Mendelian Genetics

Gregor Mendel

(20 de julio de 1822 – 6 de enero de 1884)

Gregor Mendel (1822-1884)

Discovered the laws governing the inheritance of traits without any knowledge of DNA or chromosomes using pea plants.

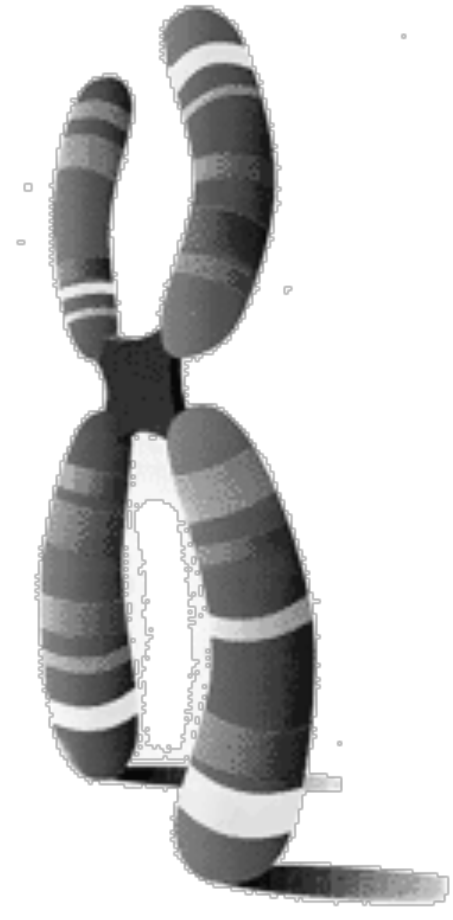
Mendel’s Work

He conducted most of his work between 1856 and 1863. He established many rules of heredity now known as Mendelian inheritance.

Particulate Inheritance

- Mendel stated that physical traits are inherited as "particles"

- Mendel did not know that the "particles" were actually chromosomes & DNA



Genetic Terminology

- Trait - any characteristic that can be passed from parent to their offspring.
- Heredity - passing of traits from parent to offspring.
- Genetics - study of heredity.

Types of Genetic Crosses

- Monohybrid cross - cross involving a single trait

  ex. flower color

- Dihybrid cross - cross involving two traits

  ex. flower color & plant height

Designer "Genes"

- Alleles - Two forms of a gene (dominant & recessive)
- Dominant - stronger of two genes expressed in the hybrid; represented by a capital letter (R)
- Recessive - gene that shows up less often in a cross; represented by a lowercase letter (r)

More Terms

- Genotype - gene combination for a trait (ex RR, Rr, rr)
- Phenotype - the physical feature resulting from a genotype (ex. red, white)

Genotypes

- Homozygous genotype – When the two alleles are same (2 dominant or 2 recessive alleles).
  ex. TT or tt; also called pure.

- Heterozygous genotype – When the 2 alleles are different- one dominant allele & one recessive allele.

- ex. Tt; also called hybrid

Genotype Examples

When choosing genotype letters, they must be the same. In most cases the dominant gene, if it's color, will get the letter of that color. If purple is dominant, we use a P and the lowercase p for the recessive color, even if the recessive color starts with a different letter like white.

P=Purple

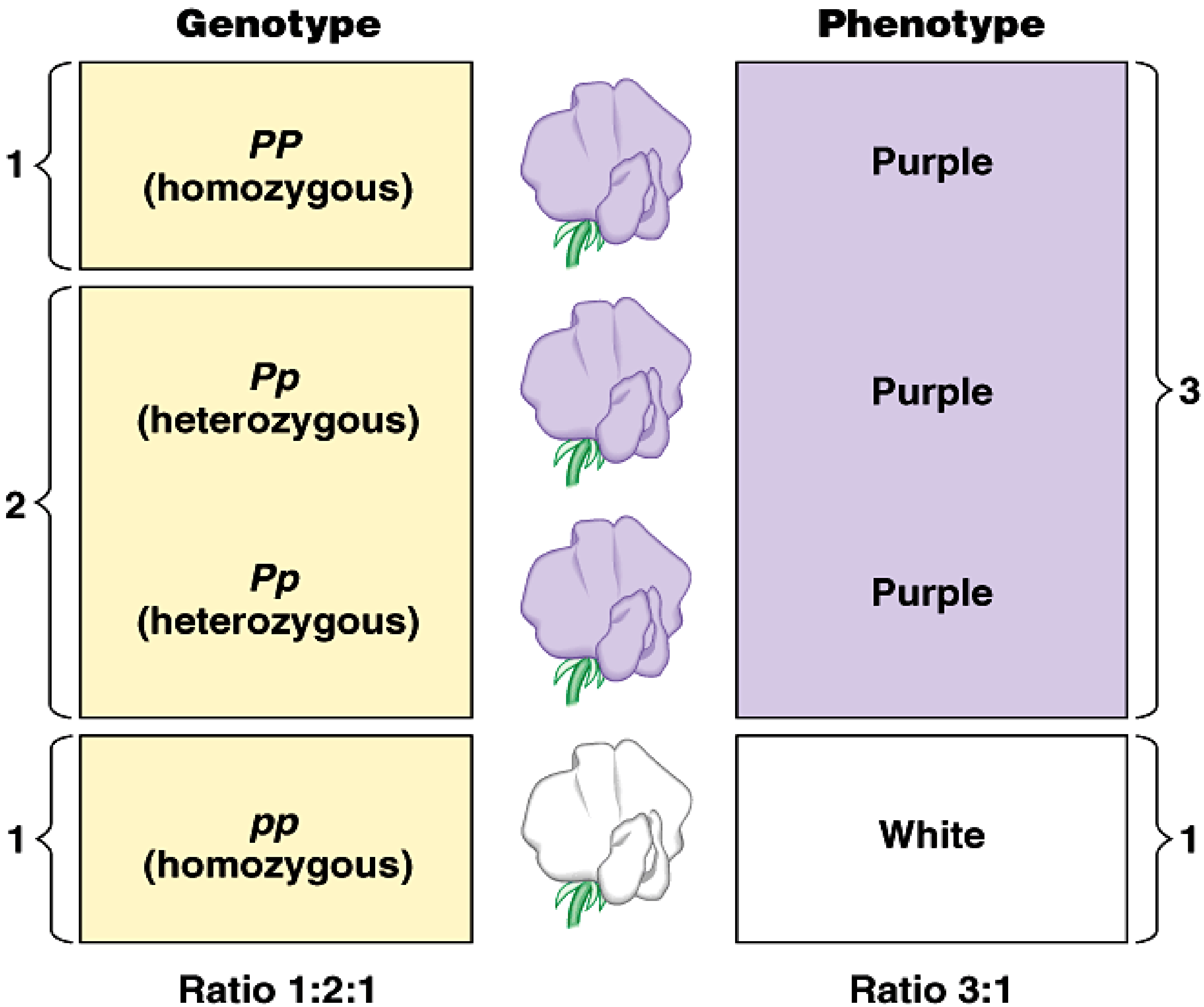
p=White

Phenotype Examples

This is the physical trait that can be seen. In this case the flower will either be purple or white.

Genotype	Phenotype
PP	Purple
Pp	Purple
pp	White

**Remember, if just one dominant allele is there, that trait will show up in the offspring.

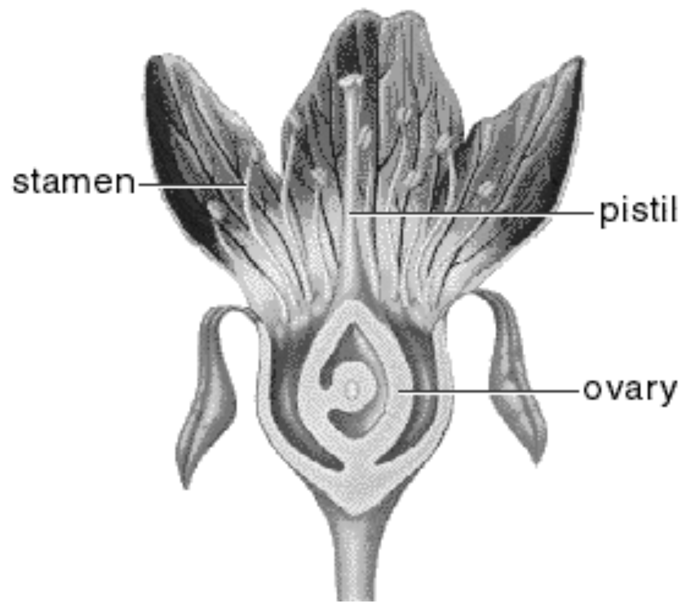

Genotype
Phenotype
1
PP
(homozygous)
Purple
2
Pp
(heterozygous)
Purple
3
Pp
(heterozygous)
Purple
1
pp
(homozygous)
White
1
Ratio 1:2:1
Ratio 3:1

Mendel's Pea Plant Experiments

Reproduction in Flowering Plants

Pollen contains sperm and is produced by the stamen.

