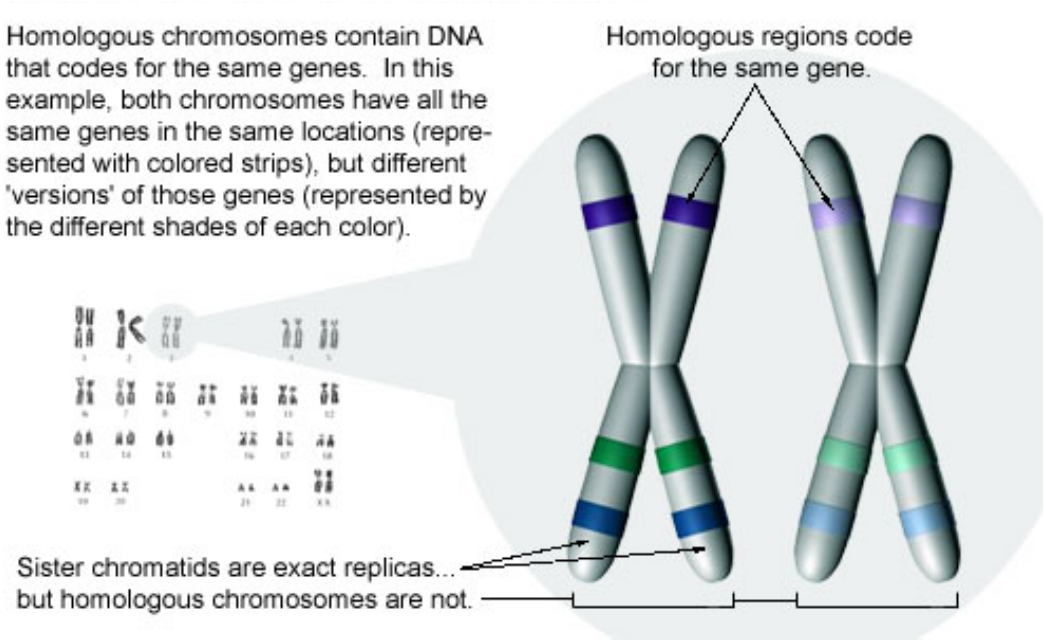
PERSONALS: ♀ FF, Se/E/Dp, seeks ♂ FF, +/+/+
for short term relationship . Enjoys romance, fermentation, and long walks on the peach...

Sex Linkage

Chromosomal Theory

- Chromosomes carry genes – units of heredity
- Homologous chromosomes segregate during meiosis
- Gametes carry half the number of chromosomes as somatic cells
- Chromosomes assort independently during meiosis



Chromosomal Theory

So far we have been looking at genes on AUTOSOMAL chromosomes (pairs 1 – 22)

But what happens if the **trait (gene)** is found **on the X chromosome** (in pair#23)?

Females have **XX**
but..
Males have **XY**

-what does this mean if a trait is on the X chromosome and males only have 1?

Gender and Inheritance

- **Breakthrough work done by Thomas Hunt Morgan – American Geneticist**
- **1908 – Work on fruit flies (*Drosophila melanogaster*) provided deeper understanding of heredity based on sex**

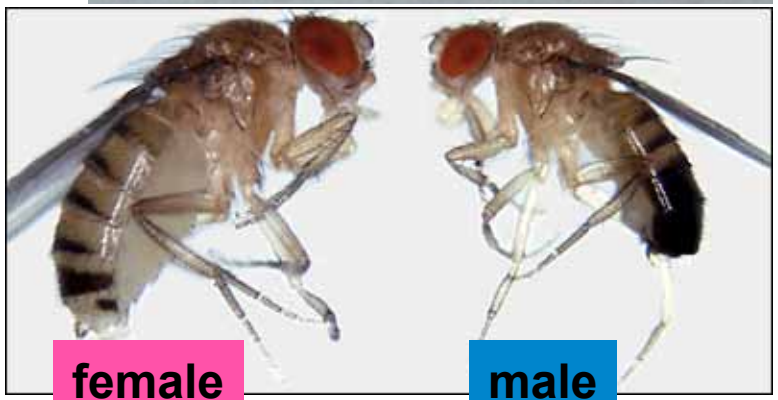
Drosophila melanogaster

OK! WHY FRUIT FLIES?

Good Question!

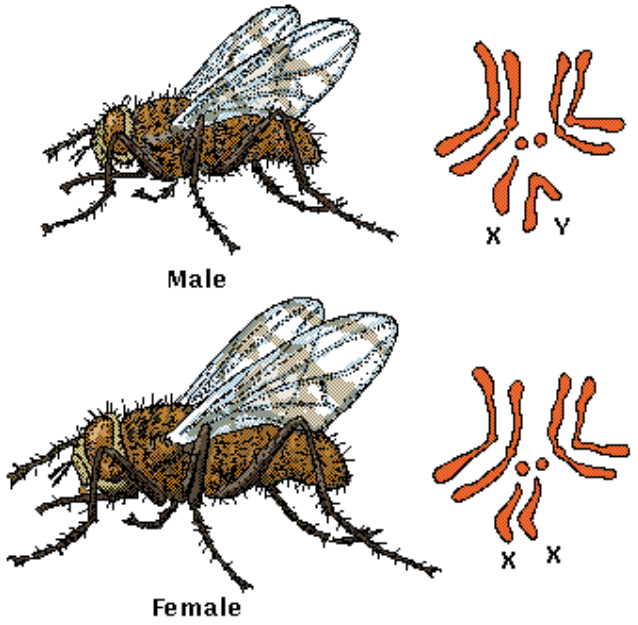
Ideal for genetic experiments for several reasons:

