

X-Linked Inheritance

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• When a gene being studied is on the X chromosome, scientists use X and an exponent to show what allele is on that particular chromosome.

• The classic example of X-linked alleles is fruit fly eye color.

• This eye color gene is on the X chromosome. The Y chromosome does not have an eye color gene.

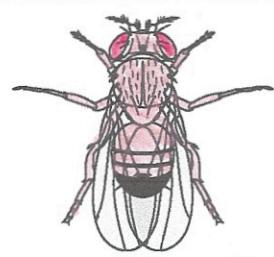
Name: _____

X-Linked Inheritance

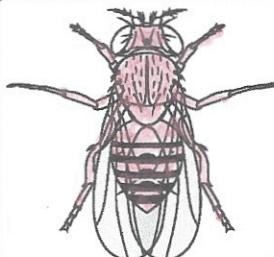
Possible Phenotypes and Genotypes



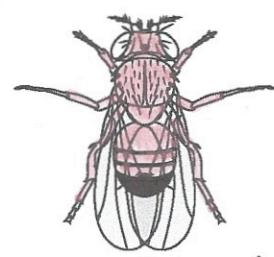
Red Eyed ♀



Red Eyed ♂



White Eyed ♀



White Eyed ♂

Genotype(s):

$X^R X^R$ or $X^R X^r$

Alleles: X^R and X^R
or X^R and X^r

The red eyed $X^R X^r$ is called a "carrier" because it "carries" the recessive allele.

Genotype(s):

$X^R Y$

Alleles: X^R and Y (no allele)

Genotype(s):

$X^r X^r$

Alleles: X^r and X^r

Genotype(s):

$X^r Y$

Alleles: X^r and Y (no allele)

- In crosses with X-linked alleles, the progeny are different depending on which parent had which alleles!
- Below is an example of a Reciprocal Cross.

Reciprocal Crosses

If you cross a true breeding white-eyed female with a true breeding red eyed male:

If you cross a true breeding red-eyed female with a true breeding white eyed male:

		White Eye ♀ $X^r X^r$	
		X^r	X^r
Red Eye ♂ $X^R Y$	X^R	$X^R X^r ♀$ 	$X^R X^r ♀$ 
	Y	$X^r Y ♂$ 	$X^r Y ♂$ 

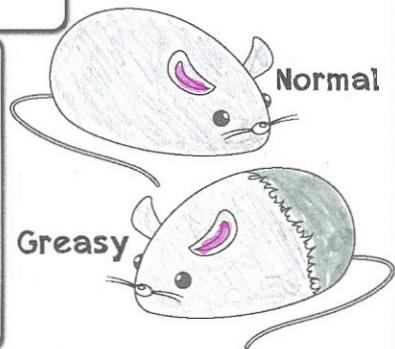
		Red Eye ♀ $X^R X^R$	
		X^R	X^R
White Eye ♂ $X^r Y$	X^r	$X^R X^r ♀$ 	$X^R X^r ♀$ 
	Y	$X^R Y ♂$ 	$X^R Y ♂$ 

When you complete a genetics problem with an X-linked gene, you need to specify which progeny are female and male.

Name: _____

Example Genetic Cross:

Mice with the recessive "greasy" allele (n) have shiny fur. Normal fur is not "greasy-looking" and is caused by a dominant allele (N). The coat-shininess gene is on the X chromosome. If a normal male is crossed to a carrier female, what percent of their male progeny will have greasy fur?



1 Which trait/allele is dominant?

Normal fur (X^N)

Which trait/allele is recessive?

Greasy fur (X^n)

2



X



Phenotype: normal ♂
Parent #1:

normal (carrier) ♀
Parent #2:

Genotype: $X^N Y$

$X^N X^n$

Alleles: $X^N Y$

X^N, X^n

3			Carrier ♀ $X^N X^n$
	X^N	X^n	
4	X^N	$X^N X^N$	$X^N X^n$
	Y		

Why are there very few genetics problems with Y chromosome alleles?

The Y chromosome in most organisms has very few genes on it!

The human Y chromosome has many repeated "junk" sections and only a few genes. One gene is the SRY gene, the most important gene in testis development.

5 Genotype Ratio:

$1 X^N X^N : 1 X^N X^n : 1 X^N Y : 1 X^n Y$

6 Phenotype Ratio:

normal ♀	: carrier ♀	: normal ♂	: greasy ♂
----------	-------------	------------	------------

25% of all progeny are greasy
50% of all male progeny are greasy.

TIPS FOR USING DOODLE DIAGRAMS AS GUIDED NOTES

The thing that most students struggle with in middle school and high school, in every class, is how to take notes. So often, they are lost without some sort of model. Many teachers expect them to have a blank notebook page, watch a Powerpoint, listen to the teacher lecture, somehow know what is important enough to write down, and physically write while trying to listen. This is mentally exhausting and so often students struggle all year, year after year, doing the same thing. A friend of mine used to call this teaching style: "Death by Powerpoint". Students benefit by taking notes, by physically writing, but there has to be a balance and there has to be a model for them to follow.

I have found in the past that the best way to help students take notes is to give them a notes packet for each unit with headers and a list of topics I'm going to cover in class: basically a space where they can put their notes on the page. Every year, I have improved my notes packets and class discussions to better help my students learn without being overwhelmed while taking notes. I'm creating these doodle diagrams so that students have pictures to help them really visualize each concept in their notes.

