

Chapter 14

Mendel and the Gene Idea

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview:

- What genetic principles account for the passing of traits from parents to offspring?
- During the 1800s, The “**blending**” **hypothesis** is the idea that genetic material from the two parents blends together (**like blue and yellow paint blend to make green**)

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- The “**particulate**” **hypothesis** is the idea that parents pass on **discrete heritable units (genes)**
 - **Mendel documented a particulate mechanism** through his experiments with garden peas

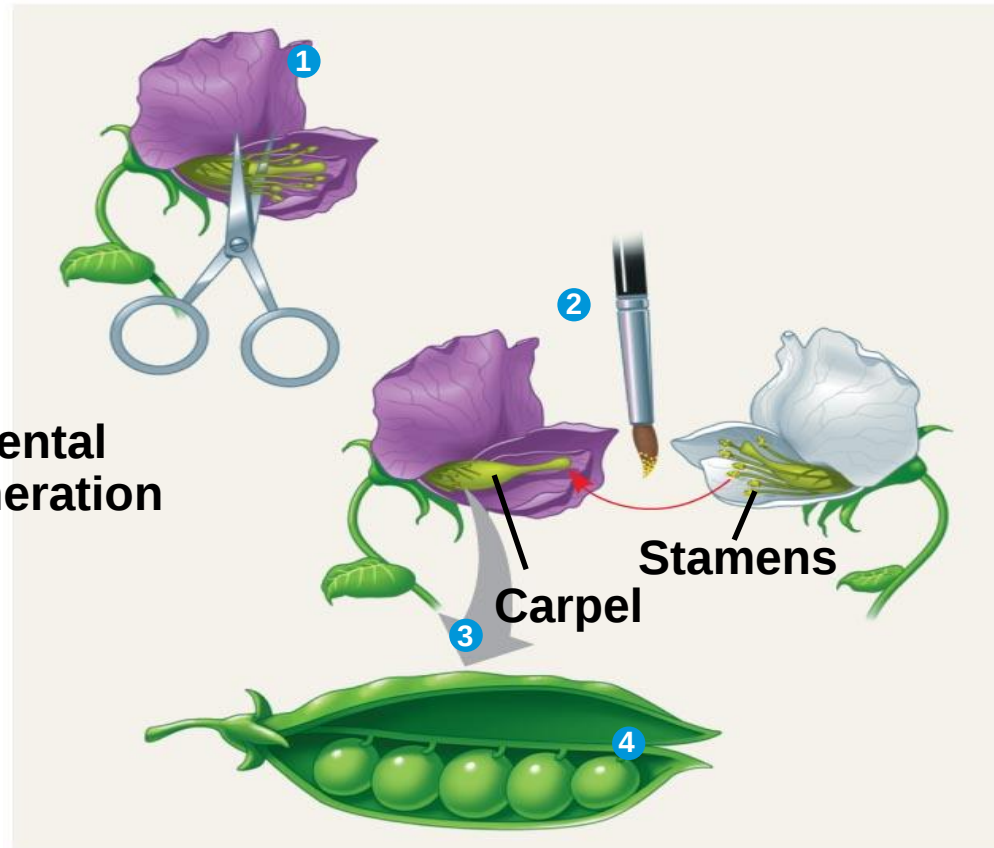
Concept 14.1: Mendel used the scientific approach to identify two laws of inheritance

- Mendel discovered the basic principles of heredity by **breeding garden peas** in carefully planned experiments

Crossing pea plants

TECHNIQUE

Parental
generation
(**P**)



RESULTS

First filial
generation
offspring
(**F₁**)



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- Mendel chose to track only those **characters that varied in an either-or manner**
 - He also used varieties that were **true-breeding** (*plants that produce offspring of the same variety when they self-pollinate*)
 - *A true breeding is a kind of breeding wherein the parents would produce offspring that would carry the same phenotype. This means that the parents are homozygous for every trait.*

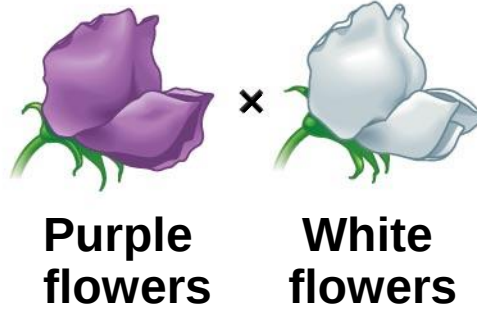
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- In a typical experiment, Mendel mated two contrasting, true-breeding varieties, a process called **hybridization**
 - The **true-breeding parents** are the **P generation**
 - The **hybrid offspring of the P generation** are called the **F₁ generation**
 - When **F₁ individuals self-pollinate**, the **F₂ generation** is produced

