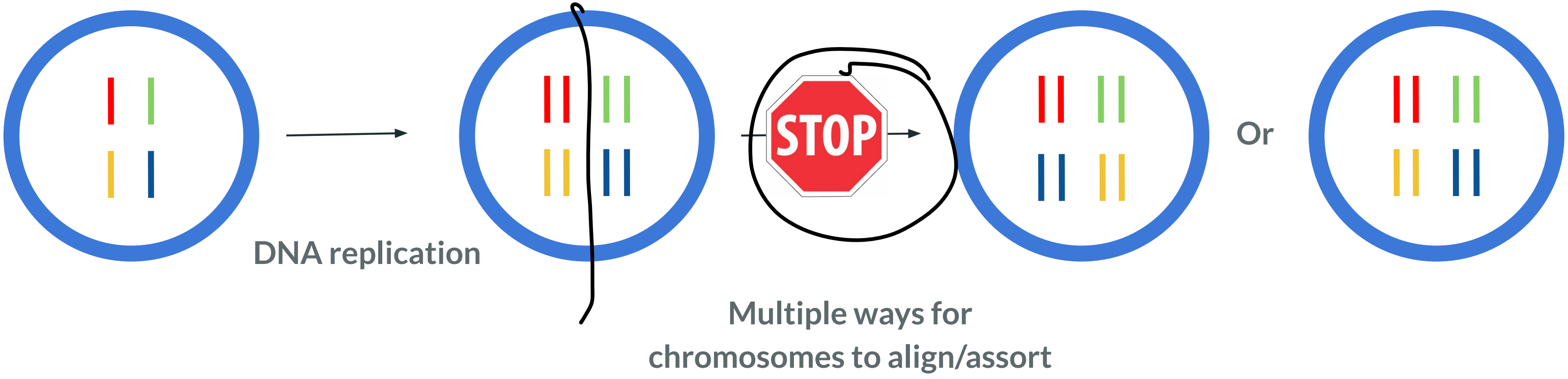
Genetics: Meiosis II

BMC Spring ‘23

Beginners I

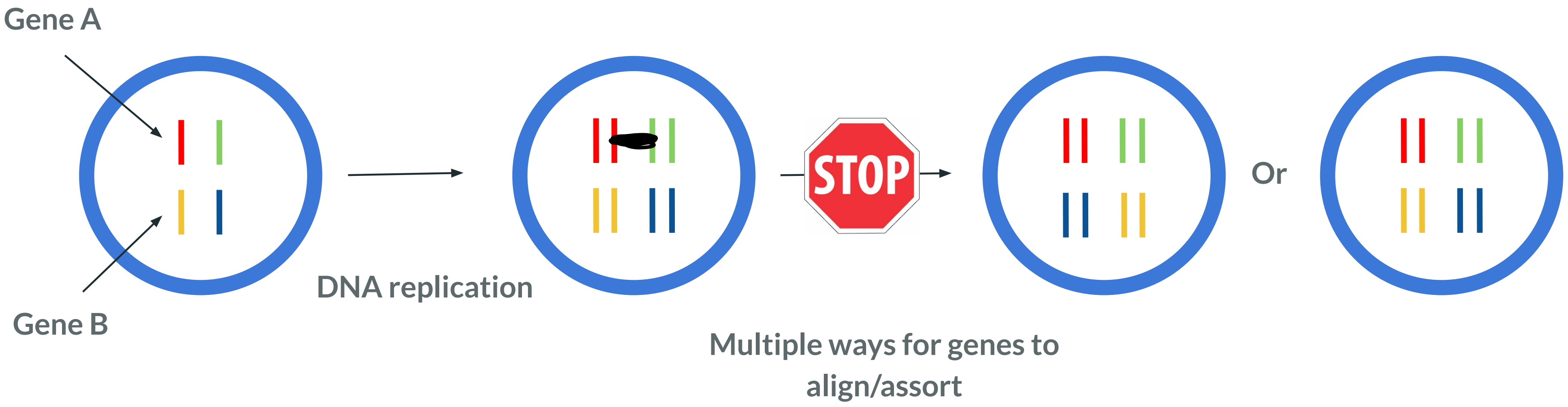
Selena Ding

Meiosis with two pairs of homologous chromosomes



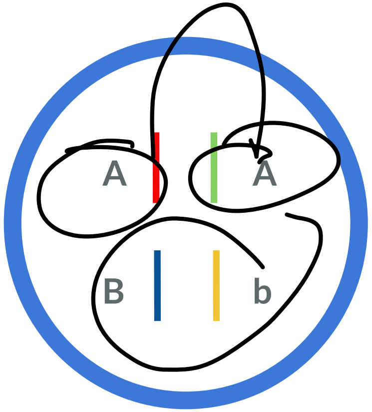
Assortment of different pairs of homologous chromosomes are <u>independent</u> of each other

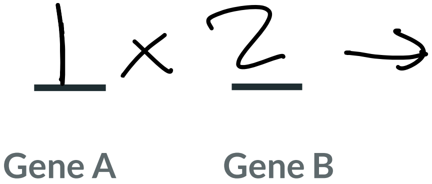
Unlinked genes



Assortment of different pairs of homologous chromosomes are <u>independent</u> of each other

Calculating combinations of daughter cells: heterozygosity v. homozygosity





Linked Genes and Homologous recombination

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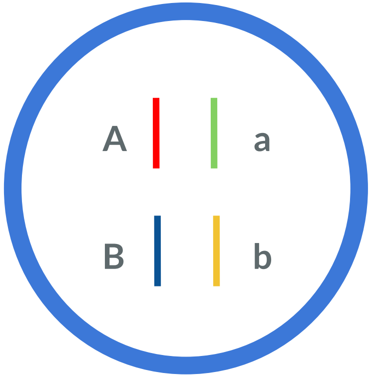
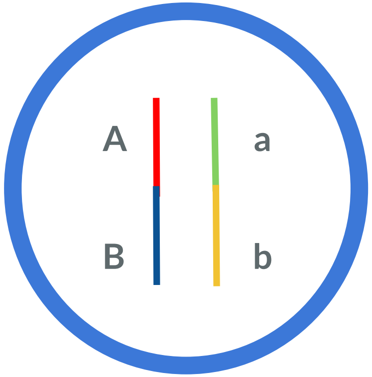
Linked genes v. unlinked genes



