Mendelian Genetics

Gregor Mendel (1822-1884)

Responsible for the Laws governing Inheritance of Traits

- Austrian monk
- Studied the inheritance of traits in pea plants
- Developed the laws of inheritance
- Mendel's work was not recognized until the turn of the 20th century
- Between 1856 and 1863, Mendel cultivated and tested some 28,000 pea plants
- He found that the plants' offspring retained traits of the parents
- Called the “Father of Genetics"

Particulate Inheritance

- Mendel stated that physical traits are inherited as “particles”
- Mendel did not know that the “particles” were actually Chromosomes (Genes) & DNA

Genetic Terminology

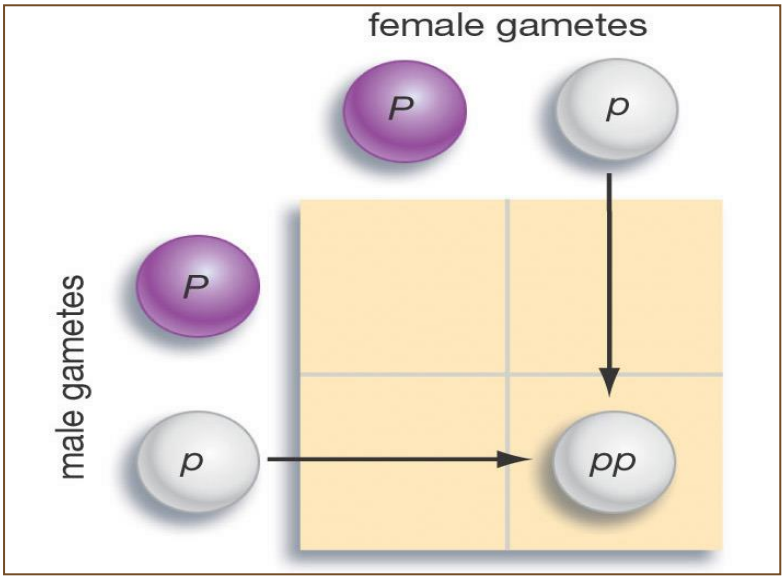
- **Trait** - any characteristic that can be passed from parent to offspring
- **Heredity** - passing of traits from parent to offspring
- **Genetics** - study of heredity