The ovary contains eggs and is found inside the flower



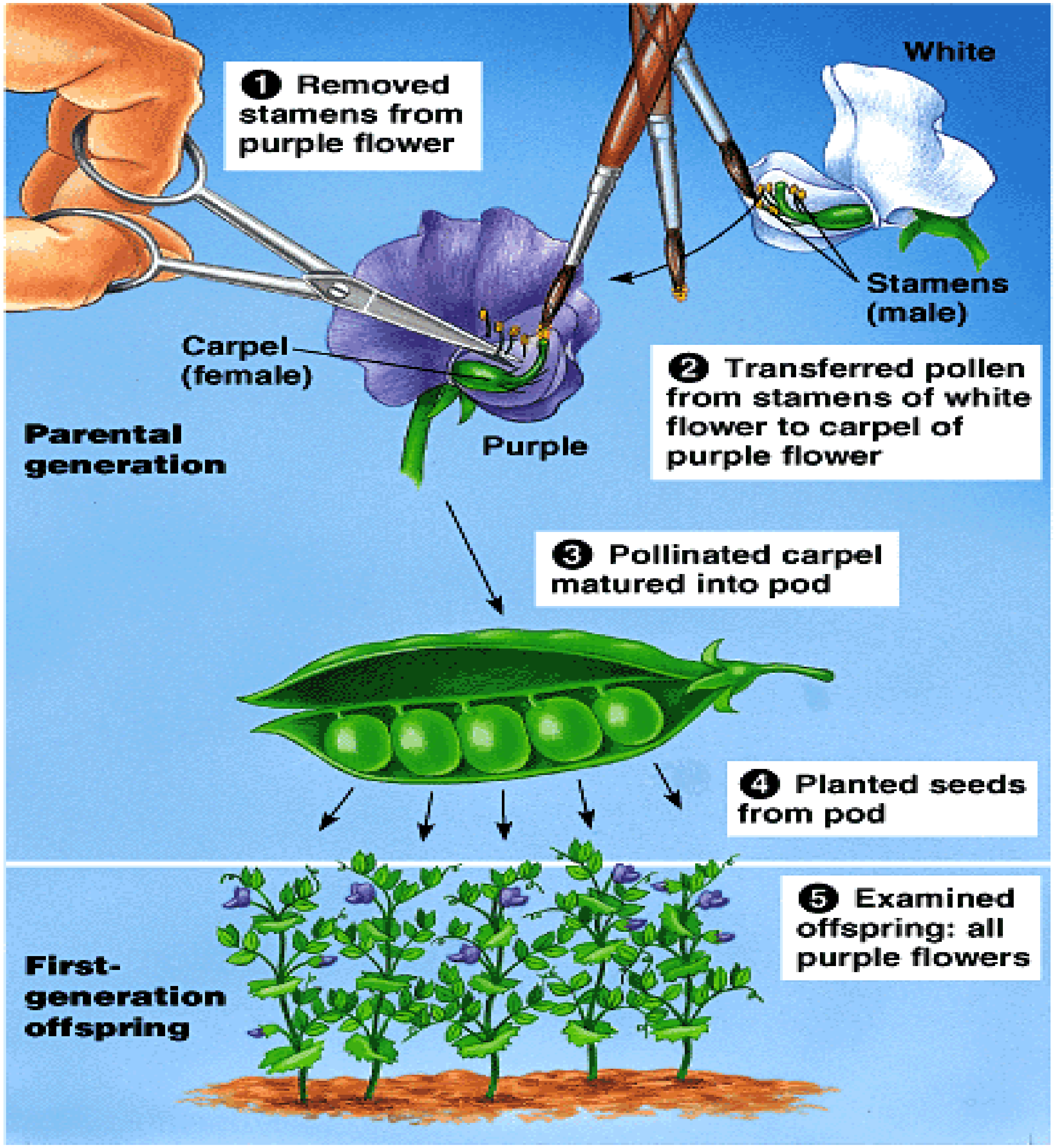
Self vs. Cross Pollination

Pollen carries sperm to the eggs for fertilization.

- *Self-fertilization* can occur in the same flower
- *Cross-fertilization* occurs between two flowers

He chose the garden pea
Pisum sativum

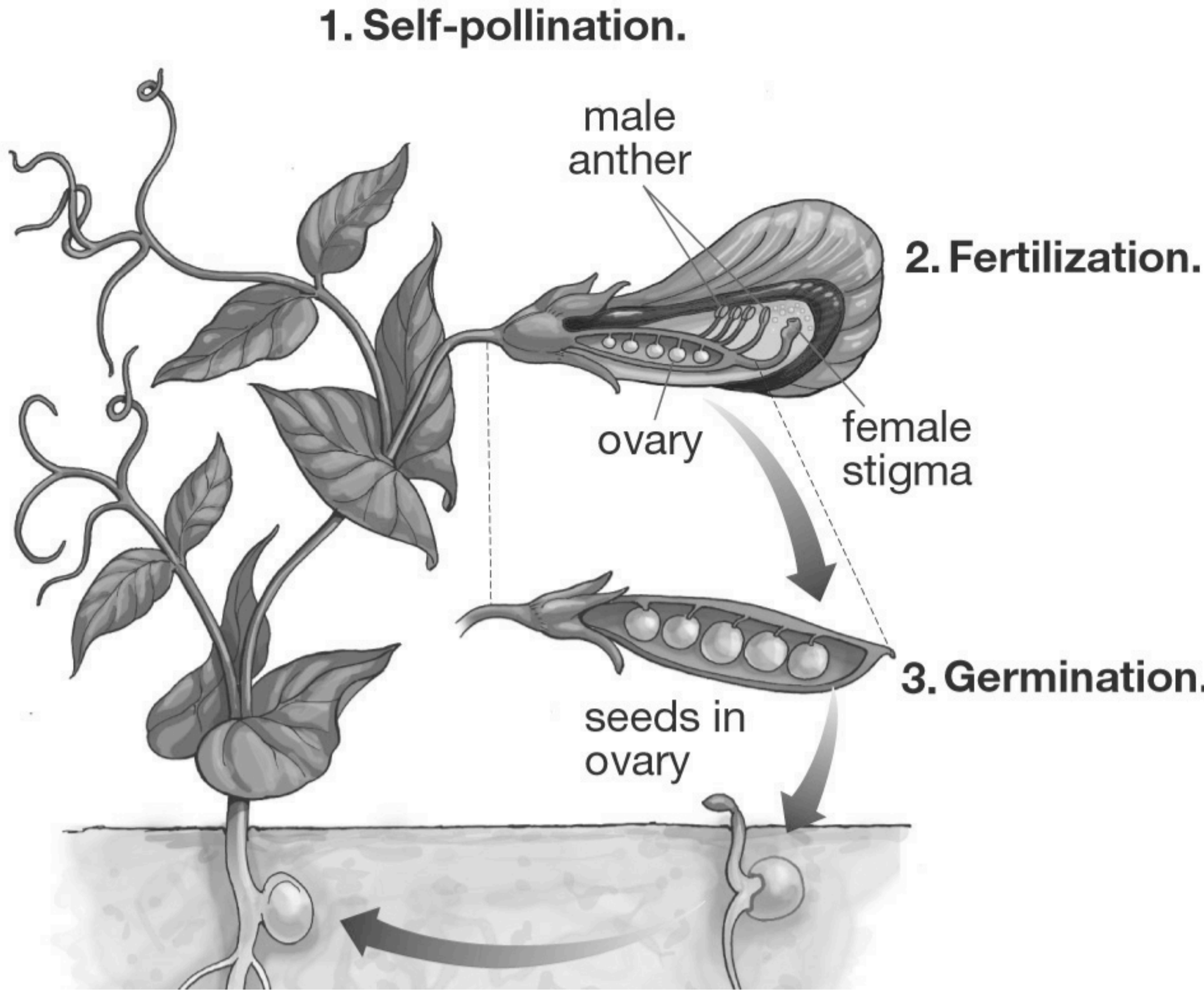
- Can be grown in a small area easily
- Produce lots of offspring
- Produce pure plants when allowed to self-pollinate
- Several generations
- Can be artificially cross-pollinated
- Bisexual.
- Many traits known.



White
1 Removed stamens from purple flower
Stamens (male)
Carpel (female)
2 Transferred pollen from stamens of white flower to carpel of purple flower
Parental generation
Purple
3 Pollinated carpel matured into pod
4 Planted seeds from pod
5 Examined offspring: all purple flowers
First-generation offspring

How Mendel Began?

