UNIT 7 TOPIC 2

Dihybrid Cross

Non-Mendelian Genetics

Objectives

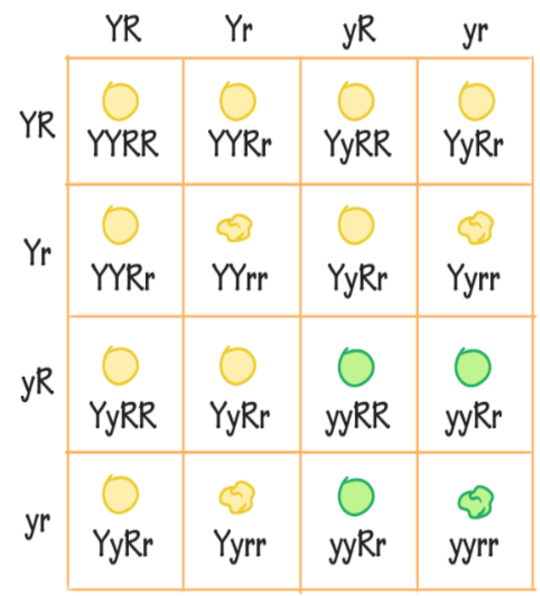
- Determine the possible gamete combination for dihybrid cross
- Predict the outcomes of a dihybrid cross by using Punnett square

Prior Knowledge

- What is the meaning of dihybrid cross?
- Explain Mendel's Law of segregation
- What is the name of gamete formation process?

Dihybrid Cross

- Genetic cross between parental generations that differ in **two** traits
- The genotype of the parent is represented by **four** alleles, **why?**
- Example: YyRr
- a **16 square** grid Punnett square is used to predict the genetic variations that result from crossing **2 different** traits of two organisms



Think-Pair-Share

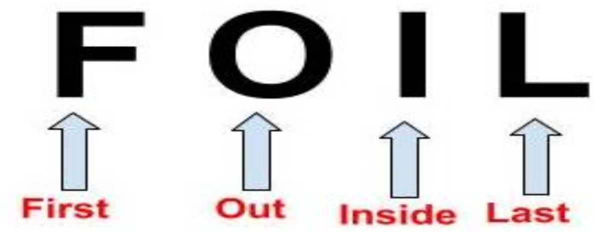
- If a parent somatic cell has the following genotype **TtRr**
- Apply Mendel's law of segregation to figure out the gamete genotypes
- Try on your own for 1 minutes
- Pair up with a classmate next to you and share your answers
- Share the answer with the whole class

Dihybrid Cross

- Each gamete will have **two alleles**, one allele for each trait
- Example:
  - T= tall t = short
  - R =red r = white
  - These are the possible gamete combinations
    TR Tr tR or **tr**

	TR	Tr	tR	tr
TR	TTRR	TTRr	TtRR	TtRr
Tr	TTRr	TTrr	TtRr	Ttrr
tR	TtRR	TtRr	ttRR	ttRr
tr	TtRr	Ttrr	ttRr	ttrr

How can we determine the gamete combinations?



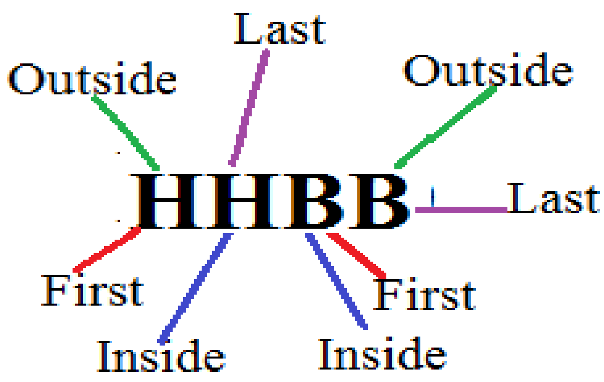
A) FOIL method

#1 Homozygous dominant

HHBB

Gamete combinations are:

HB, HB, HB, HB

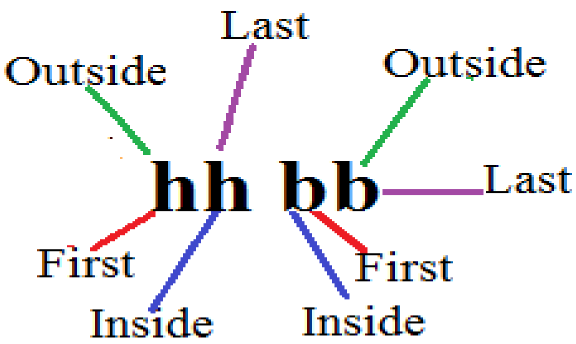


#2 Homozygous recessive

hhbb

Gamete combinations are:

hb, hb, hb, hb

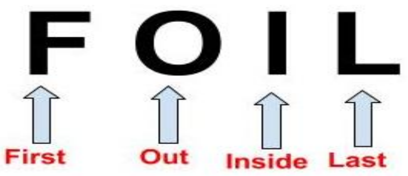


How can we determine the gamete combinations?

A) FOIL method

#3 heterozygous

HhBb



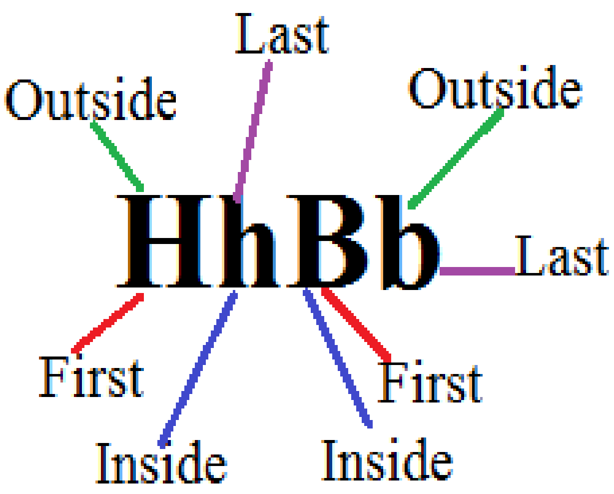
The possible gamete combinations are:

HB (first)

Hb (outside)

hB (inside)

Hb (last)

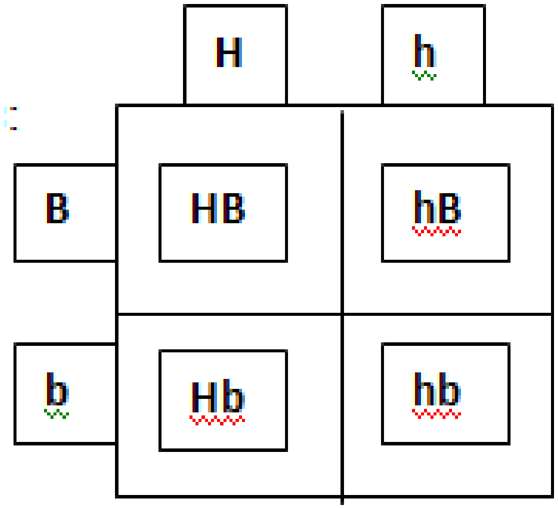


How can we determine the gamete combinations?

B) Crossing the two traits

Example:

- The parent genotype is **HhBb**
- The alleles of the first trait are **Hh**
- The alleles of the second trait are **Bb**



- The possible gamete combinations are:

HB hB Hb hb

Quick Practice

1) Find out the possible gamete combinations for this parent genotype **RrWw** using the FOIL method

The Answer

The four possible gamete combinations are:

- RW
- Rw
- rW
- rw

Quick Practice

2) Find out the possible gamete combinations for the parent genotype **AAQQ** using the second method (crossing the two traits)

The Answer

The four possible gamete combinations are:

- AQ
- AQ
- AQ
- AQ

How To Do The Dihybrid-Cross Punnett Square?