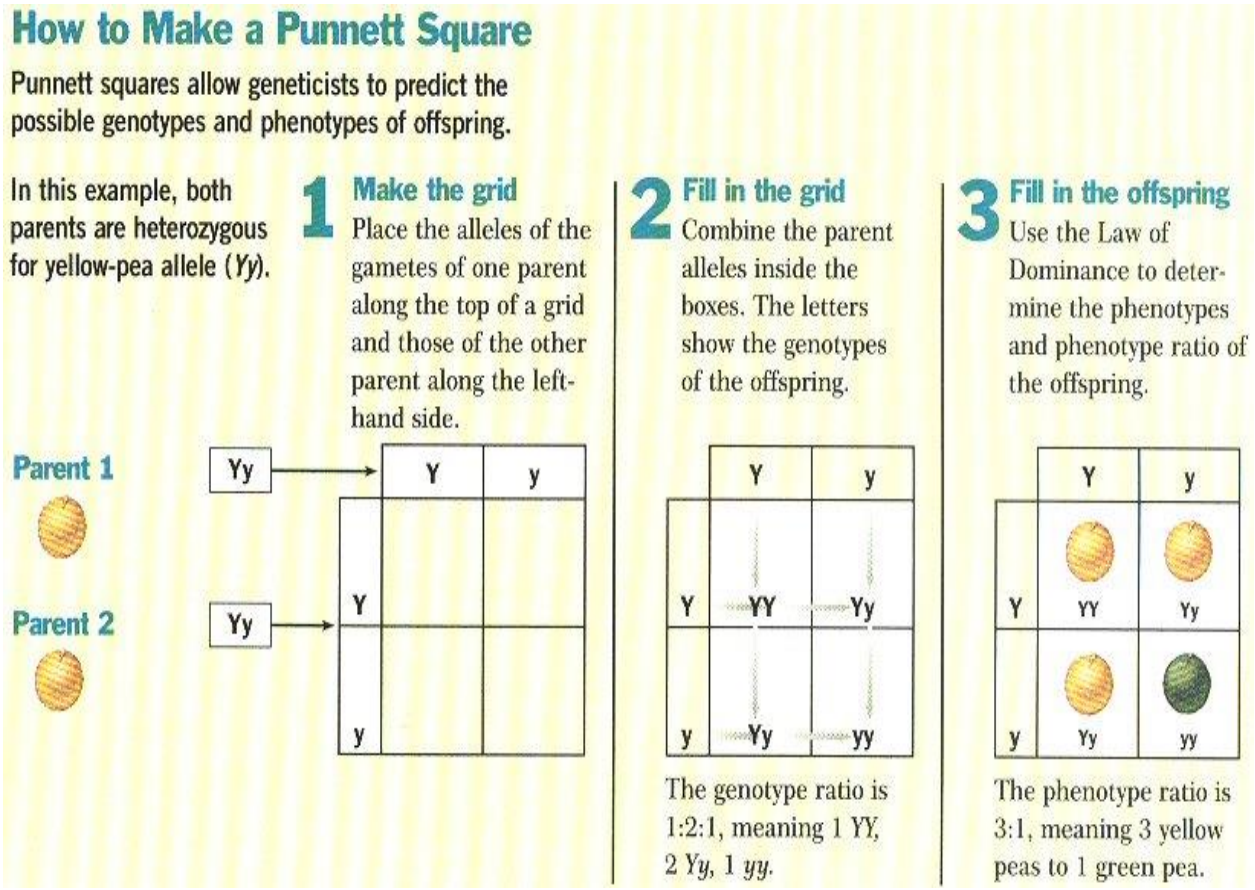
Types of Genetic Crosses

- Monohybrid cross - cross involving a single trait e.g. flower color
- Dihybrid cross - cross involving two traits e.g. flower color & plant height

Punnett Square

Used to help solve genetics problems





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 Terminology

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

Genotype & Phenotype in Flowers

Genotype of alleles: **R** = red flower **r** = yellow flower

All genes occur in pairs, so 2 alleles affect a characteristic

Possible combinations are:

Genotypes	**RR**	**Rr**	**rr**
Phenotypes	RED	RED	YELLOW

Genotypes

- **Homozygous genotype** - gene combination involving 2 dominant or 2 recessive genes (e.g. RR or rr); also called pure
- **Heterozygous genotype** - gene combination of one dominant & one recessive allele (e.g. Rr); also called hybrid

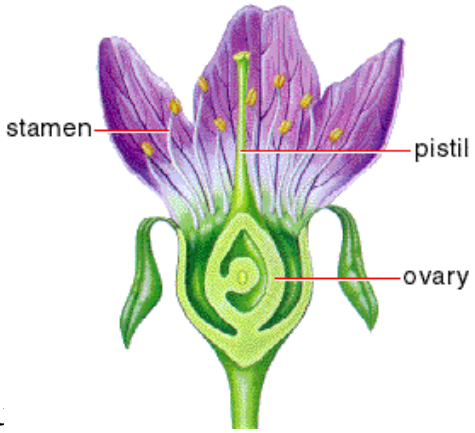
Genes and Environment Determine Characteristics

Mendel's Pea Plant Experiments

Why peas, *Pisum sativum*?

- Can be grown in a small area
- Produce lots of offspring
- Produce pure plants when allowed to self-pollinate several generations
- Can be artificially cross-pollinated