- **Rapid life cycle (10-15 days)**
- **Hundreds of eggs at one time**
- **Crossing experiments can be repeated many times**
- **Offspring mature quickly**
- **Males/females different**
- **Small**
- **Markedly contrasting traits**
- **Only 8 chromosomes (4 pairs)**



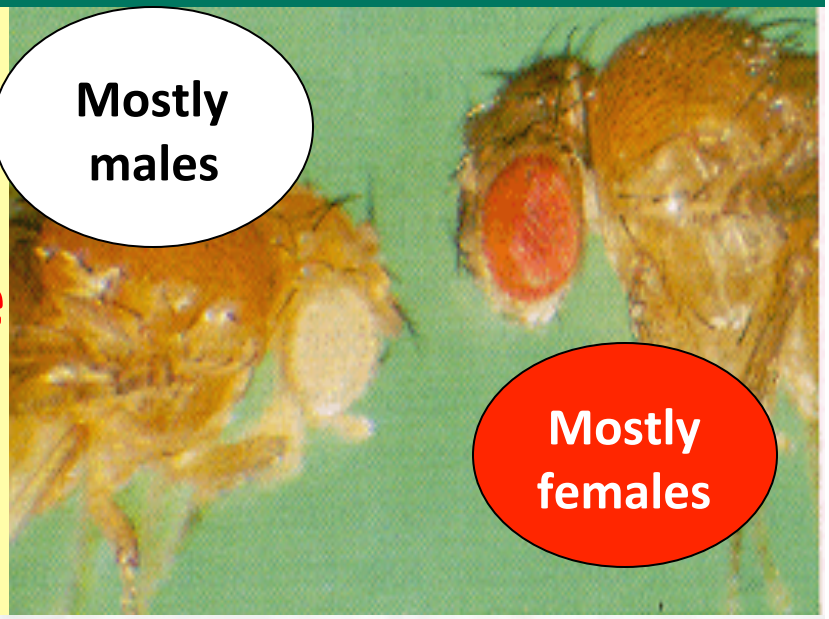
Chromosomes in Fruit Flies

- **Morgan found the following:**
- **Females had 4 homologous pairs of chromosomes:**
  - **3 autosomal pairs, one sex pair (XX)**
- **Males only had 3 homologous pairs:**
  - **3 autosomal pairs**
  - **Sex chromosomes were not homologous**
    - **one X and one Y (XY)**



Eye Color In Drosophila

- **Let R = red, r = white**
- **Assume these alleles are found on the X chromosome only**
- **Let's look at 2 crosses**
  - 1. X^RX^R x X^rY
  - 2. X^RX^r x X^RY



First Cross

1. X^RX^R x X^rY

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

1 : 1

female with RED eyes **male with RED eyes**

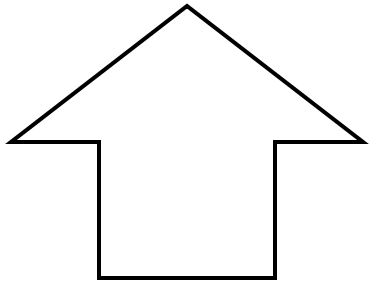
Second Generation (F1 Cross)

2. X^RX^r x X^RY

	X^R	X^r
X^R	$X^R X^R$	$X^R X^r$
Y	X^RY	X^rY

RESULTS

- 2 RED females
- 1 RED male
- 1 WHITE MALE



The white male has NO RED EYE COLOUR which means eye color is sex linked (on the X)

Morgan's Conclusions

- **Genes controlling eye color must be on X Chromosome**
- **Y does not carry gene for eye color**
- **Males cannot be heterozygous for X- linked traits**
  (eg. no X^RY^r or Y^R)

Female	Male
$X^R X^R$	$X^R Y$
$X^R X^r$	$X^r Y$
$X^r X^r$	

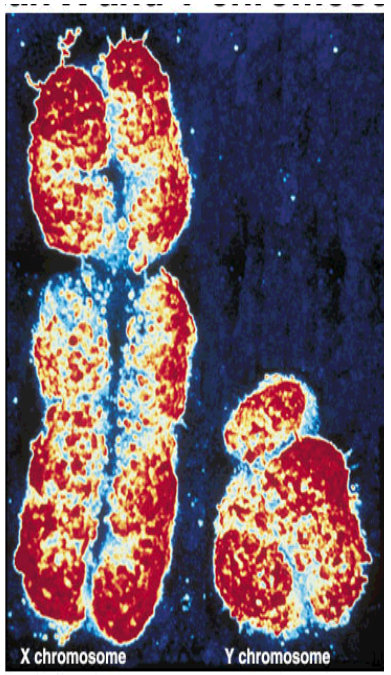
Traits controlled by genes carried on Y chromosome only affect males