What I find helps students the most when I am helping them to learn content together in a class discussion format:

- * I decide which note format would be best for my students. I have pages with more or less text, so I can customize it for each student or class depending on their ability to take notes and how much time I want to spend. Some students/classes really like to draw their own pictures; some don't!
- * I print and copy a packet of the unit's doodle diagrams and have them stapled before I give them to my students. Students are much less likely to lose a packet and they are more likely to get the notes when they are absent from a friend, because they see that it's blank in their packet!
- * Give them a model to follow! Write as you go, with them on an ELMO projector, so they can see what you're writing, what you're highlighting, how you want them to take notes and process the information.
- * Use Powerpoint minimally. I do use my computer projector to show pictures or short video clips or other multimedia that I find online to supplement the guided notes. I use very little text on the screen.
- * As I go through the lesson, I never just fill in the blank on the doodle diagram. I ask questions continually. I ask students what they think are the characteristics of life, what they think will happen next in this diagram, what they think is the best way to summarize this video clip they just saw on transcription or translation. And we fill it in together.
- * I encourage students to doodle! These pages are designed to have places where students can fill in borders, fill in letters, color in pictures, and make their own doodles in the white space. Research shows that students who do this remember more of the material! Processing the material with the artistic side of their brain can aid in memory. So encourage them to use colored pencils, pens, whatever they would like on their page in the time you working through the page with them.

Teacher Tips for X-linked Inheritance:

I cover this topic after teaching simple Mendelian inheritance, incomplete dominance, and codominance.

- * As you have students fill in the genotypes for the phenotypes, make sure to tell them that the red allele is dominant; the white allele is recessive.

I recommend giving students the first genotype and alleles for the red-eyed female, and then you can ask students to help you fill in the others! This will help them see that the male only has one allele and that one allele always determines his phenotype.

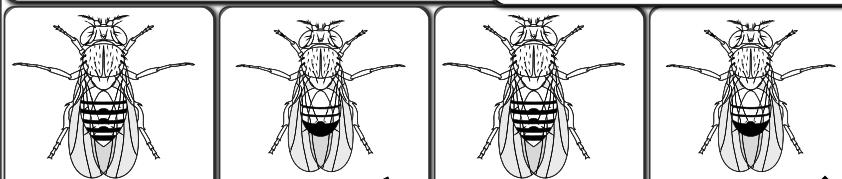
In honors, I stress the importance of the reciprocal cross. If scientists are studying a new genetic trait (assuming they don't know which chromosome it is on), they often will do a reciprocal cross with the mutant fly and a wildtype (normal) fly. If the progeny are different depending on which parent is the mutant, then the scientist knows the mutation is in a gene on the X chromosome.

- When a gene being studied is on the X chromosome, scientists use X and an exponent to show what allele is on that particular chromosome.
- The classic example of X-linked alleles is fruit fly eye color.
- This eye color gene is on the X chromosome. The Y chromosome does not have an eye color gene.

Name: _____

X-Linked Inheritance

Possible Phenotypes and Genotypes



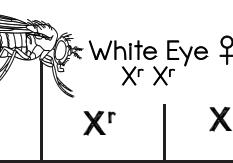
Genotype(s): $X^R X^R$ or $X^R X^r$	Genotype(s): $X^R Y$	Genotype(s): $X^r X^r$	Genotype(s): $X^r Y$
Alleles: X^R and X^R or X^R and X^r	Alleles: X^R and Y (no allele)	Alleles: X^r and X^r	Alleles: X^r and Y (no allele)

The red eyed $X^R X^r$ is called a "carrier" because it "carries" the recessive allele.

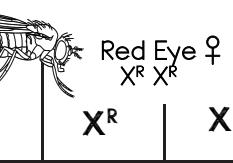
- In crosses with X-linked alleles, the progeny are different depending on which parent had which alleles!
- Below is an example of a Reciprocal Cross.

Reciprocal Crosses

If you cross a true breeding white-eyed female with a true breeding red eyed male:

		X^r	X^r
X^R	$X^R X^r ♀$	$X^R X^r ♀$	
Y	$X^r Y ♂$	$X^r Y ♂$	

If you cross a true breeding red-eyed female with a true breeding white eyed male:

		X^r	X^R
X^r	$X^R X^r ♀$	$X^R X^r ♀$	
Y	$X^R Y ♂$	$X^R Y ♂$	

- * In my regular/basic classes, I don't stress the importance of the reciprocal cross, but I show them a reciprocal cross here so they can see that the progeny are different depending on which parent had the recessive allele(s).

I use this page second in the series, to give students an example of a genetic cross problem with X linked alleles.

I. Keeping track of which parents and which progeny are male and female is important!

In this example, I specifically ask for the percent of male progeny, so that students see how some problems may ask them for a percentage of the progeny or the percentage of a particular sex.

Many students ask why the problems are always about X linked alleles and rarely Y linked alleles. I bring up that the Y chromosome really doesn't have much on it! (This brief mention of the SRY gene is a great bridge into sex determination, which many teachers teach about in this unit.)

When you complete a genetics problem with an X-linked gene, you need to specify which progeny are female and male. Name: _____

Example Genetic Cross:

Mice with the recessive "greasy" allele (n) have shiny fur. Normal fur is not "greasy-looking" and is caused by a dominant allele (N). The coat-shininess gene is on the X chromosome. If a normal male is crossed to a carrier female, what percent of their male progeny will have greasy fur?

1 Which trait/allele is dominant?
Normal fur (X^N)
Which trait/allele is recessive?
Greasy fur (X^n)

2

	X	
Parent #1: Phenotype: normal ♂		Parent #2: normal (carrier) ♀
Genotype: $X^N Y$		$X^N X^n$
Alleles: $X^N Y$		X^N, X^n

3

		Carrier ♀ $X^N X^n$	
	X^N	$X^N X^n$	$X^N X^n$
X^N			
X^n			

4

5 Genotype Ratio:

$1 X^N X^N : 1 X^N X^n : 1 X^N Y : 1 X^n Y$

6 Phenotype Ratio:

normal ♀ : carrier ♀ : normal ♂ : greasy ♂

25% of all progeny are greasy
50% of all male progeny are greasy.