Mendel' first law: The Law of Segregation

- When Mendel crossed contrasting, true-breeding **white** and **purple** flowered pea plants, **all of the F_1 hybrids were purple**
- When Mendel crossed the F_1 hybrids, **many of the F_2 plants had purple flowers**, but some had white
- Mendel discovered a ratio of about **three to one, purple to white flowers**, in the F_2 generation

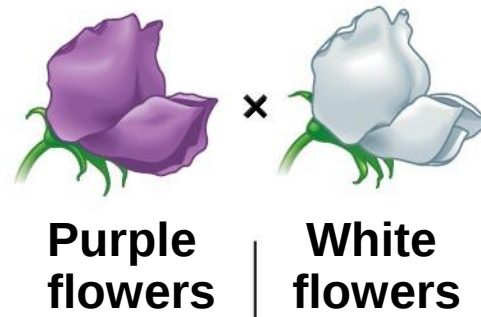
EXPERIMENT

**P Generation
(true-breeding
parents)**



EXPERIMENT

P Generation
(true-breeding
parents)

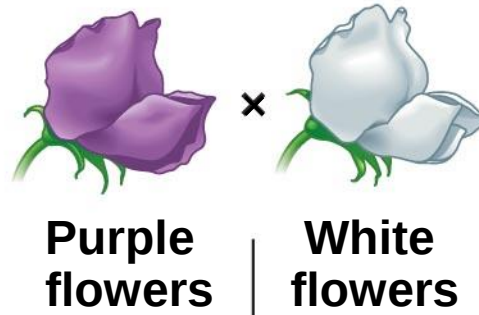


F₁ Generation
(hybrids)



EXPERIMENT

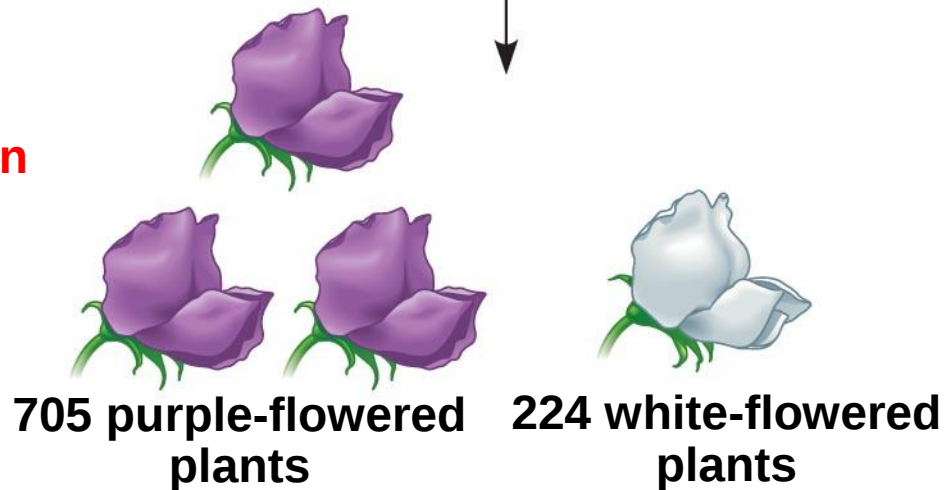
P Generation
(true-breeding
parents)



F₁ Generation
(hybrids)



F₂ Generation



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- Mendel called the **purple flower** color a **dominant trait** and the **white flower** color a **recessive trait**
 - Mendel observed the same pattern of inheritance in **six other pea plant characters**, each represented by two traits
 - What Mendel called a “**heritable factor**” is what we now call a **gene**

Table 14-1

Table 14.1 The Results of Mendel's F ₁ Crosses for Seven Characters in Pea Plants					
Character	Dominant Trait	x	Recessive Trait	F ₂ 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

Law of segregation states that *the two alleles for a heritable character separate (segregate) during gamete formation and end up in different gametes*

- Thus, **an egg or a sperm gets only one of the two alleles** that are present in the somatic cells of an organism

- Mendel's segregation model accounts for the **3:1 ratio** he observed in the F_2 generation of his numerous crosses
- The possible combinations of sperm and egg can be shown using a **Punnett square**, a diagram for predicting the results of a genetic cross between individuals of known genetic makeup
- A **capital letter represents a dominant allele**, and a **lowercase letter represents a recessive allele**