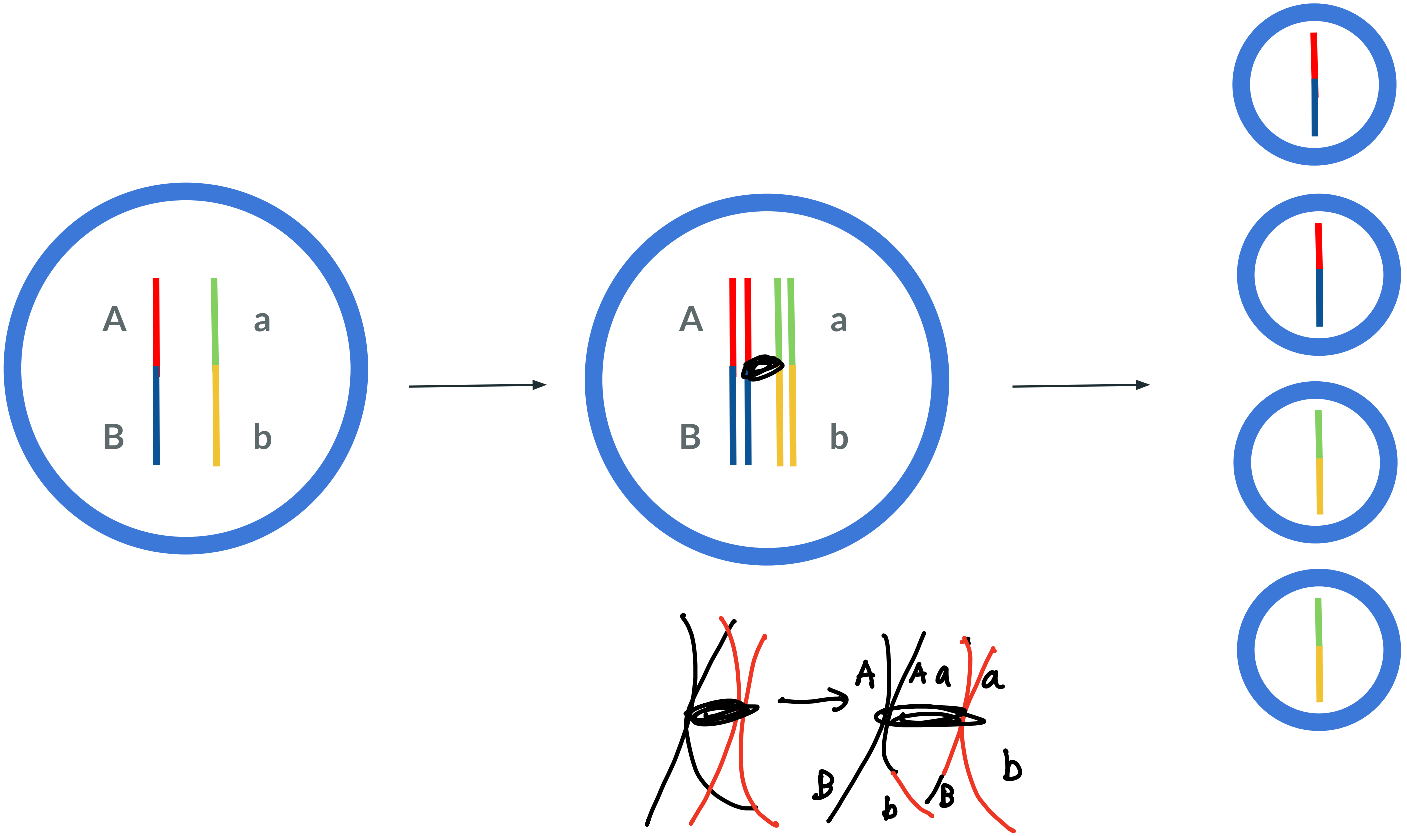
Unlinked genes



Linked genes – genes that are on the same chromosome