Students like to ask about human traits and there are two X-linked genes that come up in discussions: colorblindness (an X linked recessive allele)

and hemophilia (also X-linked recessive allele)

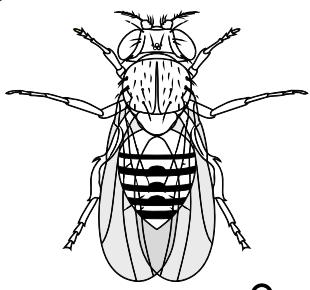
I usually hold off doing a lot of human genetics problems until I teach about pedigrees and then I do a lot of human genetics examples.

- When a gene being studied is on the X chromosome, scientists use X and an exponent to show what allele is on that particular chromosome.
- The classic example of X-linked alleles is fruit fly eye color.
- This eye color gene is on the X chromosome. The Y chromosome does not have an eye color gene.

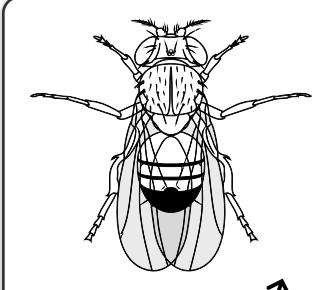
Name: _____

X-Linked Inheritance

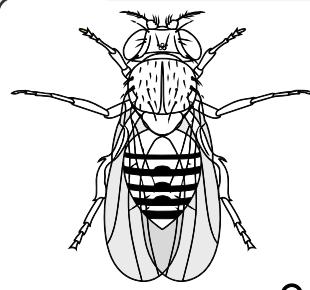
Possible Phenotypes and Genotypes



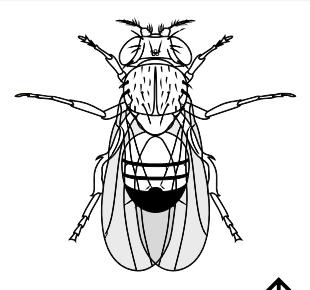
Red Eyed ♀



Red Eyed ♂



White Eyed ♀



White Eyed ♂

Genotype(s):

$X^R X^R$ or $X^R X^r$

Alleles: X^R and X^R
or X^R and X^r

The red eyed $X^R X^r$ is called a "carrier" because it "carries" the recessive allele.

Genotype(s):

$X^R Y$

Alleles: X^R and Y (no allele)

Genotype(s):

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Reciprocal Crosses

If you cross a true breeding white-eyed female with a true breeding red eyed male:

	White Eye ♀ $X^r X^r$	
	X^r	X^r
Red Eye ♂ $X^R Y$	$X^R X^r ♀$ 	$X^R X^r ♀$
Y	$X^r Y ♂$ 	$X^r Y ♂$

If you cross a true breeding red-eyed female with a true breeding white eyed male:

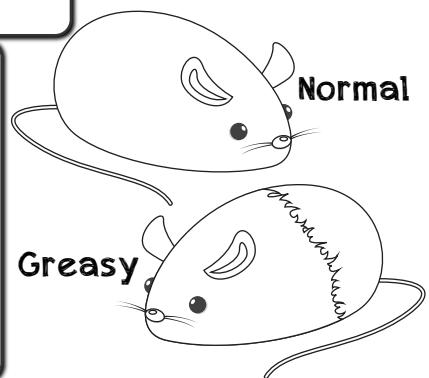
	Red Eye ♀ $X^R X^R$	
	X^R	X^R
White Eye ♂ $X^r Y$	$X^R X^r ♀$ 	$X^R X^r ♀$
Y	$X^R Y ♂$ 	$X^R Y ♂$

When you complete a genetics problem with an X-linked gene, you need to specify which progeny are female and male.

Name: _____

Example Genetic Cross:

Mice with the recessive "greasy" allele (n) have shiny fur. Normal fur is not "greasy-looking" and is caused by a dominant allele (N). The coat-shininess gene is on the X chromosome. If a normal male is crossed to a carrier female, what percent of their male progeny will have greasy fur?



1 Which trait/allele is dominant?

Normal fur (X^N) _____

Which trait/allele is recessive?

Greasy fur (X^n) _____

2



X



Phenotype: normal ♂
Genotype: $X^N Y$
Alleles: X^N , X^n

Parent #1: normal (carrier) ♀
Genotype: $X^N X^n$

		Carrier ♀ $X^N X^n$	
		X^N	X^n
3	X^N	$X^N X^N$ 	$X^N X^n$
	X^n	$X^N Y$ 	$X^n Y$
4			

Why are there very few genetics problems with Y chromosome alleles?

The Y chromosome in most organisms has very few genes on it!

The human Y chromosome has many repeated "junk" sections and only a few genes. One gene is the SRY gene, the most important gene in testis development.

5 Genotype Ratio:

$|X^N X^N| : |X^N X^n| : |X^N Y| : |X^n Y|$

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normal ♀ : carrier ♀ : normal ♂ : greasy ♂

25% of all progeny are greasy

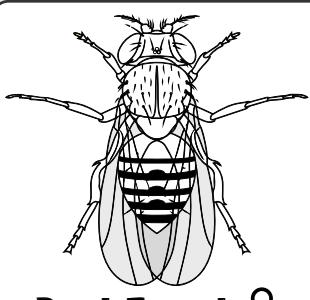
50% of all male progeny are greasy.

