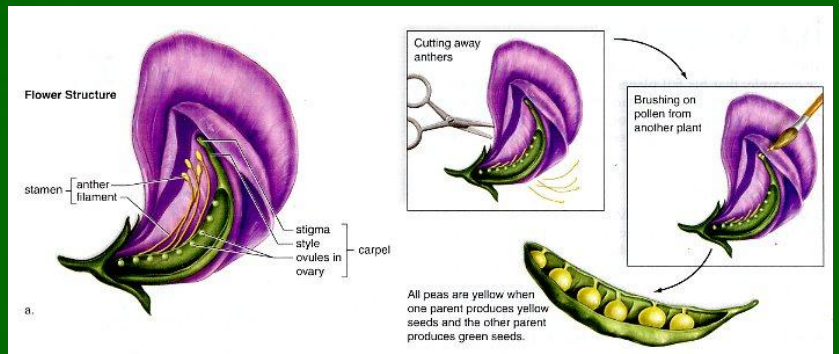
Gene Mapping, Linked & Unlinked Genes

Packet #14

Introduction I

- According to Mendel's law of independent assortment, a di-hybrid cross, between individuals that are heterozygous for both alleles, should provide a 9:3:3:1 ratio.



Trait	Characteristics *Dominant	Characteristics *Recessive	F_2 Results* Dominant	F_2 Results* Recessive
Stem length	Tall	Short	787	277
Pod shape	Inflated	Constricted	882	299
Seed shape	Round	Wrinkled	5,474	1,850
Seed color	Yellow	Green	6,022	2,001
Flower position	Axial	Terminal	651	207
Flower color	Purple	White	705	224
Pod color	Green	Yellow	428	152

*All of these produce approximately a 3:1 ratio. For example, $\frac{787}{277} = \frac{3}{1}$.

b.

FIGURE 11.2 Garden pea anatomy and a few traits.

Introduction II

- However, Bateson and Punnett discovered that while running a similar experiment, they discovered that there was a higher amount of flowers with the same parental genotype vs. new recombinant genotypes.
- This did not meet the 9:3:3:1 ratio as results should have.
- The results were due to the fact that the two alleles were linked to each other and were not crossing over independent of each other.

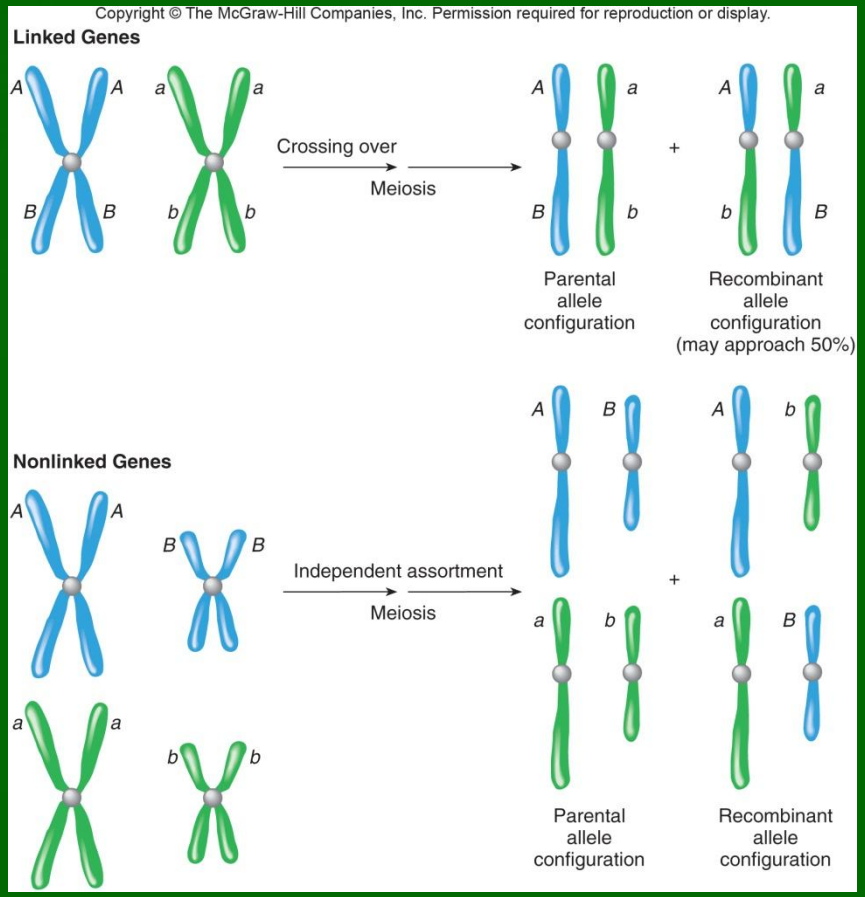
LINKED GENES VS. UNLINKED GENES

Linkage

- Each chromosome behaves genetically as if it consisted of genes arranged in a linear order
- *Linkage* is the tendency for a group of genes, *on the same chromosome*, to be inherited *together* via crossing over

