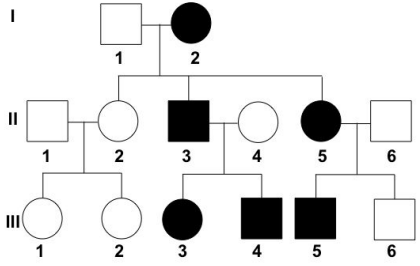
Genetics

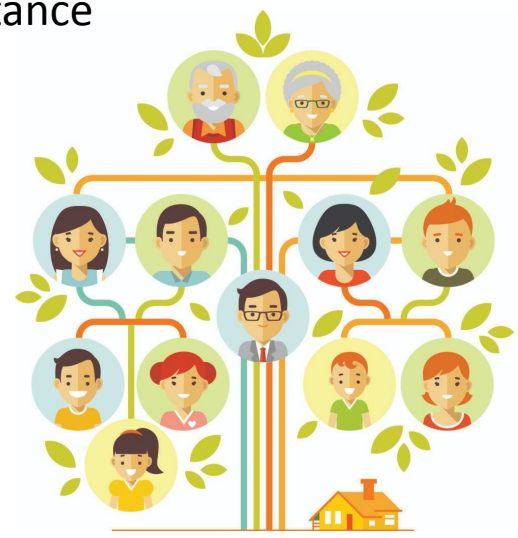


Berkeley Math Circle

Beginners I-II

Genetics

Genetics is the study of traits and their inheritance

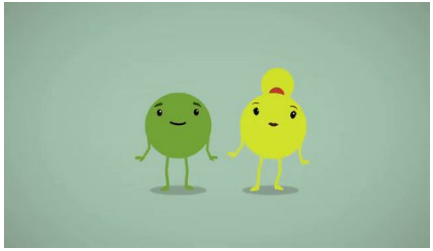


Vocabulary

- Genes – heritable unit that determine traits
- Traits – physical characteristics

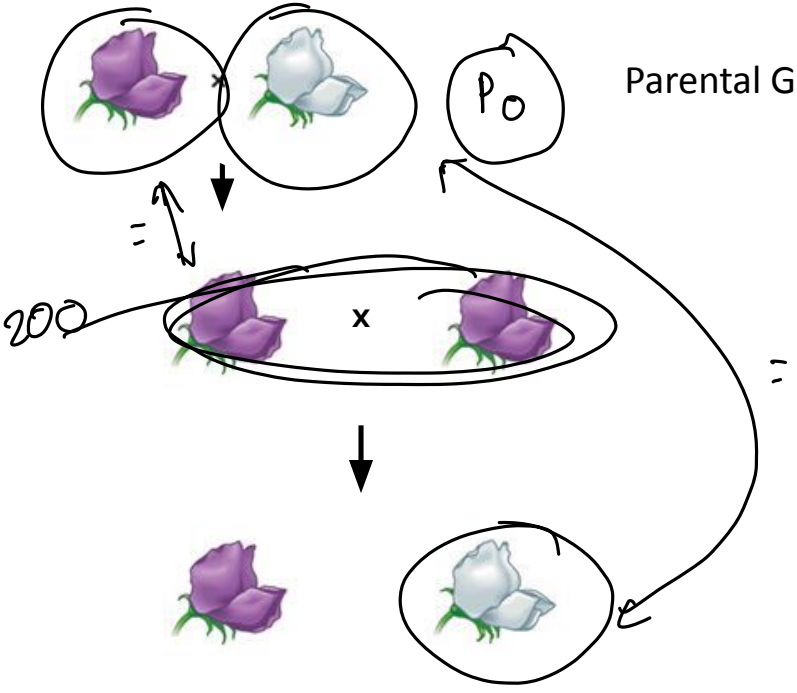
Gregor Mendel (~~1822-1884~~)