Sex-linked traits

Autosomes: chromosomes #1-22

Sex chromosomes : chromosome #23

Sex linked traits are controlled by genes on the sex chromosomes



- Sex-linked traits are almost always on the
  X chromosome
  - Y chromosome is for
    sex determination
- Sex linked traits occur more in males than females because males have only one **X chromosome (what it says, goes…)**

MALE - Sex-linked traits

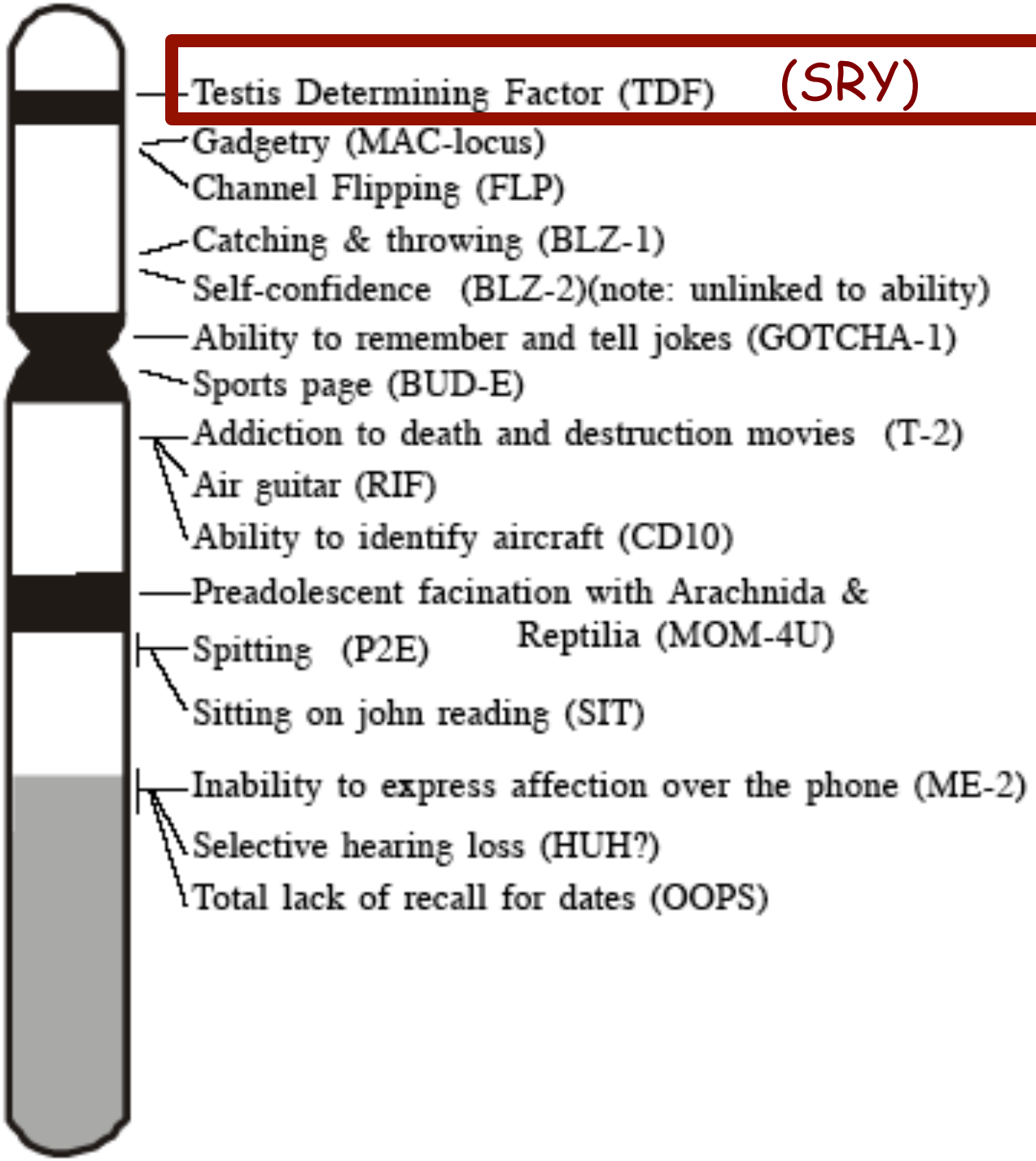
- are either **affected** by x-linked traits, or are **not affected at all**
- can **NEVER** be **carriers**
- **always** inherit their **X-linked traits** from their **MOTHER**

*NOTE: Dad ALWAYS gives sons his **Y** chromosome*

- *The y chromosome is small and contains mostly gender information.*

Possible Map of Male Y chromosome?