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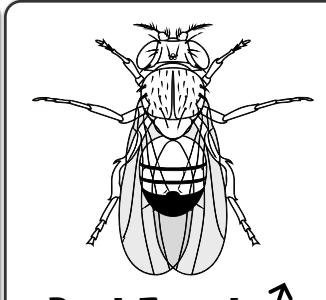
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X-Linked Inheritance

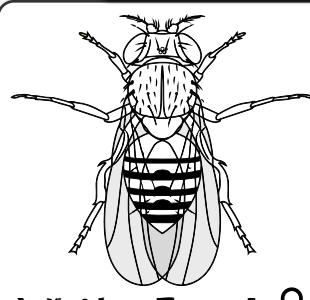
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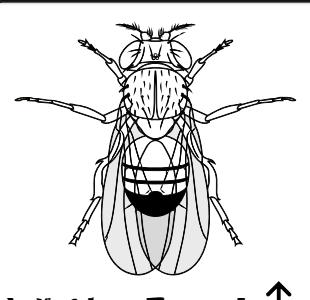
Red Eyed ♀



Red Eyed ♂



White Eyed ♀



White Eyed ♂

Genotype(s):
$X^R X^R$ or $X^R X^r$
Alleles: X^R and X^R or X^R and X^r
The red eyed $X^R X^r$ is called a <u>"carrier"</u> because it <u>"carries"</u> the <u>recessive</u> allele.

Genotype(s):
$X^R Y$
Alleles:
X^R and Y (no allele)

Genotype(s):
$X^r X^r$
Alleles:
X^r and X^r

Genotype(s):
$X^r Y$
Alleles:
X^r and Y (no allele)

- In crosses with X-linked alleles, the progeny are different depending on which parent had which alleles!
- Below is an example of a Reciprocal Cross.

Reciprocal Crosses

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	X^r	X^r
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	$X^r Y$ 	$X^r Y$

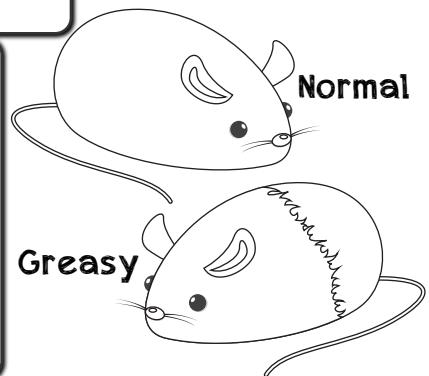
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White Eye ♂ $X^r Y$	$X^R X^r ♀$ 	$X^R X^r ♀$
	$X^r Y$ 	$X^R Y$

When you complete a genetics problem with an X-linked gene, you need to specify which progeny are female and male.

Name: _____

Example Genetic Cross:

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Normal fur (X^N) _____

Which trait/allele is recessive?

Greasy fur (X^n) _____

2



X



Phenotype: normal ♂
Genotype: $X^N Y$
Alleles: X^N , X^n

Parent #1: normal (carrier) ♀
Genotype: $X^N X^n$

		Carrier ♀ $X^N X^n$	
		X^N	X^n
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	X^n	$X^N Y$ 	$X^n Y$
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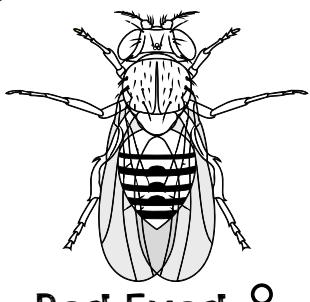
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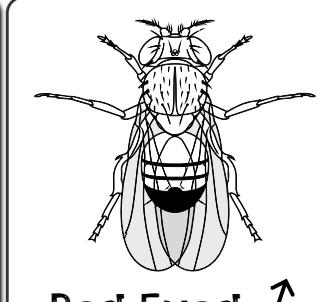
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X-Linked Inheritance

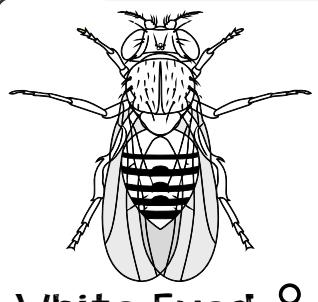
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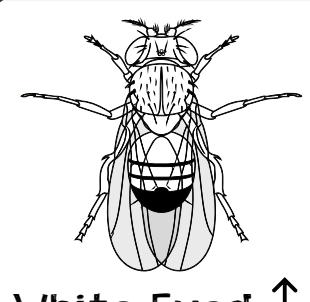
Red Eyed ♀



Red Eyed ♂



White Eyed ♀



White Eyed ♂

Genotype(s):

Genotype(s):

Genotype(s):

Genotype(s):

Alleles:

Alleles:

Alleles:

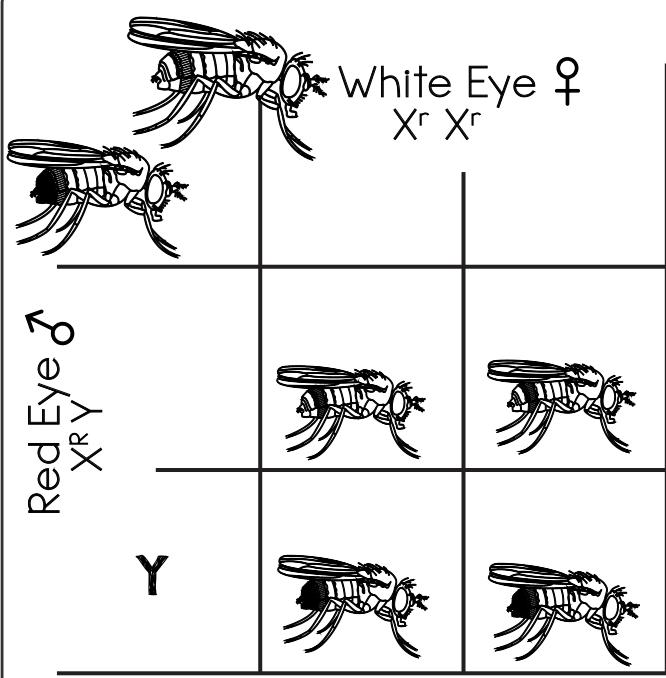
Alleles:

The red eyed $X^R X^r$ is called a _____ because it "carries" the _____ allele.