Fig. 14-5-1

P Generation



Appearance: **Purple flowers** **White flowers**

Genetic makeup: *PP* *pp*

Gametes: *P* *p*

Fig. 14-5-2

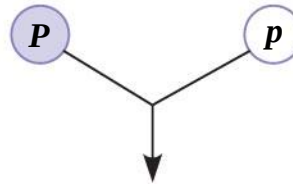
P Generation



Appearance: Purple flowers White flowers

Genetic makeup: *PP* *pp*

Gametes:



F₁ Generation



Appearance: Purple flowers

Genetic makeup: *Pp*

Gametes:



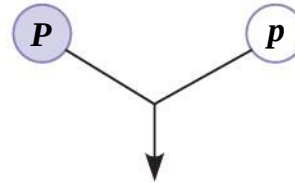
Mendel's law of segregation

P Generation



Appearance: Purple flowers White flowers
Genetic makeup: PP pp

Gametes:



F₁ Generation

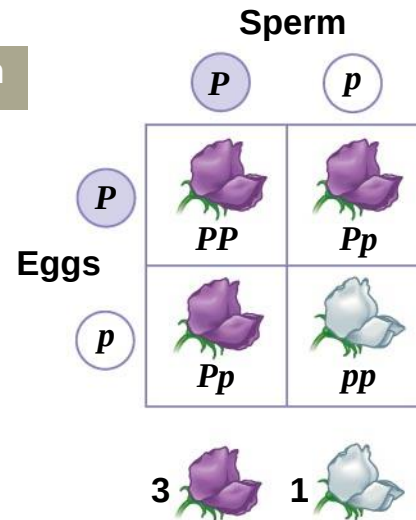


Appearance: Purple flowers
Genetic makeup: Pp

Gametes:



F₂ Generation

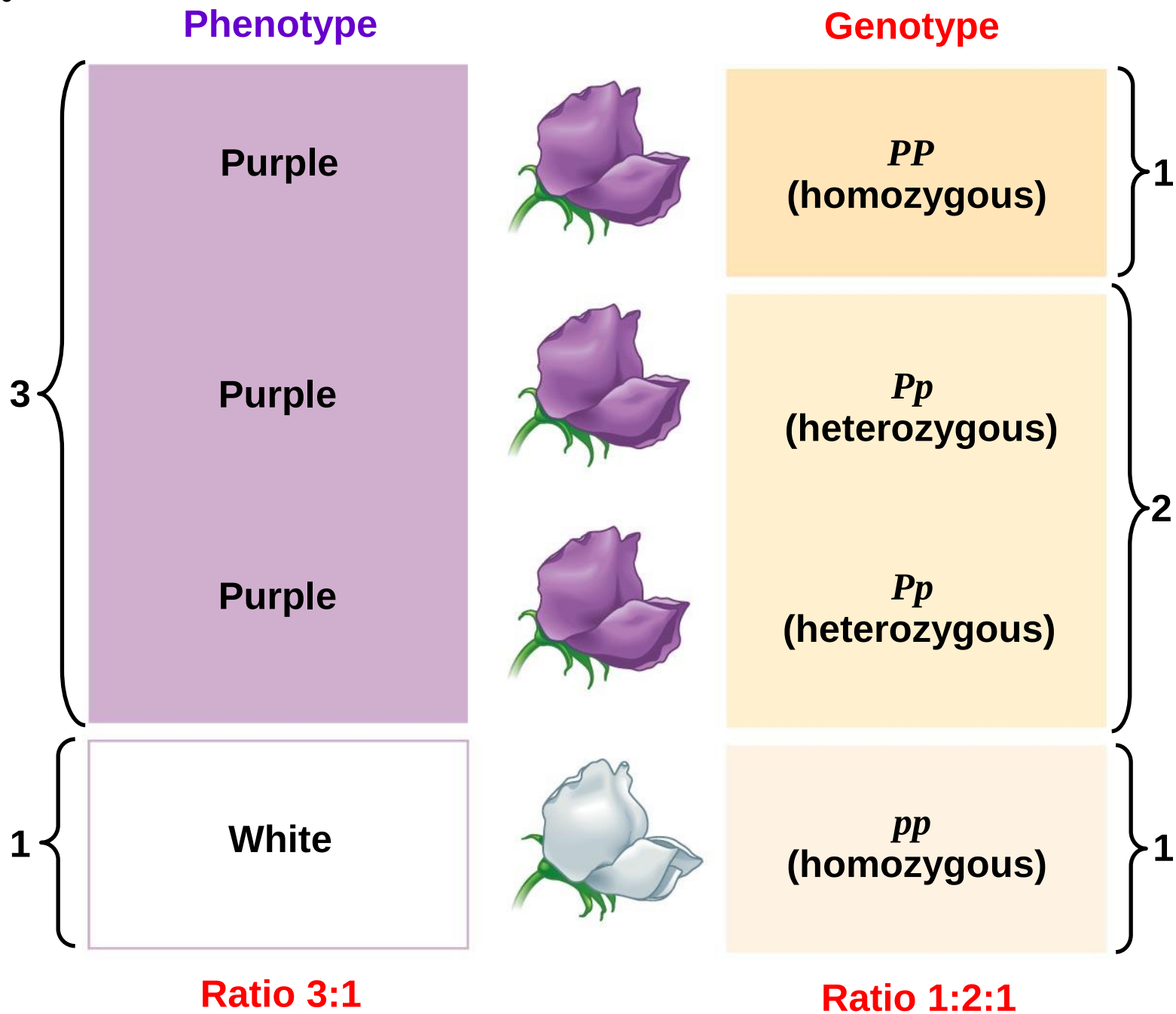


Useful Genetic Vocabulary

- 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

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- An organism's **physical appearance**: is called its **phenotype**
 - An organism's **genetic makeup** is called its **genotype**.
 - In the example of flower color in pea plants, ***PP*** and ***Pp*** plants have the **same phenotype** (purple) but **different genotypes**

Fig. 14-6

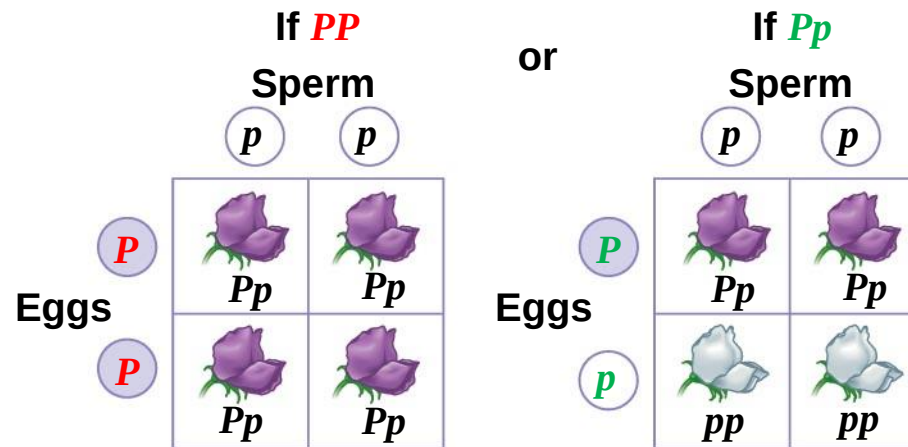
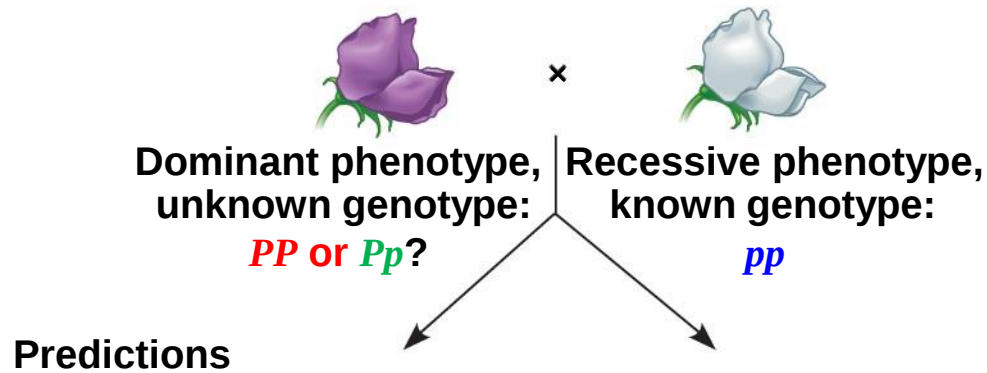