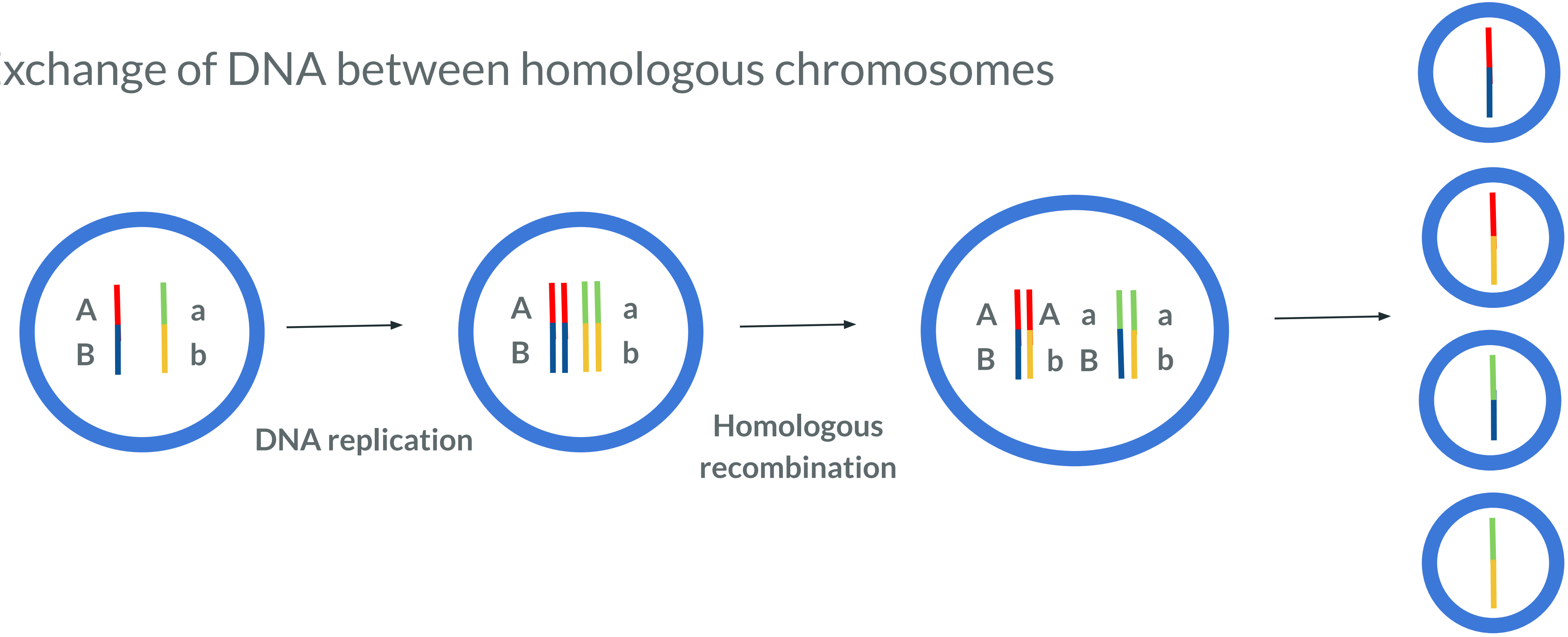
For unlinked genes, the genes no longer sort out independently