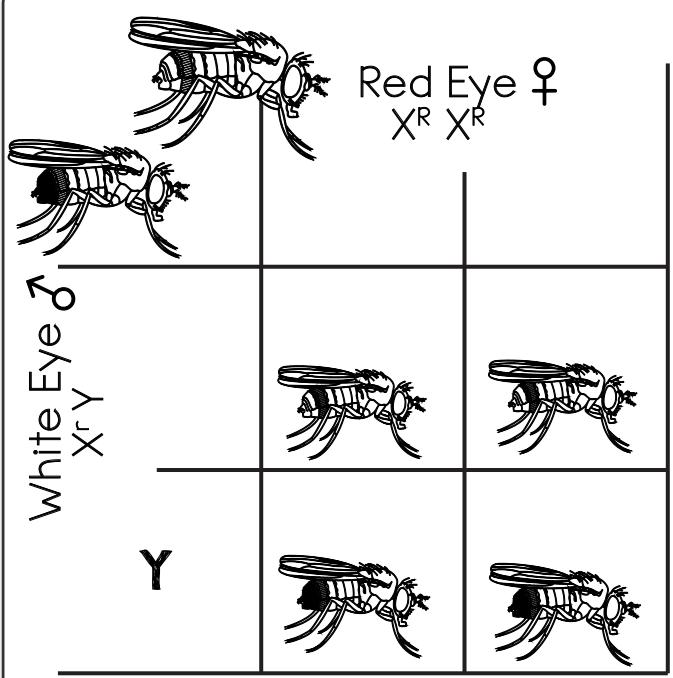
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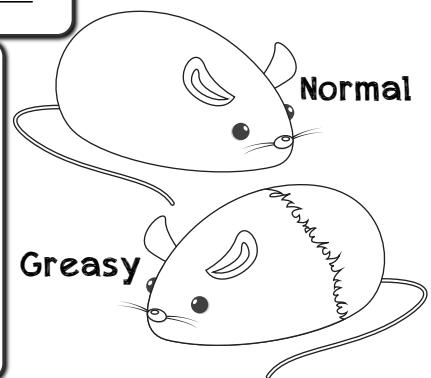


When you complete a genetics problem with an X-linked gene, you need to specify which progeny are _____ and _____.

Name: _____

Example Genetic Cross:

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1 Which trait/allele is dominant?

Which trait/allele is recessive?

2



Parent #1:

X

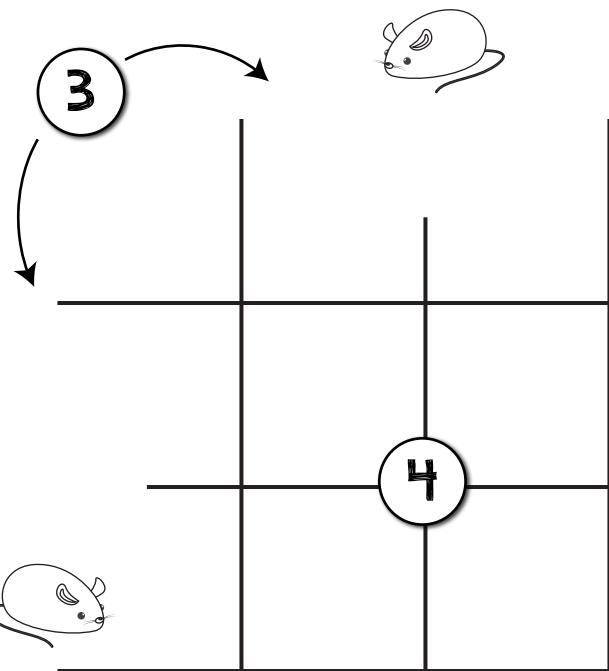


Parent #2:

Phenotype: _____

Genotype: _____

Alleles: _____



Why are there very few genetics problems with Y chromosome alleles?

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The human Y chromosome has many repeated _____ sections and only a few genes. One gene is the _____, the most important gene in testis development.

5 Genotype Ratio:

: : : _____

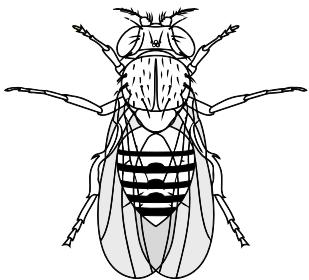
6 Phenotype Ratio:

: : : _____

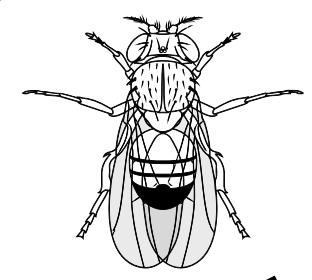
Name: _____

X-Linked Inheritance

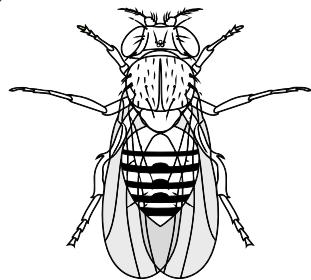
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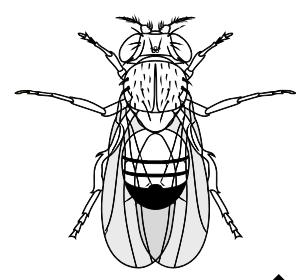
Red Eyed ♀



Red Eyed ♂



White Eyed ♀



White Eyed ♂

Genotype(s):

Genotype(s):

Genotype(s):

Genotype(s):

Alleles:

Alleles:

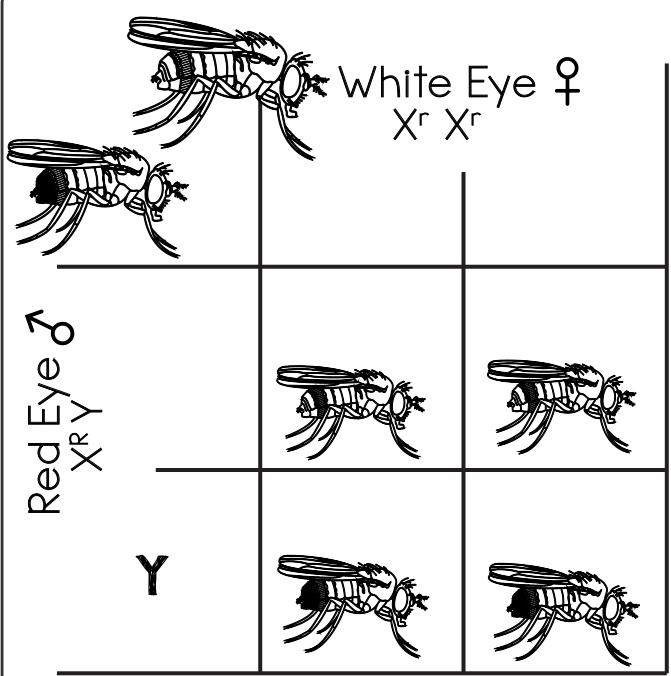
Alleles:

Alleles:

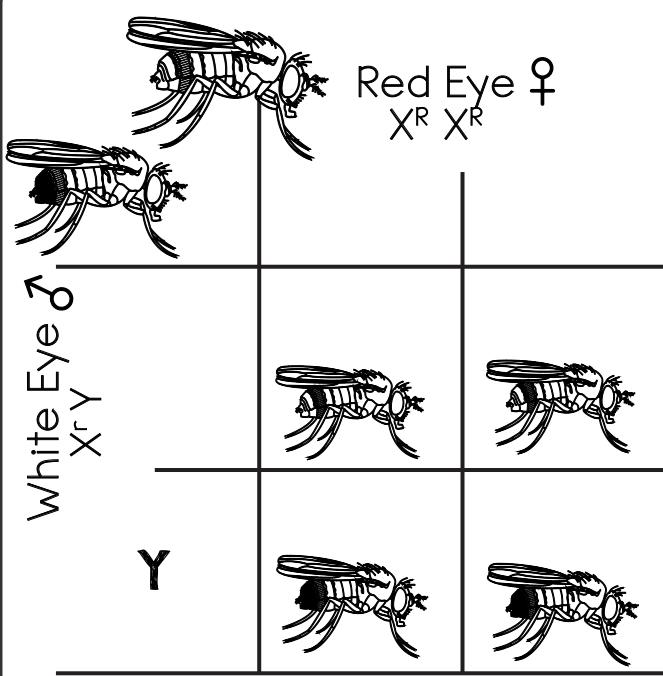
The red eyed $X^R X^r$ is called a _____ because it "carries" the _____ allele.

Reciprocal Crosses

If you cross a true breeding white-eyed female with a true breeding red eyed male:



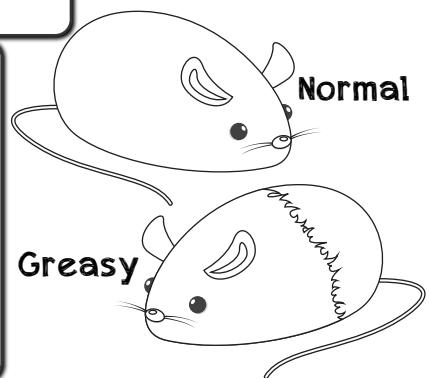
If you cross a true breeding red-eyed female with a true breeding white eyed male:



Name: _____

Example Genetic Cross:

Mice with the recessive "greasy" allele (n) have shiny fur. Normal fur is not "greasy-looking" and is caused by a dominant allele (N). The coat-shininess gene is on the X chromosome. If a normal male is crossed to a carrier female, what percent of their male progeny will have greasy fur?



1 Which trait/allele is dominant?

Which trait/allele is recessive?

2



X

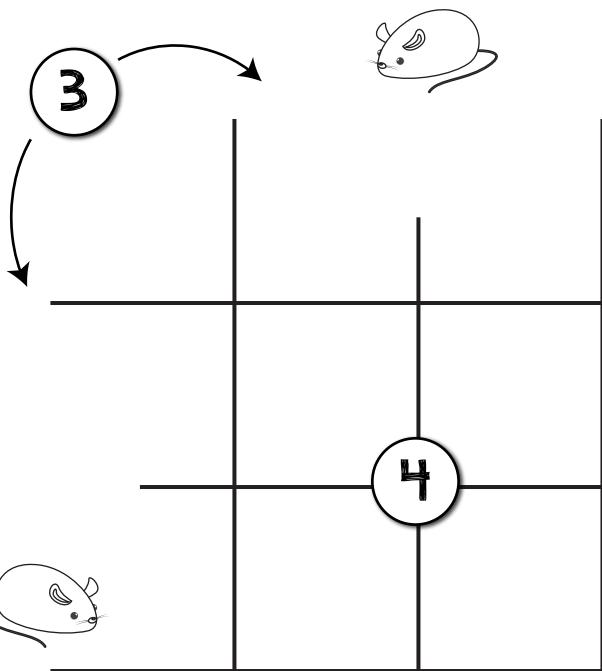


Parent #2:

Phenotype: _____

Genotype: _____

Alleles: _____



Why are there very few genetics problems with Y chromosome alleles?