SRY-sex determining region on Y



FEMALE - Sex-linked traits

- CAN have dominant/recessive allele interactions on X chromosomes
- CAN be **carriers (heterozygous)**

  (carrier: has the gene but it does not surface)

- always inherit one X from Mom, and one X from dad

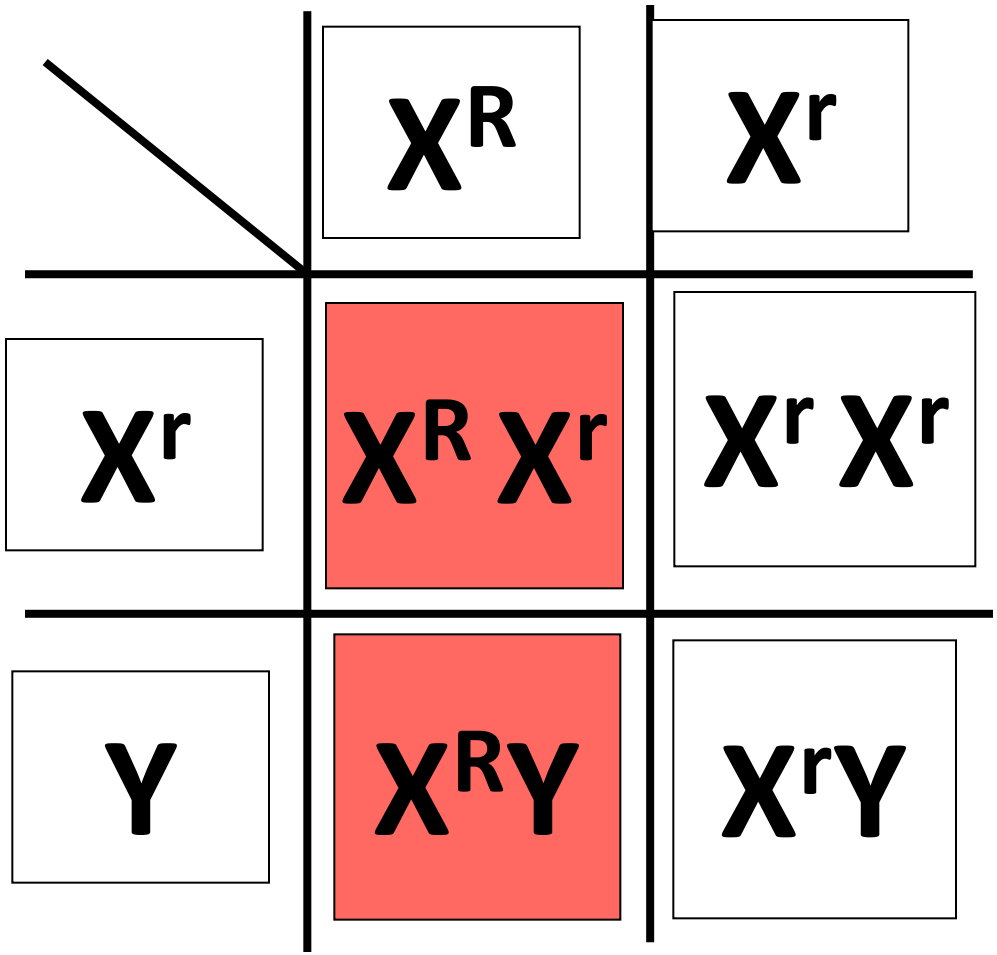
Question: Cross a red eyed female (heterozygous) with a white eyed male.

Legend

Red eye = R
White eye = r
Male = XY
Female = XX

Parent Genotypes

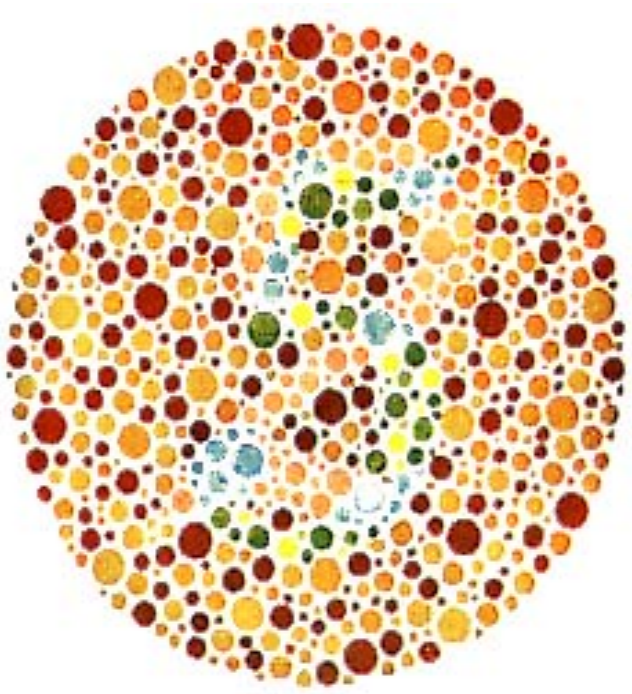
X^RX^r X X^rY



1 Red female, 1 Red male,
1 White female, 1 White male

Examples of Sex-Linkage in Humans

- **Color Blindness**
  - **genes for visual pigments responsible for perception of red and green are found on the X chromosome**



Can you see what number this is?

More colorblind tests

Color blindness in males and females

Caused by gene carried on X only

- **Female Genotypes:**
  - X^NX^N – normal female
  - X^NX^n – carrier female
  - X^nX^n – colorblind female
- **Phenotypes:**
  - Normal or colorblind
- Will the carrier be colorblind?

NO: is a "N"(normal) on genotype

- **Male Genotypes:**
  - X^NY – normal male
  - X^nY – colorblind male
- **Phenotypes:**
  - normal and colorblind
- Can males ever be carriers?

