Topics 4, 5, and 6

Non-Mendelian Genetics

Many traits do not follow the ratios predicted by Mendel's laws. Why?

- Varying ____
- Many traits are produced through ___________________________________ acting together
- Some traits are determined by genes on the _____________________________________
- Some genes are ___________________ or ______________ to one another on the same chromosome and will _____________________________________
- Some traits are the result of ____ (i.e. chloroplast and mitochondrial DNA)

Degrees of Dominance

Alleles can show varying degrees of dominance

In Mendel's experiments, he worked with traits that showed __________________ dominance.

Incomplete dominance:

Codominance:

Multiple Alleles:

➔ Questions?
➔ Textbook chapters/pages to review

Practice Problems:

1. A black mouse (BB) is crossed with a white mouse (bb) and the resulting offspring are gray. What is the easiest explanation for this phenomenon?

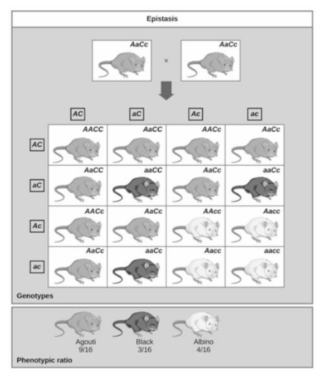
2. Cattle can be red (RR= all red hair), white (WW= all white hair), or roan (RW= red and white hair). What is the best explanation for this phenomenon?

3. A red cow is crossed with a roan cow. What would the phenotypic ratio of the offspring be?

4. A woman with type A blood has a child with a man who has type B blood. With this limited information, what are possible genotypes for the woman? For the man?

Multiple Genes

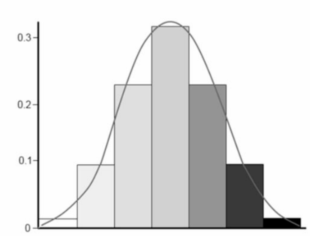
In many cases, two or more genes are responsible in determining phenotypes.



Epistasis:

Polygenic inheritance:

	ABC	ABc	AbC	aBC	Abc	aBc	abC	abc
ABC	6	5	5	5	4	4	4	3
ABc	5	4	4	4	3	3	3	2
AbC	5	4	4	4	3	3	3	2
aBC	5	4	4	4	3	3	3	2
Abc	4	3	3	3	2	2	2	1
aBc	4	3	3	3	2	2	2	1
abC	4	3	3	3	2	2	2	1
abc	3	2	2	2	1	1	1	0



- Questions?
- Textbook chapters/pages to review

Sex Chromosomes

Thomas Hunt Morgan experimented with fruit flies and determined that specific genes can be carried on sex chromosomes

Sex-Linked Genes:

Y-linked gene:

X-linked genes:

Inheritance of X-Linked Genes

N = normal
n = affected

Affected father

X^NX^N x X^nY

	X^n	Y
X^N	X^NX^n	X^NY
X^N	X^NX^n	X^NY

Affected mother

X^NX^n x X^NY

	X^N	Y
X^N	X^NX^N	X^NY
X^n	X^NX^n	X^nY

If an X-linked trait is due to a recessive allele:

➔ Questions?
➔ Textbook chapters/pages to review

X-Linked Disorders

Duchenne muscular dystrophy:

Hemophilia:

Color blindness:

X-Inactivation

Females inherit two X chromosomes, which is double than males!

Go back to page 32 of your packet and complete the remaining practice problems on pedigrees.

Linked Genes

Genetic Recombination

Genetic Recombination:

Parental types:

Recombinants:

➔ Questions?
➔ Textbook chapters/pages to review

Mendel also observed recombinants during his crosses

Example: green wrinkled plant crossed with a yellow-round plant (yyrr x YyRr)

	YR	yr	Yr	yR
yr	YyRr	yyrr	Yyrr	yyRr

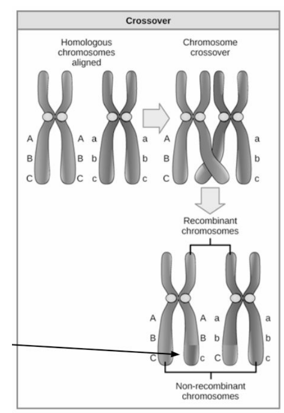
Linked Genes

Linked genes:

Meiosis and random fertilization generate genetic variation in offspring due to:

Linked Genes: Crossing Over

Linked genes show parental phenotypes in offspring at higher than ______%



Crossing over helps to explain why some linked genes become separated during meiosis

The _____________________________ two genes are on the same chromosome, the ___________________ the probability that a crossing over event will occur between them and the ______________________ the recombination frequency.