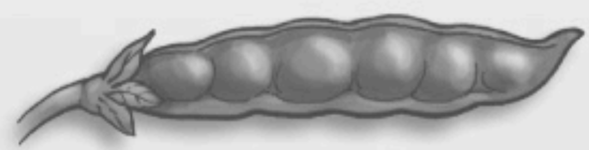
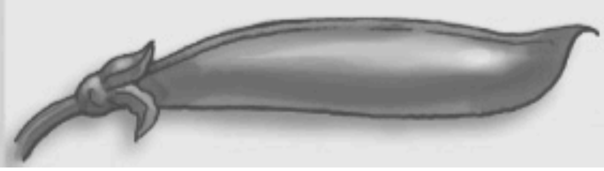
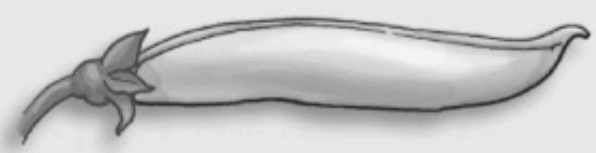
Mendel produced pure strains by allowing the plants to self-pollinate for several generations

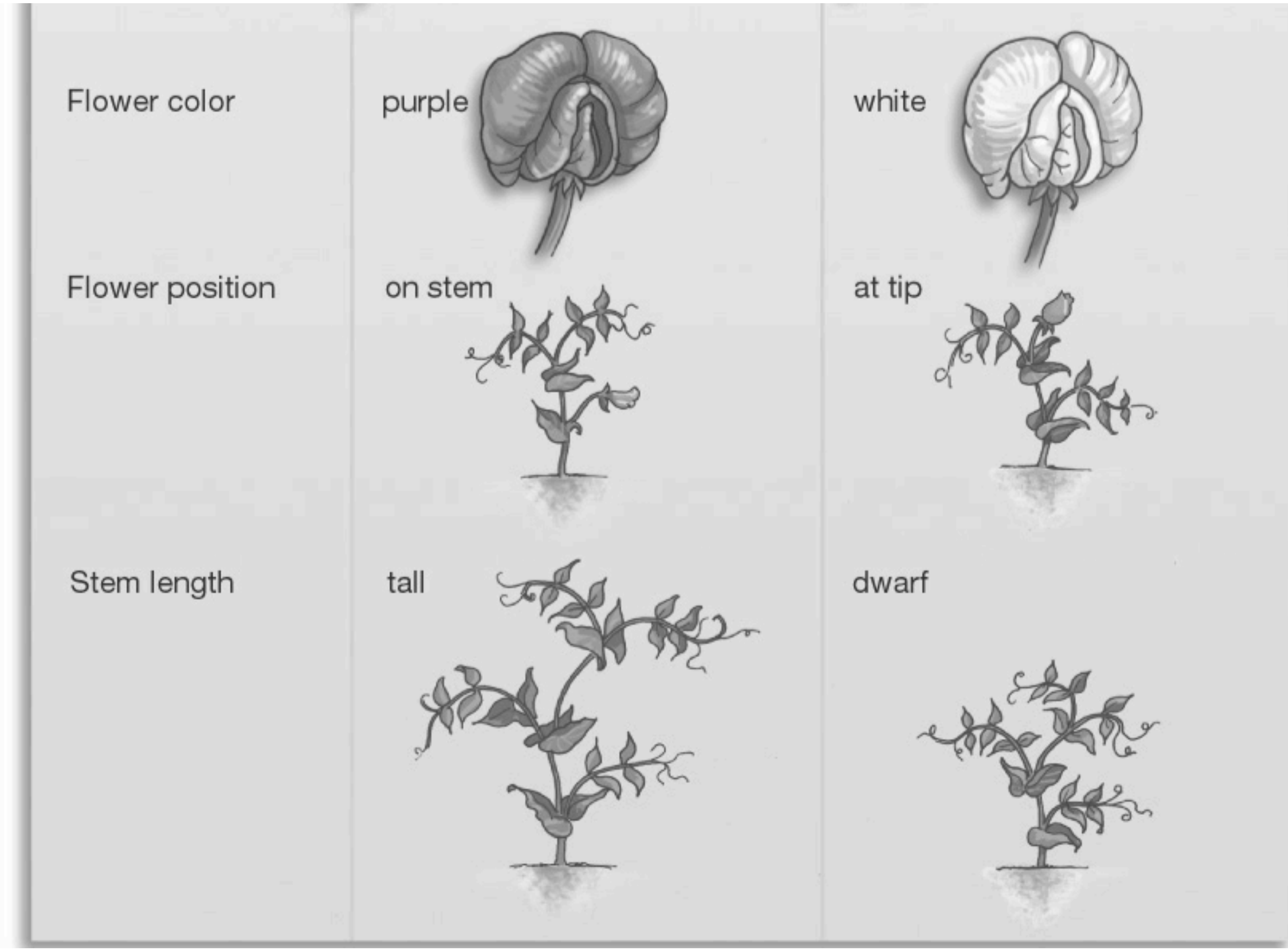


Eight Pea Plant Traits

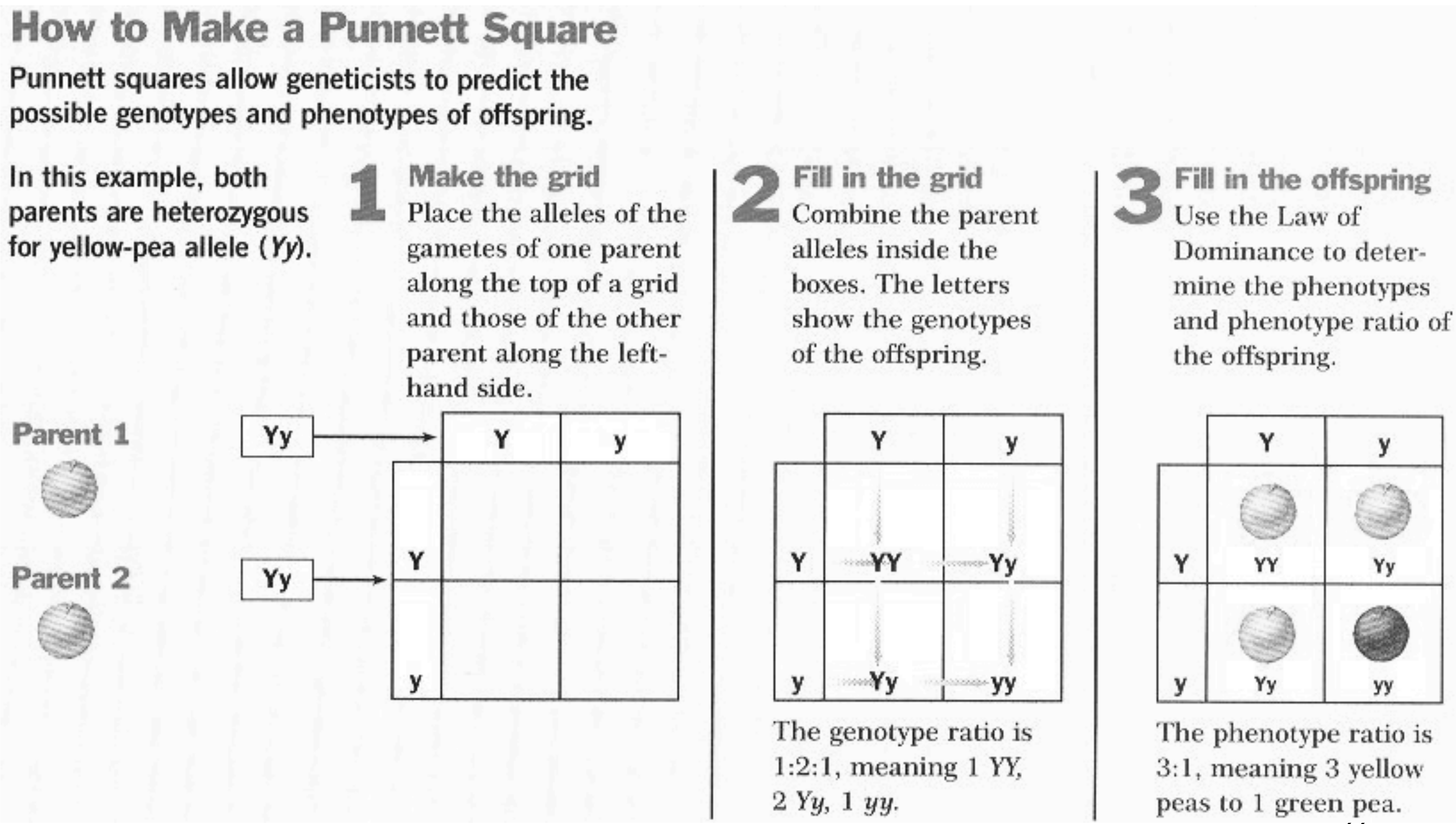
- *Seed shape* --- Round (R) or Wrinkled (r)
- *Seed Color* ---- Yellow (Y) or Green (y)
- *Pod Shape* --- Smooth (S) or wrinkled (s)
- *Pod Color* --- Green (G) or Yellow (g)
- *Seed Coat Color* ---Gray (G) or White (g)
- *Flower position*---Axial (A) or Terminal (a)
- *Plant Height* --- Tall (T) or Short (t)
- *Flower color* --- Purple (P) or white (p)

Table 11.1 Pea-Plant Characters Studied by Mendel

Character studied	Dominant trait	Recessive trait
Seed shape	smooth 	wrinkled 
Seed color	yellow 	green 
Pod shape	inflated 	wrinkled 
Pod color	green 	yellow 


Flower color
purple
white
Flower position
on stem
at tip
Stem length
tall
dwarf

How He Used a Punnett Square



How to Make a Punnett Square

Punnett squares allow geneticists to predict the possible genotypes and phenotypes of offspring.