- Identify which trait is dominant and which is recessive
- Determine the letters for the alleles of each trait
- Write the genotype of each parent
- Determine the gametes combinations for each parent
- Draw a box with 16 squares
- Label each side of the box with the 4 gametes of each parent
- Put the dominant alleles First
- Cross the gametes
- Find out the offspring phenotypes
- Find out the offspring genotypes

Crossing homozygous X homozygous

Parental (P) generation

Phenotype: hairy&black **X** hairless&white

Genotype: **HHBB** **X** **hhbb**

- 1st parent gamete combinations are:

  HB, HB, HB, HB

- 2nd parent gamete combinations are:

  hb, hb , hb, hb

- Offspring phenotypic ratio:

  100% hairy & black

- Offspring genotypic ratio

  100% heterozygous

	HB	HB	HB	HB
hb	HhBb	HhBb	HhBb	HhBb
hb	HhBb	HhBb	HhBb	HhBb
hb	HhBb	HhBb	HhBb	HhBb
hb	HhBb	HhBb	HhBb	HhBb

Crossing Heterozygous X Heterozygous

P-generation

Phenotype: hairy&black **X** hairy&black

Genotype: **HhBb X HhBb**

- 1st parent possible gamete combinations

  HB Hb hB Hb

- 2nd parent gamete combinations

  HB Hb hB Hb

- Offspring phenotypic ratio:

  9/16 hairy & black **3/16 hairy & white**

  3/16 hairless & black **1/16 hairless & white**

- Offspring genotypic ratio:

  1:2:2:1:4:1:2:2:1

Good news: you do not need to memorize this ratio!

	HB	Hb	hB	hb
HB	HHBB	HHBb	HhBB	HhBb
Hb	HHBb	HHbb	HhBb	Hhbb
hB	HhBB	HhBb	hhBB	hhBb
hb	HhBb	Hhbb	hhBb	hhbb

Phenotypic ratio is 9:3:3:1

Let’s Try The Dihybrid Cross!

Cross two yellow and round pea plants that are heterozygous for BOTH traits **(YyRr)**

Dominant traits

- Yellow =Y
- Round =R

Recessive traits

- Green =y
- Wrinkled=r

What are the possible gamete combinations?

- Gamete 1?
- Gamete 2?
- Gamete 3?
- Gamete 4?

Dihybrid-Cross Punnett Square Cont.

- Gamete 1= RY
- Gamete 2= Ry
- Gamete 3= rY
- Gamete 4= ry

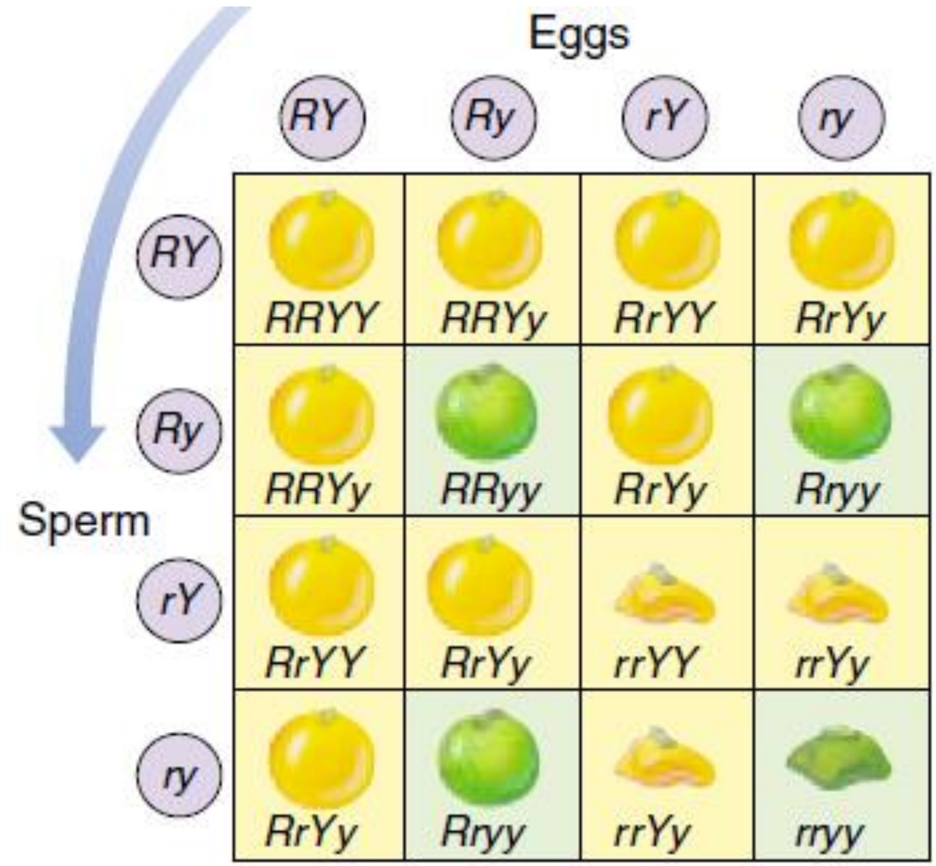
- The offspring phenotypes

  9/16 round &yellow

  3/16 round & green

  3/16 wrinkled & yellow

  1/16 wrinkled & green



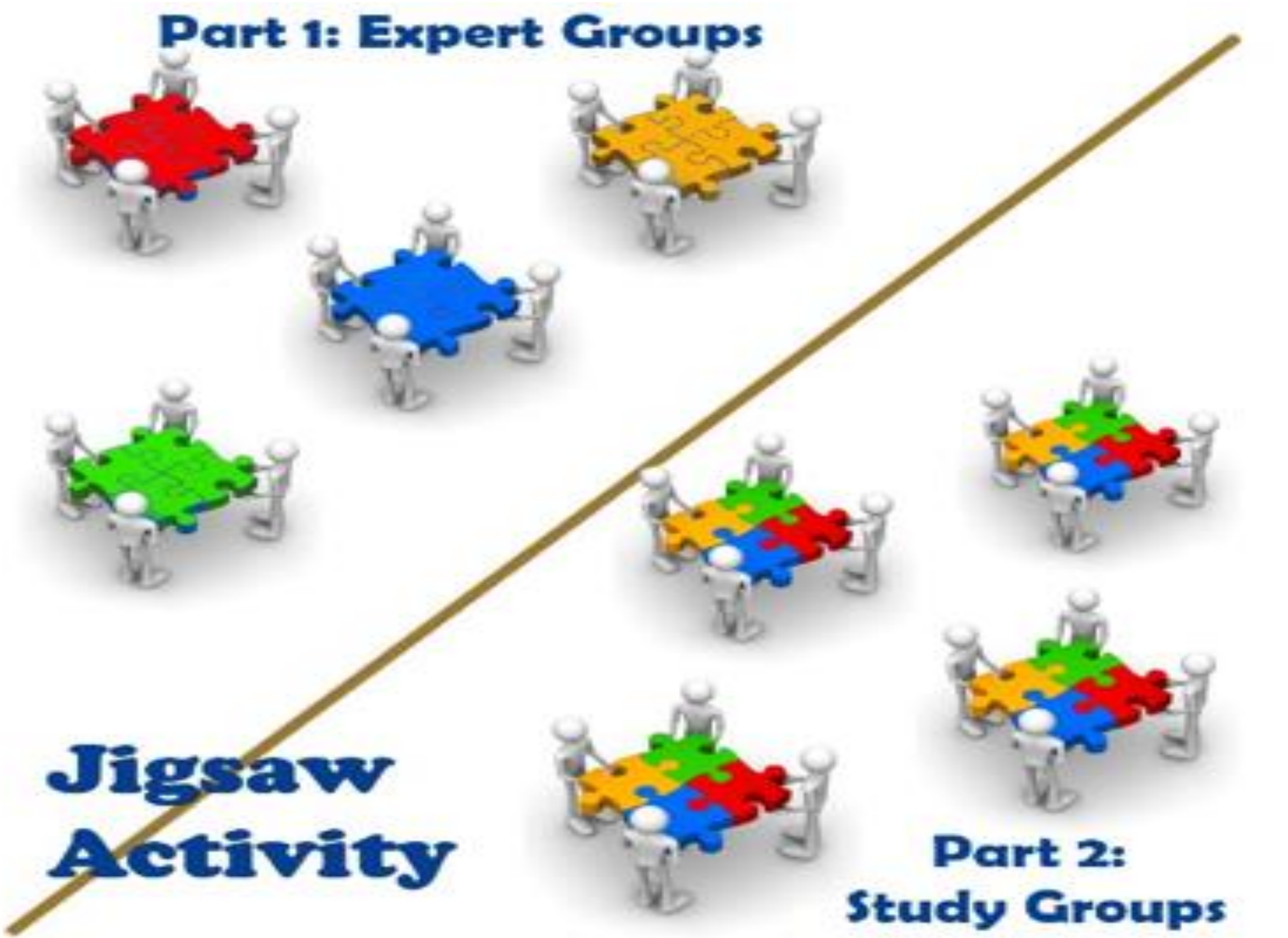
- The offspring genotypes 1:2:2:1:4:1:2:2:1(not required)