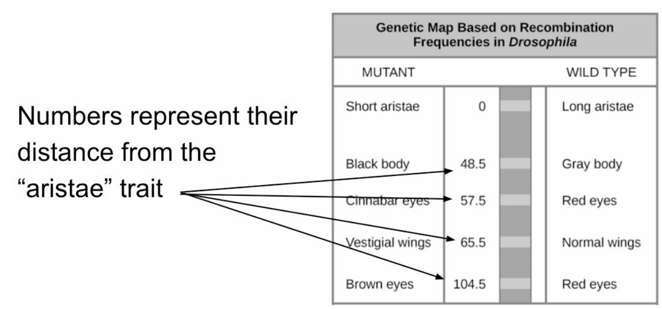
➔ Questions?
➔ Textbook chapters/pages to review

Mapping Distance

Experiments performed by Sturtevant allowed scientists to map genes and their locations on chromosomes

Linkage map:

The distance between genes are ________________________.



Non-Nuclear DNA

Some traits are located on DNA found in the _______________________ or ______________________

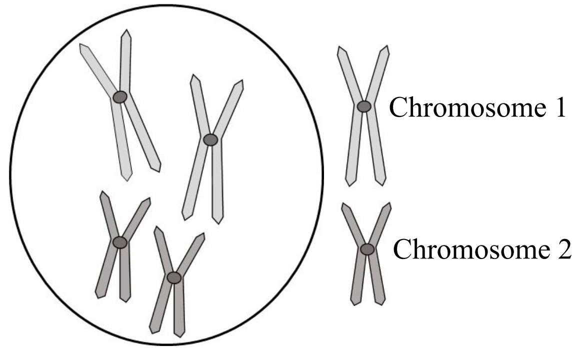
Both chloroplasts and mitochondria are ________________ assorted to gametes and daughter cells

➔ Questions?
➔ Textbook chapters/pages to review

Gene Mapping

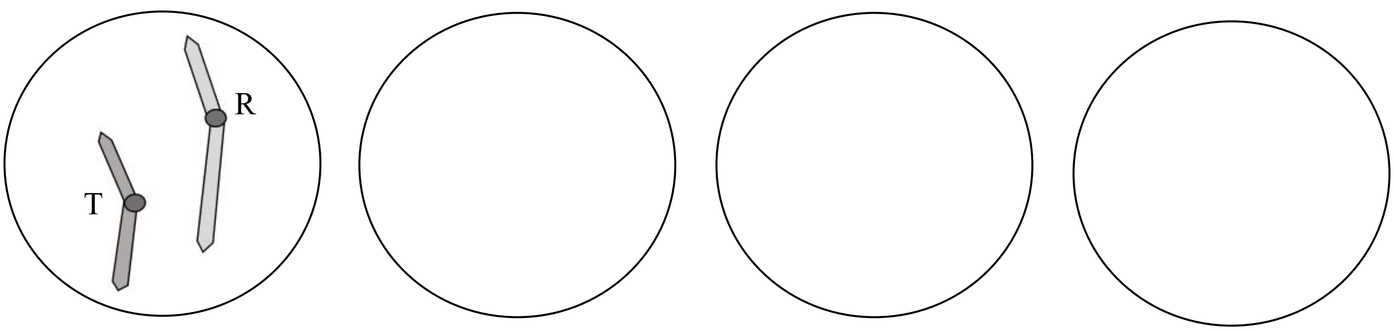
The fact that Gregor Mendel decided to study pea plants was a stroke of sheer luck. Not only is it a simple organism to study, but the characteristics he studied assorted independently from each other, which allowed him to create the foundation of modern genetics.