In this example, both parents are heterozygous for yellow-pea allele (*Yy*).

Parent 1 — Yy

Parent 2 — Yy

1 Make the grid
Place the alleles of the gametes of one parent along the top of a grid and those of the other parent along the left-hand side.

	Y	y
Y		
y		

2 Fill in the grid
Combine the parent alleles inside the boxes. The letters show the genotypes of the offspring.

	Y	y
Y	YY	Yy
y	Yy	yy

The genotype ratio is 1:2:1, meaning 1 *YY*, 2 *Yy*, 1 *yy*.

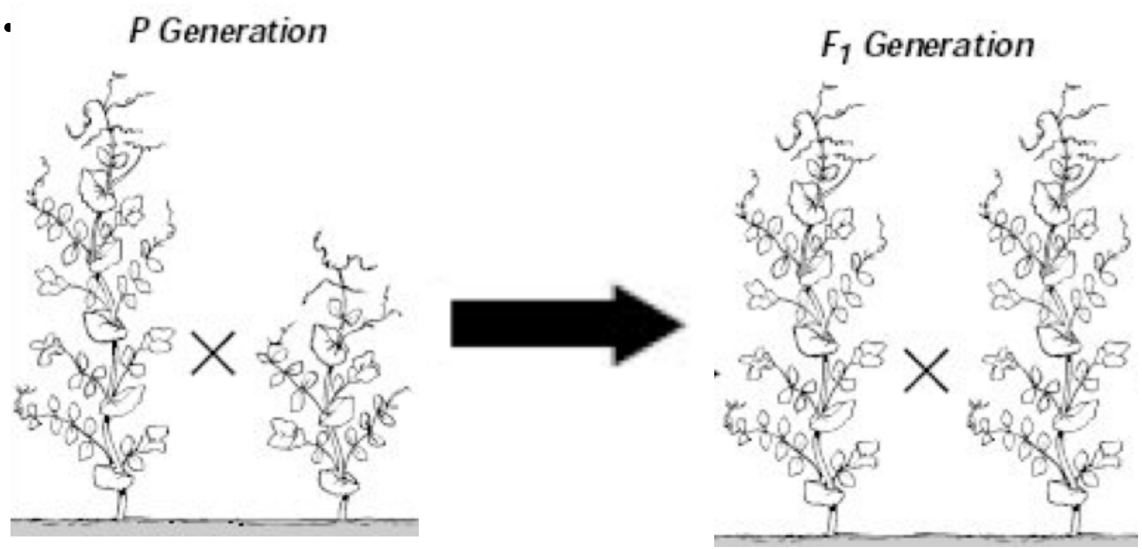
3 Fill in the offspring
Use the Law of Dominance to determine the phenotypes and phenotype ratio of the offspring.

	Y	y
Y	YY	Yy
y	Yy	yy

The phenotype ratio is 3:1, meaning 3 yellow peas to 1 green pea.

Steps To His 3:1 Ratio

Step 1-Starts with two pure pea plants. One is pure dominant tall (TT) and the other is pure recessive short (tt). This cross is called the P generation. The offspring are called the F_1 generation.



TT x tt   Tt x Tt

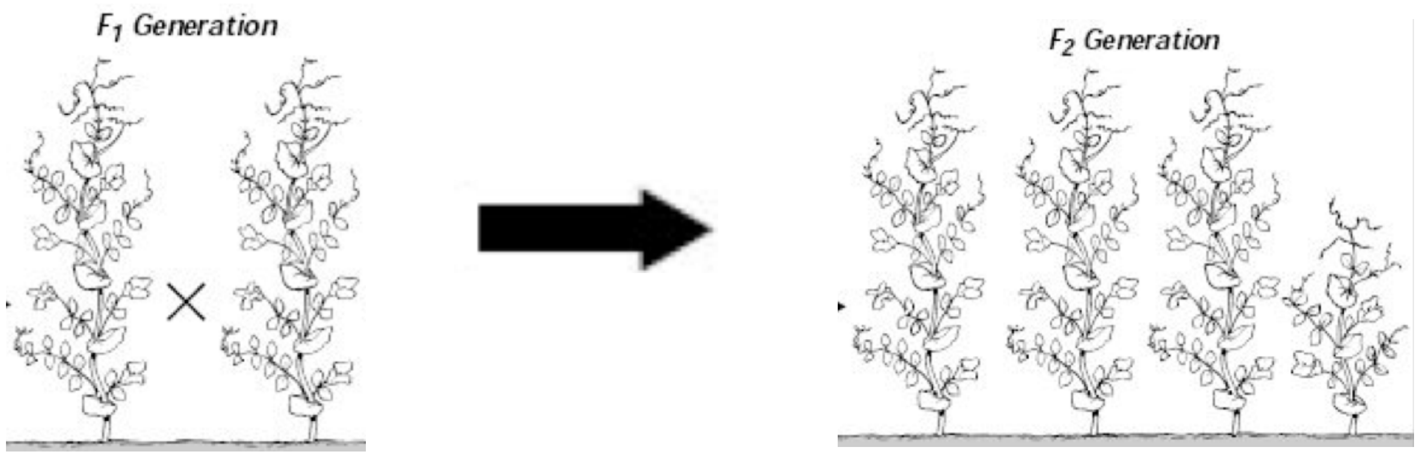
F_1 Generation

	T	T
t		
t		

**All of the offspring will be hybrids (Tt) showing the dominant trait.

F_2 Generation

Step 2-Take two of the offspring from the F_1 generation and cross them. This will yield offspring in a 3:1 phenotypic ratio. Three plants will possess a dominant allele so they will show the dominant trait. One will have two copies of the recessive alleles and show the recessive trait.



Tt x Tt

TT Tt Tt tt

F_2 Generation-Crossing offspring from the F_1 generation

	T	t
T		
t		

Here is his 3:1 ration- 3 show the dominant trait and one shows the recessive trait.

TT × tt

tall dwarf

↓

Gametes T , T × t , t

F1 generation

	T	T
t	Tt	Tt
t	Tt	Tt

Tt × Tt

tall selfing tall

Gametes T , t × T , t

F2 generation

	T	t
T	TT	Tt
t	Tt	tt

Did the observed ratio match the theoretical ratio?

The theoretical or expected ratio of plants producing round or wrinkled seeds is
3 round : 1 wrinkled

Mendel's observed ratio was 2.96:1

The discrepancy is due to statistical error.

The larger the sample the more nearly the results approximate to the theoretical ratio.