Possible daughter cells with linked genes



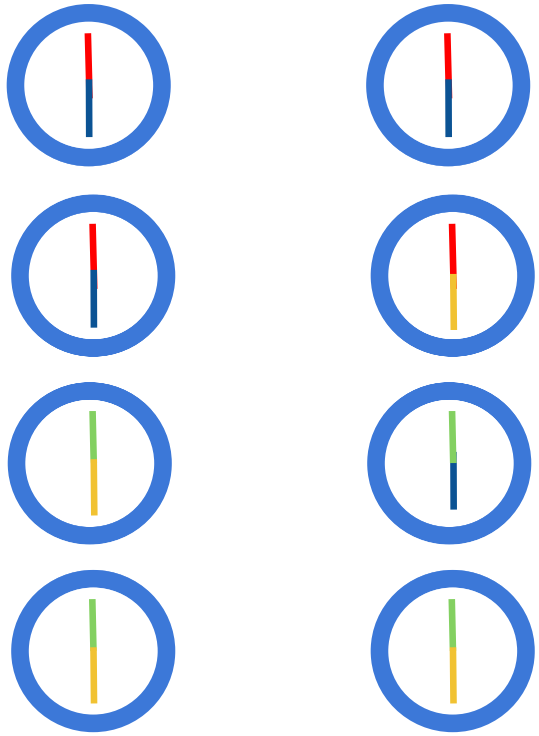
Homologous recombination

Exchange of DNA between homologous chromosomes



Recombination v. no recombination

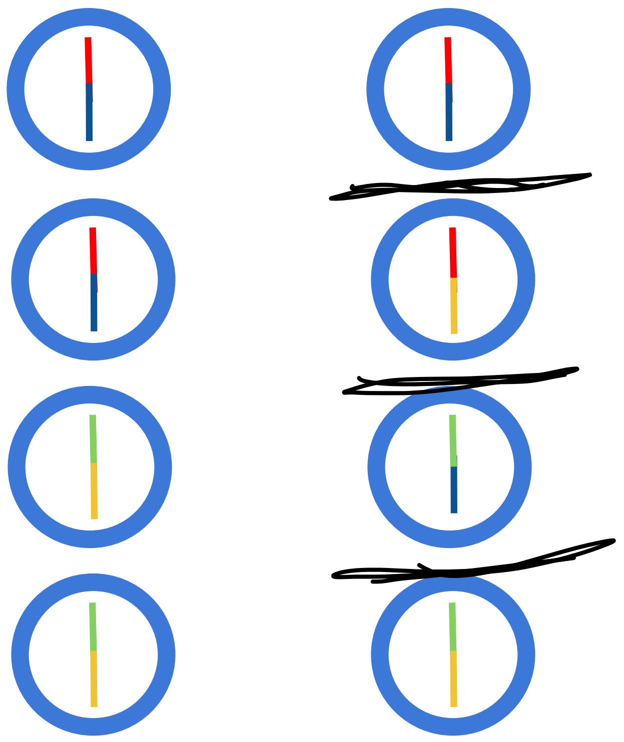
No homologous recombination



Homologous recombination