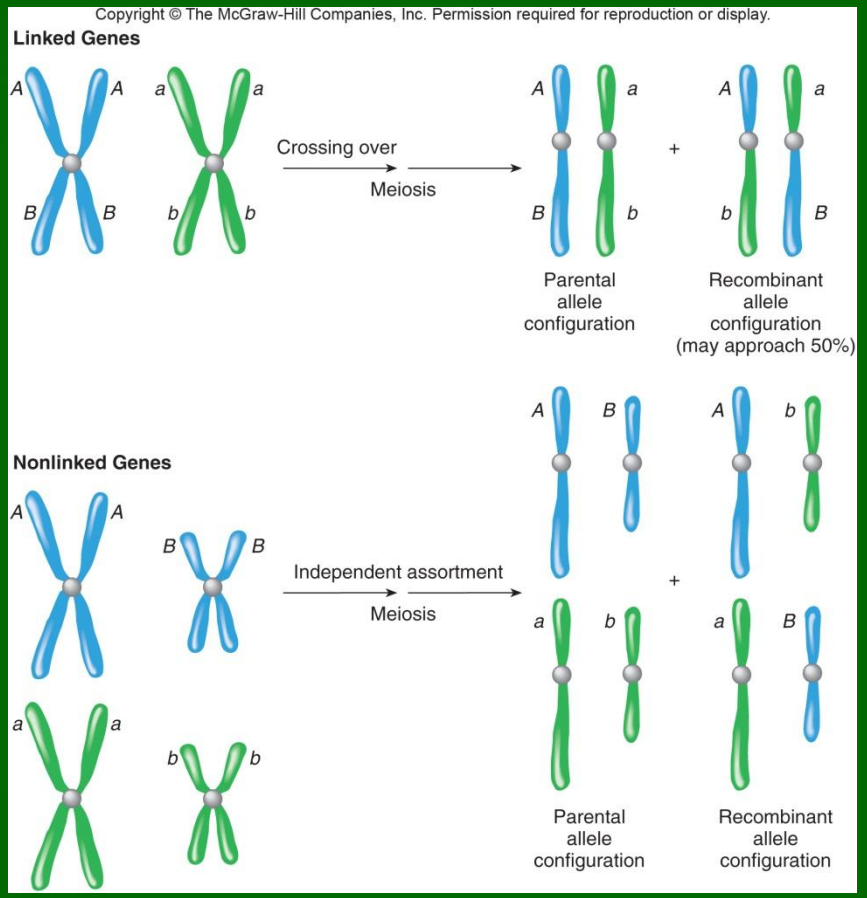
Linkage II

- However, for linkage to occur, the genes, located on the same chromosome, **must be close enough to each other.**
- If the genes are close enough to each other, and have a high probability of crossing over together, then they are considered to be *linked genes*.