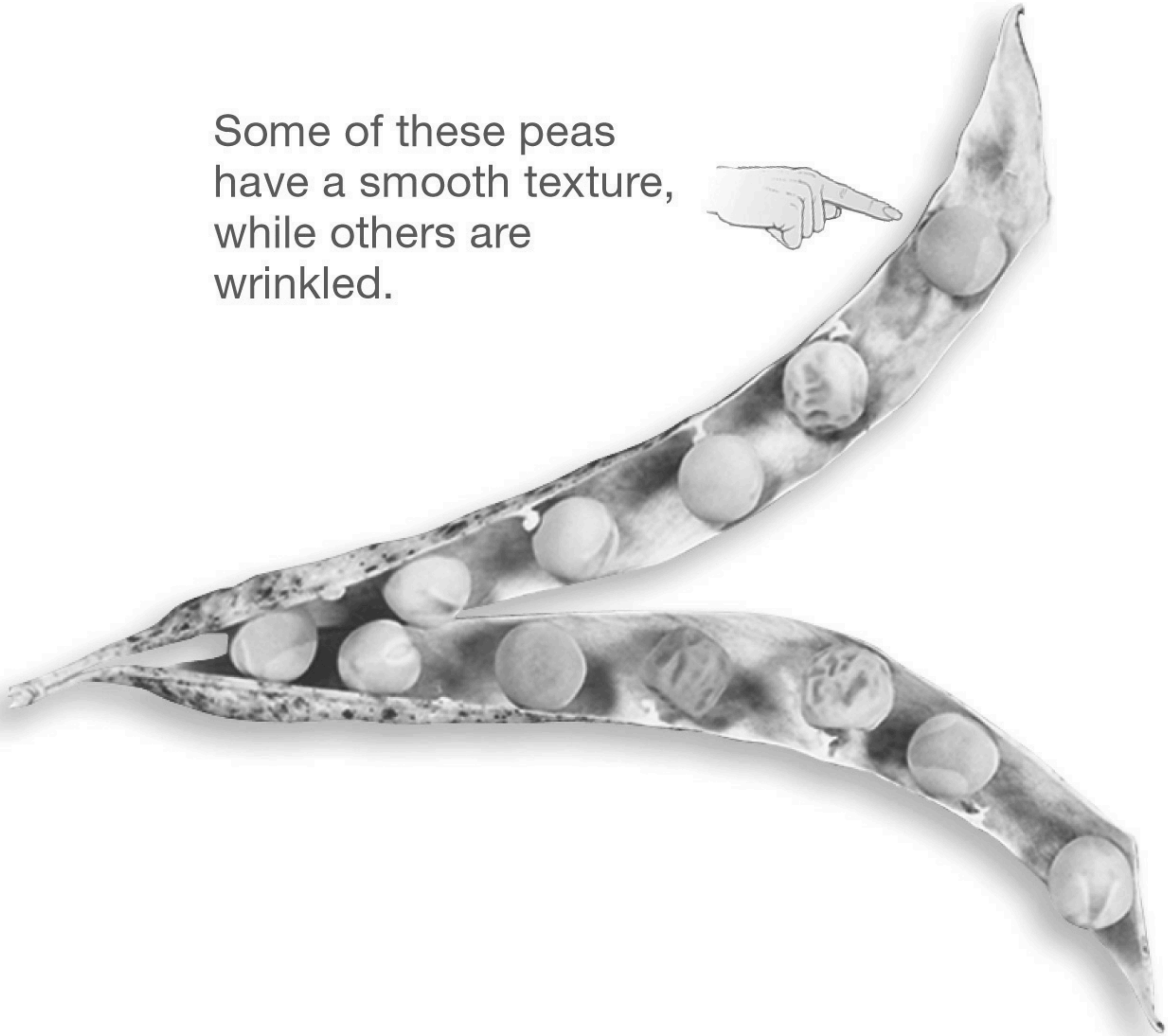
Mendel's Experimental Results

Table 11.2 Ratios of Dominant to Recessive in Mendel's Plants

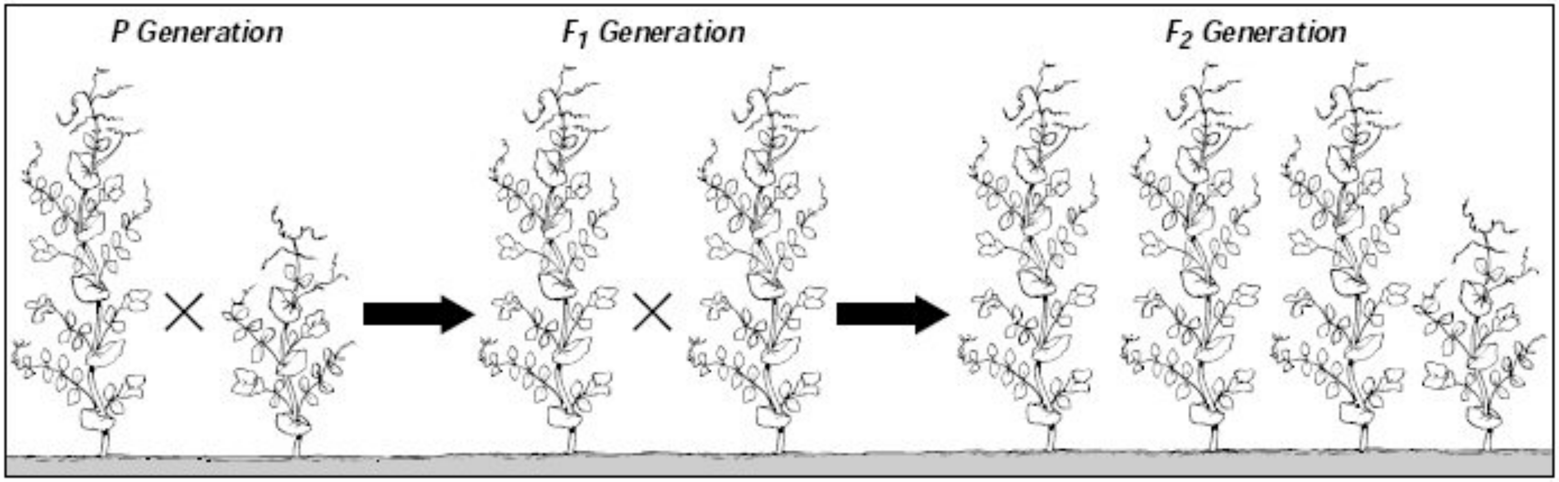
Dominant trait	**Recessive trait**	**Ratio of dominant to recessive in F_2 generation**
Smooth seed	Wrinkled seed	2.96:1 (5,474 smooth, 1,850 wrinkled)
Yellow seed	Green seed	3.01:1 (6,022 yellow, 2,001 green)
Inflated pod	Wrinkled pod	2.95:1 (882 inflated, 299 wrinkled)
Green pod	Yellow pod	2.82:1 (428 green, 152 yellow)
Purple flower	White flower	3.14:1 (705 purple, 224 white)
Flower on stem	Flower at tip	3.14:1 (651 along stem, 207 at tip)
Tall stem	Dwarf stem	2.84:1 (787 tall plants, 277 dwarfs)
	Average ratio, all traits:	**3:1**

What Do the Peas Look Like?

Some of these peas have a smooth texture, while others are wrinkled.



Following the Generations



Cross 2 Pure Plants TT x tt	Results in all Hybrids Tt	Cross 2 Hybrids get 3 Dominant & 1 Recessive TT, (2)Tt, tt

Practice

Cross a single trait (Monohybrid) using phenotypic and genotypic ratios.

P_1 Monohybrid Cross

Trait: Seed Shape

Alleles: R – Round r – Wrinkled

Cross: Round seeds x Wrinkled seeds

RR x rr

	r	r
R	Rr	Rr
R	Rr	Rr

Genotype: Rr

Phenotype: Round

Genotypic Ratio: All Rr

Phenotypic Ratio: All round

P_1 Monohybrid Cross Review

- Homozygous dominant x Homozygous recessive
- Offspring all Heterozygous (hybrids)
- Offspring called F_1 generation
- Genotypic & Phenotypic ratio is ALL ALIKE

F_1 Monohybrid Cross

Trait: Seed Shape

Alleles: R – Round r – Wrinkled

Cross: Round seeds x Round seeds

Rr Rr

	R	r
R	RR	Rr
r	Rr	rr

Genotype: RR, Rr, rr

Phenotype: round & wrinkled

Genotypic Ratio:

1 RR : 2 Rr : 1 rr

Phenotypic Ratio:

3 round:1 wrinkled

F_1 Monohybrid Cross Review

- Heterozygous x Heterozygous
- Offspring:
  25% Homozygous dominant RR
  50% Heterozygous Rr
  25% Homozygous Recessive rr
- Offspring called F_2 generation
- Genotypic ratio is 1:2:1
- Phenotypic Ratio is 3:1

…And Now the Test Cross

The only way Mendel could tell if one of his F_2 plants was pure, was to cross it with a pure recessive.

This is known as an test cross

Here is what he did:

Homozygous Recessive x Hybrid

Why Do A Test Cross?

If you look at a sample you can SEE the dominant phenotype but you do not KNOW if the sample is PURE DOMINANT or HYBRID.

A test cross will let you know very quickly.

F_2 Monohybrid Cross (1st)

Trait: Seed Shape

Alleles: R – Round r – Wrinkled

Cross: Wrinkled seeds × Round seeds (you think)

rr × RR

	r	r
R	Rr	Rr
R	Rr	Rr

Genotypes: Rr

Phenotype: Round

Genotypic Ratio: ALL Rr

Phenotypic Ratio: ALL Round

You Have A Pure

- If this is your outcome, you know the plant that shows the dominant trait is actually pure dominant.

F_2 Monohybrid Cross (2nd)*****

Trait: Seed Shape

Alleles: R – Round r – Wrinkled

Cross: Wrinkled seeds x Round seeds

Rr x rr

	R	r
r	Rr	rr
r	Rr	rr

Genotypes: Rr, rr

Phenotypes: round & wrinkled

Genotypic Ratio:
2 Rr : 2 rr

Phenotypic Ratio:
2 round : 2 wrinkled

You Have an Imposter

- If half of your offspring show the recessive trait, you did NOT have a pure sample but a HYBRID.
- This is the ultimate TEST CROSS

In pea plants, the trait for tall stems is dominant over the trait for short stems. If two heterozygous tall plants are crossed, what percentage of the offspring would be expected to have the same *phenotype* as the parents?

