

## LECTURE PRESENTATIONS

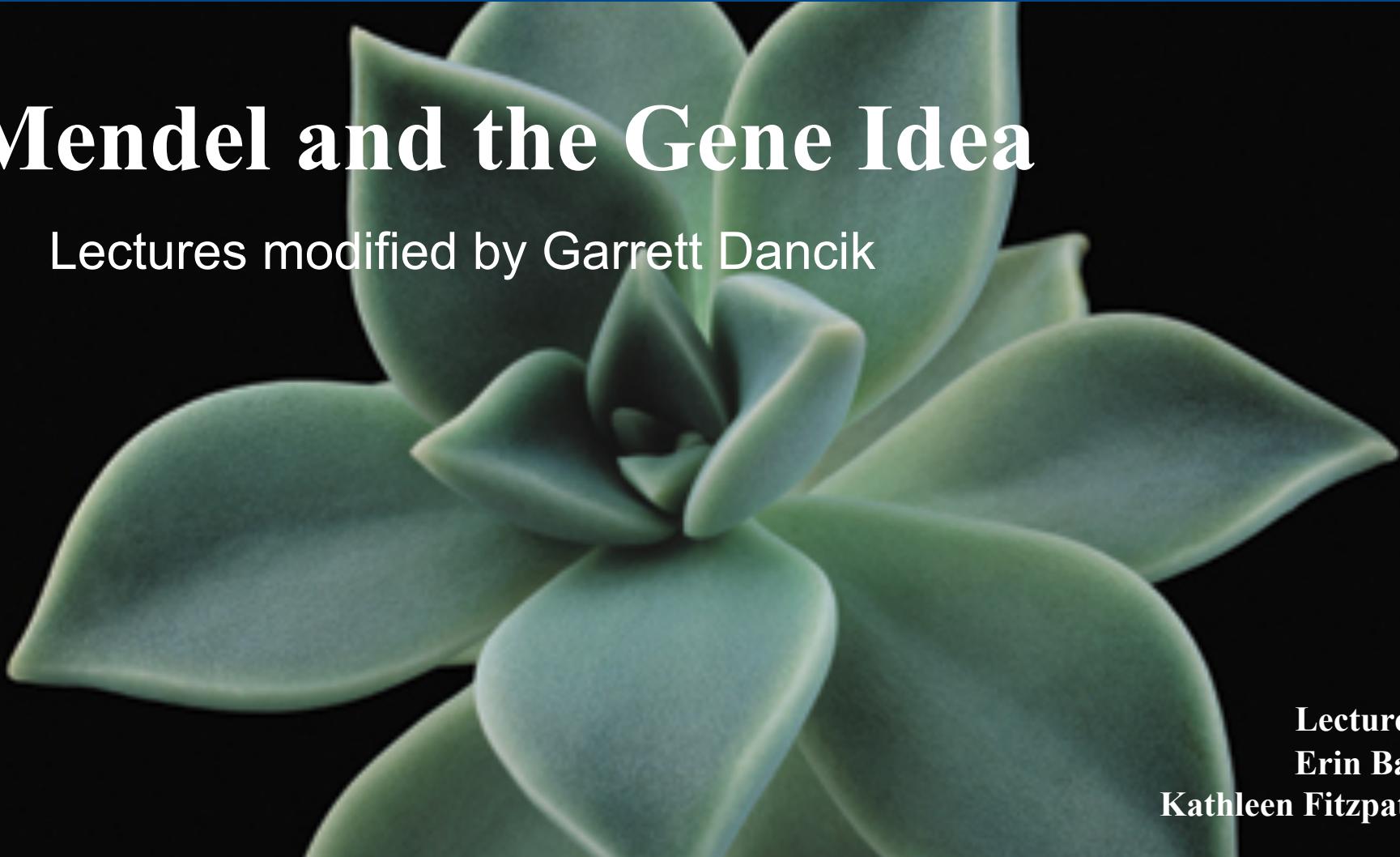
For CAMPBELL BIOLOGY, NINTH EDITION

Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

# Chapter 14

## Mendel and the Gene Idea

Lectures modified by Garrett Dancik



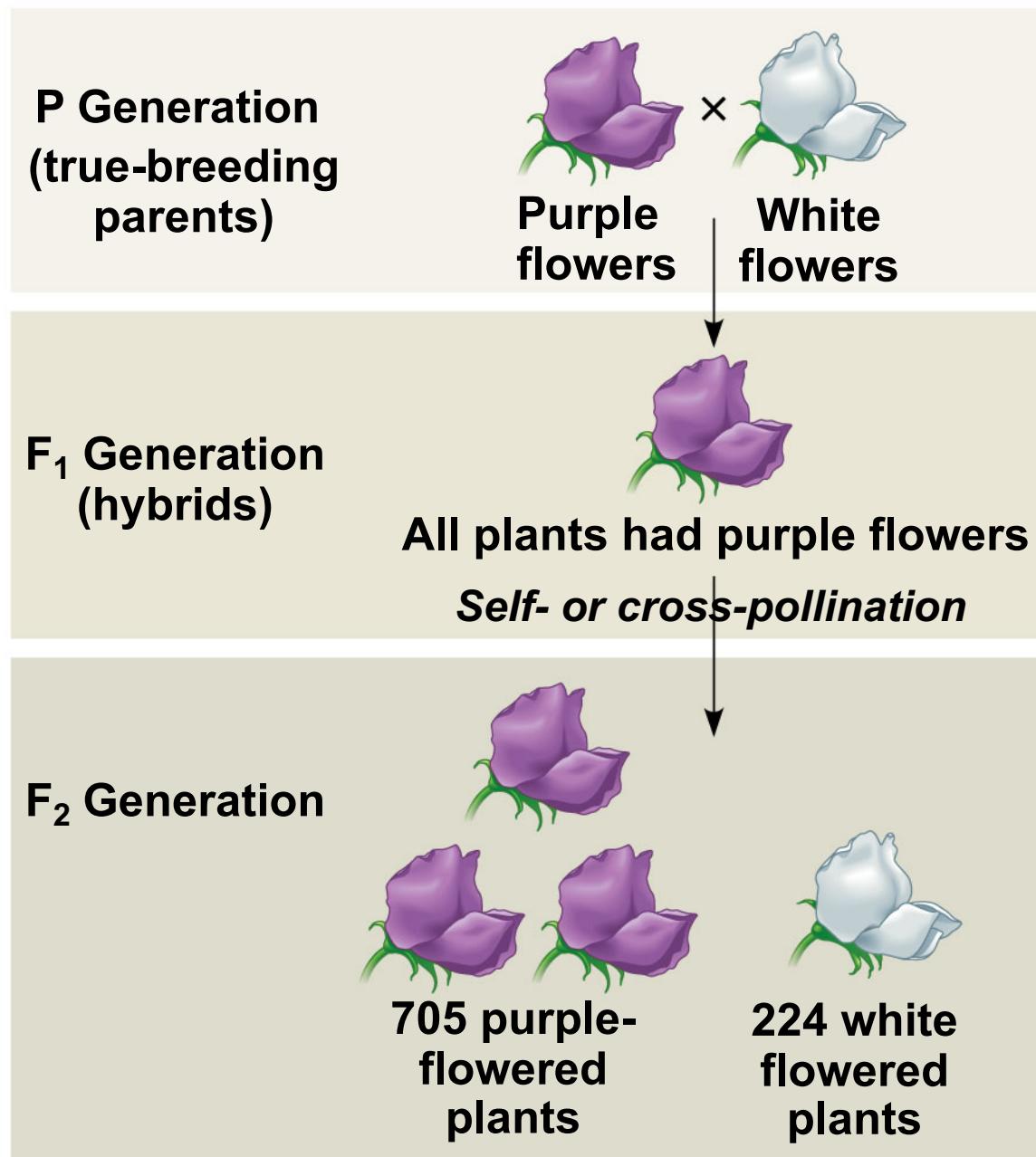
Lectures by  
Erin Barley  
Kathleen Fitzpatrick

# Mendel's Experiments

- Mendel discovered the basic principles of heredity by breeding garden peas in carefully planned experiments
- In a typical experiment, Mendel mated two contrasting, true-breeding varieties, a process called **hybridization**
- The true-breeding parents are the **P generation**
- The hybrid offspring of the P generation are called the **F<sub>1</sub> generation**
- When F<sub>1</sub> individuals self-pollinate or cross-pollinate with other F<sub>1</sub> hybrids, the **F<sub>2</sub> generation**

Figure 14.3-3

## EXPERIMENT



- Mendel reasoned that only the purple flower factor was affecting flower color in the  $F_1$  hybrids
- Mendel called the purple flower color a dominant trait and the white flower color a recessive trait
- The factor for white flowers was not diluted or destroyed because it reappeared in the  $F_2$  generation

Table 14.1

- Mendel observed the same pattern of inheritance in six other pea plant characters, each represented by two possible traits
- What Mendel called a “heritable factor” is what we now call a gene