5 Genotype Ratio:

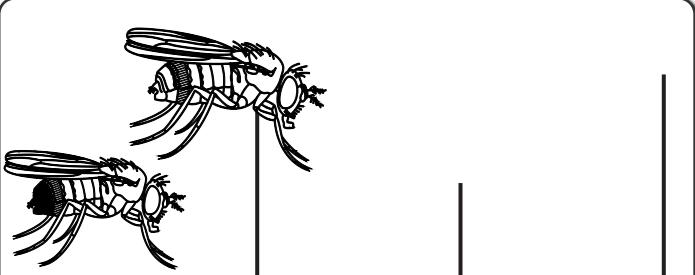
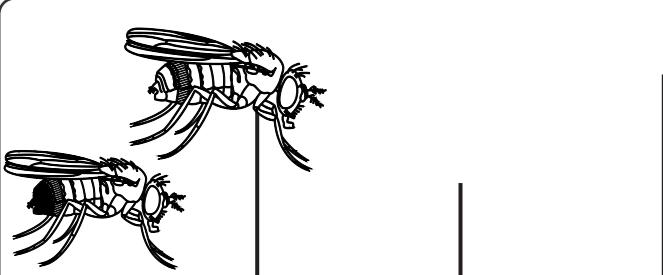
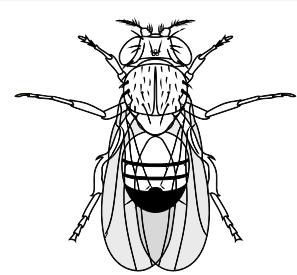
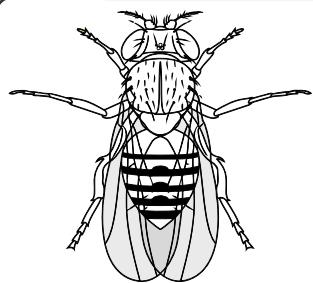
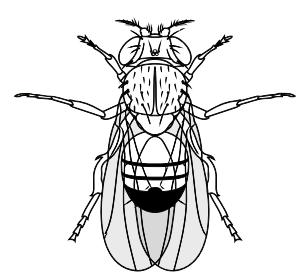
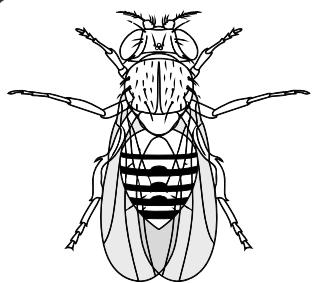
: : : : _____

6 Phenotype Ratio:

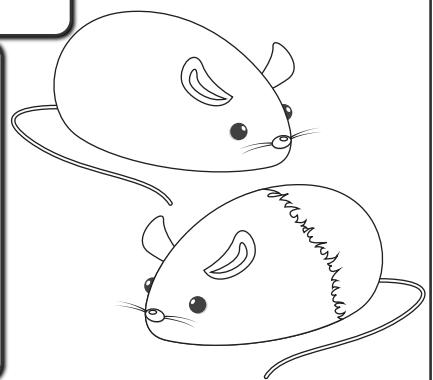
: : : : _____

Name: _____

X-Linked Inheritance



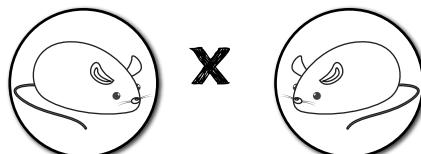
Name: _____



1

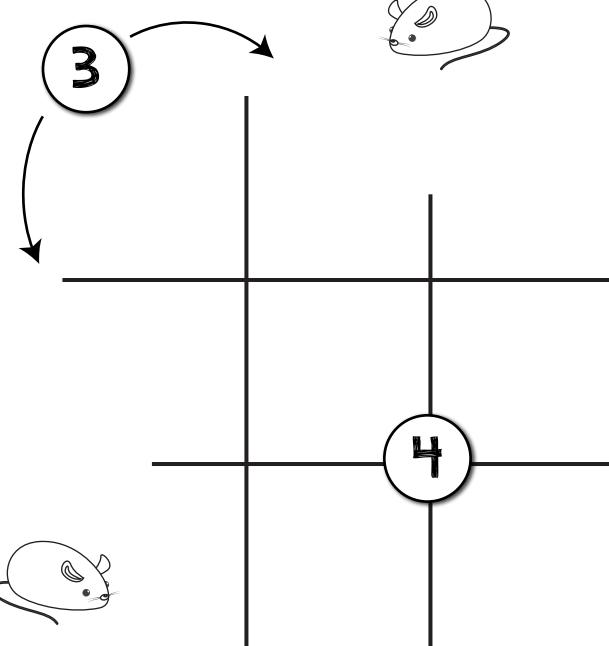
Handwriting practice lines for the number 1.

2



Handwriting practice lines for the number 2.

3



4



5

Handwriting practice lines for the number 5.

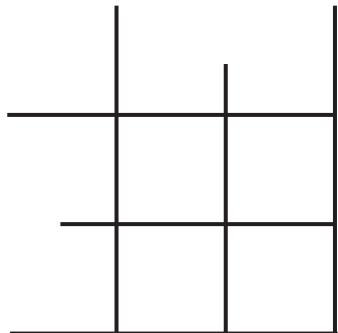
6

Handwriting practice lines for the number 6.

Name: _____

X-linked

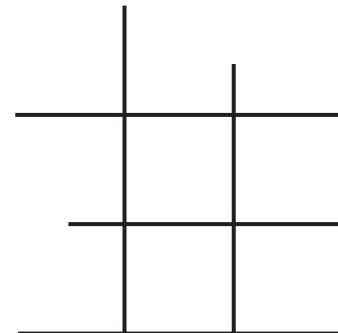
What percent of female progeny will have red eyes when a carrier female fly is crossed to a white eyed male fly?



Name: _____

X-linked

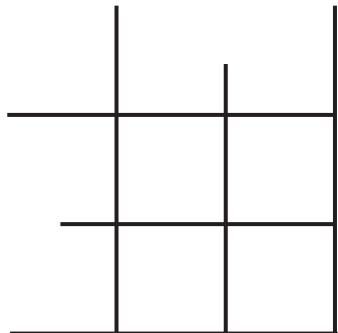
What percent of female progeny will have red eyes when a carrier female fly is crossed to a white eyed male fly?



