Chapter 2 ~ Mendel's Second Law: Independent Assortmant

Introduction:

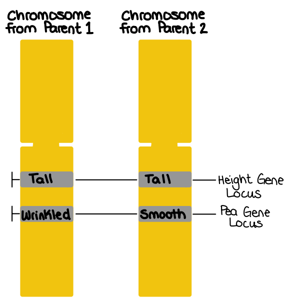
Mendel looked at the simultaneous inheritance of TWO or MORE UNRELATED traits...

↳ He considered how two pairs of alleles would segregate into a DIHYBRID individual (ie. a plant that is heterozygous for two genes)

Law of Independant Assortment

- States that during gamete formation, alleles at seperate loci segregate INDEPENDANTLY, and this produces characteristic genotypic & phenotypic ratios...

✱ The analysis of two loci in the SAME cross provides information ✱ for genetic mapping & testing gene interactions



When dealing w/ alleles at two different loci, we have to use nomenclature that makes the arrangment clear

There are 3 different possible arrangments:

1. Both loci are on the same chromosome
   - AB/ab
2. Different chromosomes
   - A/a ; B/b
3. Unknown
   - AaBb

Before Mendel... → After Mendel...

Blended Inheritance

- was the accepted model to explain the transmission of traits

Heritable Traits

- Are controlled by discrete factors, now known as alleles in a particular inheritance model

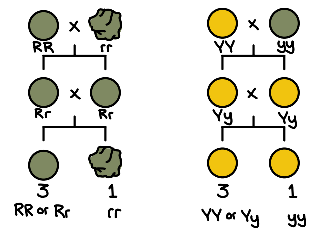
Important Question:

- Whether heritable traits, controlled by discrete factors, are inherited together in ONE individual

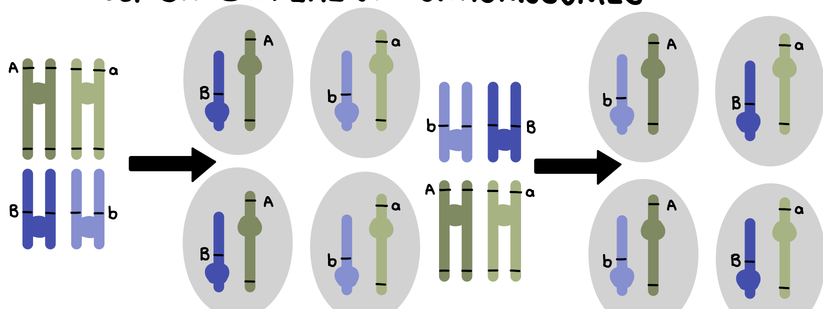
To answer this, I took two apparently unrelated traits (seed colour & seed shape) and studied the inheritance together in one individual

Example:

When studied (along w/ 7 traits each on a diff chromosome) the phenotype segregated in the classical 3:1 ratio among the progeny of a monohybrid cross.



Two Loci on Different Chromosomes



The seperation of gametes through the process of meiosis has already been introduced

What does that mean when you are taking multiple, different genes into account?

Recall: Main stage of meiosis

- Homologous pairs align during Metaphase I, & complete one round of cell division
- During Metaphase II, the replicated chromosomes in those two cells align individually & sister chromatid seperates
  - ↳ You have TWO daughter cells

Theoretically: 1 chromosome has gene A on it & anothe gene B & the individual is heterozygous @ each egen

↓

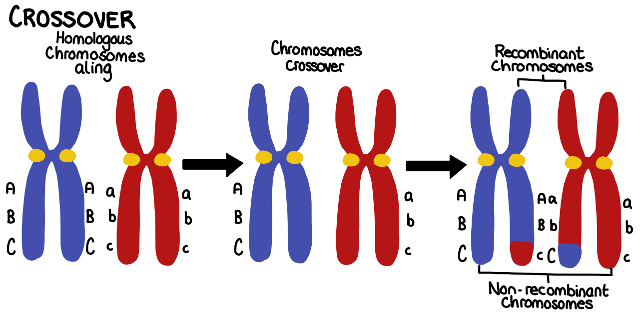
There is a variety of way that the homologous during metaphase I pairs can align themselves

✱ Orientation of alignment will affect the alleles each gamete receives at the end of telophase II

Note: Random aligment @ Metaphase I is random so random, equal distribution of alleles in ALL gametes produced

Two Loci on One Chromosomes

Crossover



The FARTHER apart on the chromosome the MORE crossover events will take place between the two loci. Ultimately, this will result in similar allele combinations to those observed in independent assortment shown, even IF they are on the SAME chromosome