Linkage III

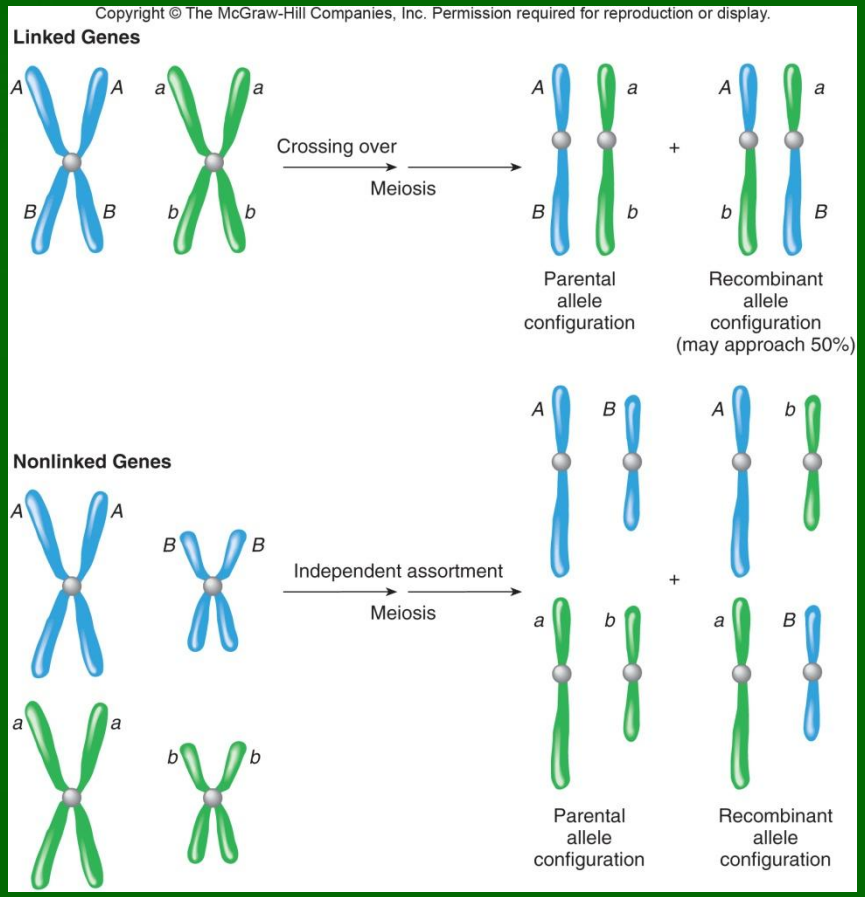
- If genes are linked together, then Mendel's law of independent assortment does not apply.
  - Genes, in this case, are not passed on independent of another gene.
  - However, linked genes may recombine during crossing over.
  - The ratio of 9:3:3:1 is not met



DETERMINING WHETHER GENES ARE LINKED OR UNLINKED

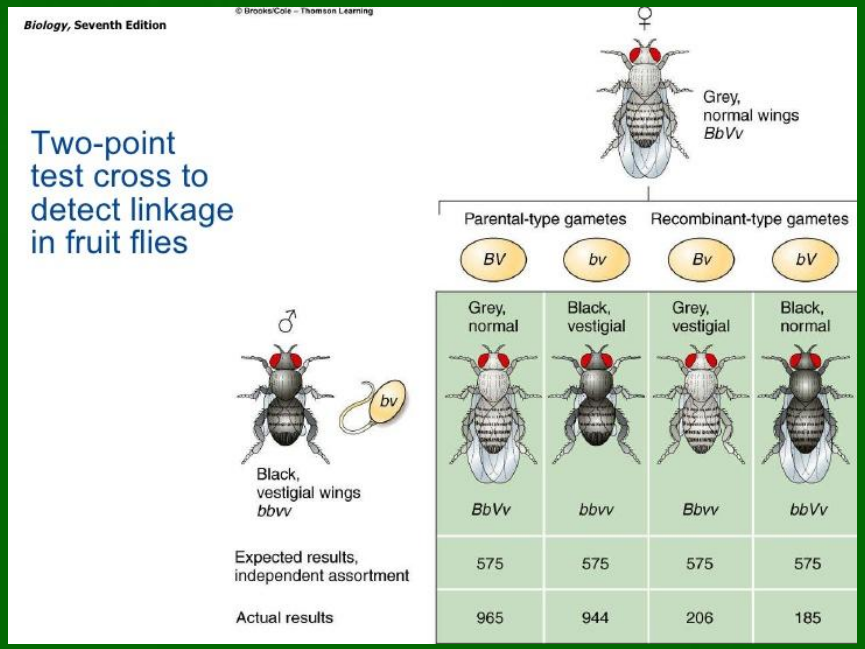
Recombination of Genes

- Recombination of unlinked genes is achieved via independent assortment of chromosomes
  - Mendel's Law
- Recombination of linked genes is only possible during crossing over.



Two-point Cross I

- The two-point test cross allows scientists to determine whether genes are linked or unlinked.
- In order to perform a *two-point test cross* one parent ***must be heterozygous for both alleles*** while the other must be ***homozygous recessive for both alleles.***
  - The results of the cross is observed in **the F_2 generation.**