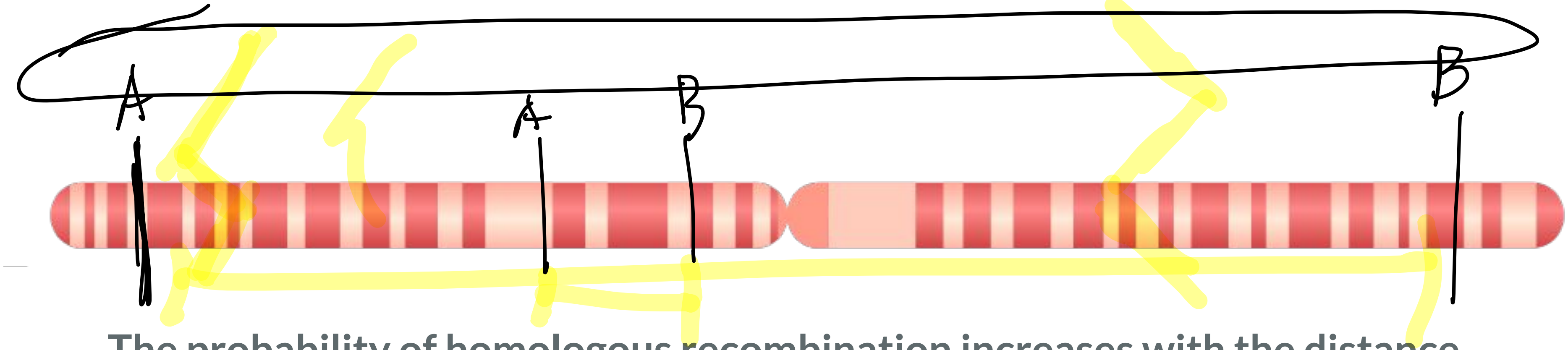
Recombination v. no recombination

Homologous recombination does not always occur



No homologous recombination

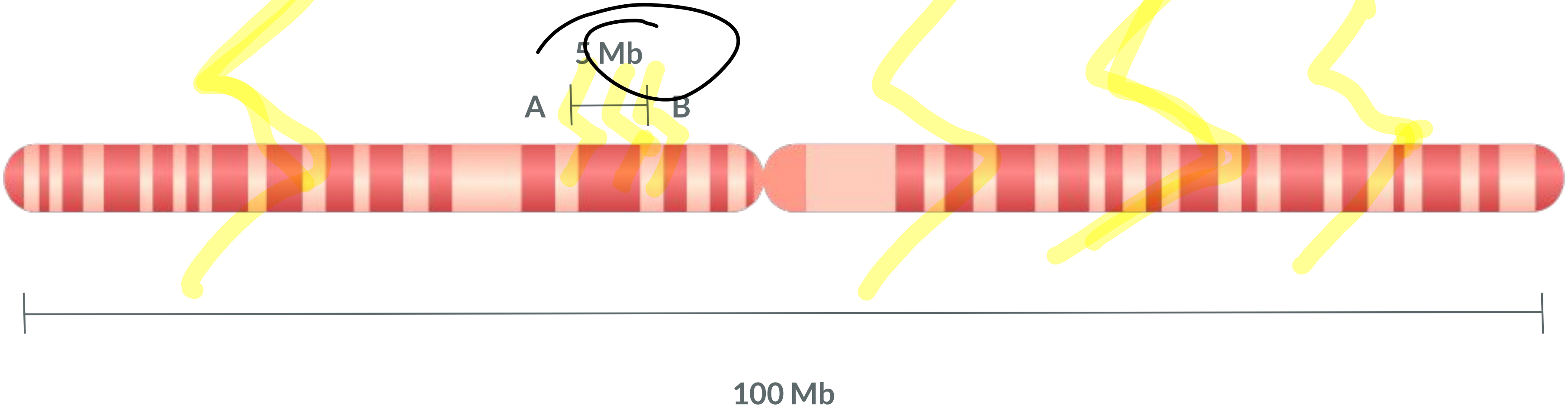
Finding probability of producing a daughter cell: Recombination events as function of length of chromosome