Let's Practice!

NON-MENDELIAN GENETICS:

Objectives

- Differentiate between Mendelian and non-Mendelian inheritance patterns
- Describe different non-Mendelian inheritance patterns
- Predict and interpret incomplete trait, co-dominant trait, and sex-linked traits Punnett square crosses


Part 1: Expert Groups
Jigsaw
Activity
Part 2:
Study Groups

Jigsaw Activity

- Students will be divided into 5 Expert groups (A-E)
- Each expert group will have reading material -**DO NOT TAKE IT & DO NOT WRITE ON IT-**and short video to learn about 1 topic (10 minutes)
- Each expert group member will **answer the question** on the reading passage then all the members will **develop a question for their home groups.** (you can modify the question that you have in the passage)
- Each member will go back to his/her home group to teach them what he/she have just learned and ask them a question to assess their understanding (20 minutes)
- Be careful with the time, each member need to have enough time to explain his/her topic

Quick check!

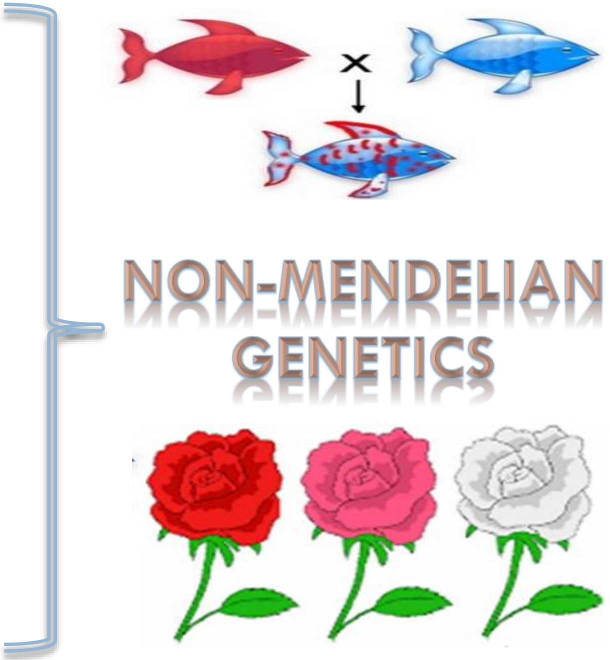
Essential Questions

1. Can we apply Mendel's laws to all the genetic traits?
2. Are an organism's characteristics determined only by genes?

Non-Mendelian Genetics

There are other types of inheritance that do not follow Mendel's laws:

- Incomplete Dominance
- Co-dominance
- Multiple Alleles
- Sex-linked
- Polygenic Traits

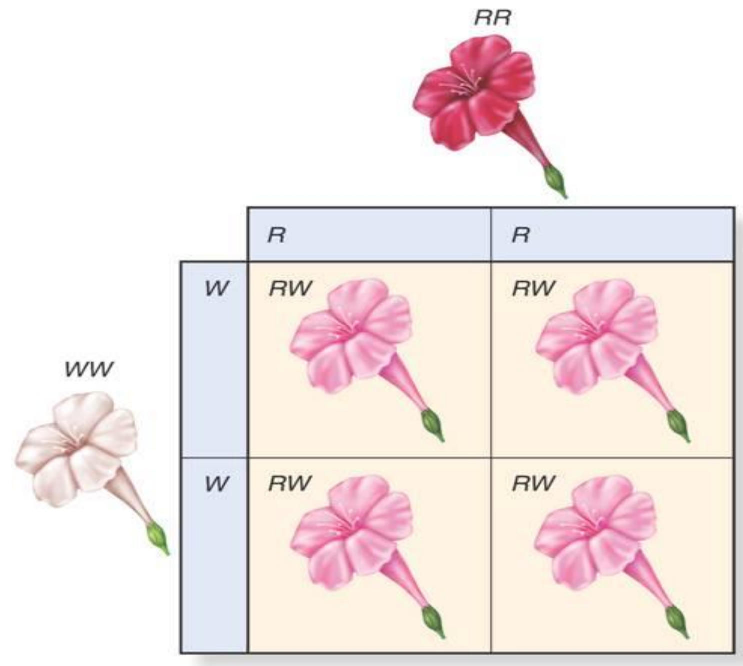


Incomplete Dominance

- There is NO dominant or recessive alleles
- None of the alleles of the same gene is completely dominant over the other
- The heterozygous phenotype is a **blend** of the 2 homozygous phenotypes
- Example: Homozygous red flowers (RR) crossed with homozygous white flowers (WW). Neither trait is completely dominant which results in heterozygous pink flowers (RW).
  - 3 different phenotypes (red, white, and pink)
  - 3 different genotypes (RR, WW, and RW)

NOTE: No lower-case alleles are used

Red Flower X White Flower = Pink
(RR) (WW) (RW)



Other Examples of Incomplete dominance

- In humans, wavy hair is an example of incomplete dominance
  - Offspring of straight-haired and curly-haired parents comes with a wavy hair
- Tail length in dogs is often determined by incomplete dominance
  - Pups of long-tailed and short-tailed parents often split the difference and have medium-length tails

Incomplete Dominance Problem

What is the probability of having pink flowers if **pink** flowers are bred with **red** flowers?

Red genotype=RR

White genotype=WW

Pink genotype=RW

Answer:

50% pink flowers

The other 50% red flowers

	R	R
R	RR	RR
W	RW	RW

It is your turn!

What is the probability of having white flowers if pink flowers are bred with pink flowers?

Red genotype=RR

White genotype=WW

Pink genotype=RW

The Answer

Parents genotypes: **RW** X **RW**
Answer: **25%** chance of white Flowers

	R	W
R	RR	RW
W	RW	WW

25% white flowers flowers   25% red flowers   50% pink

Co-dominance

- **No** dominant or recessive alleles. **Both** traits show up in the offspring phenotype
- **Co** means **"together"**
- Traits are **not blended**; they appear separately
- Both alleles can be represented by **CAPITAL LETTERS**
- Example:

Black cow BB

White cow WW

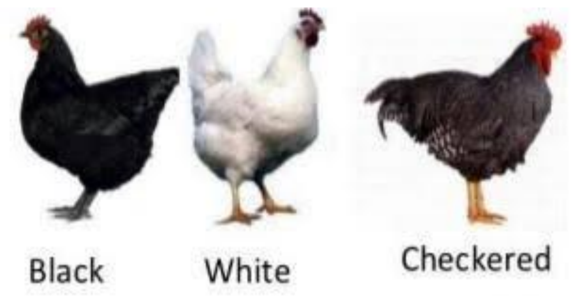
spotted cow BW

- Also, we can use **letters & superscripts** when dealing with codominance to differentiate it from incomplete dominance for example: use "F" for the flower color allele.