- Father of Genetics



x = mating or crossing

First Experiment

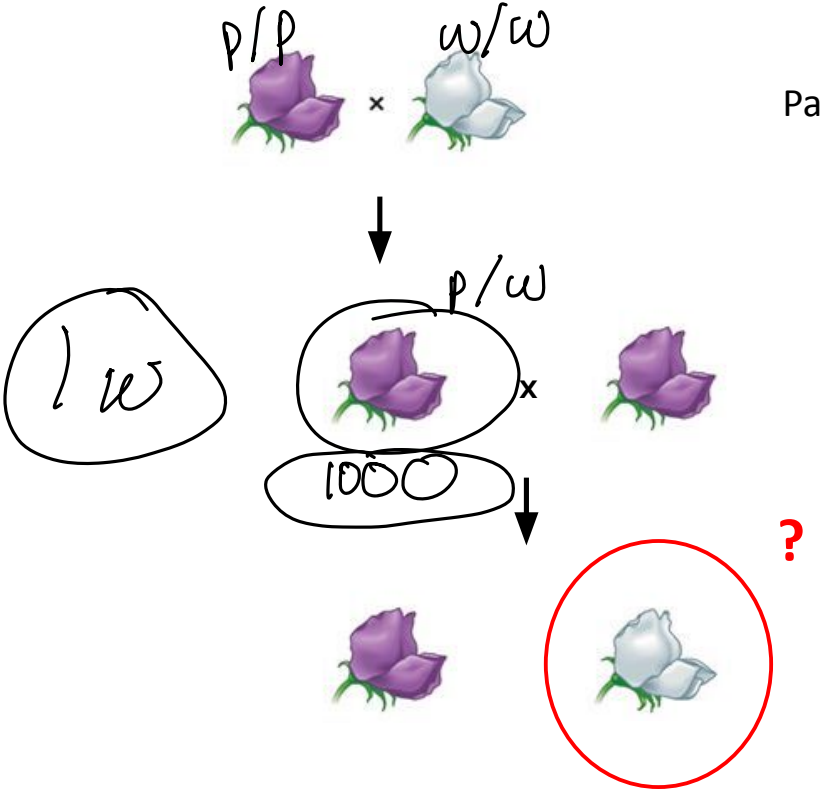


Parental Generation = true-breeding

F1

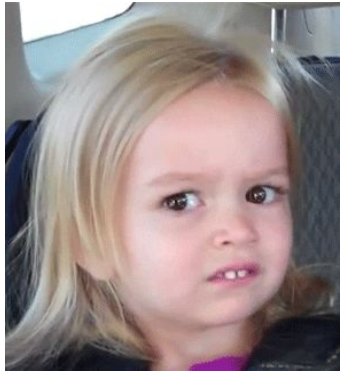
F2

First Experiment



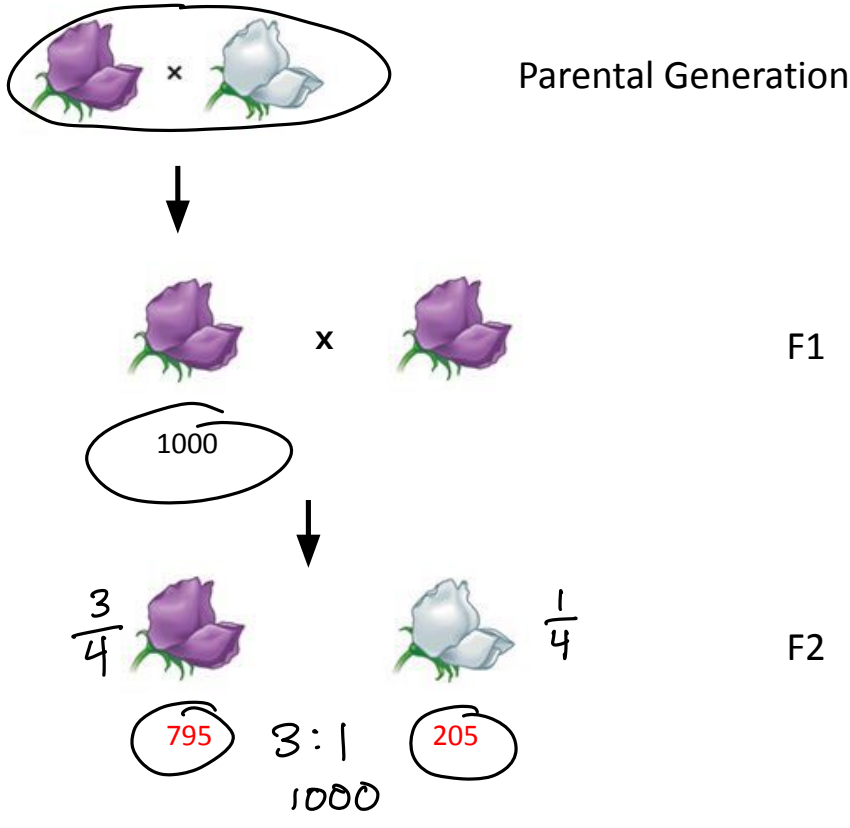
Parental Generation = true-breeding

F1



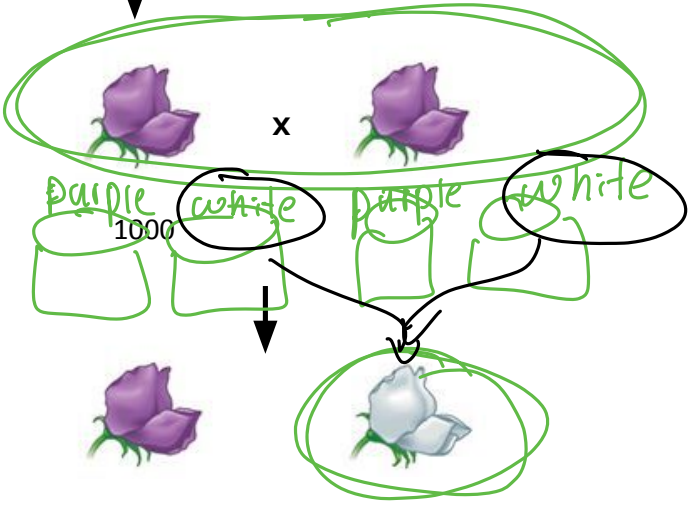
F2

First Experiment



Mendel's 1st Law:
Law of segregation

Parental Generation



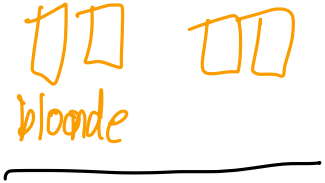
F1

F2

Vocabulary

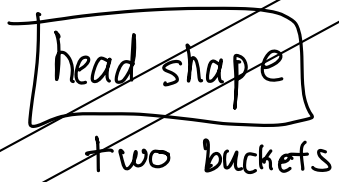
- Genes – heritable unit that determine traits
- Traits – physical characteristics
- Allele – different versions of a gene
- Recessive
- Dominant

Dominant allele outcompetes recessive allele

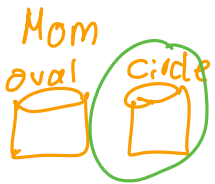


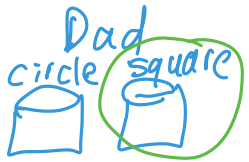
Alleles – Dominant and recessive

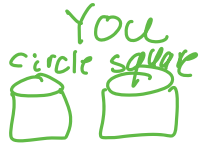
Each parent carries a bucket of paint and chooses one color to contribute to their offspring



oval
circle
square
rectangle
cylinder





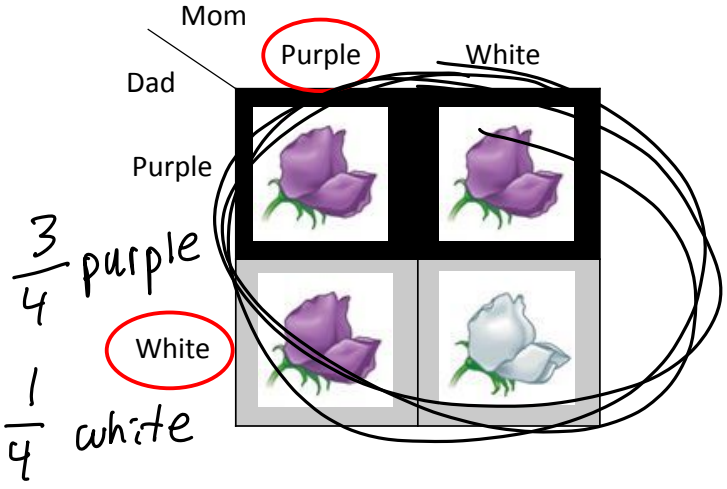


purple dominant to white

Mom / Dad	Purple	White
Purple	p/p purple	p/w purple
White	p/w purple	w/w white

Alleles – Dominant and recessive

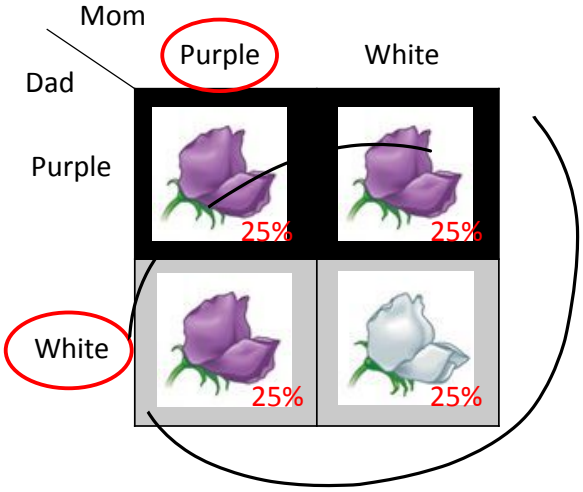
Each parent carries a bucket of paint and chooses one color to contribute to their offspring