The probability of homologous recombination increases with the distance between the two genes

Making assumption that any place on the chromosome has an equal chance of undergoing recombination.

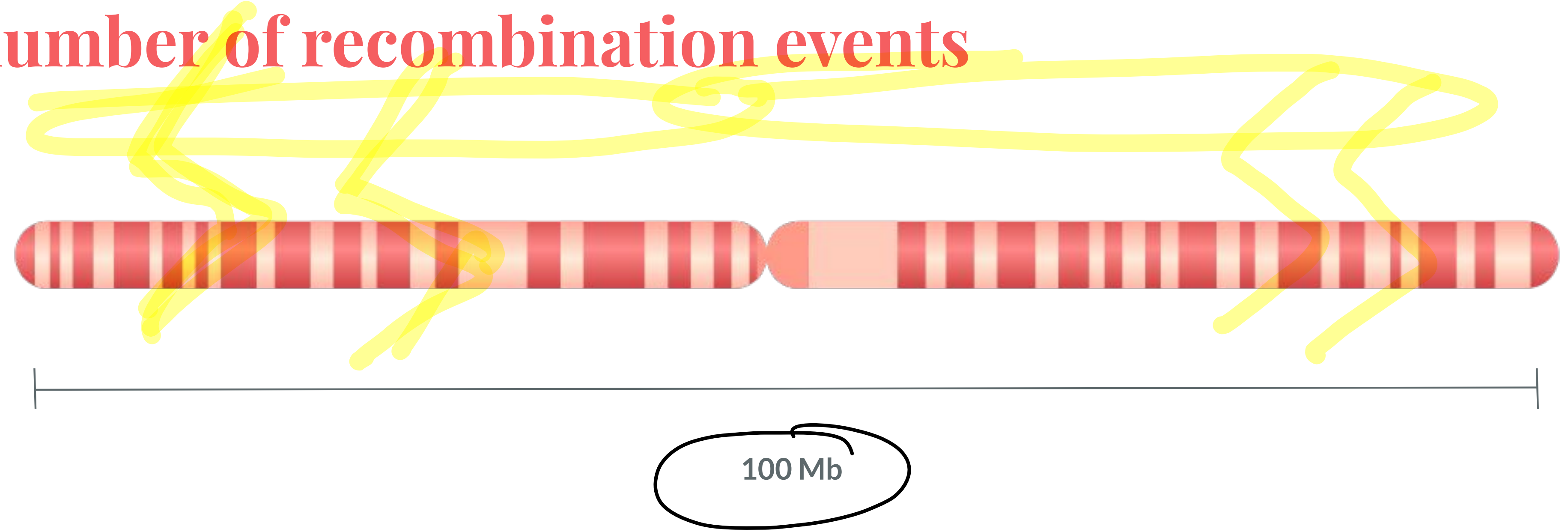
Finding probability of producing a daughter cell: probability of recombination between two genes



Mb = unit of measurement along a chromosome

Probability of recombination between A and B = $\frac{5}{100} = \frac{1}{20}$

Finding probability of producing a daughter cell: number of recombination events



In males: there is one crossover event per homologous pair + additional crossover events per 100 Mb