(carrier: has the gene but it does not surface)

NO. BUT: colorblind man can pass color blind gene to daughter "X^n" but not to son as son gets a "Y" from father

Hemophilia

- **Trouble clotting blood**
  - caused by the lack of a blood protein, called Factor VIII, that is critical for blood clotting
  - Gene for Factor VIII

  on X Chromosome
- **Occurs more in boys than girls**

- **Girls: X^hX^h = affected**

  X^HX^h = carriers

  X^HX^H = unaffected
- **Boys: X^hY = affected**

  X^HY = not affected

Other Gender Related Inherited Traits

Sex Limited

- Only expressed in one sex
- Ex. Milk production in cows is controlled by a gene
- Bulls carry the genes...
- But they do not make milk!
- So they do not express the gene

Sex Influenced

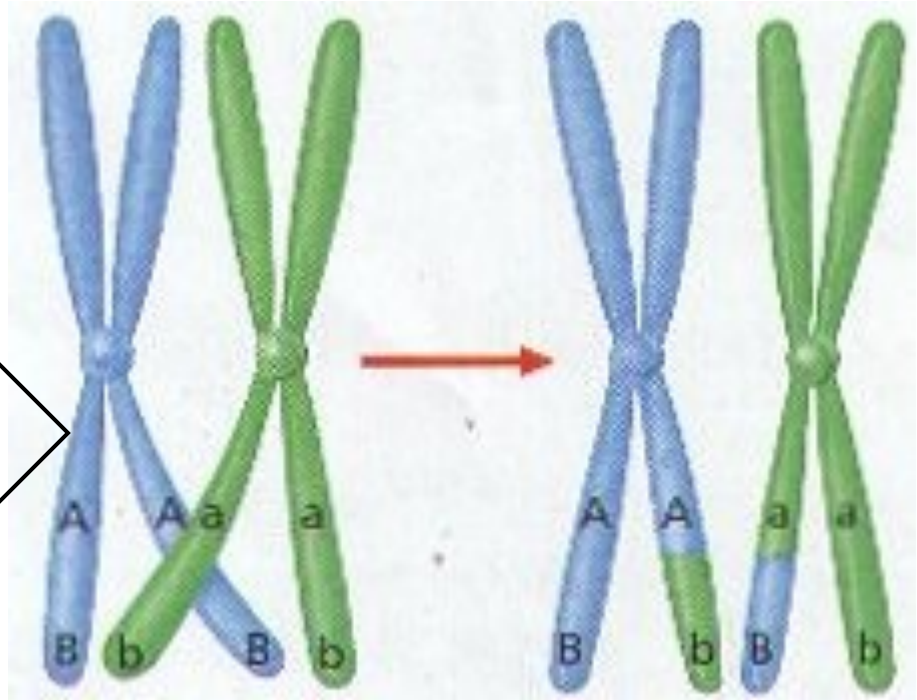
- More common in one sex than the other
- Ex. Baldness is influenced by male hormones
  - testosterone
- Gene is Dominant in males
- Recessive in females
- More common in males

Gene Linkage

- **Linked Genes are genes that are found on the same chromosome are LINKED**
- **Linked genes are inherited TOGETHER.**
- **Genes will NOT separate during meiosis…**