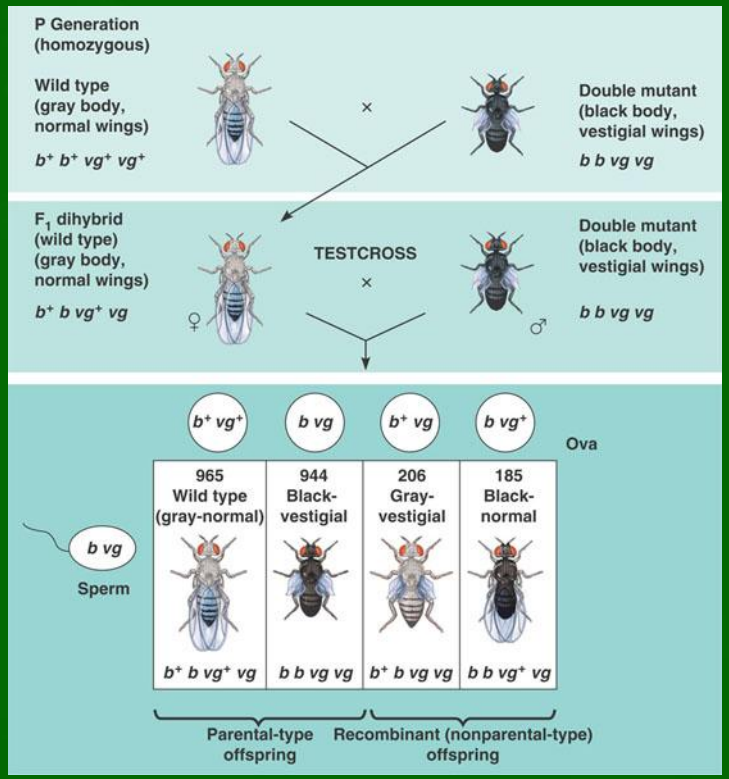


Two-point Cross II

- If the **majority of the offspring have a genotype similar to one of the parents, then the genes are linked.**
- If the **majority of the offspring have a recombinant genotype, having different genotypes than the parents, then the genes are unlinked.**

Two Point Cross Example

- Parent #1
  - b^+bvg^+vg
    - Grey with normal wings
- Parent #2
  - bbvgvg
    - Black with vestigial wings



Two-Point Cross

	b^+v^+	bv	b^+v	bvg^+
bvg	b^+bvg^+vg	bbvgvg	b^+bvgvg	$bbvg^+$ vg
Expected Results	575	575	575	575
Actual Results	965	944	206	185

- Calculations
  - Parental Genotypes
    - 965 (42%) +944 (41%) = 1909
    - 1909/2300 = 83%
  - Recombinant Genotypes
    - 206 (9%)+185 (8%) = 391
    - 391/2300 = 17%
  - If independent assortment was to occur, the percentages would be 25% a piece.
  - Based on the data, the recombinants arose because of crossing over

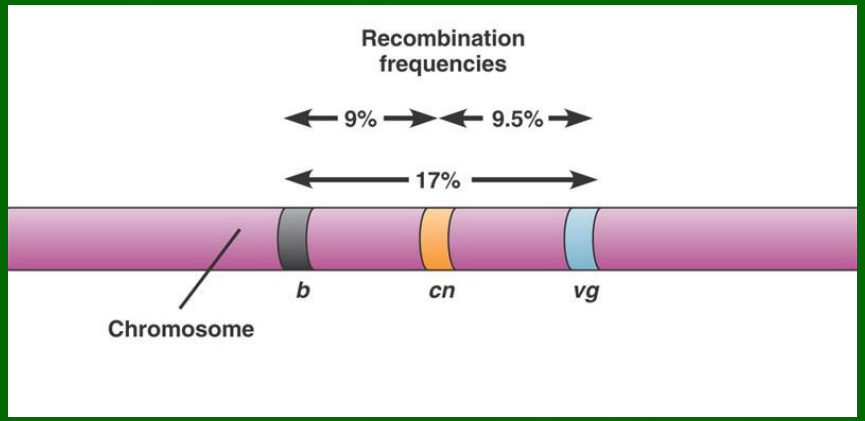
GENE MAPPING

Gene Mapping

- By measuring the **frequency of recombination** between linked genes, it is possible to construct a linkage map of a chromosome
  - Scientists were able to develop a detailed genetic map of Neurospora (fungus), fruit fly, the mouse, yeast and many plants, that are particularly important as crops, via gene mapping.

Gene Mapping II

- The information gathered from the two point cross, is used to determine the map distance between the two alleles.
- The recombinant frequencies (percentages) are used as map units (map distance)that separate two alleles.
  - Map distance = $\frac{\text{(Number of recombinant offspring)}}{\text{(Total number of offspring)}} * 100$
  - If the recombinant = 58%
    - The genes are 58 map units apart.