$1 + 100/100 \rightarrow 2$

In females: there is one crossover event per homologous pair + additional crossover events per 50 Mb

$1 + 100/50 \rightarrow 3$

Finding probability of producing a daughter cell: putting it all together

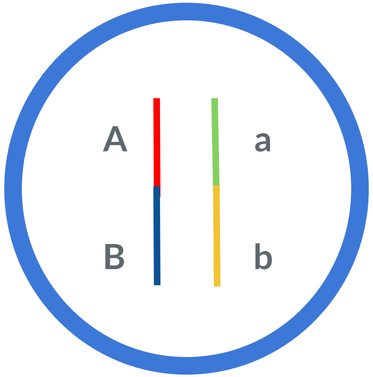
Let's say we had a male whose chromosome was 200 Mb long, and Genes A and B are 50 Mb apart

How many recombination events will occur?

$$1 + \frac{200}{100} = \boxed{3}$$

What is the probability that 1 recombination event occurs between Genes A and B?

$$\frac{50}{200} \rightarrow \frac{1}{4}$$



Finding probability of producing a daughter cell: putting it all together

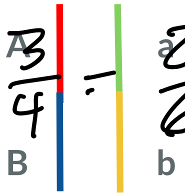
Let's say we had a male whose chromosome was 200 Mb long, and Genes A and B are 50 Mb apart

What is the probability that none of the _3_ recombination events on this chromosome occurs between Genes A and B?

For one recombination event to not occur between A+B = 75% probability

2 recomb events: $\frac{3}{4} \times \frac{3}{4} \rightarrow \frac{9}{16}$

3 events: $\frac{3}{4} \times \frac{3}{4} \times \frac{3}{4} = \frac{27}{64}$



~~What is the probability that at least one of the _3_ recombination event occurs between Genes A and B?~~

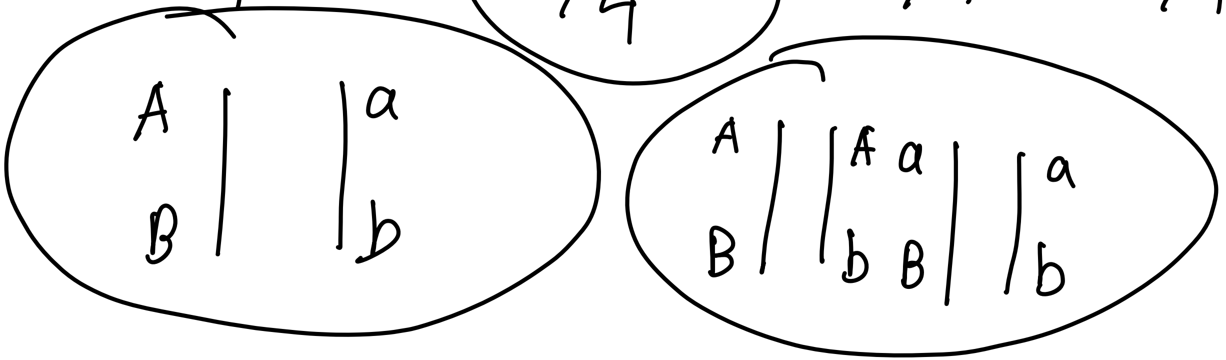
$\binom{3}{3}$ $\binom{3}{1}$

$\left(\frac{1}{4}\right)\left(\frac{3}{4}\right)\left(\frac{3}{4}\right) + \left(\frac{1}{4}\right)\left(\frac{1}{4}\right)\left(\frac{3}{4}\right) + \left(\frac{1}{4}\right)\left(\frac{1}{4}\right)\left(\frac{1}{4}\right) \rightarrow \frac{37}{64}$

$1 - \frac{27}{64} = \frac{37}{64}$

Probability of producing a daughter cell GIVEN recombination occurs or does not occur