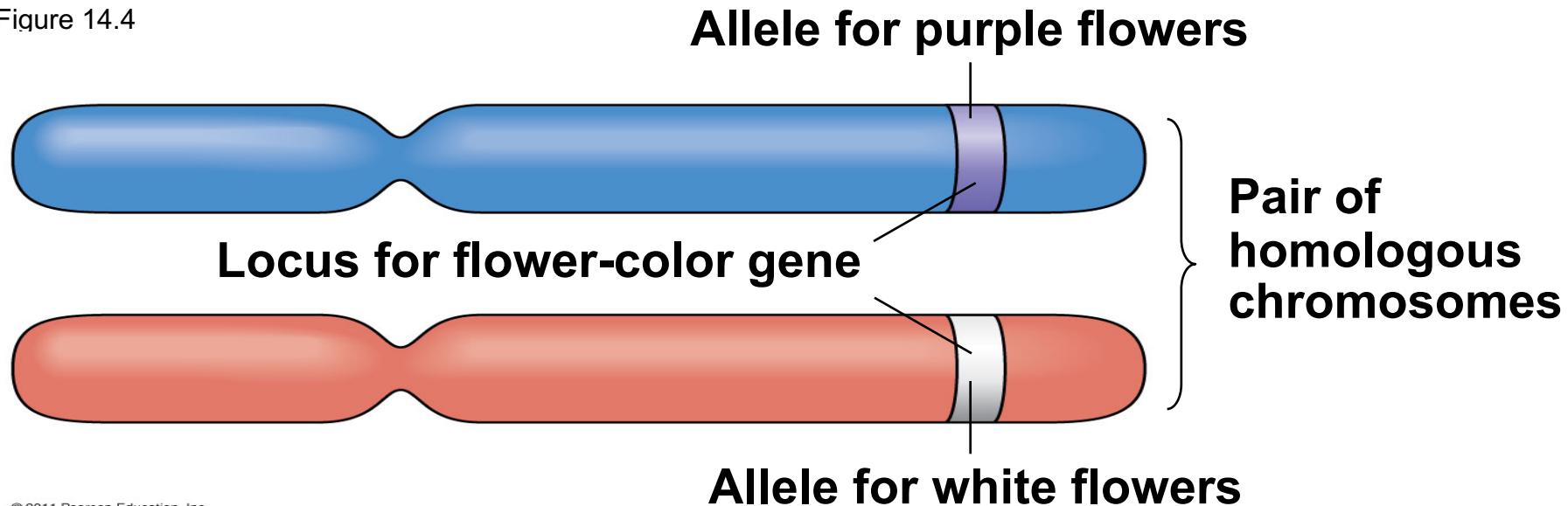
**Table 14.1** The Results of Mendel’s F<sub>1</sub> Crosses for Seven Characters in Pea Plants

Character	Dominant Trait	×	Recessive Trait	F <sub>2</sub> Generation Dominant:Recessive	Ratio
Flower color	Purple	×	White	705:224	3.15:1
					
Flower position	Axial	×	Terminal	651:207	3.14:1
					
Seed color	Yellow	×	Green	6,022:2,001	3.01:1
					
Seed shape	Round	×	Wrinkled	5,474:1,850	2.96:1
					
Pod shape	Inflated	×	Constricted	882:299	2.95:1
					
Pod color	Green	×	Yellow	428:152	2.82:1
					
Stem length	Tall	×	Dwarf	787:277	2.84:1
					

# *Mendel's Model*

- Mendel developed a hypothesis to explain the 3:1 inheritance pattern he observed in  $F_2$  offspring
- Four related concepts make up this model
- These concepts can be related to what we now know about genes and chromosomes

Figure 14.4



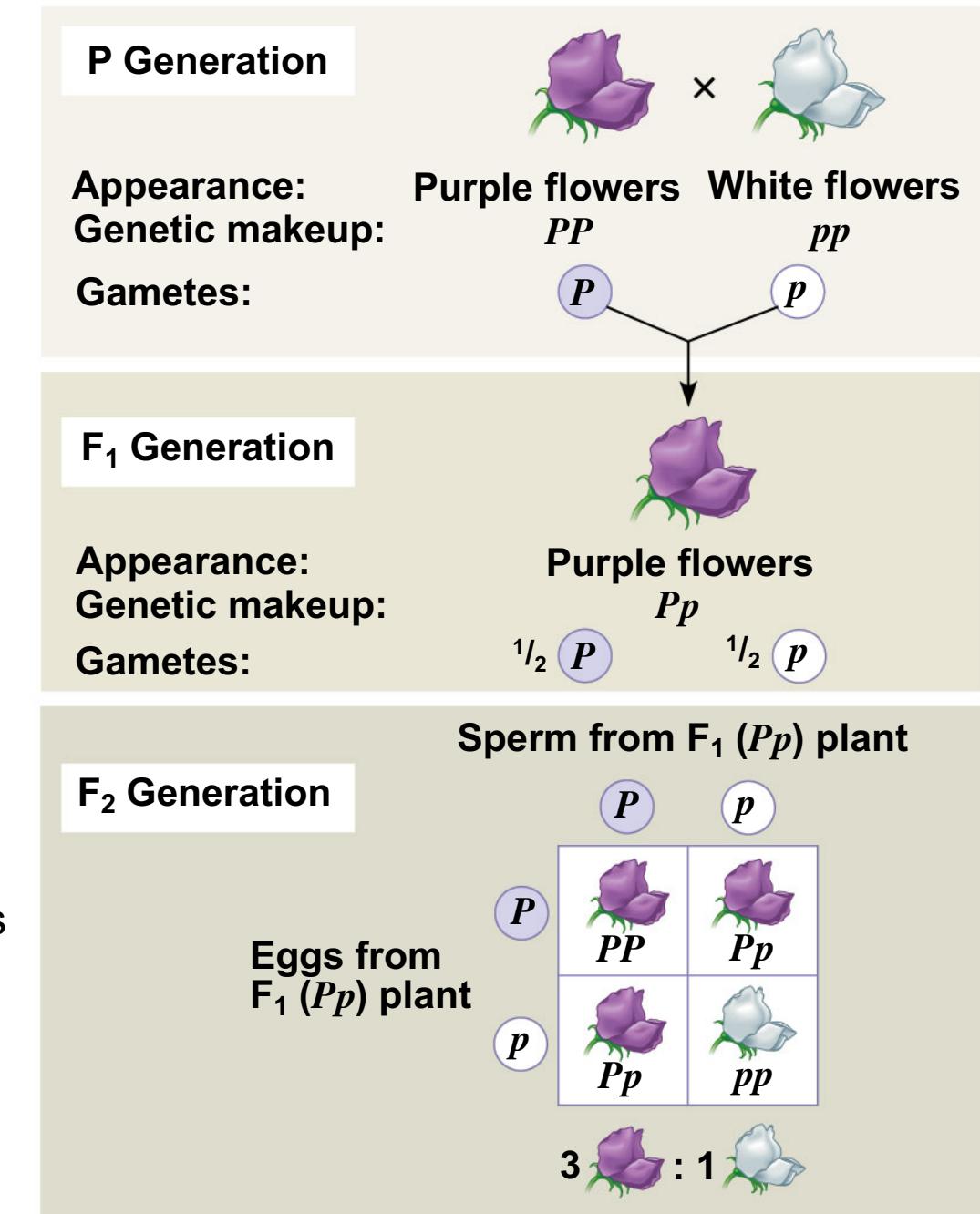
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## Mendel's model