Name: _____

X-linked

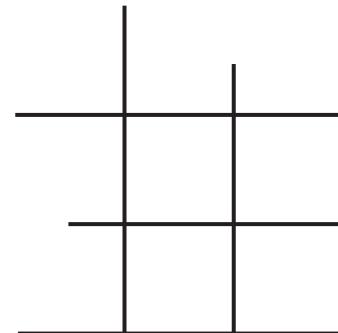
What percent of female progeny will have red eyes when a carrier female fly is crossed to a white eyed male fly?



Name: _____

X-linked

What percent of female progeny will have red eyes when a carrier female fly is crossed to a white eyed male fly?

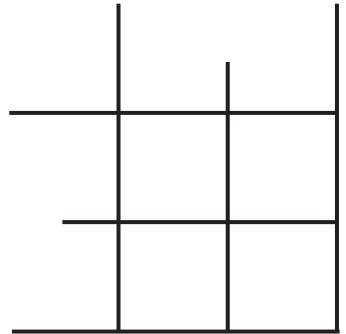


Name: _____

X-linked

2

What percent of male progeny will have greasy fur if a carrier female is crossed to a greasy male?

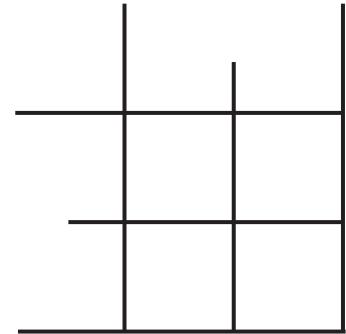


Name: _____

X-linked

2

What percent of male progeny will have greasy fur if a carrier female is crossed to a greasy male?

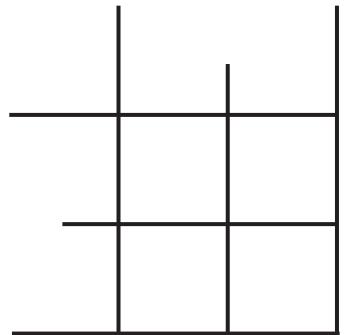


Name: _____

X-linked

2

What percent of male progeny will have greasy fur if a carrier female is crossed to a greasy male?

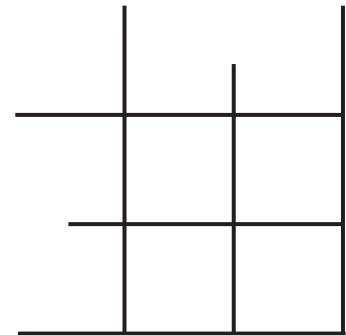


Name: _____

X-linked

2

What percent of male progeny will have greasy fur if a carrier female is crossed to a greasy male?



Name: _____

X-linked

3

What is a reciprocal cross? Why would scientists do a reciprocal cross?

Name: _____

X-linked

3

What is a reciprocal cross? Why would scientists do a reciprocal cross?

Name: _____

X-linked

3

What is a reciprocal cross? Why would scientists do a reciprocal cross?

Name: _____

X-linked

3

What is a reciprocal cross? Why would scientists do a reciprocal cross?

Name: Answer Key

X-linked

What percent of female progeny will have red eyes when a carrier female fly is crossed to a white eyed male fly?

50%

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

Name: Answer Key

X-linked

What percent of male progeny will have greasy fur if a carrier female is crossed to a greasy male?

50%

		X^N	X^n
X^n	$X^N X^n$	$X^n X^n$	
Y	$X^N Y$	$X^n Y$	

Name: Answer Key

X-linked

3

What is a reciprocal cross? Why would scientists do a reciprocal cross?

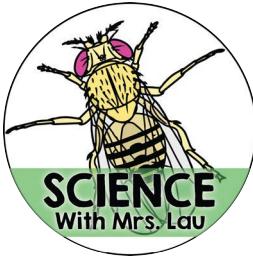
A reciprocal cross set is a cross of a mutant female with a normal male, and a cross of a normal female and a mutant male.

Scientists use it because if the progeny from the two crosses are very different, the gene is most likely on the X chromosome.

Teacher Instructions:

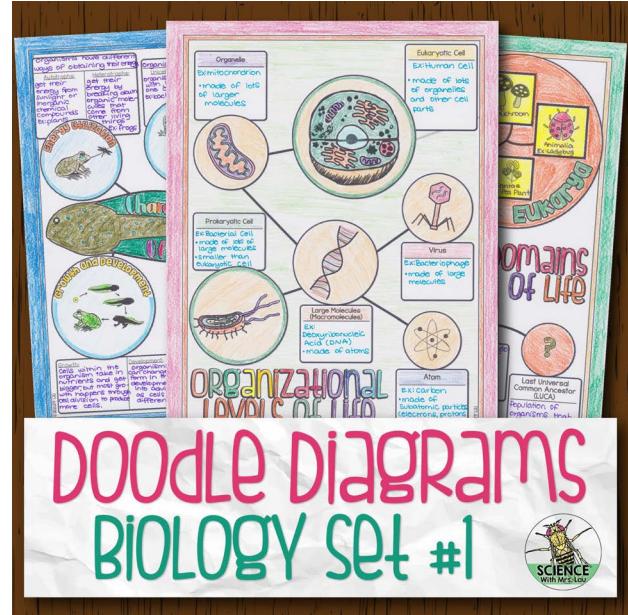
I recommend using these “exit tickets” for the last 3-5 minutes of class. Pass them out, ask your students to fill them out, and then go over the answer right then and there after they switch with their partner to correct. I recommend having the “partner switch” be different every day (Behind you, in front of you, to the left/right etc). That way you can give them a participation grade by just checking them off in your gradebook (I’m sure you don’t have time to grade 100+ of these a day...) It’s a great way to get a quick formative assessment of how they understood the lesson.

Thank You!



Thank you for downloading one of my doodle diagrams. I work hard to create the best quality content for my students and I hope this resource helps you teach in your own classroom. If you have any questions, concerns, or find an occasional typo, please email me at mrs.bethany.lau@gmail.com. :)

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