Purple paint is dominant to white paint

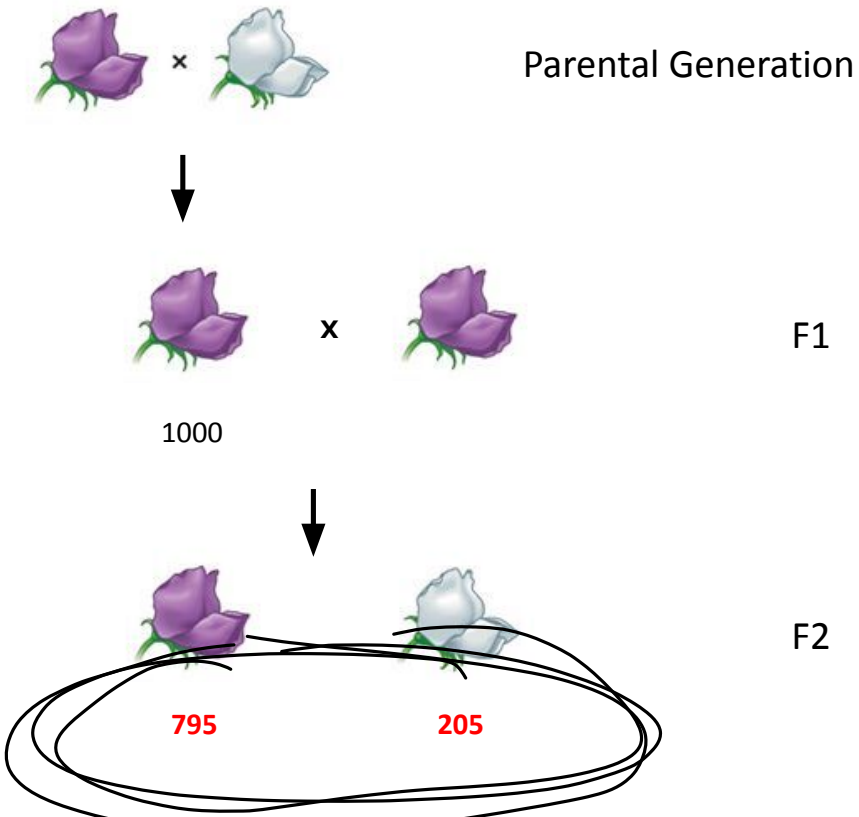
Alleles – Dominant and recessive

Each parent carries a bucket of paint and chooses one color to contribute to their offspring



Purple paint is dominant to white paint

Mendel's 1st Law: Law of segregation



Mendel's flower garden

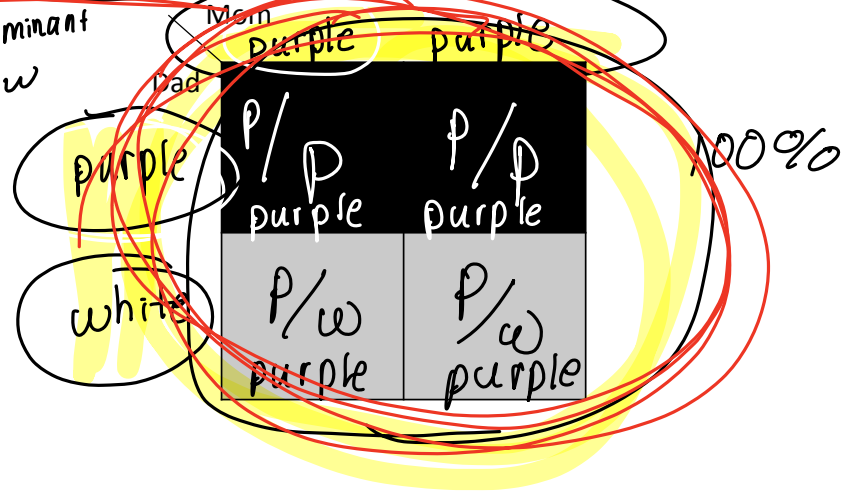
If a BMC student crosses (mates) a **purple/purple** flower with a **purple/white** flower, what is the probability that an offspring flower is purple? Purple ***and*** carries a white allele?

Blue
blue/green

Hazel
hazel/green

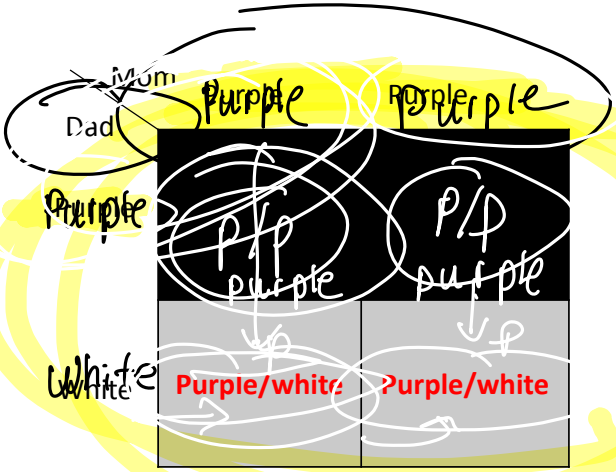
Green
green/green

50% P dominant w



Mendel's Flower Garden

Gregor Mendel crosses (mates) a **purple/purple** flower with a **purple/white** flower, what is the probability that an offspring flower is purple? Purple ***and*** carries a white allele?

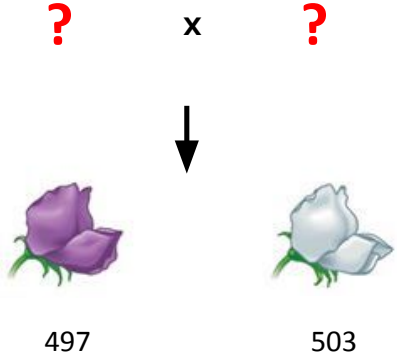


All purple offspring

50% chance that offspring carries white allele

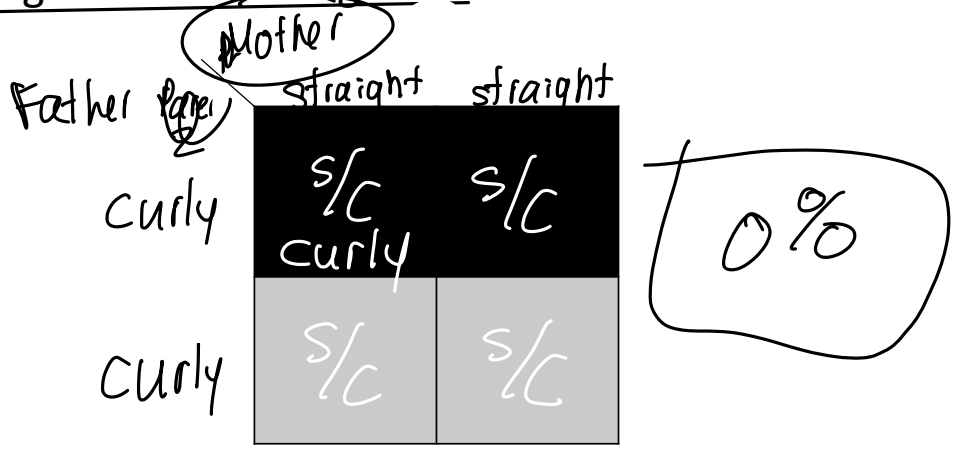
Mendel's flower garden

Gina the Geneticist breeds 1,000 flowers in his garden and observes 497 purple flowers and 503 white flowers. What alleles do the parent flowers carry?