1. Alternative versions (alleles) of hereditary factors (genes) account for variability in inherited traits
2. An organism inherits two alleles, one from each parent
3. If two alleles differ, then the trait is determined by the *dominant* allele; the *recessive* allele has no effect on appearance
4. the two alleles for a heritable character separate (segregate) during gamete formation and end up in different gametes (this is now known as the **law of segregation**)
5. Alleles for separate genes are passed independently of each other (this is now known as the law of **independent assortment** – more on this later)

Figure 14.5-3

- A capital letter denotes the dominant allele while lowercase denotes a recessive allele



# *Useful Genetic Vocabulary*

- An organism with two identical alleles for a character is said to be **homozygous** for the gene controlling that character
- An organism that has two different alleles for a gene is said to be **heterozygous** for the gene controlling that character
- We distinguish between an organism's **phenotype**, or physical appearance, and its **genotype**, or genetic makeup

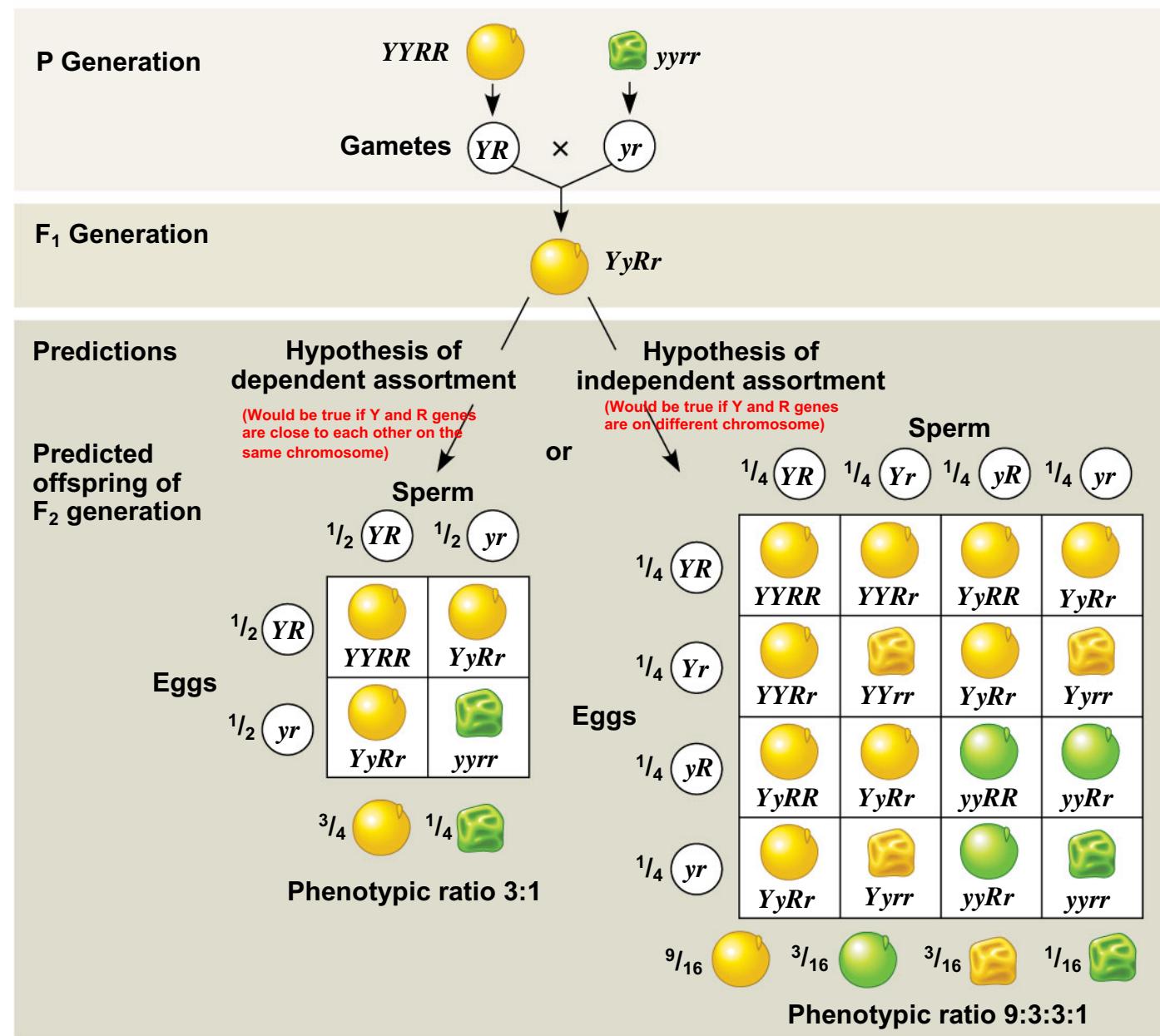
# The Law of Independent Assortment

- Mendel derived the law of segregation by following a single character
- The  $F_1$  offspring produced in this cross were **monohybrids**, individuals that are heterozygous for one character
- A cross between such heterozygotes is called a **monohybrid cross**

# Question

- Mendel identified his second law of inheritance by following two characters at the same time
- Crossing two true-breeding parents differing in two characters produces **dihybrids** in the  $F_1$  generation, heterozygous for both characters
- A **dihybrid cross**, a cross between  $F_1$  dihybrids, can determine whether two characters are transmitted to offspring as a package or independently

Figure 14.8

**EXPERIMENT****RESULTS**

315

108

101

32

Phenotypic ratio approximately 9:3:3:1

- Using a dihybrid cross, Mendel developed the **law of independent assortment**
- The law of independent assortment states that each pair of alleles segregates independently of every other pair of alleles during gamete formation (sperm/egg cells of a  $YyRr$  individual will contain *either*  $YR$  or  $yR$ )
- Strictly speaking, this law applies only to genes on different, nonhomologous chromosomes or those far apart on the same chromosome