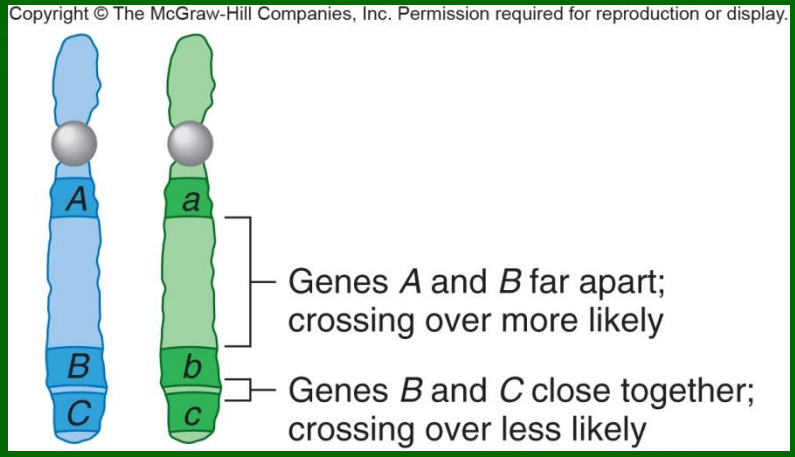


Determining the Order AND Distance Between Linked Genes

THREE POINT CROSS

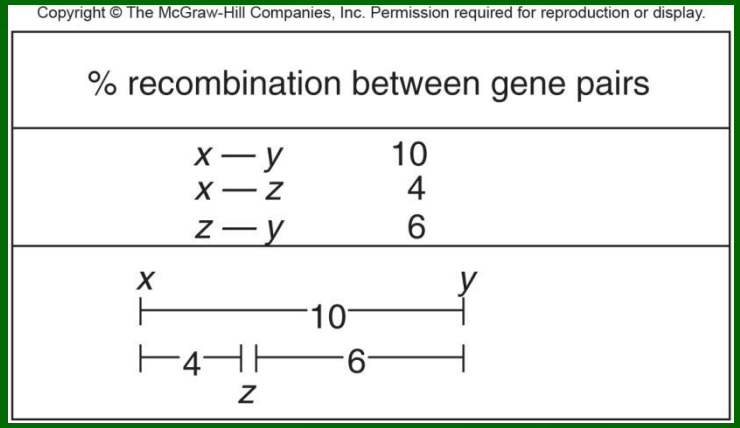
Introduction I

- A three point cross can yield additional information about **map distance AND gene order.**



Steps of Three Point Cross

1. Cross two true-breeding strains that differ with regard to alleles.
2. Perform a test cross my mating F_1 female heterozygous (all three alleles) to male flies that are homozygous recessive (for all three alleles.
3. Collect data for the F_2 generation.
4. Calculate the map distance between pairs of genes.
5. Construct map.



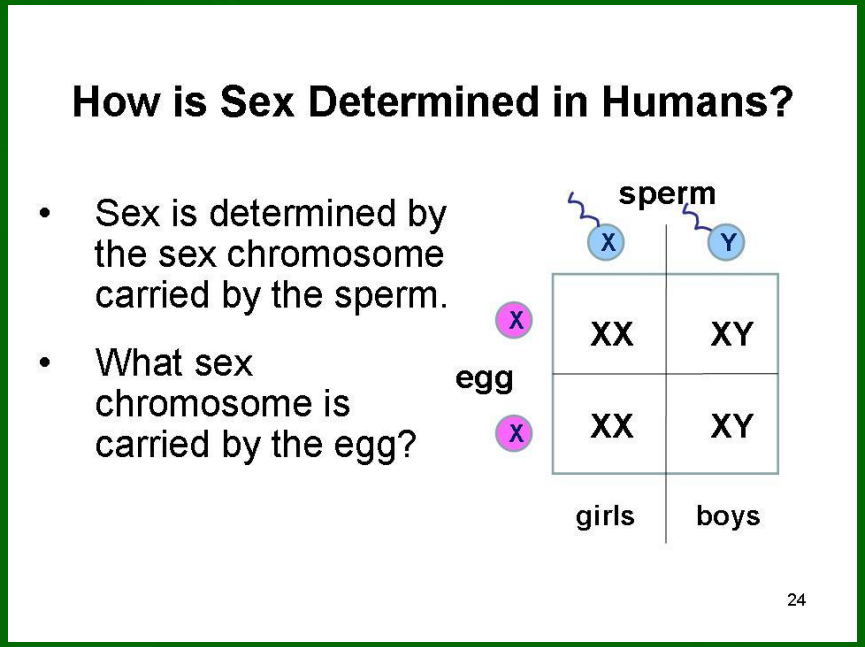
Gene Mapping III
Example

- Create a map using the information provided below.
  - A & D = 2 units (2% recombination frequency)
  - B & D = 10 units (10% recombination frequency)
  - C & B = 3 units (3% recombination frequency)
  - C & A = 5 units (5% recombination frequency)