unless…

CROSSING OVER occurs



Linked Genes

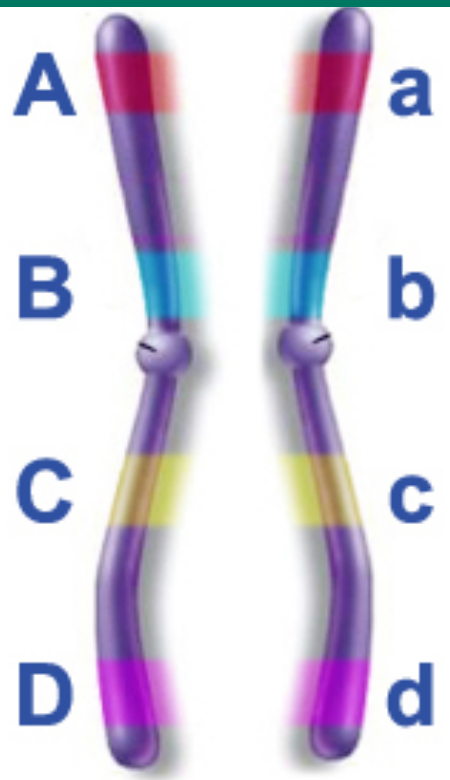
- **Chromosome "13" (first copy):**

  ------a----b----------c----------d

- **Chromosome "13" (second copy):**

  ------A----B----------C----------D

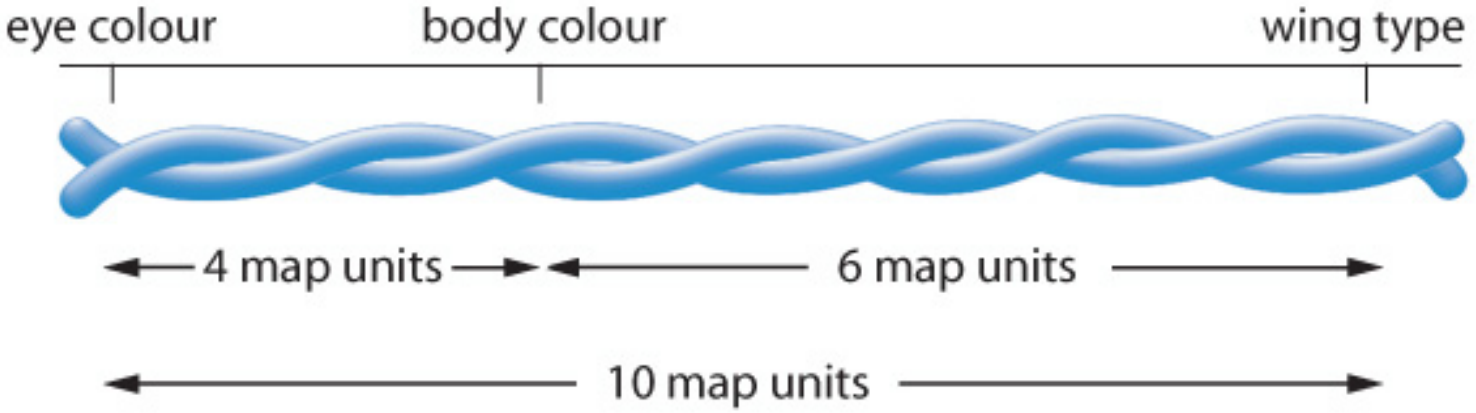
- **When separated during meiosis:**
  - **One gamete gets a,b,c,d**
  - **One gamete gets A,B,C,D**



- **What happens if cross over occurs between B and C?**
  - **One gamete gets a,b,C,D (recombinant)**
  - **One gamete gets A,B,c,d (recombinant)**
- **Finding frequency of recombinants indicates amount of crossing over**

Gene Mapping

- A linear map of genes on a chromosome
- Derived using COF's (Cross Over Frequency)
- Distance affects **Cross over Frequency**
  - Further apart the genes…higher the COF
  - Closer the genes…lower the COF



Bozeman: genetic Recombination and Gene Mapping Video 9:49

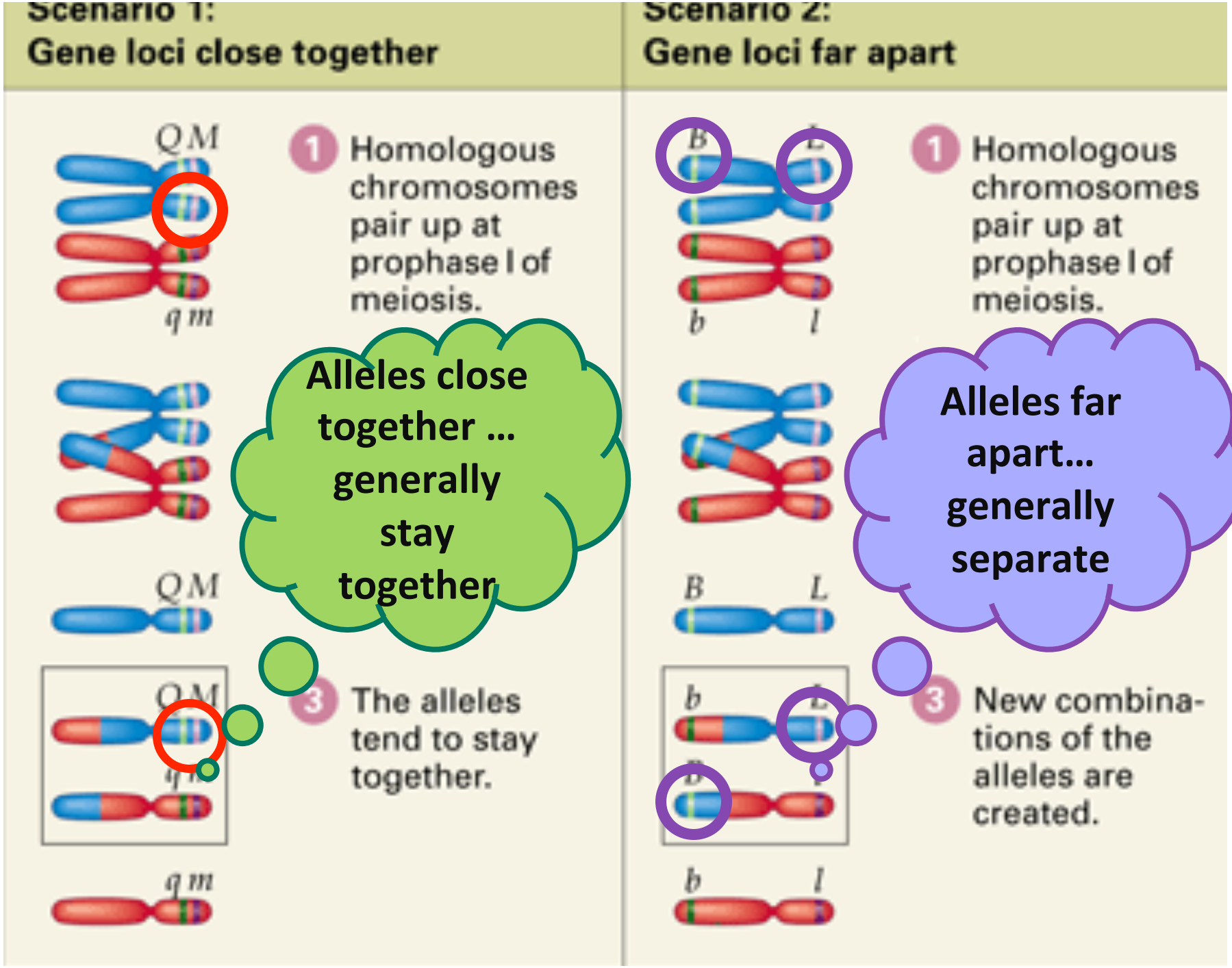
https://www.youtube.com/watch?v=TU44tR0hJ8A