Let's quickly review independent assortment using a hypothetical plant species that has a diploid number of 4 (2n = 4). For this plant, seed texture and plant height are controlled by two different genes. Seed texture can either be rough (R) or smooth (r) and plant height can either be tall (T) or short (t). We will assume independent assortment (meaning the genes for seed texture and height are on separate chromosomes; the gene for seed texture is on chromosome 1 and the gene for plant height is on chromosome 2). A cross is performed between a RRTT parent and a rrtt parent.



1. Predict the genotypes of the F1 progeny.

2. Using the four cells below, determine the possible products of meiosis that would be generated by the F_1 progeny (the first one has been done for you).

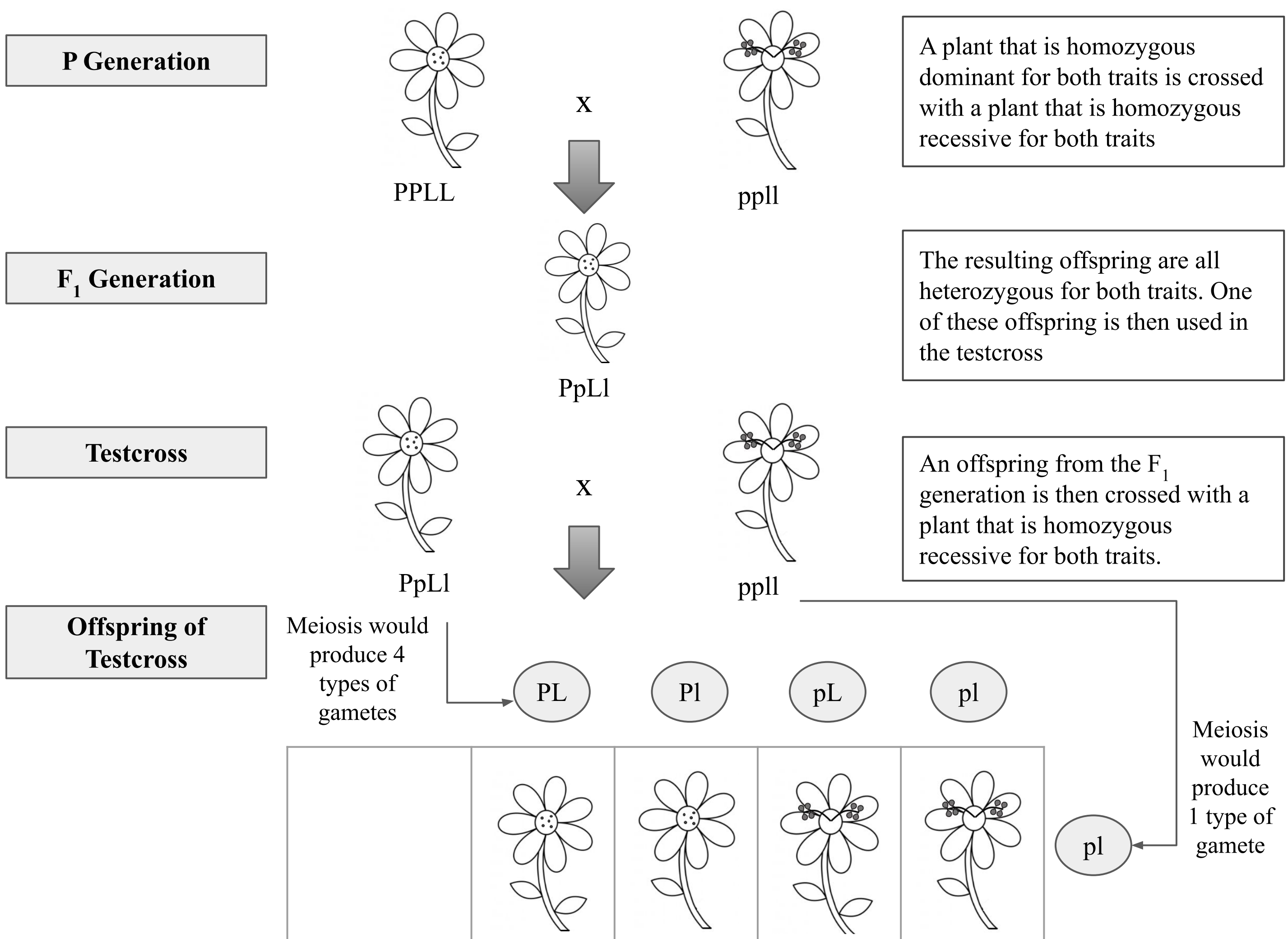


3. Next, a testcross is performed between an F1 individual and an individual that is rrtt. Use the space below to perform the cross. Identify the possible phenotypes and their ratios in the offspring.