F^R = allele for red flowers
F^W = allele for white flowers
F^RF^W = allele for spotted flowers

Co-dominance Example

- In some varieties of chickens the black feather allele is co-dominant with the white feather allele. The heterozygous chickens have feathers that are checkered with black and white
- If we cross **black** chicken with **white** one we will find out that:
- Offspring phenotype 100% checkered feather
- Offspring genotype 100% are heterozygous



	F^W	F^W
F^B	$F^B F^W$	$F^B F^W$
F^B	$F^B F^W$	$F^B F^W$

It's Your Turn!

What are all the possible phenotypes and genotypes when **two checkered** chickens are bred?

Use capital letters to solve this case

Black = BB   White = WW   checkered= BW

The Answer

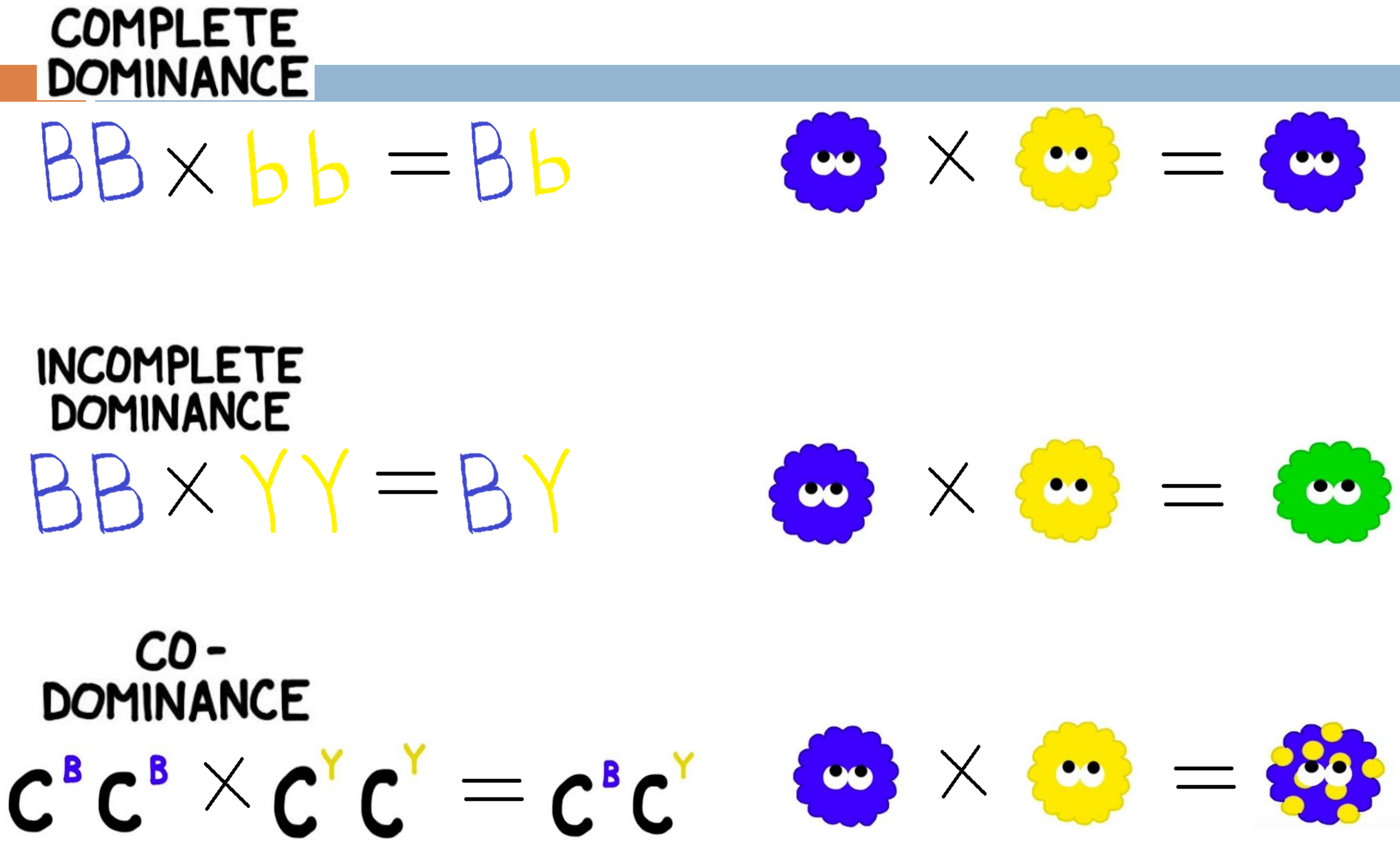
Black = BB White = WW checkered= BW

	B	W
B	BB	BW
W	BW	WW

¼ black
½ Checkered
¼ white

25% black
50% Checkered
25% white

Comparison


COMPLETE DOMINANCE
BB x bb = Bb
x =
INCOMPLETE DOMINANCE
BB x YY = BY
x =
CO-DOMINANCE
$C^B C^B \times C^Y C^Y = C^B C^Y$
x =

Let's Practice!

Multiple Alleles

- There are **more** than **2** alleles controlling one gene.
- However, **only two alleles** are inherited
- Another example: coat color in rabbit which is controlled by **4** alleles
- Example: Blood type gene is controlled by **3** alleles (I^A , I^B & i)

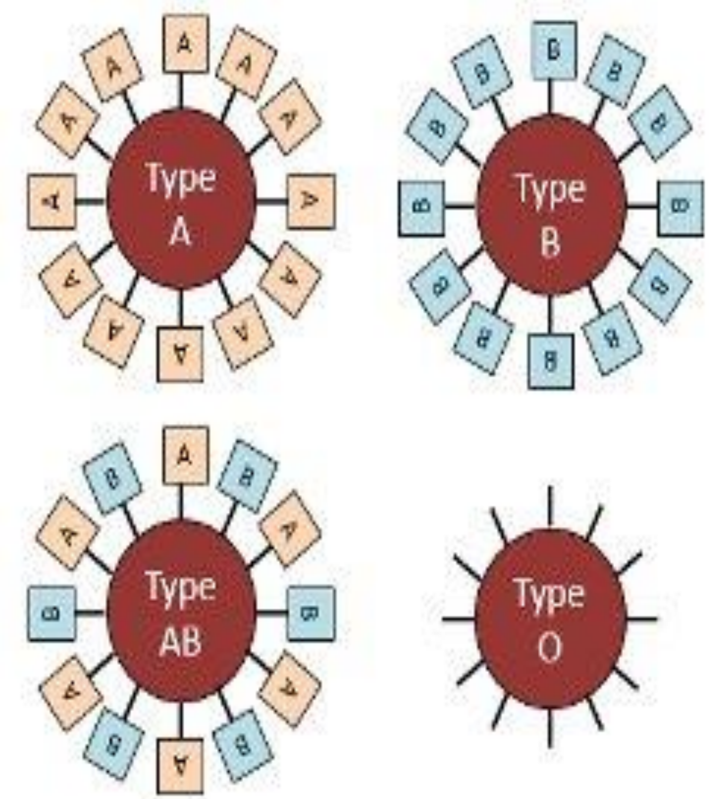
Coat Color in Rabbits

- A single gene that has at least four different alleles determines a rabbit's coat color
- The four known alleles display a pattern of simple dominance that can produce four coat colors

Phenotype	Allele	Possible Genotypes	Order of Dominance
 Full color (brown)	C (capital C)	CC Cc^{ch} Cc^{h} Cc	Dominant over all others
 Chinchilla	c^{ch} (lowercase c with ch superscript)	$c^{ch}c^{ch}$ $c^{ch}c^{h}$ $c^{ch}c$	Dominant over Himalayan and albino
 Himalayan	c^{h} (lowercase c with h superscript)	$c^{h}c^{h}$ $c^{h}c$	Dominant over albino
 Albino	c (lowercase c)	cc	Recessive to all others