- Genes located near each other on the same chromosome tend to be inherited together

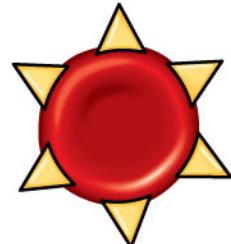
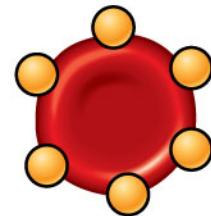
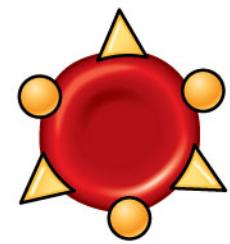
# Concept 14.3: Inheritance patterns are often more complex than predicted by simple Mendelian genetics

- The relationship between genotype and phenotype is rarely as simple as in the pea plant characters Mendel studied
- Many heritable characters are not determined by only one gene with two alleles
- However, the basic principles of segregation and independent assortment apply even to more complex patterns of inheritance
- For example, ABO blood typing is determined by three alleles and is an example of *codominance*

**(a) The three alleles for the ABO blood groups and their carbohydrates**

Allele	$I^A$	$I^B$	$i$	
Carbohydrate	A 	B 	none	
Genotype	$I^A I^A$ or $I^A i$	$I^B I^B$ or $I^B i$	$I^A I^B$	$i i$

**(b) Blood group genotypes and phenotypes**

Genotype	$I^A I^A$ or $I^A i$	$I^B I^B$ or $I^B i$	$I^A I^B$	$i i$
Red blood cell appearance				
Phenotype (blood group)	A	B	AB	O

# Nature and Nurture: The Environmental Impact on Phenotype

- Example: hydrangea flowers of the same genotype range from blue-violet to pink, depending on soil acidity



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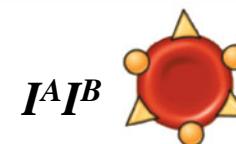


# Genetic Testing and Counseling

- Genetic counselors can provide information to prospective parents concerned about a family history for a specific disease

## Additional complexities of inheritance

- Most genetic traits are not as simple as the ones that Mendel studied.
- Incomplete dominance, codominance, multiple alleles, pleiotropy, epistasis, and polygenic inheritance are described on the remaining slides

Relationship among alleles of a single gene	Description	Example
<b>Complete dominance of one allele</b>	<b>Heterozygous phenotype same as that of homozygous dominant</b>	
<b>Incomplete dominance of either allele</b>	<b>Heterozygous phenotype intermediate between the two homozygous phenotypes</b>	 $C^R C^R$ $C^R C^W$ $C^W C^W$
<b>Codominance</b>	<b>Both phenotypes expressed in heterozygotes</b>	 $I^A I^B$
<b>Multiple alleles</b>	<b>In the whole population, some genes have more than two alleles</b>	<b>ABO blood group alleles</b> $I^A$ , $I^B$ , $i$
<b>Pleiotropy</b>	<b>One gene is able to affect multiple phenotypic characters</b>	<b>Sickle-cell disease</b>