1) 25%
2) 50%
3) 75%
4) 100%

In summer squash, white-colored fruit is dominant over yellow-colored fruit. If homozygous yellow-fruited plants are crossed with heterozygous white-fruited plants, what is the expected percentage of fruit color produced in the offspring?

1) 100 % yellow
2) 100% white
3) 50% yellow, 50% white
4) 25% yellow, 75% white

In certain rats, black fur is dominant over white fur. If two rats, both heterozygous for fur color, are mated, their offspring would be expected to have

1) four different genotypes and two different colors
2) two different genotypes and three different colors
3) three different genotypes and two different colors
4) three different genotypes and three different colors

. In humans, the ability to roll the tongue is dominant over the inability to roll the tongue. If two parents who are homozygous dominant for this trait have 8 children, how many children would be expected to be *unable* to roll their tongues?

1) 0
2) 2
3) 8
4) 4

In canaries, the gene for singing (*S*) is dominant over the gene for non-singing (*s*). When hybrid singing canaries are mated with non-singing canaries, what percentage of the offspring is likely to possess the singing trait?

1) 0%
2) 25%
3) 50%
4) 100%

Crossing More Than One Trait

- When crossing more than one trait, you first need to determine the number of possible outcomes so you can create a Punnett Square.
- In this class we will only use two traits, but I want to show you how it can be done with multiple traits.

Determine The Number of Traits

- If you are using more than one trait, you must first determine how many possible outcomes there will be.
- There is a formula:

  2^n can be used, where “n” = the number of heterozygous traits.

Practice (Be Careful)

Alleles	n=	Possible Outcomes
• MMTtFFssWwDd	___	_______
• nnHHRrYyEeQq	___	_______
• RrYyCcHHPpAa	___	_______
• TTYYnnRReeWW	___	_______

Let's Practice

T=Tall t=Short

B=Brown b=tan

- TTBb

- ttBb

- Ttbb

TtBB

TTBB

ttBB

TtBb

Let's Practice

How many gametes will form crossing

TTBb x Ttbb

2^n

n= _____ so what are the possible outcomes?
This happens to work well, but it will get harder

_______ _________ x _________ _________

T=Tall t=Short B=Brown b=Tan

2: ________ and __________

2: ________ and __________

Stretch it to 16 Boxes

- Unfortunately if you want the numbers to be correct, you need to make it fit into a 16 square Punnett Square. In this case, just double everything.

Let's Practice

- Let's try the cross:

ttBb x TTbb

______ ________ x ______

Remember to fill all four boxes on each side of the Punnett Square

What is a Dihybrid Cross?

This time the two traits will both be hybrids (heterozygous).

Two heterozygous traits will always yield 4 outcomes.

Dihybrid Example

TtBb x TtBb

T=Tall t=Short

B=Brown b=tan

Good news, when determining the possible outcomes of a dihybrid cross, you only have to do it once, since both sides of the equation are the same.

4 Outcomes

TtBb x TtBb

If you look you have 2 heterozygous traits (remember, only look at one side). So, n =2 so if you plug in the numbers:

2^n where n = 2

There will be 4 possible outcomes.

T t Bb

________ ________

________ ________

Remember you must have one of each letter.

How Will They Look?

Tt Bb

TB- ____________ Tb- ____________

tB- ____________ tb- ____________

Remember you must have one of each letter.

Filling In The Punnett Square

- Each of the outcomes you came up with will go above or next to one box on the large Punnett square. What ever is on the top will be repeated along the side. Once I determine the phenotypes, I assign each a symbol so it is easy to count the ratio.

Since both parents were the same, the top and the side will be the same.

Phenotypes

□_____ and_____

Δ_____ and_____

◊_____ and_____

*_____ and_____

Phenotypic Dihybrid Results

- **9 Red, Tall Plants**
- **3 White, Tall Plants**
- **3 Red, Short Plants**
- **1 White, Short Plants**
- ***Or:*** **9:3:3:1**

Practice Another Dihybrid Cross

Traits: Seed shape & Seed color

Alleles: R round
r wrinkled
Y yellow
y green

RrYy x RrYy

RY Ry rY ry

RY Ry rY ry

All possible gamete combinations

Dihybrid Cross Practice-SAVE FOR LATER IN THE NOTES

	RY	Ry	rY	ry
RY				
Ry				
rY				
ry				

Dihybrid Cross (Answered)

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Round/Yellow: 9

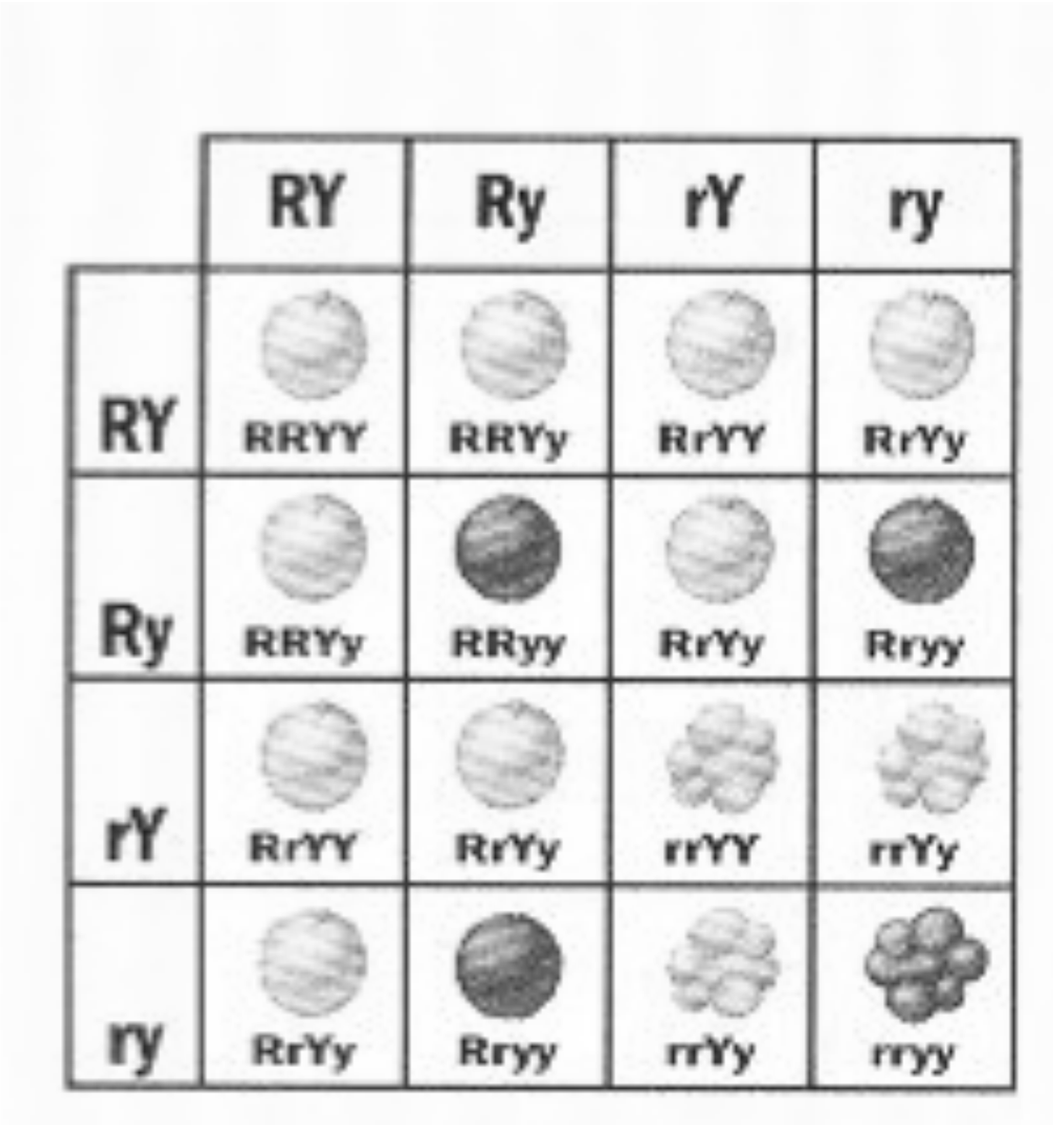
Round/green: 3

wrinkled/Yellow: 3

wrinkled/green: 1

9:3:3:1 phenotypic ratio

Dihybrid Cross (Pictures)



Round/Yellow: 9
Round/green: 3
wrinkled/Yellow: 3
wrinkled/green: 1

9:3:3:1

Mendel's Laws

1. Law of Dominance
2. Law of Segregation
3. Law of Independent Assortment

Law of Dominance

The principle stating that one factor in a pair of traits dominates the other. If one dominant allele and one recessive allele are in a pair, the dominant trait shows up in the phenotype. The only way for a recessive phenotype to show up is if both alleles are recessive.