Cross over frequency = Map distance

TAKE HOME MESSAGE:

- **Genes that are further apart:**
  - more likely to cross over (separate)
  - less likely to be inherited together

- **Genes that are closer together:**
  - less likely to cross over (separate)
  - more likely to be inherited together


Scenario 1:
Gene loci close together
Scenario 2:
Gene loci far apart
Q M
q m
1 Homologous chromosomes pair up at prophase I of meiosis.
Alleles close together … generally stay together
3 The alleles tend to stay together.
B L
b l
Alleles far apart… generally separate
3 New combinations of the alleles are created.

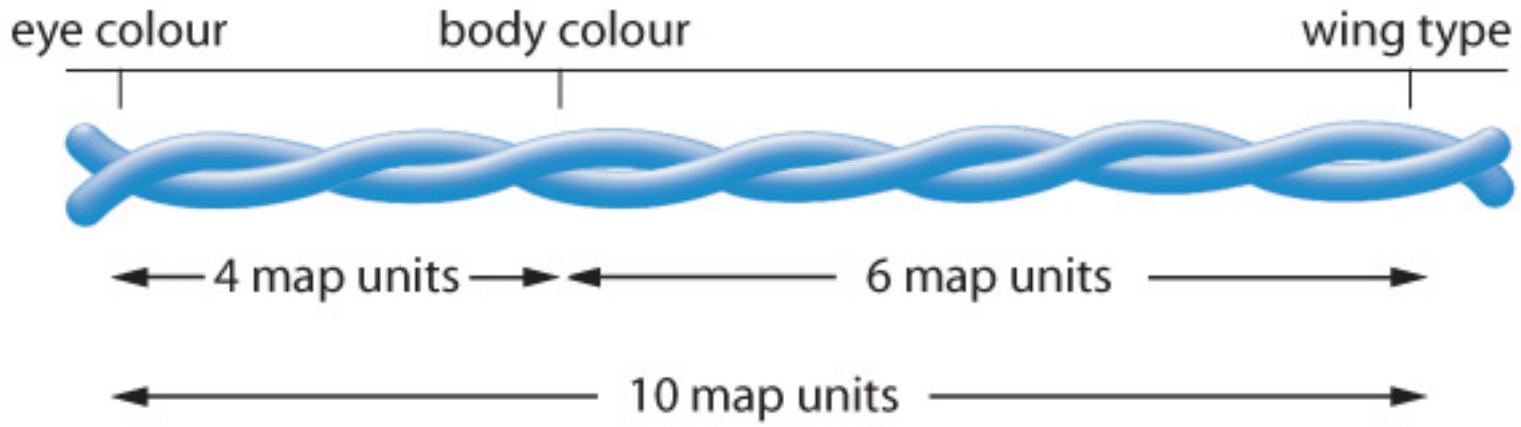
Gene Mapping

- **Cross over frequency can be expressed in map units**

-1% crossing over = 1 map unit -50% crossing over = 50 map units

The larger the map unit the more common (higher frequency) that crossing over occurs thus <u>genes are further apart on chromosome</u>

(eg) two genes crossover percentage of 1%(1 map unit) are closer together than two genes of 12%(12 map units)