Reproduction in Flowering Plants



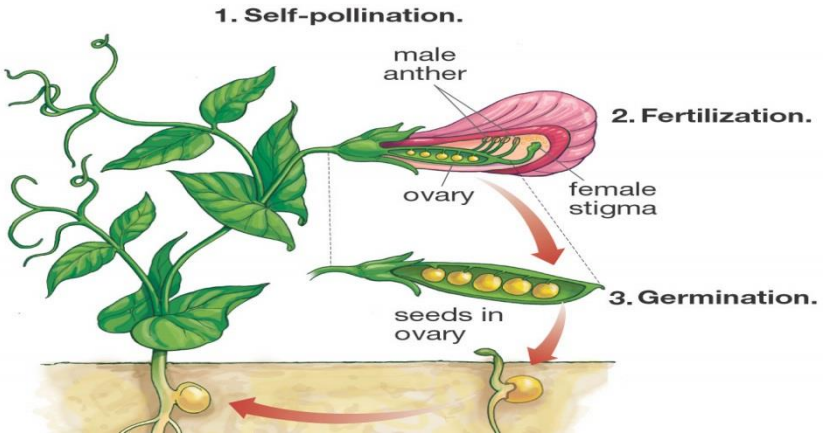
- Pollen contains sperm produced by the stamen
- Ovary contains eggs found inside the flower
- Pollen carries sperm to the eggs for fertilization
- *Self-fertilization* can occur in the same flower
- *Cross-fertilization* can occur between flowers

Mendel's Experimental Methods

- Mendel hand-pollinated flowers using a paintbru
- He could snip the stamens to prevent self-pollination
- Covered each flower with a cloth bag
- He traced traits through the several generations

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 

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**

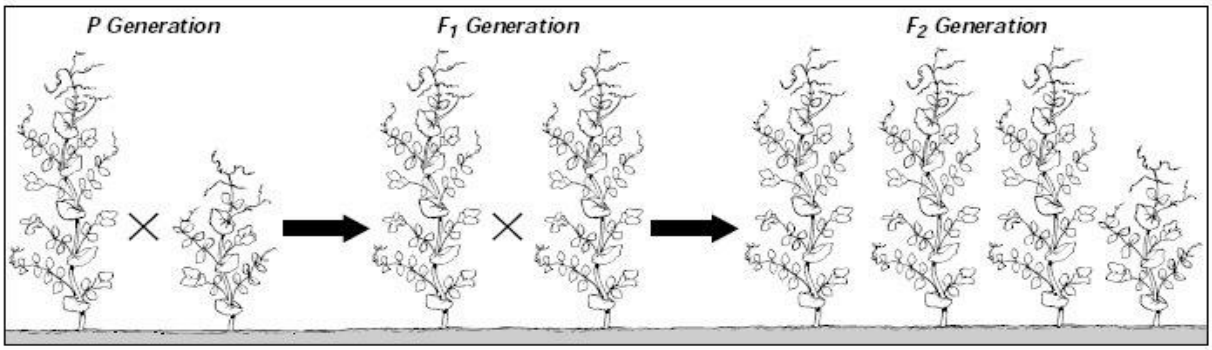
Did the observed ratio match the theoretical ratio?

- 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

Generation "Gap"

Parental P_1 Generation = the parental generation in a breeding experiment.
F_1 generation = the first-generation offspring in a breeding experiment. (1st filial generation) From breeding individuals from the P_1 generation
F_2 generation = the second-generation offspring in a breeding experiment. (2nd filial generation) From breeding individuals from the F_1 generation

Following the Generations



Cross 2 Pure Plants TT x tt | **Results in all Hybrids Tt** | **Cross 2 Hybrids get 3 Tall & 1 Short TT, Tt, tt**

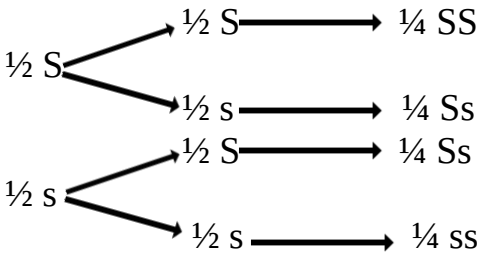
Monohybrid Crosses

Crosses can be represented by two ways:

1. Punnet square.

	S	s
S	SS	Ss
s	Ss	ss

2. Branch or Fork diagram.



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 alike

Phenotypic Ratio: All alike

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 x **Rr**

	R	r
R	RR	Rr
r	Rr	rr

Genotype: RR, Rr, rr

Phenotype: Round & wrinkled

G.Ratio: 1:2:1

P.Ratio: 3:1

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

What Do the Peas Look Like?