Relationship among two or more genes	Description	Example																																																																																																				
<b>Epistasis</b>	<b>The phenotypic expression of one gene affects that of another</b>	$BbEe \times BbEe$ <table border="1"> <tr><td>BE</td><td>bE</td><td>Be</td><td>be</td></tr> <tr><td>BE</td><td>Black</td><td>Black</td><td>Black</td></tr> <tr><td>bE</td><td>Black</td><td>Brown</td><td>Brown</td></tr> <tr><td>Be</td><td>Black</td><td>Black</td><td>Yellow</td></tr> <tr><td>be</td><td>Black</td><td>Brown</td><td>Yellow</td></tr> </table> <p>9  : 3  : 4 </p>	BE	bE	Be	be	BE	Black	Black	Black	bE	Black	Brown	Brown	Be	Black	Black	Yellow	be	Black	Brown	Yellow																																																																																
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<b>Polygenic inheritance</b>	<b>A single phenotypic character is affected by two or more genes</b>	$AaBbCc \times AaBbCc$ <table border="1"> <tr><td>...</td><td>...</td><td>...</td><td>...</td><td>...</td><td>...</td><td>...</td><td>...</td><td>...</td><td>...</td></tr> </table>	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
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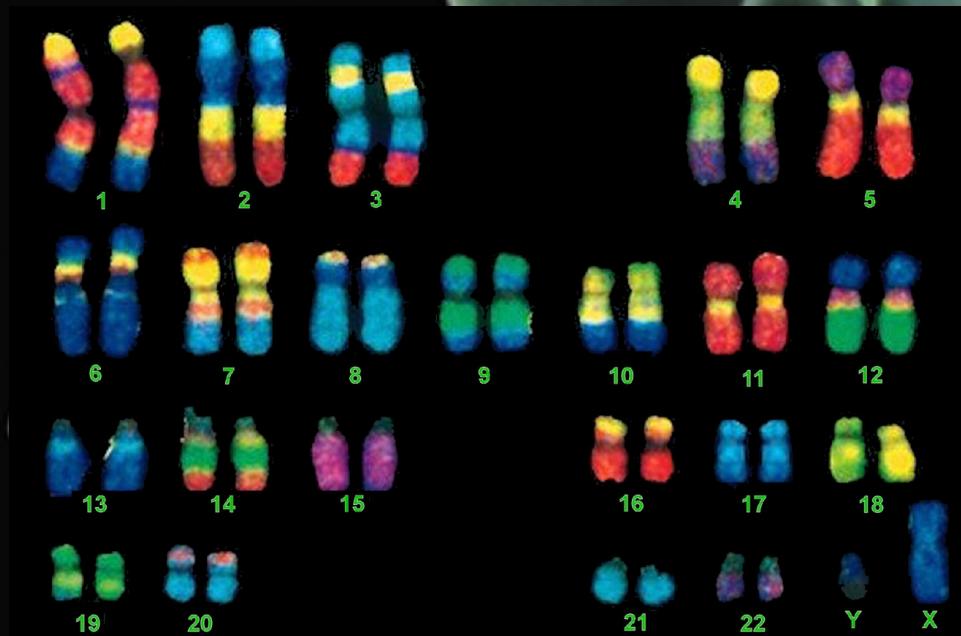
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# Chapter 15

## The Chromosomal Basis of Inheritance



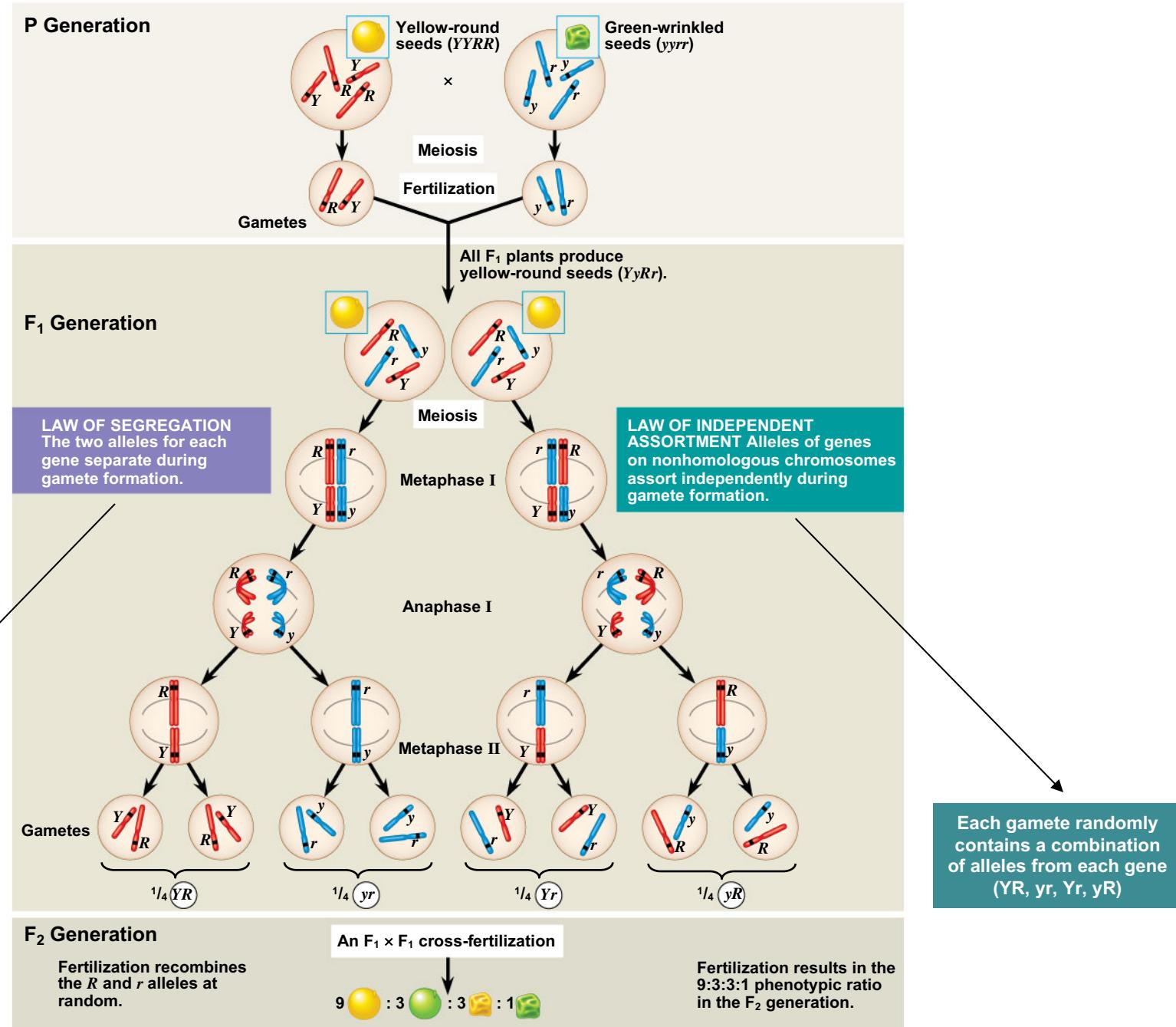
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# Concept 15.1: Mendelian inheritance has its physical basis in the behavior of chromosomes