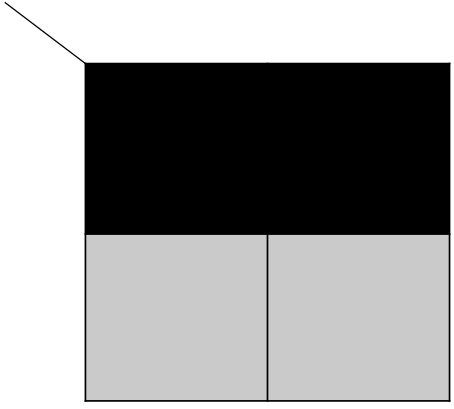
Pig tails

Mother pig has two alleles for straight tail, and Father Pig has two alleles for curly tail. If curly tail is dominant to straight tail, what is the probability that their baby pigs will have straight tails?



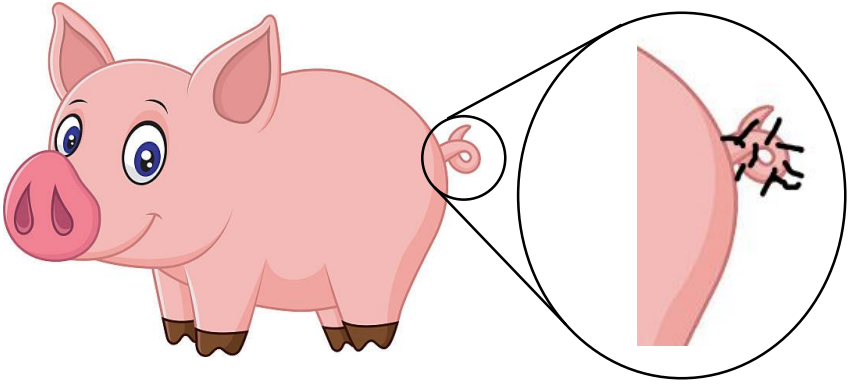
Pig tails

Sally Pig has a curly tail. If both Mother and Father Pig have curly tails and Brother Pig has a straight tail, what is the probability Sally is heterozygous for tail shape? (Heterozygous means having both a dominant and a recessive allele)



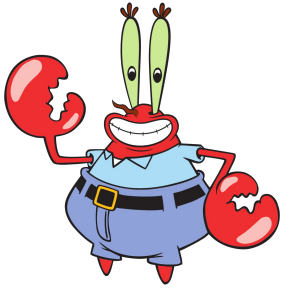
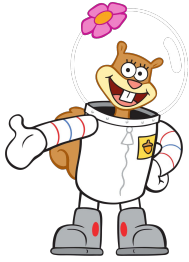
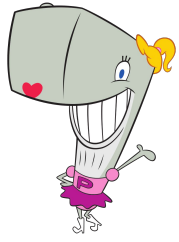
Hairy pig tails…?

Gina the Geneticist decides to inspect her pigs' tails a little more closely and finds that not only are there differences in shape but also hairiness. If Mama Pig has a hairy curly tail (heterozygote) and Papa Pig has a non-hairy straight tail, what is the probability Baby Pig has a hairy curly tail? Hairy is dominant to smooth. Curly is dominant to straight.