Law of Dominance

All the offspring will be heterozygous and express only the dominant trait.

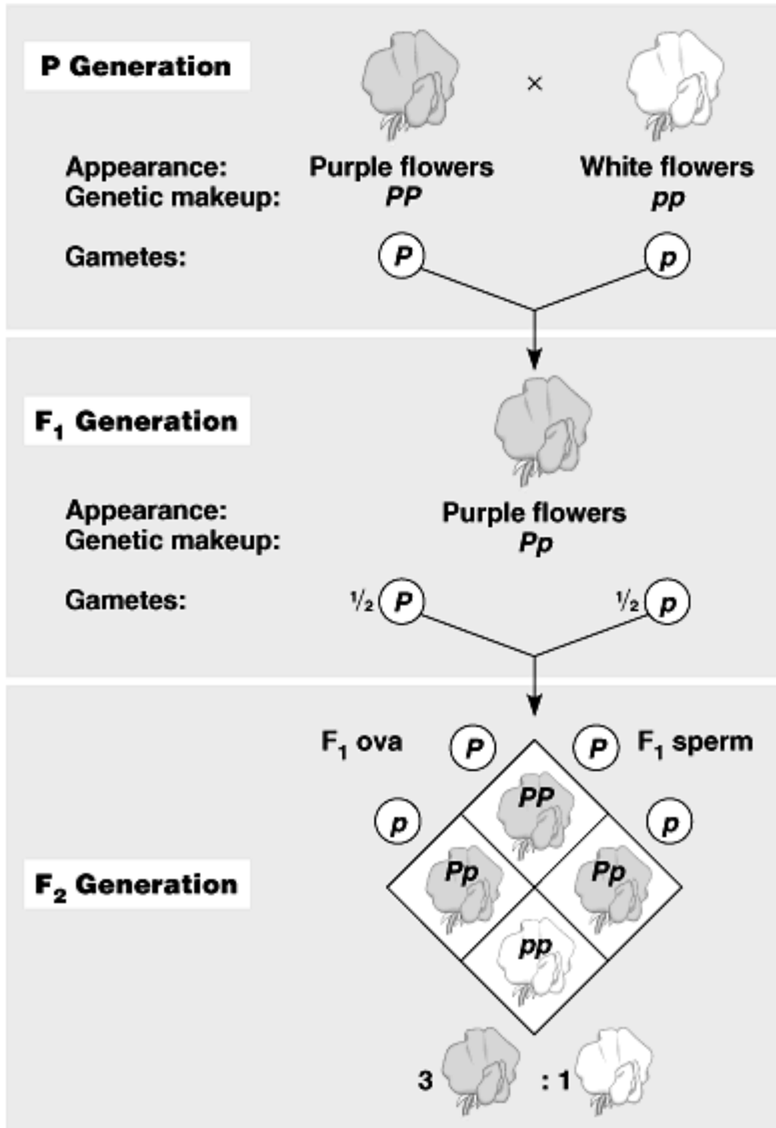
RR x rr yields all Rr (round seeds)

	Characteristic	Dominant	Recessive
Drosophila	Body Color	Gray	Black
	Eye color	Red	White
	Color of hair	Dark	Light
	Form of hair	Curly	Straight
Humans	Color of eye	Brown	Blue
	Lips	Broad and thicken	Thin
	Blood group	A,B,AB	O

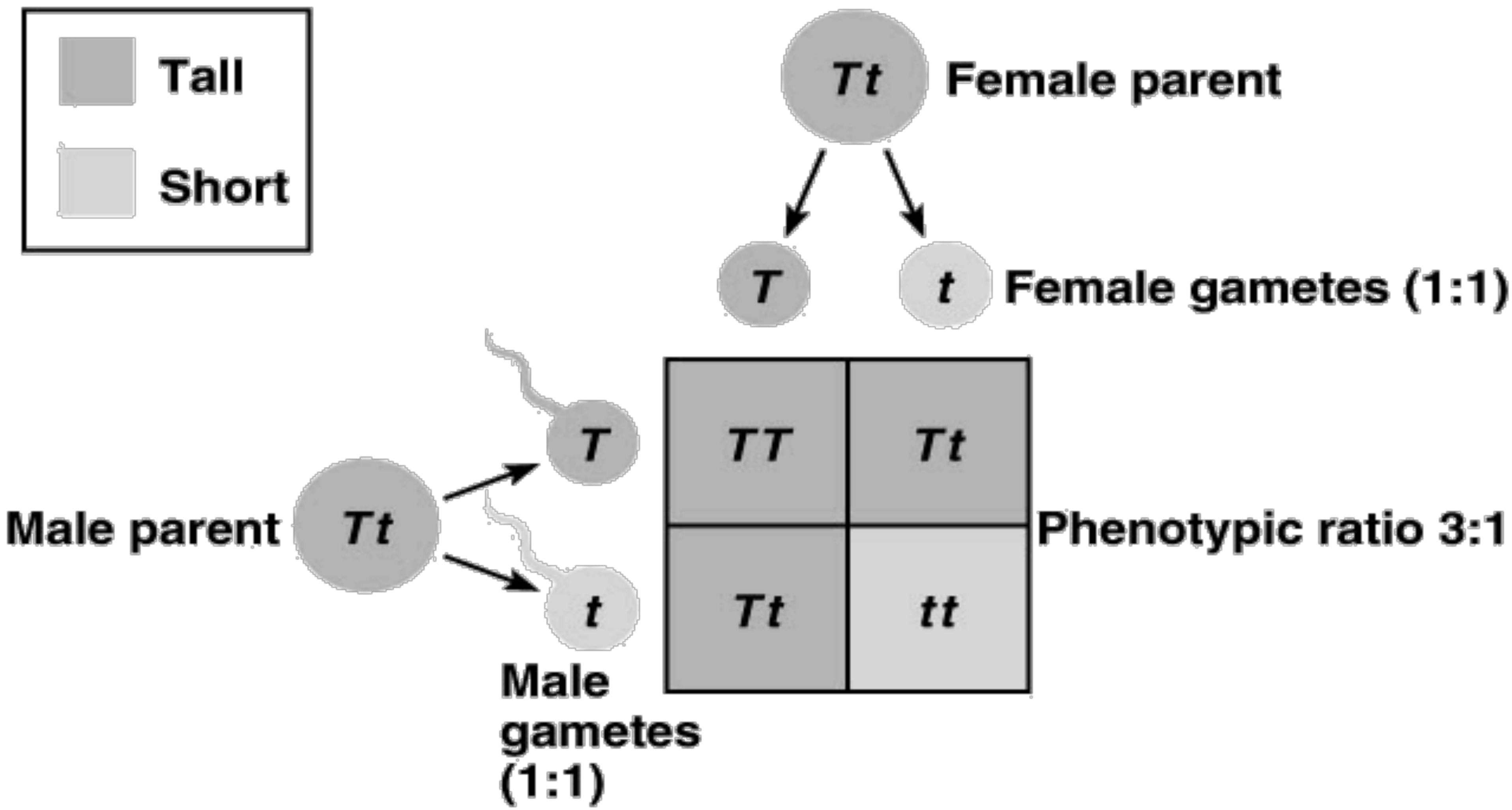
Law of Segregation

The principle stating that during the production of gametes only one allele from each parent. Two different alleles are rejoined during fertilization.

Law of Segregation



Applying the Law of Segregation



Law of Independent Assortment

If two different traits are on two different chromosomes, they can be inherited independent of each other.

Common Example

Mom has blonde hair and blue eyes
while dad has brown hair and brown eyes.