- The **chromosome theory of inheritance** states:
  - Mendelian genes have specific loci (positions) on chromosomes
  - Chromosomes undergo segregation and independent assortment
- The behavior of chromosomes during meiosis (cell division leading to the production of gametes) can account for Mendel's laws of segregation and independent assortment

Figure 15.2



# *Correlating Behavior of a Gene's Alleles with Behavior of a Chromosome Pair*

- In one experiment, Morgan mated male flies with white eyes (mutant) with female flies with red eyes (wild type)
  - The  $F_1$  generation all had red eyes
  - The  $F_2$  generation showed the 3:1 red:white eye ratio, but only males had white eyes
- Morgan determined that the white-eyed mutant allele must be located on the X chromosome
- Morgan's finding supported the chromosome theory of inheritance

Figure 15.4

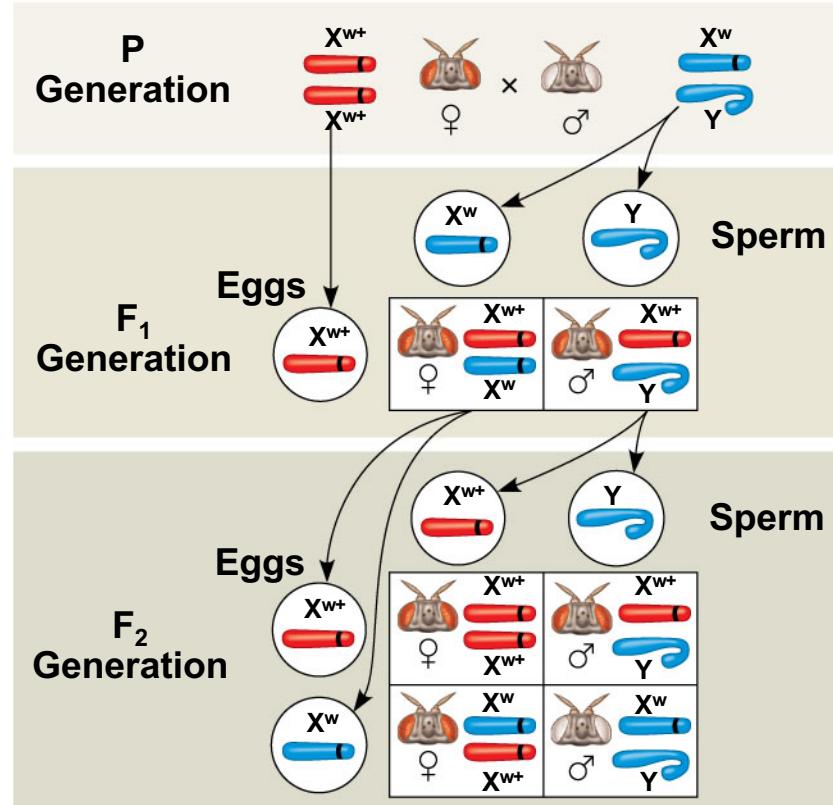
## EXPERIMENT



## RESULTS



## CONCLUSION



XX – male fly  
XY – female fly

w<sup>+</sup> - red eyes (wild type)  
w - white eyes (mutant)