Bikini Bottom Genetics

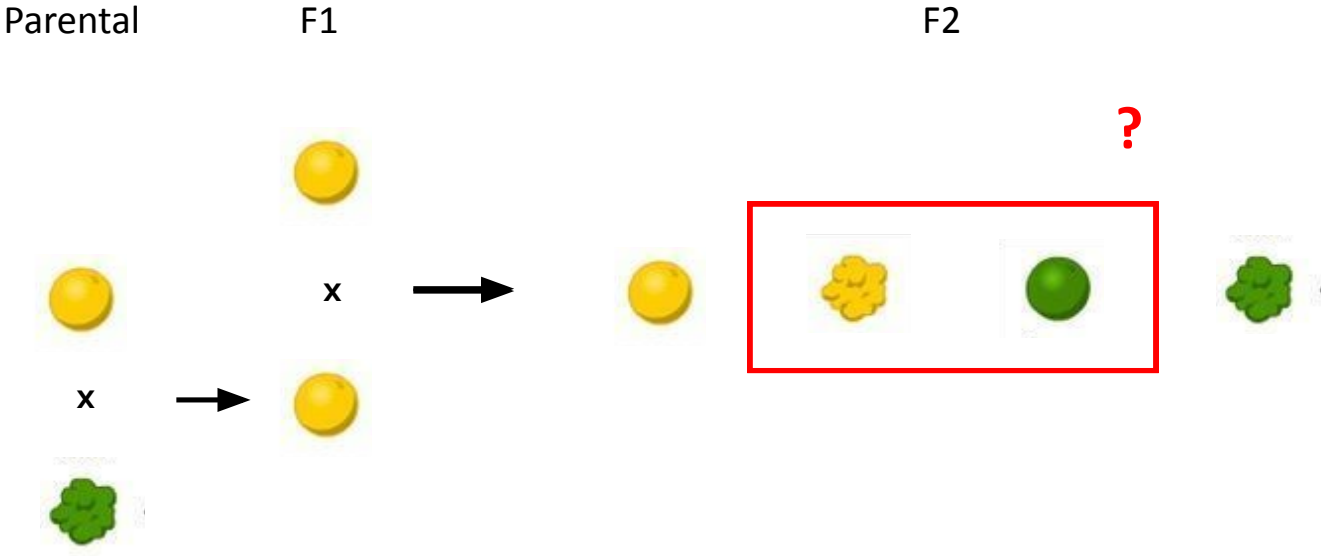


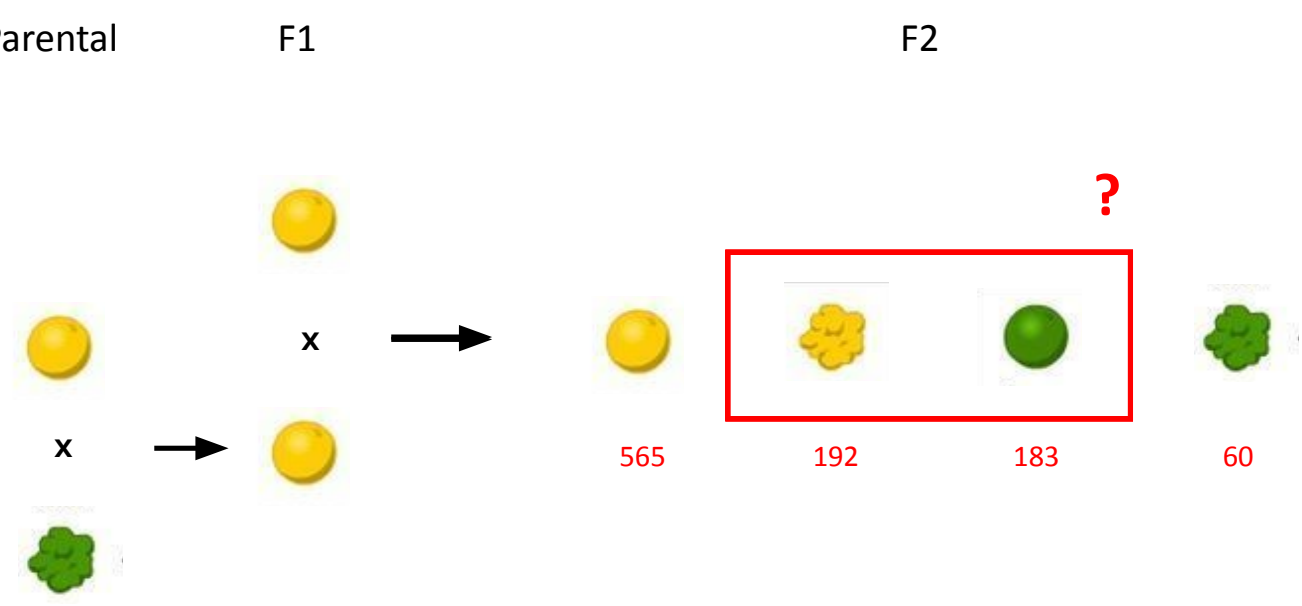


Mendel's 2nd Law

2nd Experiment – 2 traits



2nd Experiment – 2 traits



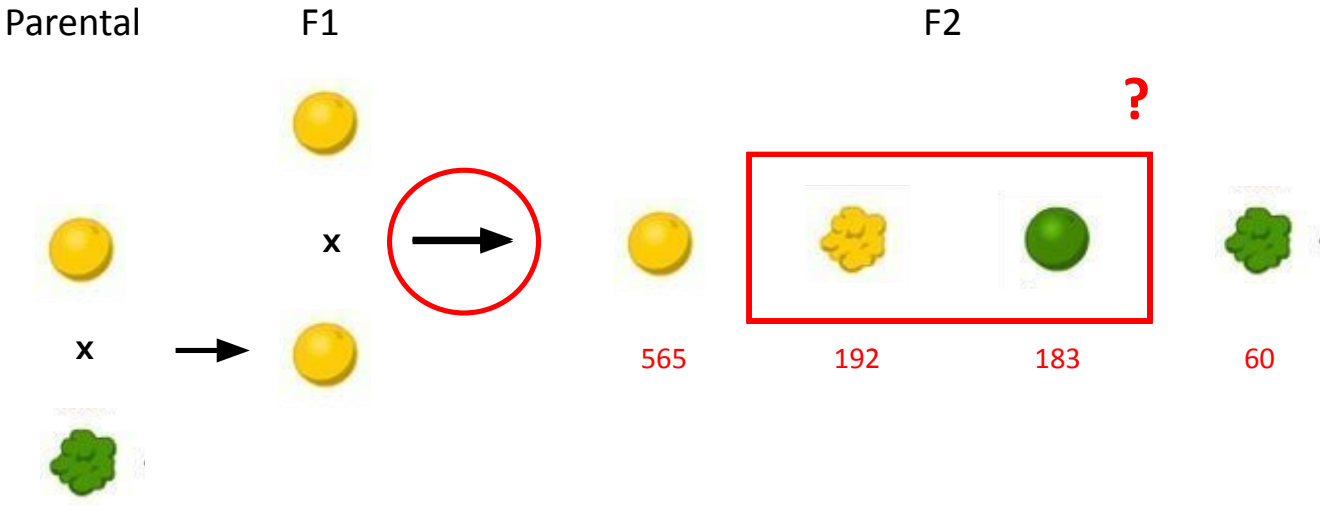
Vocabulary

- Genes – heritable unit that determine trait
- Traits – physical characteristics
- Allele – different versions of a gene
- Recessive
- Dominant

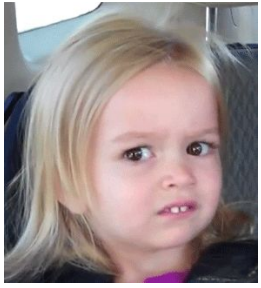
  → Dominant allele outcompetes recessive allele

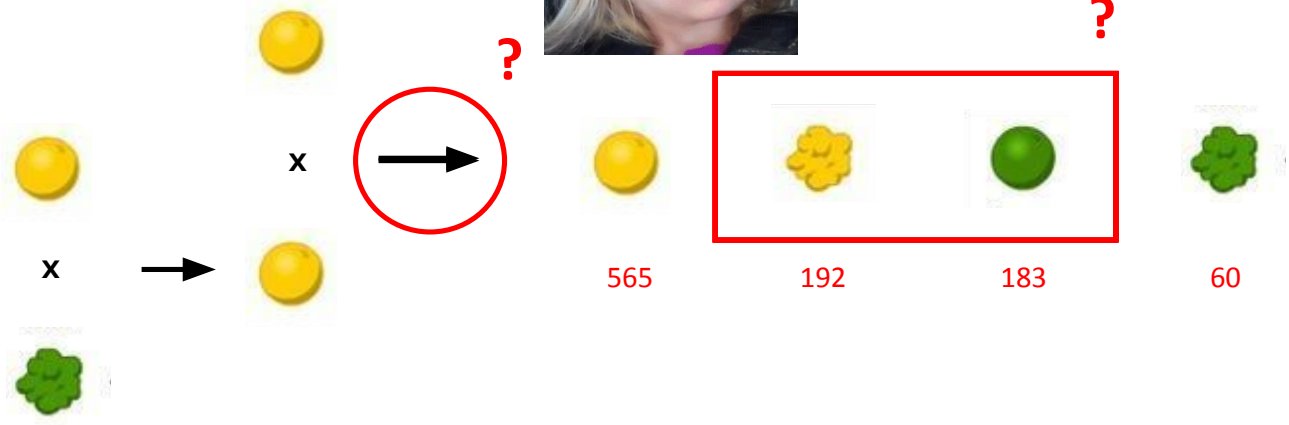
- Independent assortment – traits that mathematically/genetically distribute independently of each other from parent to offspring

2nd Experiment



2nd Experiment





Mendel's 2nd Law: Law of independent assortment

Yellow/green, smooth/wrinkled

- Yellow, smooth
- Yellow, wrinkled
- Green, smooth
- Green, wrinkled

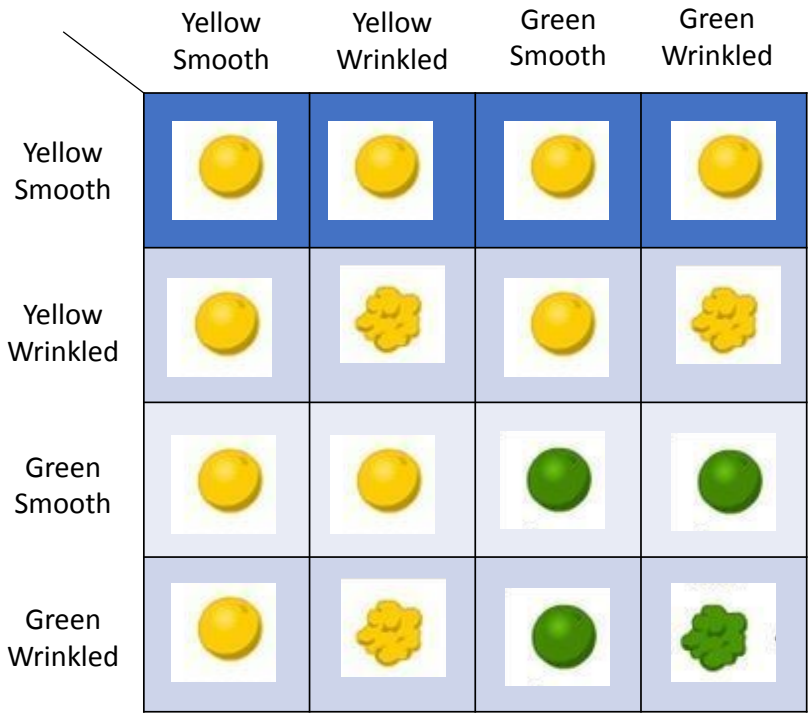
~~From Mendel's 1st Law~~

~~(Yellow, smooth)/(green, wrinkled)~~

- ~~Yellow, smooth~~
- ~~Green, wrinkled~~

Each parent carries a bucket of paint and chooses one color to contribute to their offspring