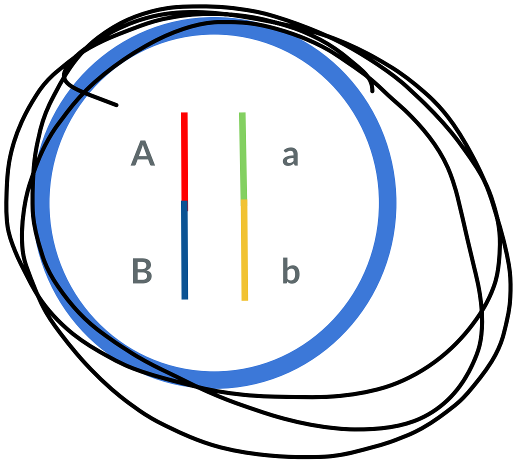
Number of recombination events	Parental 1	Parental 2	Recombinant 1	Recombinant 2
	AB	ab	Ab	aB
0	1/2	1/2		
1	1/4	1/4	1/4	1/4



Finding probability of producing a daughter cell: putting it all together

Let's say we had a male whose chromosome was 200 Mb long, and Genes A and B are 2[illegible] 50 Mb apart

What is the probability that we produce a daughter cell with Ab chromosomes?



Do we need a recombination event to occur?

Yes

Given one or more recombination events occur, what is the probability of producing daughter cells with the Ab chromosome?

$\frac{1}{4}\left(\frac{37}{64}\right) = \frac{37}{256}$

What is the probability that we produce a daughter cell with Ab chromosomes?

Finding probability of producing a daughter cell: putting it all together

Let's say we had a male whose chromosome was 200 Mb long, and Genes A and B are 25 Mb apart

What is the probability that we produce a daughter cell with AB chromosomes?

Recombination happens:

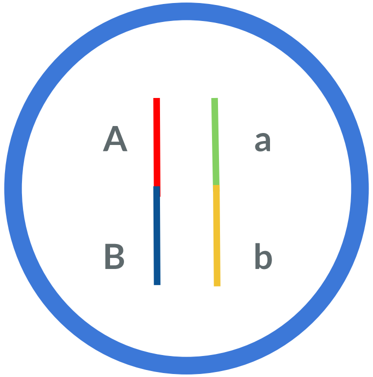
¼ (37/64) = 37/256

Recombination does NOT occur:

½ (27/64) = 27/128

Overall probability:

37/256 + 27/128 = 91/256



Probability of producing a daughter cell GIVEN recombination occurs or does not occur

Number of recombination events	Probability of producing daughter cell with ___ chromosomes			
	AB	ab	Ab	aB
0	$\frac{1}{2} (\frac{3}{4})^3$	$\frac{1}{2} (\frac{3}{4})^3$	0	0
1 or more	$\frac{1}{4} [1- (\frac{3}{4})^3]$	$\frac{1}{4} [1- (\frac{3}{4})^3]$	$\frac{1}{4} [1- (\frac{3}{4})^3]$	$\frac{1}{4} [1- (\frac{3}{4})^3]$
Total probability	0.35546875	0.35546875	0.14453125	0.14453125

In order to get the AB gene combination for the example we did in class (male chromosomes, 200 Mb, genes A and B 50 Mb apart) we have to consider 2 cases: recombination occurs, or recombination does not occur.
If recombination occurs, then the probability of picking AB out of AB, Ab, aB, and ab is ¼. The probability that at least one recombination were to even happen is 37/64. We multiply ¼ x 37/64 to get the probability of recombination even occurring and picking AB if recombination does occur.
If recombination does NOT occur, the probability of getting AB in the daughter cell is ½ because we can only get AB or ab. The probability of NO crossover event occurring between the two genes is 2/64. We multiply ½ x 27/64 to get the probability of recombination NOT occurring and picking AB if recombination does NOT occur.
The overall probability of picking AB if crossover DOES or DOES NOT is ½ x 27/64 + ¼ x 37/64.

This same process is followed for gene combination ab.

For aB and Ab, these gene combinations can only be possible if