SEX-LINKED GENES

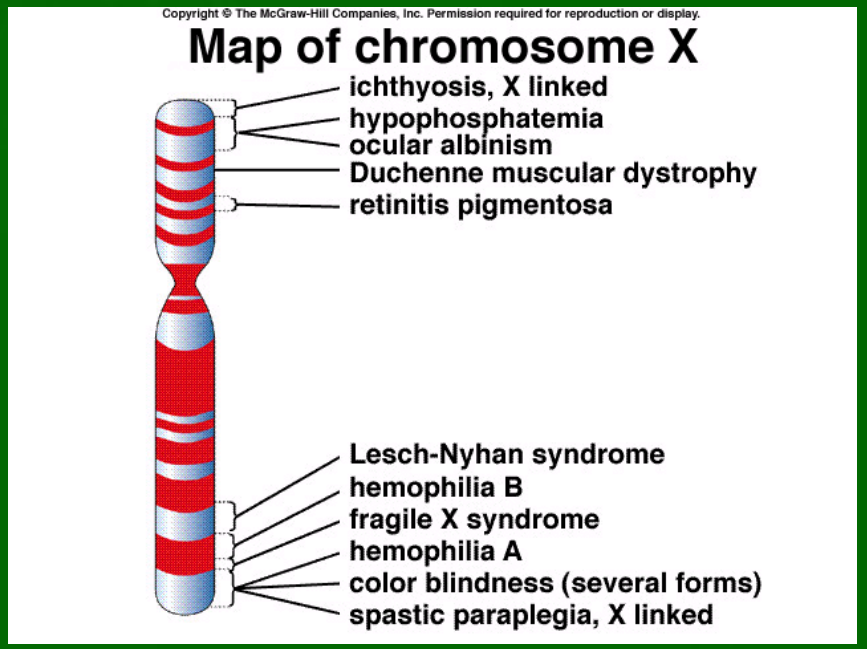
Introduction I

- Sex is determined by sex chromosomes
  - X and Y
    - XX = female
    - XY = male



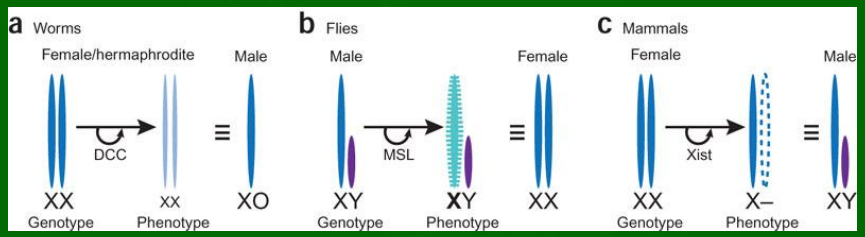
The X Chromosome

- The X chromosome contains many important genes that are *unrelated to sex determination*
  - These genes are required for both males and females
    - A male receives ALL of his *X-linked genes* from his mother while a female receives her *X-linked genes* from both parents.



Dosage Compensation

- Female mammals display dosage compensation.
  - Only one of the two chromosomes is expressed in each cell
    - The other allele is inactive
    - Seen as a dark-staining *Barr body* at the edge of the interphase nucleus.
  - Equalizes the expression of x-linked genes for both genders.



Dosage Compensation II

- A random event that occurs in each somatic cells
  - A female that is heterozygous expresses one of the alleles in about half her cells and the other allele in the other half

PRACTICE HOMEWORK ASSIGNMENTS

Practice Assignment #1

- Determine if the genes are linked together using the information provided.

	b^+v^+	bv	b^+v	bvg^+
bvg	b^+bvg^+vg	bbvgvg	b^+bvgvg	$bbvg^+$ vg
Expected Results	300	300	300	300
Actual Results	310	315	287	288

Practice Assignment #2

- Determine if the genes are linked together using the information provided.

	b^+v^+	bv	b^+v	bvg^+
bvg	b^+bvg^+vg	bbvgvg	b^+bvgvg	$bbvg^+$ vg
Expected Results	295	295	295	295
Actual Results	360	380	230	230

REVIEW