Dad \ Mom	Purple	White
Purple		
White		



Mendel's 2nd Law: Law of independent assortment

	Yellow Smooth	Yellow Wrinkled	Green Smooth	Green Wrinkled			Out of 1000 offspring
Yellow Smooth						9/16	562.5
Yellow Wrinkled						3/16	187.5
Green Smooth						3/16	187.5
Green Wrinkled						1/16	62.5

Mendel's second law: Law of independent assortment

Why independent?

Mom / Dad	Yellow	Green
Yellow		
Green	**Yellow**	**Green**

Color

Mom / Dad	Smooth	Wrinkled
Smooth		
Wrinkled	**Smooth**	**Wrinkled**

Texture

Why independent… do the probabilities match?

Dad \ Mom	Yellow	Green
Yellow	25%	25%
Green	**Yellow** 25%	**Green** 25%

Color

Dad \ Mom	Smooth	Wrinkled
Smooth	25%	25%
Wrinkled	**Smooth** 25%	**Wrinkled** 25%

Texture

9/16

3/16

3/16

1/16

Practice

Two genes

Given the traits of the parents below, what is the probability an offspring is yellow/green **AND** wrinkled/smooth? Yellow is dominant to green. Wrinkled is dominant to smooth

yellow/green
smooth/smooth

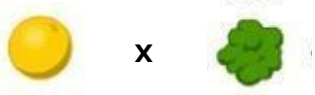
x

green/green
wrinkled/smooth

yellow/green
wrinkled/smooth

Probability?

Solution 1



yellow/green
smooth/smooth

x

green/green
wrinkled/smooth

yellow/green
wrinkled/smooth

Probability?

Dad \ Mom	Yellow Smooth	Yellow Smooth	Green Smooth	Green Smooth
Green Wrinkled	y/g w/s	y/g w/s	g/g w/s	g/g w/s
Green Smooth	y/g s/s	y/g s/s	g/g s/s	g/g s/s
Green Wrinkled	y/g w/s	y/g w/s	g/g w/s	g/g w/s
Green Smooth	y/g s/s	y/g s/s	g/g s/s	g/g s/s

¼

Solution 2

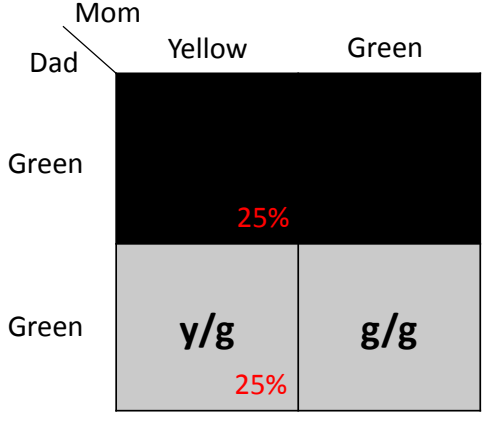
yellow/green
smooth/smooth

x

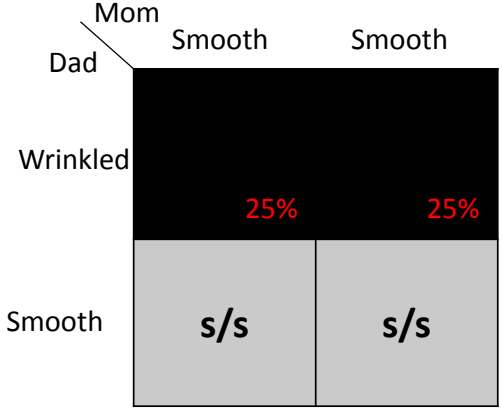
green/green
wrinkled/smooth

yellow/green
wrinkled/smooth

Probability?



Color



Texture

½ x ½ = ¼

Two genes

Given the traits of the parents below, what is the probability an offspring pea plant is yellow **AND** smooth? Yellow is dominant to green. Wrinkled is dominant to smooth.

yellow/green
smooth/smooth

x

green/green
wrinkled/smooth

Yellow
Smooth

Probability?

Solution 1

yellow/green
smooth/smooth

x

green/green
wrinkled/smooth

Yellow
Smooth

Probability?

	Yellow Smooth	Yellow Smooth	Green Smooth	Green Smooth
Green Wrinkled				
Green Smooth				
Green Wrinkled				
Green Smooth				

¼

Solution 2

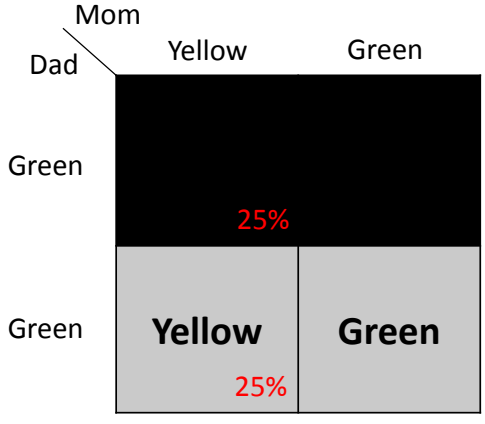
yellow/green
smooth/smooth

x

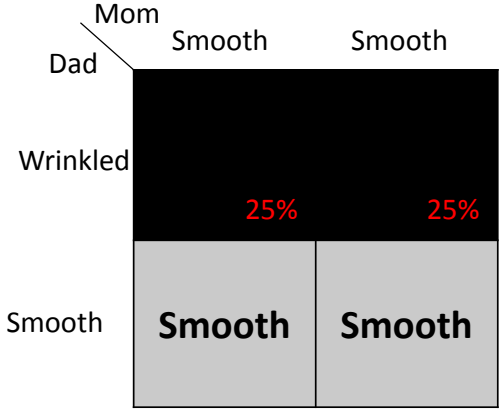
green/green
wrinkled/smooth

Yellow
Smooth

Probability?



Color



Texture

½ x ½ = ¼

Two genes

Given the traits of the parents below, what is the probability an offspring is yellow/green **OR** wrinkled/smooth?

yellow/green
smooth/smooth

x

green/green
wrinkled/smooth

Two genes

Given the traits of the parents below, what is the probability an offspring pea plant is yellow **OR** smooth? Yellow is dominant to green. Wrinkled is dominant to smooth.