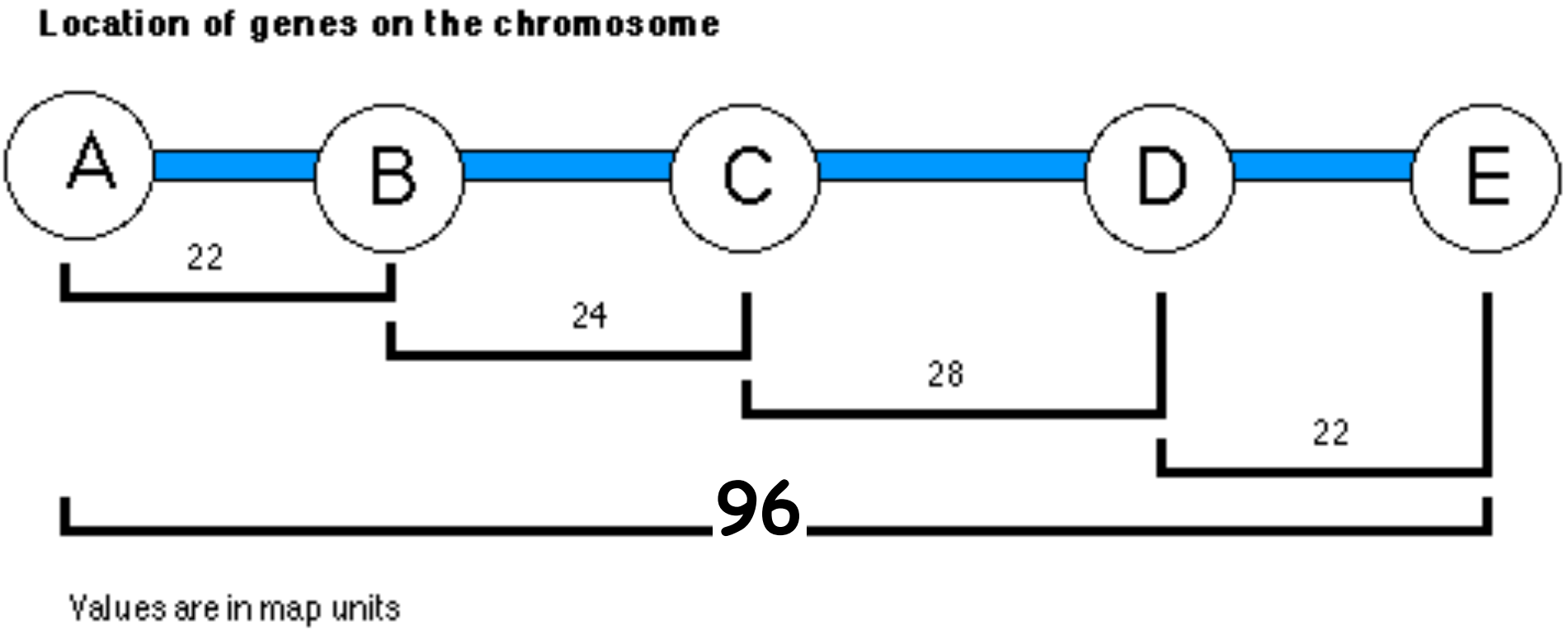


Gene Mapping

1 rule for chromosome mapping:

START WITH THE GENES THAT ARE FURTHEST APART.

Chromosome Map

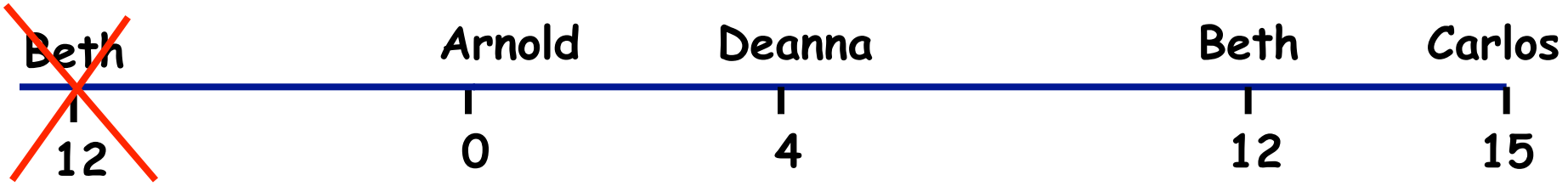


How far apart are genes B and E? 24+28+22=74mu

The Houses on Main Street

- Arnold lives 12 doors away from Beth
- Carlos lives 11 doors away from Deanna
- Beth lives 3 doors away from Carlos
- Arnold lives 4 doors away from Deanna and 15 away from Carlos

In what order are the houses on the street?



- **T. H. Morgan collected the following cross over frequencies from data with *Drosopila.***

  B = bar shaped eyes.

  C = carnation eyes.

  FV = fused veins.

  S = scalloped winged.

They are all on the same chromosome.

FV/B = 2.5% ✓

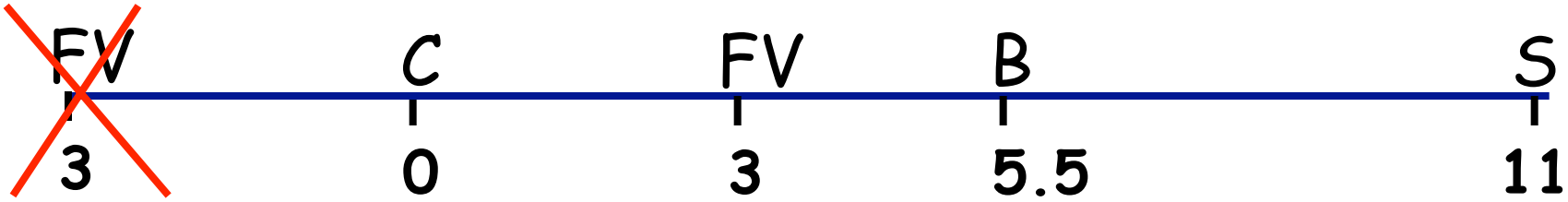
FV/C = 3% ✓

B/C = 5.5% ✓

FV/S = 8% ✓

C/S = 11% ✓

Use the crossover frequencies to plot a gene map.



Construct a Chromosome Map Using the Following COF's

- WX = 5 ✓
- XY = 2 ✓
- YW = 7 ✓
- ZW = 8 ✓
- YZ = 1 ✓