As mentioned previously, it is lucky that Mendel chose to study pea plants and even more lucky, the specific characteristics of pea plants he examined. If he were to study more plants, or more characteristics he would have seen exceptions to his principles. This is because, as we know now, each chromosome carries many genes, with each gene at a particular locus. If genes are located on different chromosomes, like we saw in the previous example, then they assort independently, which is also exactly what Mendel saw. But what happens to genes that are located on the same chromosome? Well, they may be inherited together if they are located near each other. These genes are therefore known as linked genes.

4. Refer back to the ratios of phenotypes of the offspring generated from the testcross in question 3 on the previous page. How would these ratios change if the genes for seed texture and plant height were linked? Why?

Using the same plant, let's examine two new traits: shape of pollen grains and number of leaves. To determine whether these traits assort independently or are linked, a cross is performed between a homozygous plant with round pollen grains and two leaves (PPLL) and a homozygous plant that has long pollen grains and one leaf (ppll). Examine the diagram below depicting the crosses and then fill in the chart with the expected number of offspring for each phenotype shown.



Observed	991	350	334	1025
Expected				

2,700 Total Offspring

5. Examine the results of the testcross on the previous page. Predict whether these traits are on separate chromosomes or the same chromosome. Why? (Support your prediction using the data.)

6. Using the data chart on the previous page, label the offspring as "parental phenotypes" or "recombinant phenotypes."

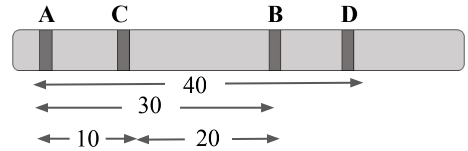
7. Using the observed data, calculate the recombination frequency (# of recombinants / total offspring). Show your work in the space below.

8. Does the recombination frequency you calculated in the previous question support or reject your prediction as to whether these traits are on the same or separate chromosomes?

9. Recombination frequencies can be used to map genes on chromosomes, because the frequency represents the relative distance between genes; the greater the distance the greater the chance of a crossing over event that can occur between the genes. In what stage of meiosis does crossing over occur?

10. What happens during a crossing over event? Draw an example of a crossing over event in the space below.

When recombination frequencies are used to map genes, the result is known as a **linkage map**. A linkage map will show the relative locations of genes on a chromosome (see figure to the right). The units used on linkage maps are known as map units (mu). Map units are equivalent to the recombination frequency (i.e. 5% recombination is 5 mu).

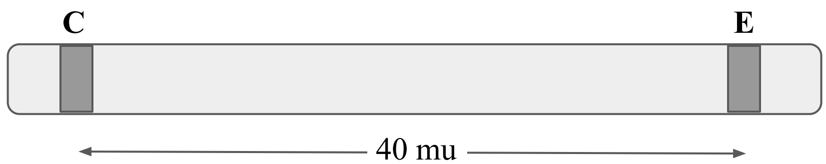


Creating a Linkage Map

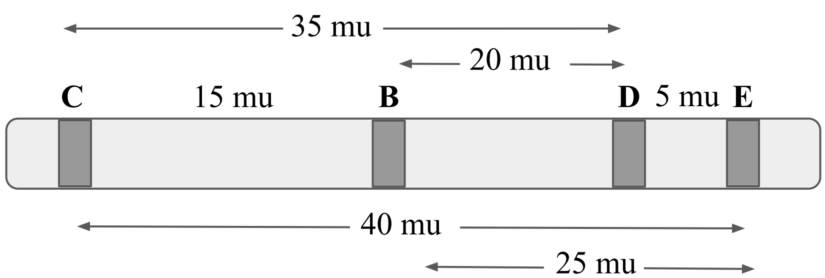
Examine the chart below showing 4 different genes (B, C, D, E).