…And Now the Test Cross

Mendel then crossed a pure & a hybrid from his F_2 generation
This is known as an F_2 or test cross
There are two possible testcrosses:
Homozygous dominant x Hybrid
Homozygous recessive x Hybrid

Test cross: A test cross is a cross of an individual of unknown genotype, usually expressing the dominant phenotype, with a known homozygous recessive individual to determine the genotype of the unknown individual. The phenotypes of the progeny of the test cross indicate the genotype of the individual tested.

- **A mating between an individual of unknown genotype and a homozygous recessive individual.**
- **Example: bbC__ x bbcc**

- **BB = brown eyes**
- **Bb = brown eyes**
- **bb = blue eyes**

- **CC = curly hair**
- **Cc = curly hair**
- **cc = straight hair**

	bC	b___
bc		

- **Possible results:**

	bC	b_C
bc	bbCc	bbCc

or

	bC	b_c
bc	bbCc	bbcc

Back cross: Is the cross of a progeny with one of its parents or an organism with the same genotype as a parent.

F_2 Monohybrid Cross (1st)
Trait: Seed Shape
Alleles: **R** – Round **r** – Wrinkled
Cross: Round seeds x Round seeds
RR x **Rr**

	R	r
R	RR	Rr
R	RR	Rr

Genotype: RR, Rr
Phenotype: Round
Genotypic Ratio: 1:1
Phenotypic Ratio: All alike

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

Genotype: Rr, rr
Phenotype: Round & Wrinkled
G. Ratio: 1:1
P.Ratio: 1:1

F_2 Monohybrid Cross Review
- Homozygous x heterozygous(hybrid)
- Offspring:
  50% Homozygous RR or rr
  50% Heterozygous Rr
- Phenotypic Ratio is 1:1
- Called Test Cross because the offspring have SAME genotype as parents

Practice Your Crosses
Work the P_1, F_1, and both F_2 Crosses for each of the other Seven Pea Plant Traits

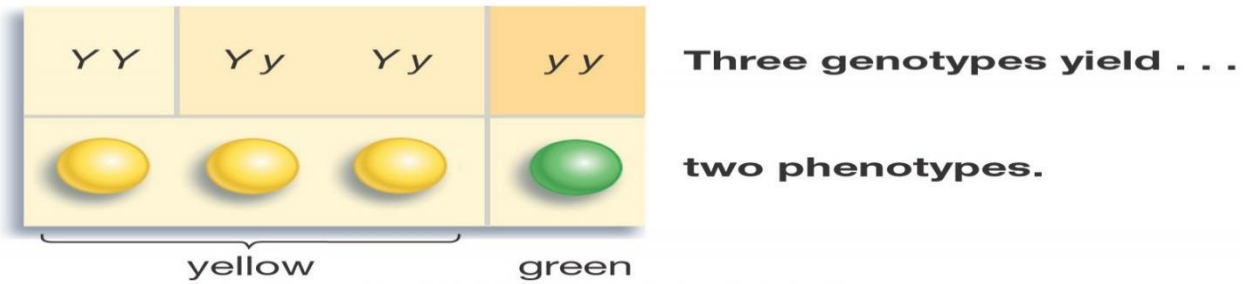
Mendel's Laws
Results of Monohybrid Crosses
- Inheritable factors or genes are responsible for all heritable characteristics
- Phenotype is based on Genotype
- Each trait is based on two genes, one from the mother and the other from the father
- True-breeding individuals are homozygous (both alleles) are the same

Law of Dominance

In a cross of parents that are pure for contrasting traits, only one form of the trait will appear in the next generation.