If the loci are very CLOSE together on the SAME chromosome, FEWER crossovers are likely to occur between them

Expected:

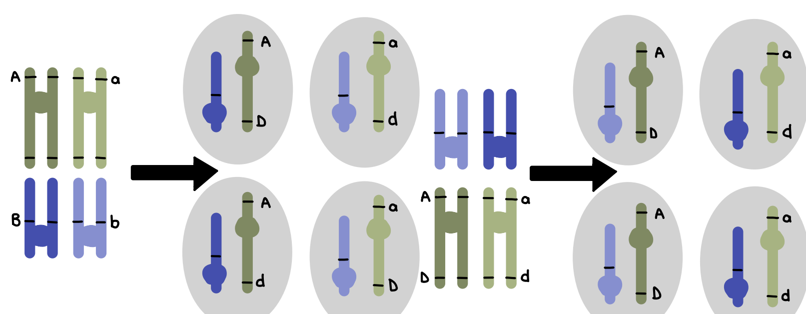
- If all genes were on the SAME chromosome the alleles would travel together through meiosis

However...

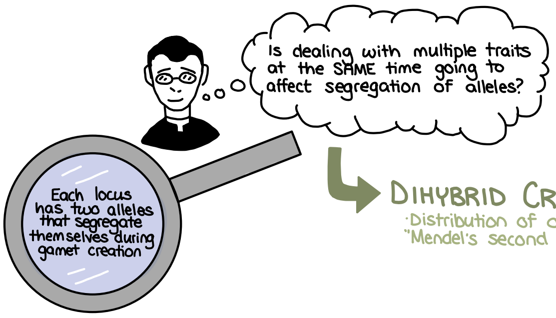
- When tested this is NOT always the case.
- Recombination of alleles can be explained through the phenomenon of crossing over, which occurs during prophase I

What is Crossing Over?

- An exchange between NON-SISTER chromatids that can occur at any position along the ENTIRE chromosome
- If the two loci that are being considered are sufficently seperated from each other on the chromosome, crossover events can occur between the two loci
- This coupled w/ random orientation that the chromosomes align during Metaphase I, will allow the other combination of alleles in the gametes



A Dihybrid Cross Showing Mendel's 2nd Law



Law of Independent Assortment

- States that the segregation of alleles at ONE locus WILL NOT INFLUENCE the segregation of alleles @ another locus during gamete formation
  - ↳ Alleles segregate INDEPENDENTLY

Dihybrid Cross

- Distribution of offspring led to "Mendel's second Law"

Dihybrids

- To analyze the simultaneous segregation of two traits at the SAME time in the SAME individual, he crossed a pure-breeding line of Green, wrinkled peas with a pure-breeding line of Yellow, round peas

P Gen: YYRR × yyrr ↓

F_1 Gen: YyRr

Phenotype: (yellow, round)

Gametes from Homozygous parent \ Gametes from Heterozygous parent	YR	yR	Yr	yr
YR	YYRR	YyRR	YYRr	YyRr
yR	YyRR	yyRR	YyRr	yyRr
Yr	YYRr	YyRr	YYrr	Yyrr
yr	yrYR	yryR	Yyrr	yyrr

F_2 Gen

Phenotype: 9 (yellow, round) : 3 (green, round) : 3 (yellow, wrinkled) : 1 (green, wrinkled)

Results:
- Yellow & round = Dominant
- Green & wrinkled = Recessive

If inheritance of seed colour was truly independent then the when F_1 dihybrids are crossed a 3:1 ratio of one trait should be observed within each phenotypic class

Frequency of Phenotypic Crosses w/i Seperate Monohybrid Crosses

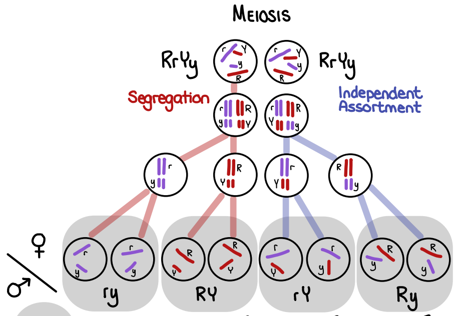
Seed shape: 3/4 (round), 1/4 (wrinkled)

Seed colour: 3/4 Yellow, 1/4 Green

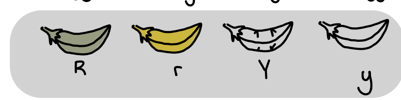
Frequency of Phenotypic Crosses w/i Seperate Dihybrid Crosses