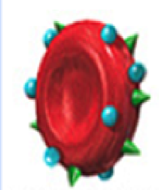
ABO System

- There are 4 blood types A, B, AB, & O which are determined by the type of antigen found on the surface of the red blood cells
- Blood type A: red blood cells have A antigens on their surface
- Blood type B: red blood cells have B antigens on their surface
- Blood type AB: red blood cells have both A & B antigens on their surface
- Blood type O: red blood cells have NO antigen on their surface(naked)



Intersecting Fact About Blood Type

- Blood type displays codominance and complete dominance inheritance pattern
- The relation between **I^A & I^B** is **codominance**
  - So person with both **I^A & I^B** alleles has blood type AB
- The relation between **I^A & i** is **complete** dominance.
  - **I^A** is dominant allele, while **i** is recessive allele
  - Person with **I^A & i** alleles has blood type A
- The relation between **I^B & i** is **complete** dominance.
  - **I^B** is dominant allele, while **i** is recessive allele
  - Person with **I^B & i** **alleles** has blood type B

Cells	Genotypes
	IAi, IAIA
	IBi, IBIB
	IAIB
	ii

Possible Genotypes For Blood Types

1. Person with **blood type A** can be homozygous $I^A I^A$ or heterozygous $I^A\ i$
2. Person with **blood type B** can be homozygous $I^B I^B$ or heterozygous $I^B\ i$
3. Person with **blood type AB** has only one genotype form which is heterozygous $I^A\ I^B$
4. A person with blood type O has one genotype form which is homozygous **ii**

Cells	Genotypes	Blood types
	I^Ai, I^AI^A	Type A blood
	I^Bi, I^BI^B	Type B blood
	I^AI^B	Type AB blood
	ii	Type O blood

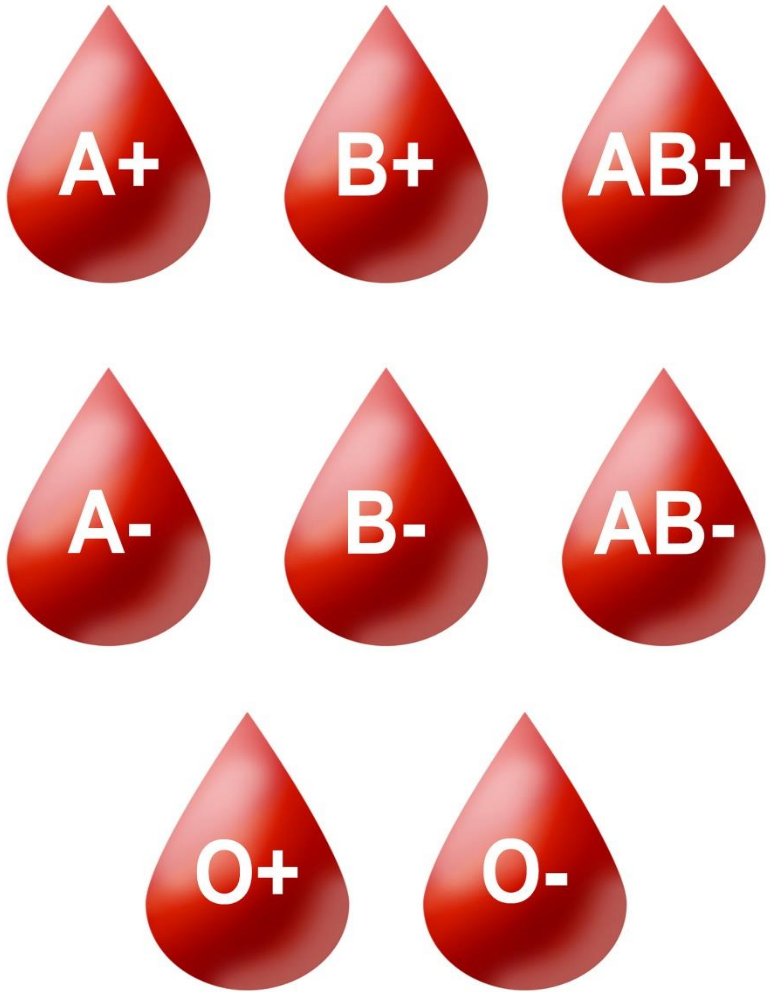
Summary Of ABO Blood System

- There are 3 different alleles for blood type
- There are 6 different genotypes
- There are 4 blood types

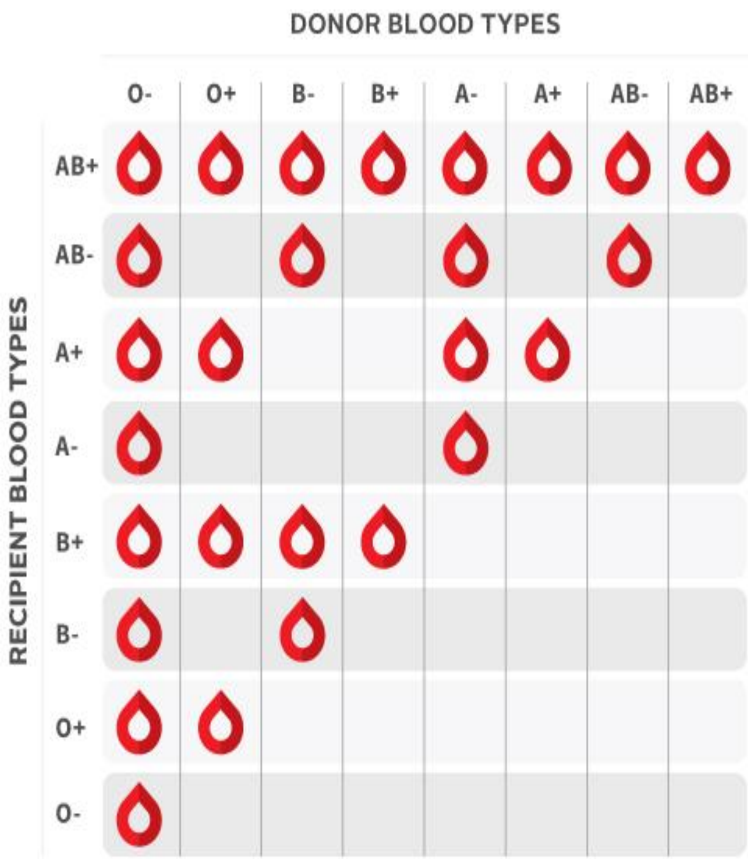
Allele from Parent 1	Allele from Parent 2	Geno-type	Blood Type
A	A	AA	A
A	B	AB	AB
A	O	AO	A
B	A	AB	AB
B	B	BB	B
B	O	BO	B
O	O	OO	O

One More Information..

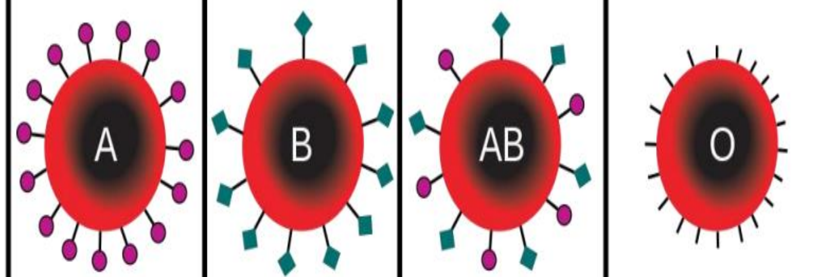
- Each blood type can be positive or negative
- This is determined by the presence of certain protein called **Rh factor**
  - If red blood cells have Rh factor the person will have **positive**
  - If red blood cells do not have Rh factor, the person will be **negative**



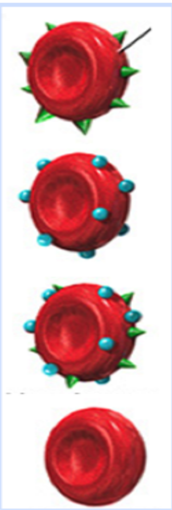
Blood Transfusion



	Group A	Group B	Group AB	Group O
Red blood cell type	A	B	AB	O
Antibodies in Plasma	Anti-B	Anti-A	None	Anti-A and Anti-B
Antigens in Red Blood Cell	A antigen	B antigen	A and B antigens	None



Blood Type Problem #1



Cells	Genotypes
	$I^A i$, $I^A I^A$
	$I^B i$, $I^B I^B$
	$I^A I^B$
	ii

If a woman with AB blood has children with a man who has type O, what will be the possible genotypes of their children? What will be their blood types?