The kids could have:

Brown hair and blue eyes
Blonde hair and brown eyes
Brown hair and brown eyes
Blonde hair and blue eyes

Summary of Mendel's laws

LAW	PARENT CROSS	OFFSPRING
DOMINANCE	TT x tt tall x short	100% Tt tall
SEGREGATION	Tt x Tt tall x tall	75% tall 25% short
INDEPENDENT ASSORTMENT	RrGg x RrGg round & green x round & green	9/16 round seeds & green pods 3/16 round seeds & yellow pods 3/16 wrinkled seeds & green pods 1/16 wrinkled seeds & yellow pods

Variations on Mendel's Laws

1. Incomplete Dominance
2. Codominance

Incomplete Dominance
and
Codominance

Incomplete Dominance

F1 hybrids have an appearance somewhat **in between** the **phenotypes** of the two parental varieties.

red (RR) x white (rr)

RR = red flower

rr = white flower

Rr = pink flower

	R	R
r		
r		

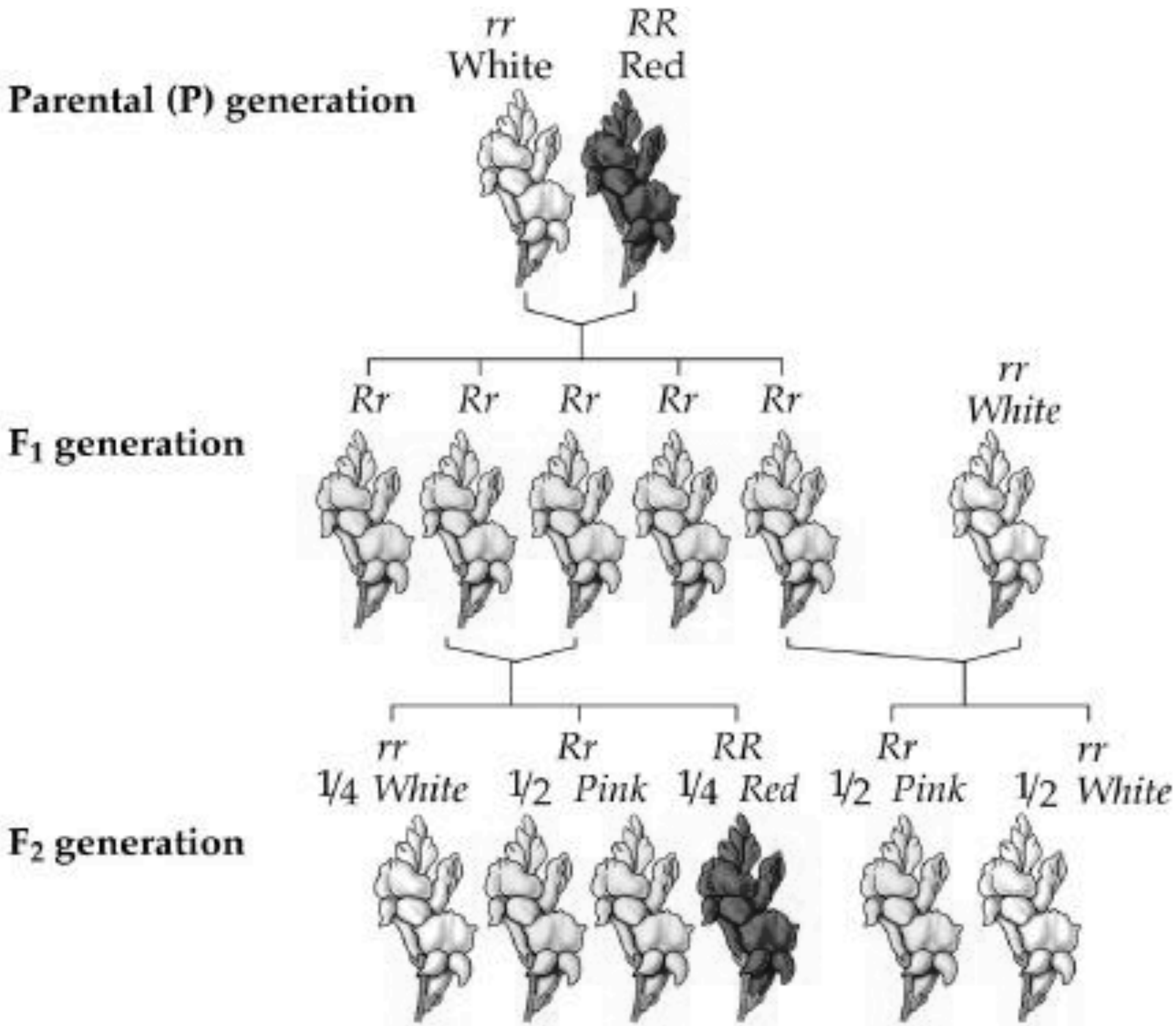
Incomplete Dominance

	R	R
r	Rr	Rr
r	Rr	Rr

produces the
F_1 generation

All Rr = pink
(heterozygous pink)

Incomplete Dominance



Carnations

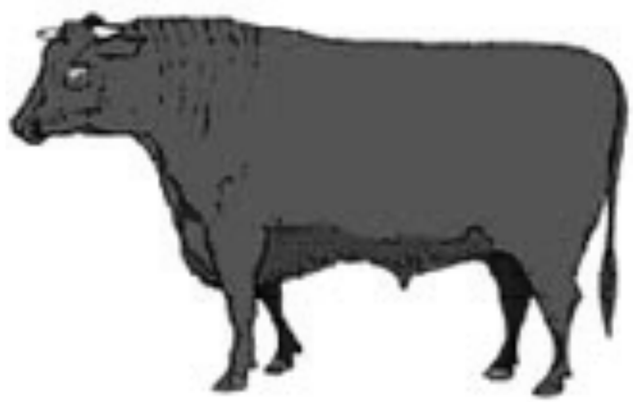
Codominance

Both the alleles can be expressed in the same organism or flower.

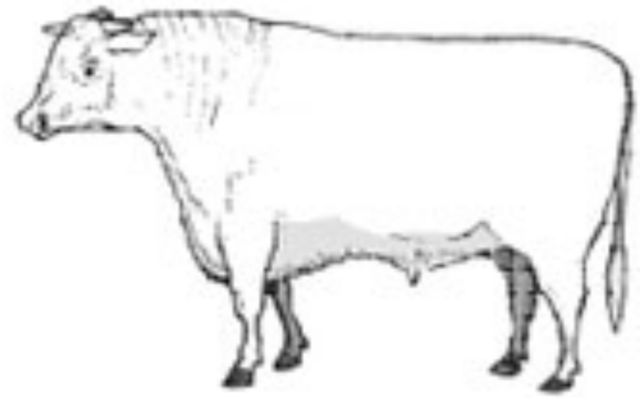
Roan Cows

A pure white cow (WW) is mated with a pure red cow (RR). The offspring will be a mixture with both color hair being expressed in one individual (RW). In this case we use two different letters because each is dominant.

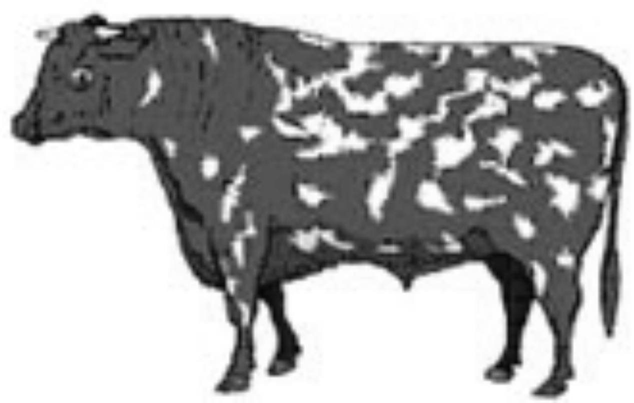
pure red
(RR)



pure white
(WW)



roan
(RW)



Pictures of Roan Animals

Dominance Relationships

					Dominance
☐	X	☐	→	☐	complete
☐	X	☐	→	☐	incomplete
☐	X	☐	→	☐	codominance

Codominance in Human Blood

Two alleles are expressed in heterozygous individuals.

Example: blood type-It is controlled by three alleles: A, B , and O

1. Type A = I^AI^A or I^Ai
2. Type B = I^BI^B or I^Bi
3. Type AB = I^AI^B
4. Type O = ii

In humans, there are four blood types:
A,B,AB and O

O is recessive (i), two O alleles must be present for the person to have type O blood (ii)

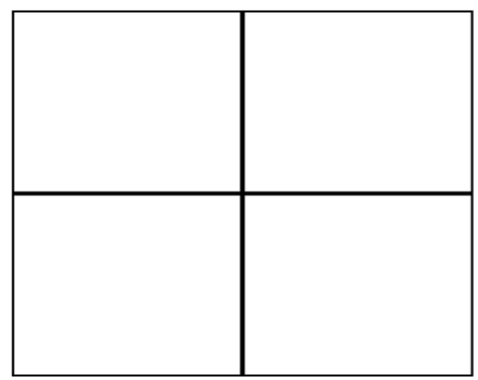
A (I^A) and B (I^B) are Codominant. If a person receives an A allele and B allele, their blood type is AB type.

Crosses involving blood type often use an *I* to denote the alleles

Blood Practice Questions

- Can parents (mom has type A blood and dad has type O blood) have a child with type O blood if type O blood is recessive?

Yes or No…Prove it.



- Can parents (mom has type AB blood and dad has type O blood) have a child with type O blood

Yes or No…Prove it.

- Can parents (mom has type AB blood and dad has type A blood) have a child with type B blood?

Yes or No…Prove it.

- Can parents (mom has type AB blood and dad has PURE type A blood) have a child with type B blood?

Yes or No…Prove it.