Now we use notation to  
that the eye color allele is  
on the X chromosome,

X<sup>w+</sup> - an X chromosome  
with the red eye allele

# Concept 15.2: Sex-linked genes exhibit unique patterns of inheritance

- In humans and some other animals, there is a chromosomal basis of sex determination
- Females are XX, and males are XY\*
- Each ovum contains an X chromosome, while a sperm may contain either an X or a Y chromosome
- Other animals have different methods of sex determination

\*Actually, it's more complicated than that,

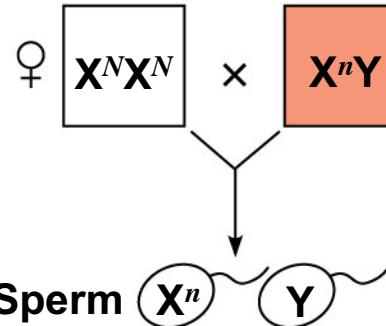
<https://www.sciencealert.com/a-baby-s-sex-is-about-more-than-just-its-x-and-y-chromosomes-new-research-reveals>

- A gene that is located on either sex chromosome is called a **sex-linked gene**
- Genes on the Y chromosome are called Y-linked genes; there are few of these
- Genes on the X chromosome are called **X-linked genes**

- X-linked genes follow specific patterns of inheritance
- For a recessive X-linked trait to be expressed
  - A female needs two copies of the allele (homozygous)
  - A male needs only one copy of the allele (hemizygous)
- X-linked recessive disorders are much more common in males than in females

Figure 15.7

# Inheritance of X-linked recessive traits

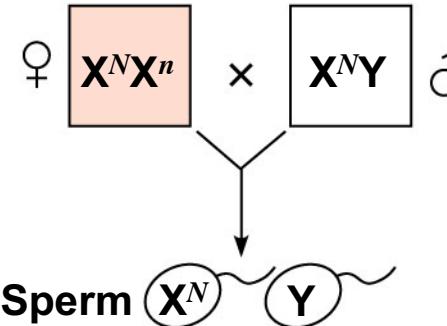


Eggs  $X^N$

$X^N X^N$	$X^N Y$
$X^n X^n$	$X^N Y$

$X^N$

(a)

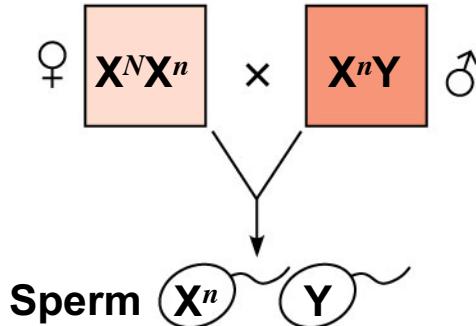


Eggs  $X^N$

$X^N X^N$	$X^N Y$
$X^N X^n$	$X^n Y$

$X^n$

(b)



Eggs  $X^N$

$X^N X^n$	$X^N Y$
$X^n X^n$	$X^n Y$

$X^n$

(c)

- Some disorders caused by recessive alleles on the X chromosome in humans
  - Color blindness (mostly X-linked)
  - Duchenne muscular dystrophy
  - Hemophilia

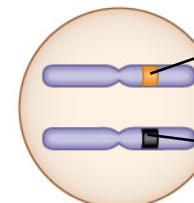
# X Inactivation in Female Mammals

- In mammalian females, one of the two X chromosomes in each cell is randomly inactivated during embryonic development
- The inactive X condenses into a **Barr body**
- If a female is heterozygous for a particular gene located on the X chromosome, she will be a mosaic for that character

Figure 15.8

Early embryo:

X chromosomes

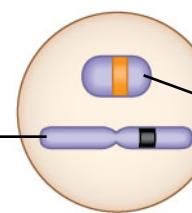


Allele for  
orange fur

Allele for  
black fur

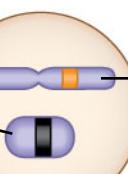
Cell division and  
X chromosome  
inactivation

Two cell  
populations  
in adult cat:



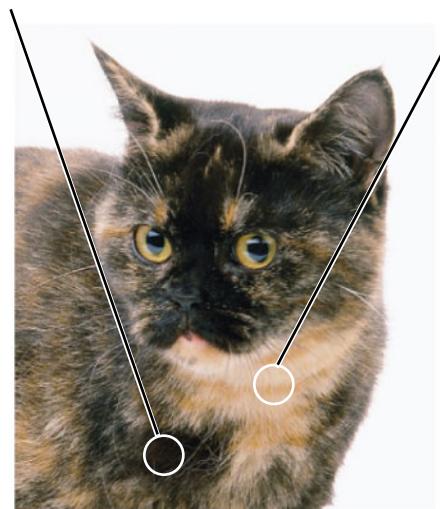
Active X

Black fur



Active X

Orange fur



# *Recombination of Linked Genes: Crossing Over*

- Morgan discovered that genes can be linked, but the linkage was incomplete, because some recombinant phenotypes were observed
- He proposed that some process must occasionally break the physical connection between genes on the same chromosome
- That mechanism was the **crossing over** of homologous chromosomes

- Genes that are far apart on the same chromosome can have a recombination frequency near 50%
  - This is due to crossing over:
    - <https://www.youtube.com/watch?v=pdJUvagZjYA>
- Such genes are physically linked, but genetically unlinked, and behave as if found on different chromosomes