- 3/4 (round) × 3/4 (yellow) = 9/16 (round, yellow)
- 3/4 (round) × 1/4 (green) = 3/16 (round, green)
- 1/4 (wrinkled) × 3/4 (yellow) = 3/16 (wrinkled, yellow)
- 1/4 (wrinkled) × 1/4 (green) = 1/16 (wrinkled, green)

Meiosis



♂ \ ♀	ry	RY	rY	Ry
ry	rryy	RrYy	rrYy	Rryy
RY	RrYy	RRYY	RrYY	RRYy
rY	rrYy	RrYY	rrYY	YyRr
Ry	Rryy	RRYy	RrYy	RRyy



Assumption of 9:3:3:1 Ratio

- Both the product rule & punnett square approches showed that a 9:3:3:1 phenotypic ratio is expected among the progeny of a dihybrid cross such as Mendel's RrYy × RrYy.
- These calculations require the following assumptions:
  1. Alleles at each locus segregate INDEPENDENTLY from one another
  2. 1 allele at each locus is COMPLETELY dominant (other is recessive)
  3. Each of 4 possible phenotypes can be distinguished unambiguously w/ NO interactions b/w the two genes that would interfer w/ determining the genotype CORRECTLY

Product Law

If 3/4 progeny = Yellow & 3/4 progeny = Round, then... $3/4 \times 3/4 = 9/16$. So 9/16 progeny would be Yellow & Round

If 3/4 progeny = Yellow & 1/4 progeny = Wrinkled, then... $3/4 \times 1/4 = 3/16$. So 3/16 progeny would be Yellow & Wrinkled

If 3/4 progeny = Green & 1/4 progeny = Round, then... $3/4 \times 1/4 = 3/16$. So 3/16 progeny would be Green & Round

If 1/4 progeny = Green & 1/4 progeny = Wrinkled, then... $3/4 \times 1/4 = 3/16$. So 1/16 progeny would be Green & Wrinkled

Deviation from 9:3:3:1 Phenotypic Ratio

- Deviation from 9:3:3:1 MAY indicate that ONE or MORE of the above listed conditions has NOT been met
- Modified ratios in the progeny of a dihybrid cross can, therefore, reveal useful information about the genes involved
- ex: Linkage
  - It is one of THE most important reasons for distortion of the expected ratios from independent assortment
  - 2 loci show linkage if they are located CLOSE together on the SAME chromosome
  - Close proximity alters the frequency of allele combinations in the gametes

* Deviations can also be due to interactions b/w genes such as epistasis, duplicate gene action and complementary gene action

Dihybrid Test Cross

While the cross of $F_1 \times F_1$ gives a ratio of 9:3:3:1, there is a better easier cross

In a dihybrid cross...
- Independent assortment = 1:1:1:1

*It is easier to score than 9:3:3:1
- Helps determine the genotype of an individual w/ dominant phenotypes to determine if heterozygous or homozygous

Unknown genotype in 2 loci × homozygous recessive for both loci

♂ \ ♀	RY	RY	RY	RY
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy

Only Dominant Phenotype

♂ \ ♀	RY	Ry	RY	Ry
ry	RrYy	Rryy	RrYy	Rryy
ry	RrYy	Rryy	RrYy	Rryy
ry	RrYy	Rryy	RrYy	Rryy
ry	RrYy	Rryy	RrYy	Rryy

50% Green & 50% Yellow

Complete for last 2 possible genotypes...

♂ \ ♀				
ry				
ry				
ry				
ry				

Tips & Practice set up
- Do punett squares before
- ex: Cross a double homozygous recessive pea plant to a unknown w/ 2 dominant phenotypes (R_Y_)

4 possible genotypes
- RRYY → 100% Green
- RRYy → 50% Yellow, 50% Green
- RrYY
- RrYy

- Try it! -

Predicting Ratios...

"Rules of Probability"

① Multiplication / Product Rule

- Can be applied to the phenomenon of INDEPENDENT transmission of traits. It states that the probability of 2 independent events occuring together can be calculated by multiplying the individual probabilities of EACH event occuring ALONE

ex: Probability of event A AND event B occuring =
$P(A \text{ and } B) = P(A) \times P(B)$

② Addition / Sum Rule

- Applied when considering two mutually-exclusive outcomes that can result from MORE than one pathway
- States that the probability of occurence of one event or the other, of the two mutually-exclusive events is the SUM of their individual probability

ex: Probability of event A OR event B occuring is = $P(A \text{ or } B) = P(A) + P(B)$