Gene	Recombination Frequency
B-E	25%
C-E	40%
C-D	35%
B-D	20%

Start by finding the genes that are farthest apart. In this case, C and E are 40 map units apart. Using the chromosome below, genes C and E will be placed far apart and the map units between this is labeled.



To determine the location of the remaining genes, use trial and error. Think of the chart like a riddle and the frequencies as clues. It may take some time, but once you have all of the genes placed on the chromosome, use subtraction to finish filling in all of the map units between each gene.

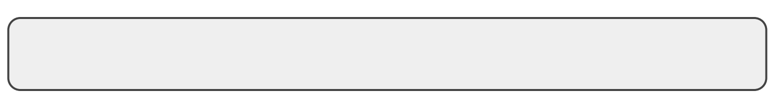


Practice Problems

Construct a linkage map on the chromosome for each data set given.

1.

Gene	Recombination Frequency
M-P	21%
M-J	42%
R-J	16%
P-R	5%



2.

Gene	Recombination Frequency
C-D	5%
C-B	48%
A-E	7%
D-E	25%
C-E	30%
D-A	18%

3.

Gene	Recombination Frequency
vr-ag	3%
tn-pq	2%
ag-tn	10%
vr-pq	15%

4.

Gene	Recombination Frequency
cr-gp	20%
tz-ab	2%
ab-gp	16%
cr-tz	2%

Non Mendelian Genetics

1. Define complete dominance, incomplete dominance, and codominance. Give an example of each.

2. What is it called when one gene at one locus affects another gene at another locus? (A common example is coat color in animals).

3. Why are there more X-linked disorders than there are Y-linked disorders?

4. Why is it that for X-linked genes, fathers can pass their X-linked alleles to ALL of their daughters, but NONE of their sons?

5. Explain why both mitochondrial and chloroplast DNA are only inherited by offspring through the mother.

6. What are linked genes?

7. Will linked genes always be inherited together? Why or why not?

8. How are pedigrees used in genetics?

Non Mendelian Genetics Practice Problems

1. In some breeds of mice, yellow coat color is dominant to gray coat color. Inheriting two copies of the dominant yellow trait, however, is lethal during embryonic development. In a cross between two yellow mice, what proportion of the offspring is expected to be yellow? What proportion is expected to be gray? What is the phenotypic ratio of the offspring?	Show work here:
2. When a true breeding black feathered rooster is mated with a true breeding white feathered hen, the resulting F_1 offspring are all blue feathered. ● What is the simplest explanation for this observation? ● What would the phenotypic ratios of the F_2 generation be?	Show work here:
3.When true breeding red snapdragons (genotype RR) are crossed with true breeding white snapdragons (genotype WW), the resulting F_1 offspring are all pink heterozygotes (genotype RW). If a self cross of the F_1 generation produces an F_2 generation of 600 offspring, how many of the F_2 are expected to be red?	Show work here:
4. Roan coat color is an example of codominance. When a white cow (C^WC^W) is mated with a red cow (C^RC^R) they produce the red and white, or roan (C^RC^W), coat color in their offspring. Predict the phenotypic and genotypic ratios for the offspring of a cross between a roan cow and a white cow.	Show work here:
5. Human blood groups are an example of codominance. The blood types are A (I^Ai, I^AI^A), B (I^Bi, I^BI^B), AB (I^AI^B), and O (ii). A man who is type AB (I^AI^B) marries a woman who is type O (ii). What are the chances that their child will have a) type AB blood, b) type O blood, c) type A blood, and d) type B blood?	Show work here:

6. Many species of plants provide an excellent example of epistasis, where multiple genes can control the phenotype. In the case of corn, there is a gene that controls color. The kernels can either be blue (B) or red (b). A different gene determines whether or not that color will actually appear in the kernel. The dominant allele (A) inhibits color, meaning the kernels will be white, while the recessive allele (a) allows color (either red or blue). If a plant that is heterozygous for both traits is self crossed, what will the resulting phenotypic ratios of the F_1 generation be? (Hint: this is a dihybrid cross, but since epistasis does not follow Mendelian genetics, it will not be a 9:3:3:1 phenotypic ratio.)	Show work here:
7. Coat color in mice is another excellent example of epistasis. In mice agouti (A) is the wild type, yellow, coat color, which is dominant to the black (a) coat color. A different gene controls whether or not the pigment is deposited in the fur. The dominant allele (D) allows the pigment, while the recessive allele (d) causes albinism in the mouse, regardless of the A/ a allele. If a mouse with the genotype AaDd is crossed with a mouse that has the genotype aaDD, what will the phenotypic ratios of the offspring be?	Show work here:
8. Color blindness is a common recessive X-linked disorder. Normal vision (X^N) is dominant to color blindness (X^C). If a colorblind male has a child with a woman who is a carrier for the disorder, what is the probability that their child will be color blind?	Show work here:

9. Duchenne muscular dystrophy is an example of an X-linked recessive disorder that causes progressive muscular weakness. If a man who is normal (X^NY), has a child with a woman who is a carrier for the disease (X^NX^C), what is the chance that their child will have the disease?	Show work here:
10. Eye color (red or white) in the fly *Drosophila* is determined by the X chromosome. The dominant version of the allele (X^R) causes red eyes, while the recessive allele causes white eyes (X^r). Females can have red eyes (X^RX^R, X^RX^r) or white eyes (X^rX^r). Males only receive one copy of the X chromosome, so whatever allele version they receive determines their eye color. If a white eyed male is crossed with a red eyed heterozygous female, what will the phenotypic ratios of the offspring be?	Show work here:
11. A scientist named Thomas Hunt Morgan studied genetics in fruit flies. Specifically he looked at wild type (normal) wings versus vestigial (shortened) wings. When he crossed a wild type female with a vestigial male he expected to see 50% parental phenotypes and 50% recombinant phenotypes in the offspring. However, what he actually found was 83% parental phenotypes and 17% recombinant phenotypes. What does this suggest about the genes he was studying? How do the percentages help us determine this?	Show work here:
12. Recombination frequencies can be easily calculated by adding the number of offspring that are different from the parents, then dividing by the total number of offspring. Let's say you are studying fruit flies and you cross a wild type, grey female with a vestigial, black male. The F_1 offspring are as follows: 650 wild type/grey, 595 vestigial/black, 107 wild type/black, and 91 vestigial/grey. What is the recombination frequency between the genes for wing type and body color?	Show work here:

Statistical Analysis: Chi Square

Goodness of Fit Test

Chi-square:

Helps to:

Designed to analyze ______________________ data.

Chi Square (X^2)

$$\chi^2 = \Sigma \left(\frac{(\text{observed results} - \text{expected results})^2}{\text{expected results}} \right)$$

➔ Questions?
➔ Textbook chapters/pages to review

Example: How to Solve

You are interested in examining the trait that allows people to roll their tongue.

- Tongue rolling is dominant to non tongue rolling
- You survey 100 people and you find:
  - 90 people were able to roll their tongue
  - 10 people could not roll their tongue
- You also took genetic data from the parents of all 100 people
  - The parental genotypes for all 100 people was Rr
- Null: any difference between the observed and expected data is due to chance

Step 1: Determine what your expected and observed values are.

Observed (actual) values:

Expected values:

Step 2: Make a table

Fill in the table with the trait you are looking at

			Total
Observed- O			
Expected- E			
O-E			
$(O-E)^2$			
$(O-E)^2/E$			

Step 3: Plug in your data to the table (above) and solve.

➔ Questions?
➔ Textbook chapters/pages to review

Step 4: Determine the degrees of freedom for **your** experiment

To calculate the degrees of freedom:

CHI-SQUARE TABLE								
Degrees of Freedom								
p	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.32	11.34	13.28	15.09	16.81	18.48	20.09

P represents the ______________________

_________ means you are ______% confident that your observed data fits your expected data extremely well

_________ means you are ______% confident that your observed data fits your expected data extremely well

As a general rule of thumb, you look at the $p = 0.05$ row, unless instructed otherwise

Interpreting results and degrees of freedom chart:

If $X^2 >$ critical value:

If $X^2 <$ critical value:

For this example: $X^2 = 12$

➔ Questions?
➔ Textbook chapters/pages to review

Practice Problem

1. In peas, yellow seeds (A) are dominant over green (a) seeds. In a cross between two plants both heterozygous for seed color, the following was observed:

Yellow = 4400
Green = 1624

Does the data fit the predicted phenotypic ratio?