Mother genotype = I^A I^B

Father genotype = $i\,i$

	I^A	I^B
i	$I^A i$	$I^B i$
i	$I^A i$	$I^B i$

Offspring genotype:

½ $I^A i$

½ $I^B i$

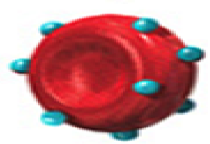
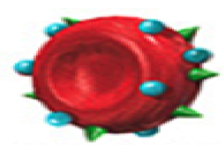
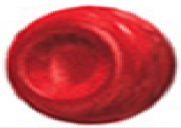
Offspring blood type (phenotype)

½ blood type A

½ blood type B

Try to solve Problem #2

Woman with type B blood has a child with type O blood. How is this possible if her husband has type A blood?

Cells	Genotypes
	I^Ai, I^AI^A
	I^Bi, I^BI^B
	I^AI^B
	ii

Problem #2 Answer

Because the child has type O blood which has only one possible genotype (homozygous recessive ii) we can conclude that both parents must be heterozygous

Mother genotype= I^Bi

Father genotype = I^Ai

Offspring phenotypes:

¼ blood type AB

¼ blood type A

¼ blood type B

¼ blood type O

Offspring genotypes

25% I^AI^B

25% I^Ai

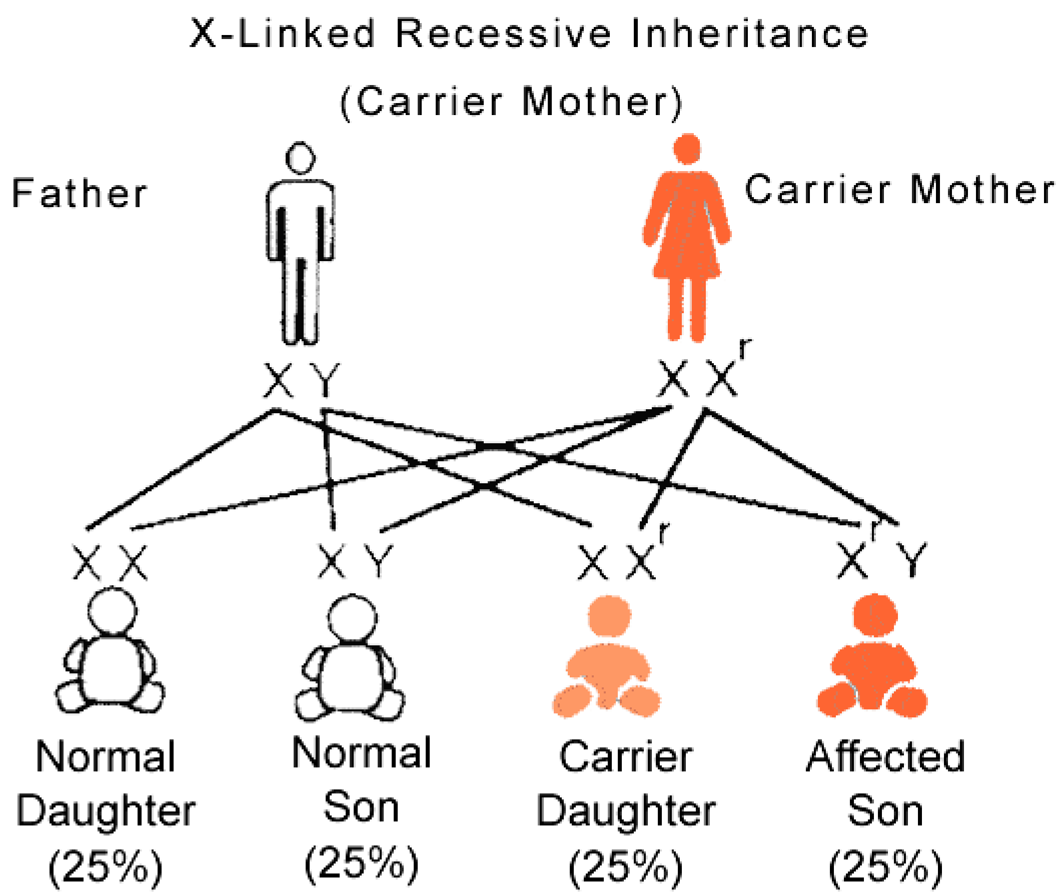
25% I^Bi

25% ii

	I^A	i
I^B	I^BI^A	I^B i
i	I^Ai	i i

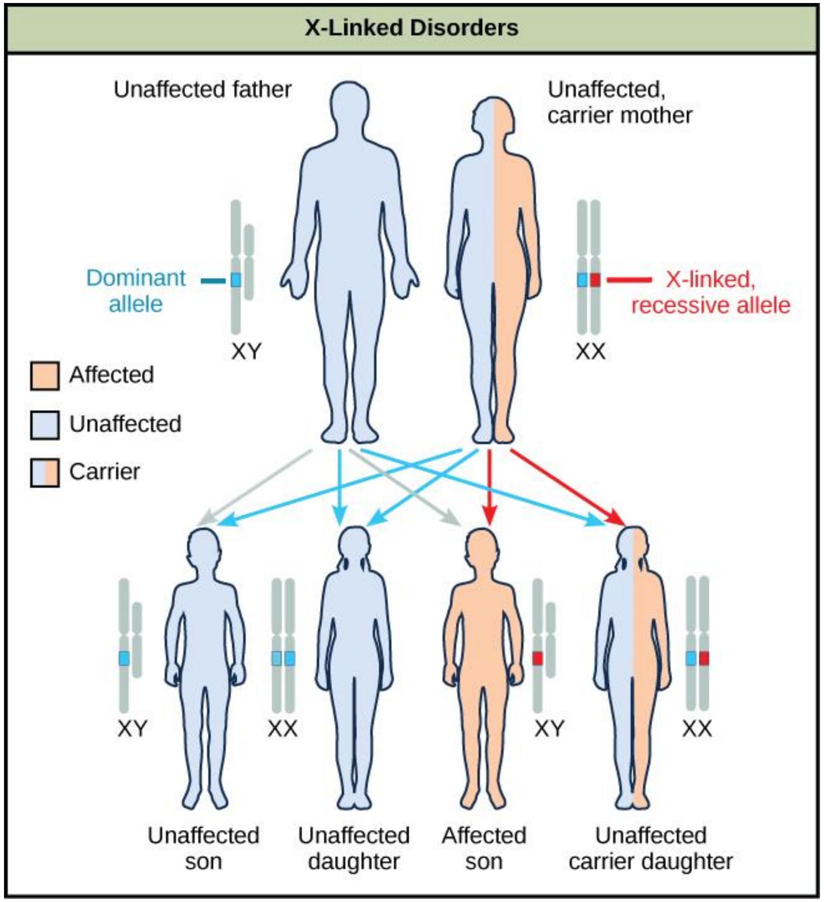
Let's Practice!