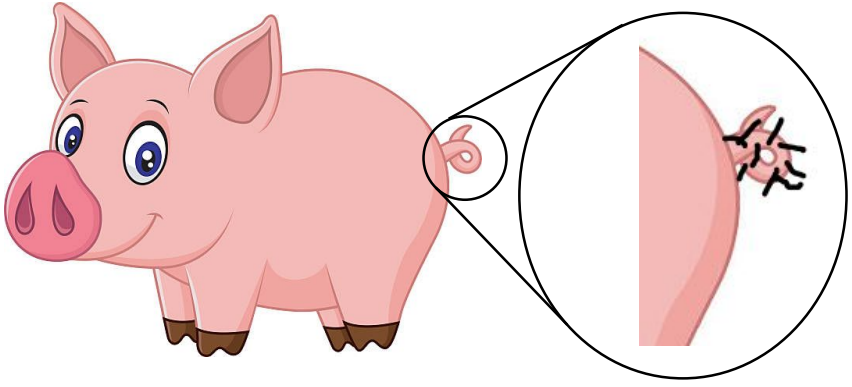
yellow/green
smooth/smooth

x

green/green
wrinkled/smooth

Hairy pig tails!

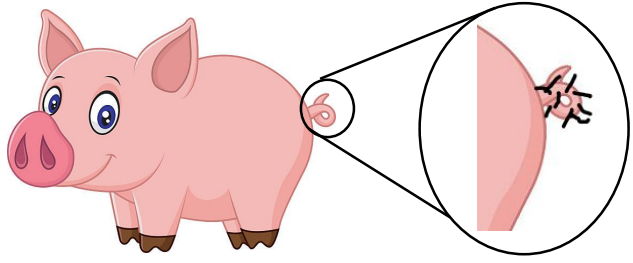
Gina the Geneticist decides to inspect her pigs' tails a little more closely and finds that not only are there differences in shape but also hairiness. If Mama Pig has a hairy curly tail (heterozygote) and Papa Pig has a non-hairy straight tail, what is the probability Baby Pig has a hairy curly tail? Hairy is dominant to smooth. Curly is dominant to straight.



Wrinkled hairy pigtails…?

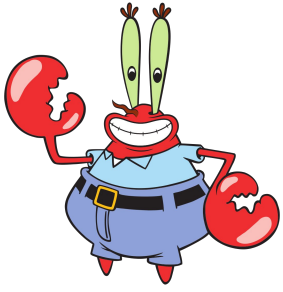
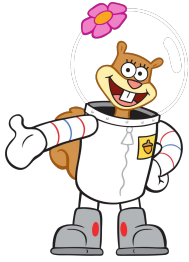
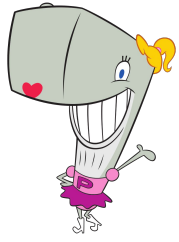
Given the allele combinations of Mama and Papa Pig, what is the probability Baby Pig is **wrinkled/smooth**, **hairy/hairy**, **curly/straight**? The three genes **independently** assort.

	Texture	Hairiness	Straightness
Mama Pig	smooth/smooth	hairy/hairless	curly/curly
Papa Pig	wrinkled/smooth	hairy/hairless	curly/straight



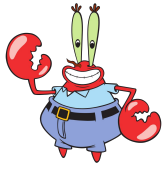
Bikini Bottom Genetics

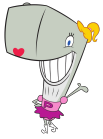










Name	Spongebob	Patrick	Squidward	Mr. Krabs	Sandy	Pearl	Plankton	Mrs. Puff	Karen	Gary
Eye	blue blue	black blue	green black	blue green	green green	blue green	black black	green black	black black	green green
Earlobe	attached attached	detached detached	attached detached	attached detached	detached detached	attached attached	attached attached	detached detached	attached detached	attached detached
Krabbiness	unkrabby unkrabby	krabby unkrabby	krabby unkrabby	krabby krabby	krabby krabby	krabby unkrabby	unkrabby unkrabby	Krabby unkrabby	krabby krabby	unkrabby unkrabby
Height	short short	medium short	tall short	medium short	medium tall	tall tall	short short	medium medium	medium short	short short
Handedness	right right	toe toe	left toe	toe right	left left	right left	left left	toe right	right right	toe toe

Eye color
- Black dominant to blue
- Blue dominant to green
- Green dominant to black

Earlobe
- Attached dominant to detached

Krabbiness
- Krabby dominant to unkrabby

Height
- Medium dominant to tall
- Tall dominant to short
- Medium dominant to short

Handedness
- Right dominant to left
- Left dominant to toe
- Toe dominant to right

Genetic pedigrees

What is the most likely allele combination of Mrs. Higginbottom?

Mendel's second law: Law of independent assortment

What are the allele combinations of this pea plant?

Combinations – 2 genes

x

Color Texture

From Mendel's 1st Law

Yellow/green, smooth/wrinkled

- Yellow, smooth
- Yellow, wrinkled
- Green, smooth
- Green, wrinkled

From Mendel's 1st Law

(Yellow, smooth)/(green,wrinkled)

- Yellow, smooth
- Green, wrinkled

Combinations – 2 genes

From Mendel's 1st Law

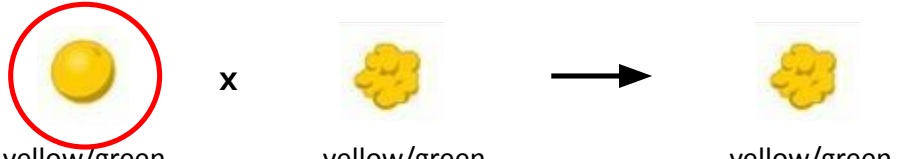
Yellow/green, smooth/wrinkled

- Yellow, smooth
- Yellow, wrinkled
- Green, smooth
- Green, wrinkled

$$\frac{2}{\text{Color}} \times \frac{2}{\text{Texture}}$$

Two genes

Given the traits of the parents below, how many **different** allele combinations can the yellow parent pea plant contribute?



yellow/green
smooth/wrinkled

x

yellow/green
wrinkled/smooth

yellow/green
wrinkled/smooth

# of allele combinations?

Two genes

Given the traits of the parents below, how many **different** allele combinations can the yellow parent pea plant contribute?