➔ Questions?
➔ Textbook chapters/pages to review

Chi Square Practice Problems

Reminders:
Chi-square is a form of statistical analysis used to compare the actual results (observed) with the expected results. The equation tests the null hypothesis for the problem being analyzed. The formula for Chi Square is:

$$\chi^2 = \Sigma\left(\frac{\text{(observed results – expected results)}^2}{\text{expected results}}\right)$$

The calculated X^2 value is always compared to the degrees of freedom chart, as seen on the right. Unless instructed otherwise, compare your value to the p = 0.05 row.

CHI-SQUARE TABLE								
Degrees of Freedom								
p	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.32	11.34	13.28	15.09	16.81	18.48	20.09

1. A science teacher is bothered because of all the noise outside of his classroom each day. He decides to see where the noise is coming from and finds that several groups of freshman students use the water fountain located by the door to his classroom. There are three other water stations on campus, and after studying the frequency at which students visit each water fountain, he becomes convinced that students prefer the water fountain by his room, rather than the other three fountains. The teacher assigns a student to be at each water fountain and count the total number of students getting water from each one. The data is as follows: water fountain #1 (by the teachers door): 45 students, water fountain #2: 36 students, water fountain #3: 25 students, and water fountain #4: 30 students. Is the teacher correct that students prefer to use the water fountain by his door?

Step 1: state the null hypothesis:

Step 2: determine your expected values

Step 3: complete the Chi square chart:

					Total
Observed- O					
Expected- E					
O-E					
$(O-E)^2$					
$(O-E)^2/E$					

Step 4: calculate your degrees of freedom

Step 5: interpret results

2. You are interested in researching whether or not AP biology students who use a test prep book perform better on the exam than those who do not use a test prep book. You take 60 random students and give 30 of them a test prep book, while the other 30 will use the resources they already have. After the students take the exam, you analyze the data and find that, of the students who used a test prep book, 26 passed. For the students who used only the resources they already had, you found that 12 passed. With this data would you suggest to future students to use a test prep book?

Step 1: state the null hypothesis:

Step 2: determine your expected values

Step 3: complete the Chi square chart:

Step 4: calculate your degrees of freedom

Step 5: interpret results

			Total
Observed- O			
Expected- E			
O-E			
$(O-E)^2$			
$(O-E)^2/E$			

3. In pea plants, purple flowers (P) are dominant to white flowers (p). A plant that is heterozygous is self crossed. The following phenotypes were observed:

Purple flowers: 543

White flowers: 213

Does this data fit the predicted phenotypic ratios?

Step 1: state the null hypothesis:

Step 2: determine your expected values (Hint: what should the phenotypic ratio be?)

Step 3: complete the Chi square chart:

Step 4: calculate your degrees of freedom

Step 5: interpret results

			Total
Observed- O			
Expected- E			
O-E			
$(O-E)^2$			
$(O-E)^2/E$			

Environmental Effects on Phenotype

Environmental Factors

Various environmental factors can influence gene expression and lead to ____________________________

Examples:

➔ Questions?
➔ Textbook chapters/pages to review

Chromosomal Inheritance and Disorders

Genetic Disorders

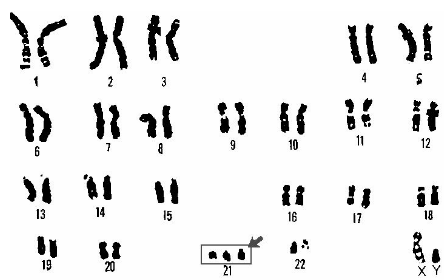
Mutated Alleles

Tay-Sachs disease:

Sickle cell anemia:

Chromosomal Changes

Nondisjunction:



- ➔ Use this space to reflect on Topics 4, 5, and 6
- ➔ Textbook chapters/pages to review