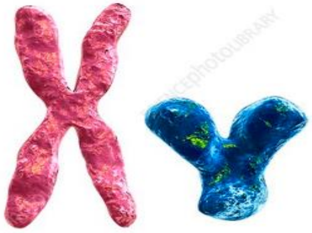
Sex-Linked Inheritance



Sex-Linked Inheritance

- Some traits are located on the sex chromosomes (X or Y), so the inheritance of these traits depends on the sex of the parent carrying the trait.
- Most known sex-linked traits are X-linked (carried on the X chromosome).
- This is probably because the X chromosome is much larger than the Y chromosome

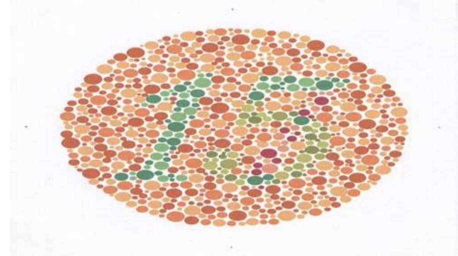




Sex-linked Inheritance Cont.

- Most of sex-linked traits are **recessive** while the **normal gene is dominant**
- Heterozygous Females $X^C X^c$ are **carriers**
- What is the meaning of "carrier"?
- **Homozygous** recessive Females (**X^cX^c**) have the trait
- Males with the recessive gene (**X^cY**) have the trait. They do not have another **X** to counterbalance the affected gene
- Males **cannot** be carriers
- Examples – color blindness, hemophilia, and male pattern baldness

Color blindness



X-linked recessive trait

- If a woman who is a carrier for color blindness gene (she has normal vision) has children with a man who has normal vision

- What are the chances that they will have colorblind children?

- What are the chances that they will have colorblind carrier children?

Punnett Square for colorblindness

	X^C	Y
X^C	X^CX^C (normal)	X^CY (normal)
X^c	X^CX^c (normal)	X^cY (colorblind)

X^C= normal
X^c= colorblind
Y =normal

Think About This Situation

- If a homozygous woman with normal vision has children with color blinded man, do you think the male children will be color blinded like their dad?
- Remember:

X^C is a chromosome with normal allele

X^c is a chromosome with color blindness allele

Y is a normal chromosome

Solution

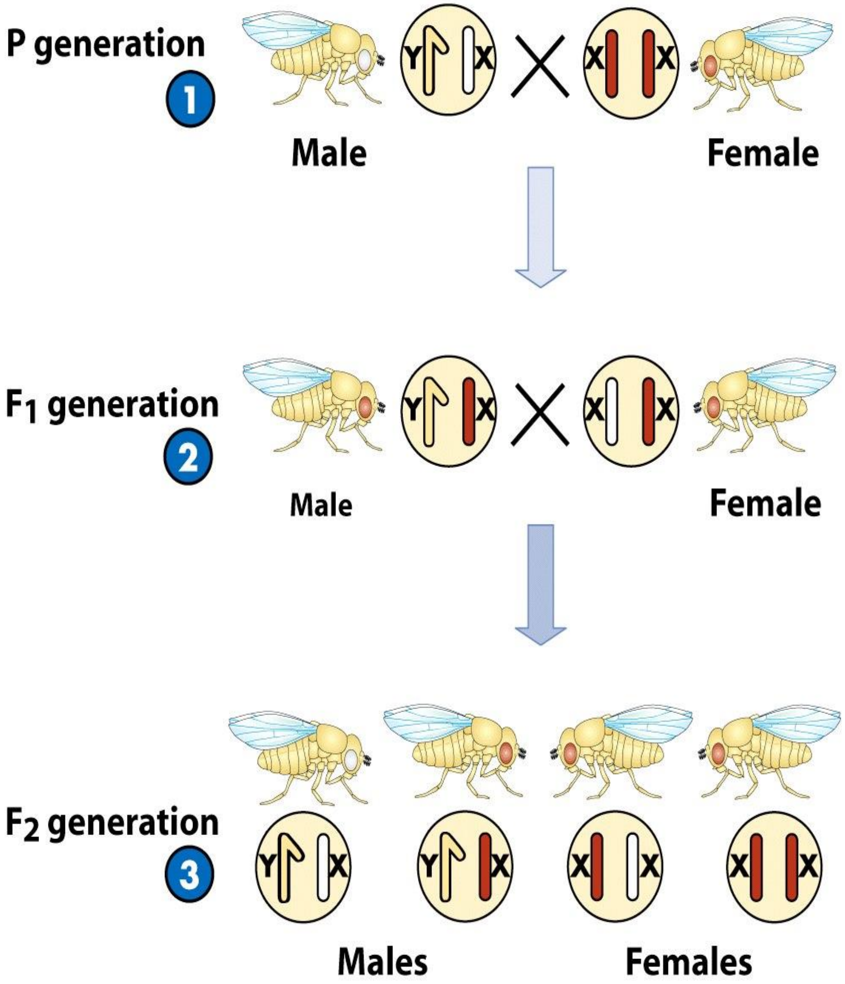
- Mother phenotype
  - Homozygous normal vision
- Mother genotype
  - $X^C X^C$
- Father phenotype
  - Color blinded
- Father genotype
  - X^c Y
- Offspring phenotype
  - All females will be carriers
  - **All males will be normal**

	X^c	Y
X^C	X^C X^c	X^C Y
X^C	X^C X^c	X^CY

Who Discovered The Sex-Linked Inheritance?

Thomas Morgan

- Studied fruit flies (*Drosophila melanogaster*)
- He tested Mendelian inheritance
- Morgan's crossed:
  - White-eyed male
  - Red-eyed female (normal eye color)



Punnett Square For Morgan's Experiment

Cross homozygous red-eyed female with white-eyed male

	X^R	X^R
X^r	X^RX^r	X^RX^r
Y	X^RY	X^RY

Offspring phenotype ratio:

50% red-eyed females

50% red-eyed males

Cross heterozygous red-eyed female with red-eyed male

	X^R	X^r
X^R	X^RX^R	X^RX^r
Y	X^RY	X^rY

Offspring phenotype ratio:

50% red-eyed females

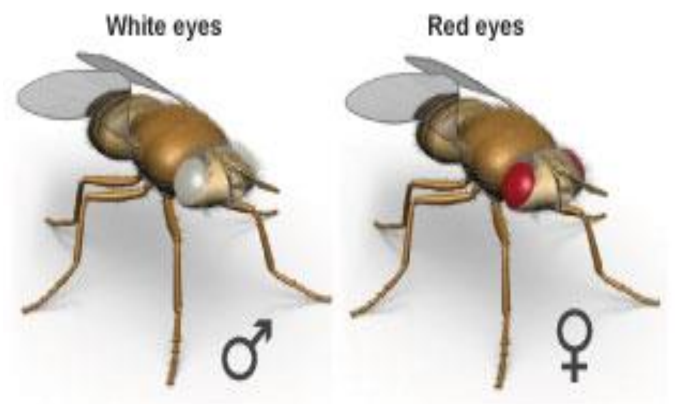
25% red-eyed males

25% white-eyed males

Red to white eyes ratio is 3:1

Conclusion of Morgan's Experiment

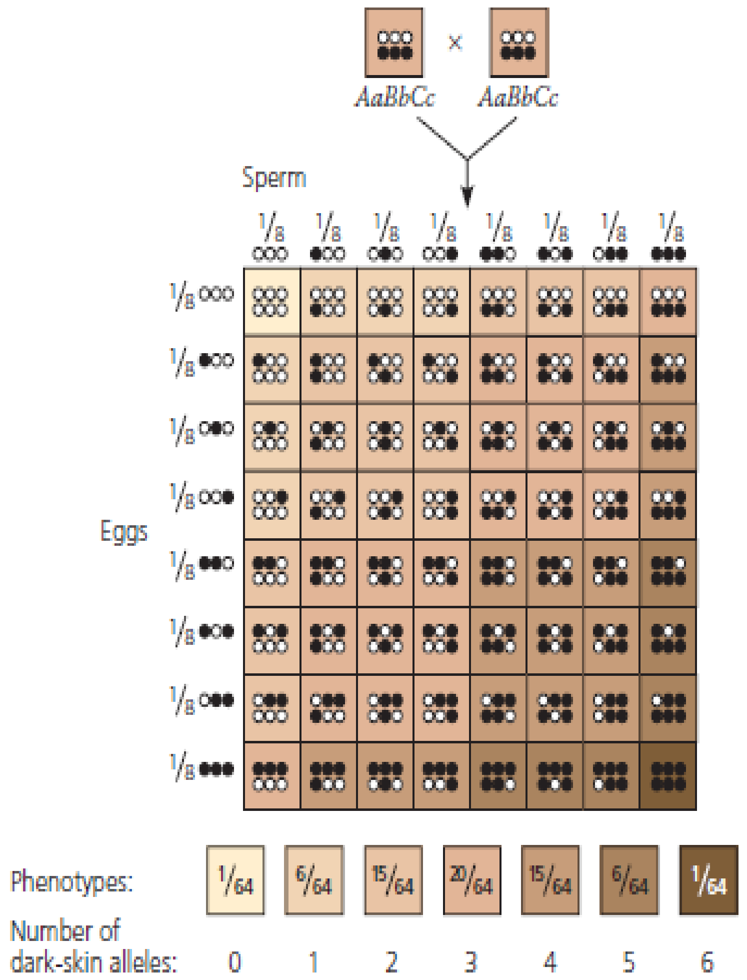
- White eyes were mostly linked to **males**
- Some traits are sex-linked
- Trait was found on X chromosome
- Red eye allele is **dominant**
- White eye allele is **recessive**
  - Female homozygous Dominant red-eyed $X^R X^R$
  - Female heterozygous red-eyed $X^R X^r$
  - Female homozygous recessive white-eyed $X^r X^r$
- Males have 2 possible genotypes & 2 phenotypes:
  - Red-eyed $X^R Y$
  - White-eyed $X^r Y$



Let's Practice!

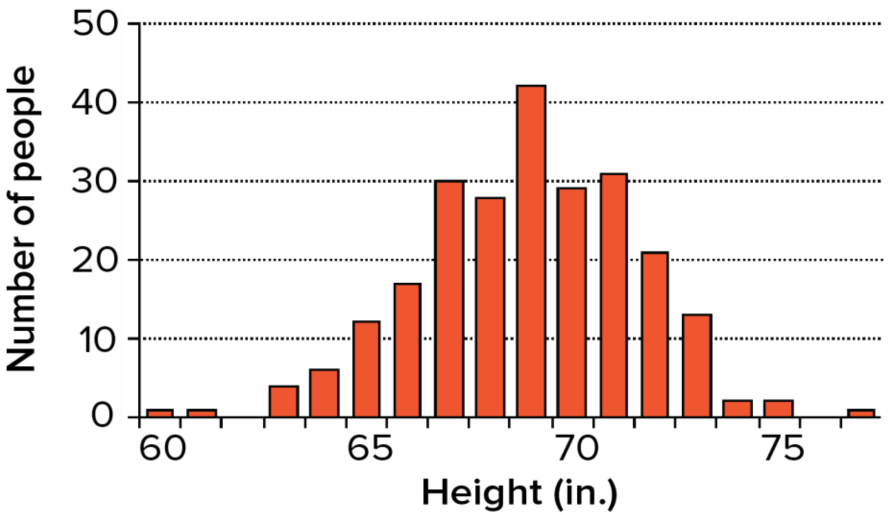
Polygenic inheritance

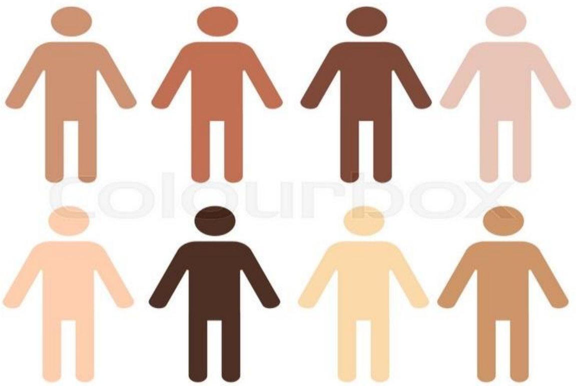
- Polygenic traits are traits that are controlled by **two** or **more** genes
- Polygenic = having many genes
- When multiple genes act together to produce a physical (phenotypic) character, **a range** of differences occur



Examples of Polygenic inheritance

- Human height
- Eye color
- Skin tone is determined by 4-6 genes—that means that there may be 4-6 different chromosomes involved!



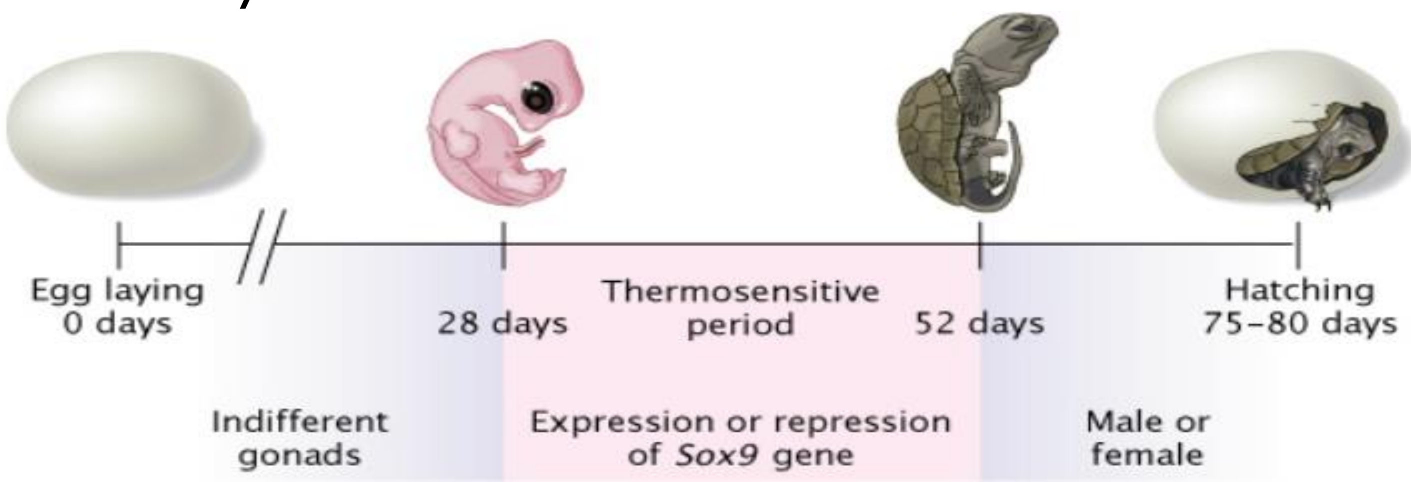


Environmental Effect on Genes Expression

- Characteristics are not solely determined by genes, they are also determined by the interaction between genes and the environment.
- Environmental factors such as diet, temperature, oxygen level, humidity, light cycles, and the presence of mutagens can all impact which of an animal's genes are expressed, which ultimately affects the animal's phenotype

Thermosensitivity of freshwater turtle embryos.

- Scientists have shown that intermediate temperatures (28.5°C) can yield a mixed of both males and females turtle
- The thermosensitive period that regulates sex differentiation last about 2 weeks during the middle of the development of the animal.
- At 30°C (during thermosensitivity period)all *E. oribicularis* to be females
- At 25°C only males hatch.



Exit Ticket

1. Can we apply Mendel's laws to all the genetic traits? Explain
2. Are an organism's traits determined only by its genes? Explain