yellow/green
smooth/smooth

x

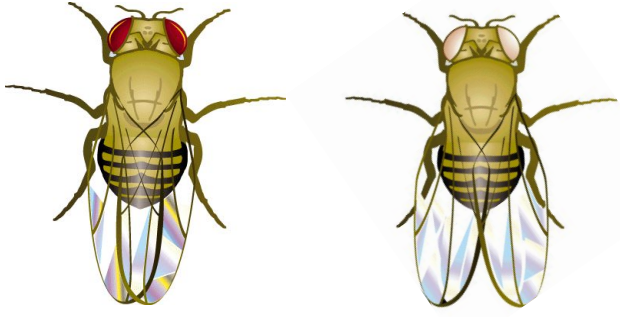
green/green
wrinkled/smooth

yellow/green
wrinkled/smooth

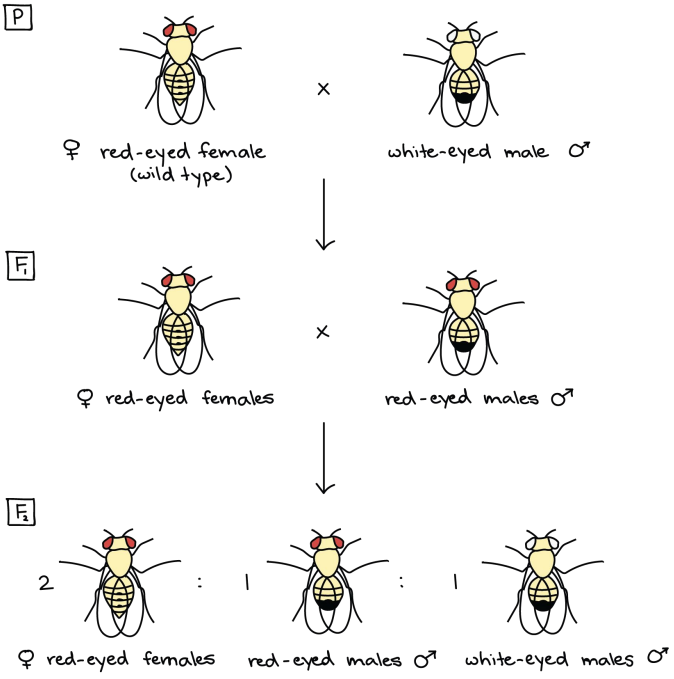
# of allele combinations?

Sex-linked traits

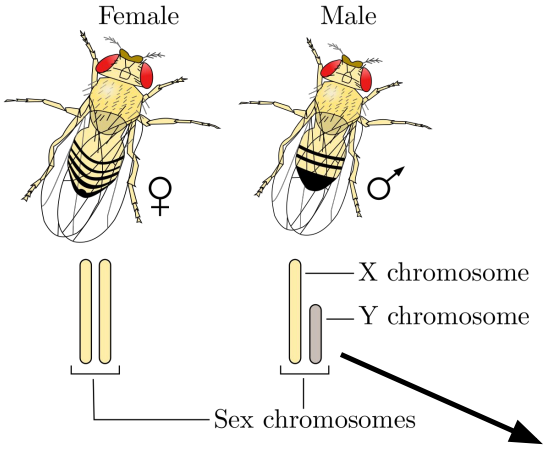
- Thomas H. Morgan



Drosophila Melanogaster (common fruit fly)

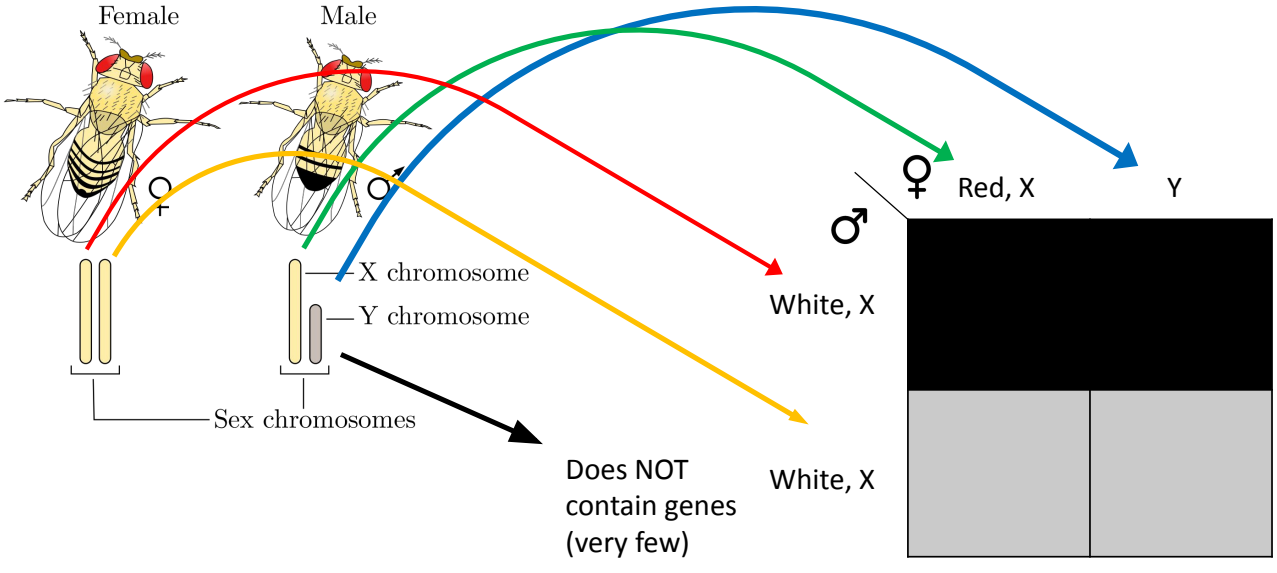


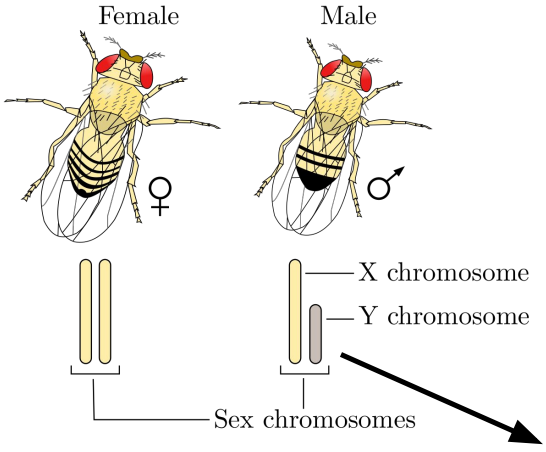
- Different phenotype frequencies observed between male and female
- NOTE: Observed when female holds double recessive genotype, not ALL crosses
- **Males only carry one allele for a sex-linked trait**



Does NOT contain genes (very few)

♂ \ ♀	Red	Y
White		
White	**Red**	**White**


Female
Male
X chromosome
Y chromosome
Sex chromosomes
Does NOT contain genes (very few)
♀
Red, X
Y
♂
White, X
White, X



Does NOT contain genes (very few)

♂ \ ♀	Red	Y
White		
White	**Red**	**White**

Morgan's fruit fly nest

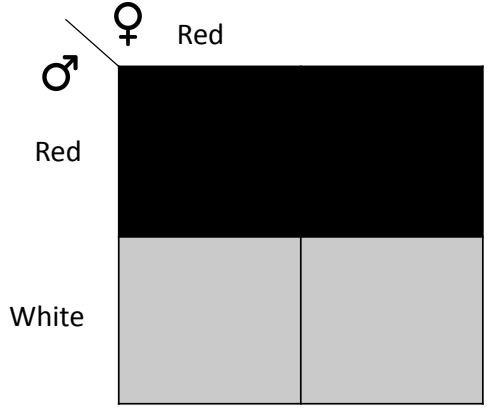
Gina the Geneticist wants to replicate… She observes the following data, what are possible genotypes of the parent flies?

Eye color	Female	Male
Red		
White		

Morgan's fruit fly nest

Gina the Geneticist wants to replicate… She observes the following data, what are possible genotypes of the parent flies?

Eye color	Female	Male
Red		
White		



Mary and Tyler have normal vision.

Challenge