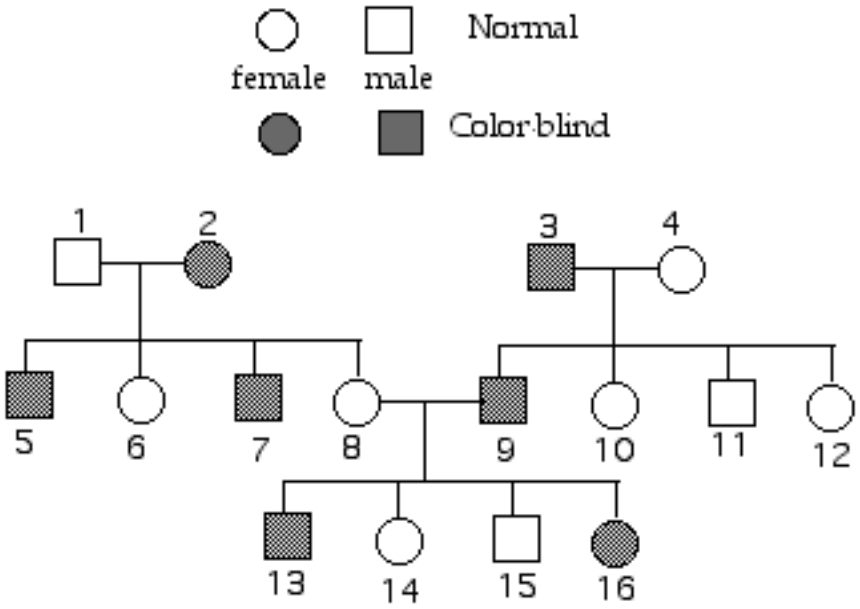
2. Label the genotype for each of the individuals below its symbol on the pedigree chart (note: eye color is **not** a sex-linked trait).



3. List the possible genotypes of the following hemophilia pedigree chart below. **Remember** hemophilia **<u>is</u>** a **sex linked trait** that is caused by a **recessive allele,** therefore you must denote the individuals sex chromosomes (X^NX^n and X^nY or Nn and nY) as well as the hemophilia allele (n).



4. Examine the following pedigree chart of color-blindness. In humans, color blindness is caused by a **recessive sex-linked** allele. On the diagram, label the genotypes of the individuals 1-16.



5. A blue-eyed man (1) whose parents were brown eyed (2 & 3), marries a brown eyed woman (4), whose father was brown eyed (5) and whose mother (6) was blue eyed. They have one female child who is blue eyed!(7). Blue eyes are recessive.

   a. Make a pedigree chart based on the above information.

   b. Label the genotypes of the individuals in the chart.

Crew, F. A. E. (1967). "Reginald Crundall Punnett 1875-1967". *Biographical Memoirs of Fellows of the Royal Society*. **13**: 309–326. doi:10.1098/rsbm.1967.0016.

Key

Part 1

1.

c. Homozygous recessive
d. Homozygous recessive
e. Heterozygous
f. Homozygous dominant

2.

a. Brown eyes
b. Blue eyes
c. Brown eyes

Part 3

1

a. Ss x ss
b. Filled in Punnett Square
c. Filled in Punnett Square
d. 1 Ss : 1ss
e. 1 smooth : 1 wrinkled
f. 25

2 Should have a filled in Punnett Square

a. 25% or 1/4 or 1:3
b. 25% or 1/4 or 1:3
c. 50% or 1/2
d. 25% or 1/4 or 1:3

3 Should have a filled in Punnett Square and the answer is **No**

4 Should have a filled in Punnett Square

a. WW, Ww and ww
b. 3 Widows Peak : 1 Straight

Part 4

1. Yy x yy

2 Yy x Yy

Part 5

1a. **2** Punnentt squares should be filled in.
b. Bb or heterozygous
c. There were too few offspring to form a conclusion

Part 6.

1.

a. **Should have a filled in Punnett Square**
b. Round Yellow : Round Green : Wrinkled Yellow : Wrinkled Green
c. **3 1 3 1**

2 **Should have a filled in Punnett Square**

Normal for both : Normal, Galactosemia : PKU; Normal : Have both disorders
9 3 3 1

Part 7

1.

a. **Should have a filled in Punnett Square**
b. 1 : 2 : 1
rr rw ww

c. . 1 : 2 : 1

red : pink : white

2.

3.

a. **Should have a filled in Punnett Square**
b. 50%
c. CC

Part 8

a. BB or BO
b. OO
c. AB

1.

a. **Should have a filled in Punnett Square**
b. Type A and Type B blood

2

a. **2 Punnentt squares should be drawn and filled in**
b. **No**

3.

a. **2 Punnentt squares should be drawn and filled in**

b. Mr. And Mrs. Smith

Part 9

1.
Nn x NY

c. **Should have a filled in Punnett Square**
d. **50%**
e. **0%**

c. No
d. HY x Hh and hY x hh

Part 10

1.

a.1. ff 2. **?** 3. **Ff** 4. **Ff** 5. **Ff** 6 **Ff** 7. **Ff** 8. **Ff** 9. **Ff** 10 **ff** 11 **?** 12. **ff** 13. **?** 14. **ff**

b. **Ff and Ff**

c. **No**

d. **12 is** the grandson of 2

2.

1. bb 2. ? 3. Bb 4. Bb 5. Bb 6. Bb 7. Bb 8. Bb 9. Bb 10. bb 11. ? 12. ? 13. bb 14. ? 15 ? 16. bb

3.

1. nY 2. Nn 3. Nn 4. nY 5. nn 6.NY 7. Nn 8. NY 9. nY 10. Nn 11. NY 12. ? 13. nY 14. ?

4.

1. NY 2. Nn 3. nY 4. Nn 5. NY 6 ? 7. nY 8. Nn 9. nY 10. Nn 11. NY 12. Nn 13. nY 14. Nn 15.

NY 16. nn