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

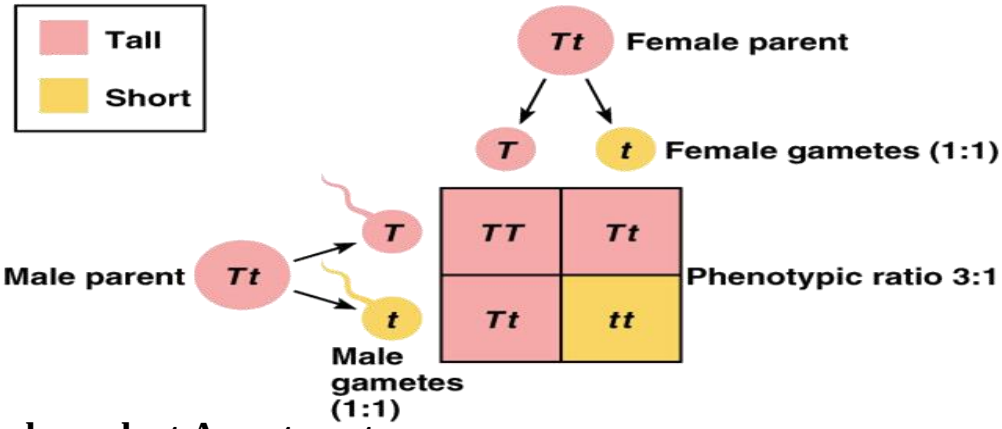
RR x rr yields all Rr (round seeds)



Law of Segregation

- During the formation of gametes (eggs or sperm), the two alleles responsible for a trait separate from each other.
- Alleles for a trait are then "recombined" at fertilization, producing the genotype for the traits of the offspring.

Applying the Law of Segregation



Law of Independent Assortment

- Alleles for *different* traits are distributed to sex cells (& offspring) independently of one another.
- This law can be illustrated using *dihybrid crosses*.

Dihybrid Cross

A breeding experiment that tracks the inheritance of two traits.

(Mendel's "Law of Independent Assortment")

a. Each pair of alleles segregates independently during gamete formation

b. Formula: 2^n (n = # of heterozygotes)

Question:

How many gametes will be produced for the following allele arrangements?

Remember: 2^n (n = # of heterozygotes)

1. RrYy
2. AaBbCCDd
3. MmNnOoPPQQRrssTtQq

Answer:

1. RrYy: $2^n = 2^2 = 4$ gametes
   RY Ry rY ry
2. AaBbCCDd: $2^n = 2^3 = 8$ gametes
   ABCD ABCd AbCD AbCd
   aBCD aBCd abCD abCD
3. MmNnOoPPQQRrssTtQq: $2^n = 2^6 = 64$ gametes

Dihybrid Cross

Traits: Seed shape & Seed color

Alleles: R round
r wrinkled
Y yellow
y green

	RY	Ry	rY	ry
RY				
Ry				
rY				
ry				

	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

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

Home work:

Q1/ Consider the case in which testcrossing a black male produced black and white offspring in approximately equal numbers?

Q2/ In the garden pea, Mendel found that yellow seed color was dominant to green (*Y*>*y*) and round seed shape was dominant to shrunken (*S*>*s*). (a) What phenotypic ratio would be expected in the F_2 from a cross of a pure yellow, round X green, shrunken? (b) What is the F_2 ratio of yellow: green and of round: shrunken?

Questions /

1. Why was Mendel's approach to the study of heredity so successful?
2. What is the relation between the terms *allele, locus, gene,*and *genotype?*
3. What is the principle of segregation? Why is it important?
4. What is the concept of dominance? How does dominance differ from incomplete dominance?
5. Give the phenotypic ratios that may appear among the progeny of simple crosses and the genotypes of the parents that may give rise to each ratio.
6. Give the genotypic ratios that may appear among the progeny of simple crosses and the genotypes of the parents that may give rise to each ratio.
7. What is the chromosome theory of inheritance? Why was it important?
8. What is the principle of independent assortment? How is it related to the principle of segregation?
9. How is the principle of independent assortment related to meiosis?
10. In cucumbers, orange fruit color (*R*) is dominant over cream fruit color (*r*). A cucumber plant homozygous for orange fruits is crossed with a plant homozygous for cream fruits. The F1 are intercrossed to produce the F2.

a. Give the genotypes and phenotypes of the parents, the F1, and the F2.
b. Give the genotypes and phenotypes of the offspring of a backcross between the F1 and the orange parent.
c. Give the genotypes and phenotypes of a backcross between the F1 and the cream parent.