The Testcross

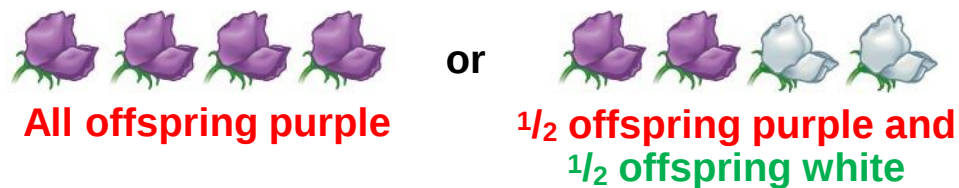
- Used to determine **the genotype** of an organism that shows the **dominant phenotype**.
- Such an individual must have one dominant allele, but the individual could be either homozygous dominant or heterozygous
- **The answer is to carry out a testcross: breeding the mystery individual with a homozygous recessive individual**

- If any offspring display the recessive phenotype, the mystery parent must be **heterozygous**

TECHNIQUE



RESULTS



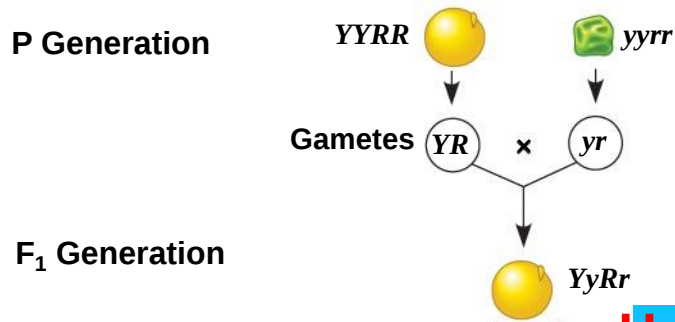
Mendel's second law: The Law of Independent Assortment

- Mendel derived the law of segregation by following **a single character**
- The F₁ offspring produced in this cross were **monohybrids**, *individuals that are heterozygous for one character*
- A cross between such heterozygotes is called a **monohybrid cross**

-
- 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

EXPERIMENT

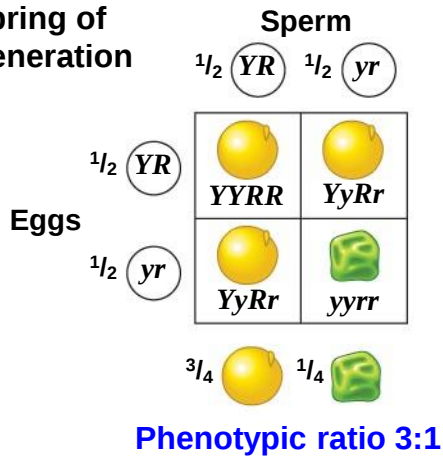


Dihybrid cross

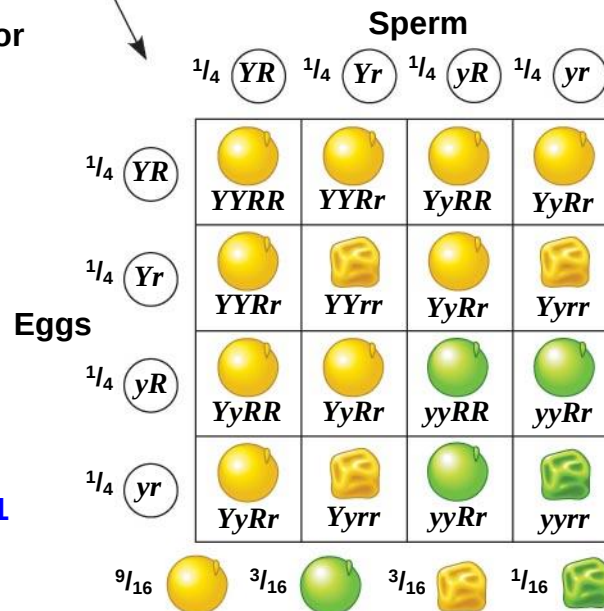
Predictions

Hypothesis of dependent assortment

Predicted offspring of F₂ generation



or



Hypothesis of independent assortment

Phenotypic ratio 9:3:3:1

RESULTS

315 yellow round 108 green round 101 yellow wrinkled 32 green wrinkled

Phenotypic ratio approximately 9:3:3:1

- The law of independent assortment states that each pair of alleles segregates independently of each other pair of alleles during gamete formation
- Strictly speaking, **this law applies only to genes on different, nonhomologous chromosomes**
- *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

Extending Mendelian Genetics for a Single Gene

- Inheritance of characters by a single gene **may deviate from simple Mendelian patterns** in the following situations:
 - When alleles are not completely dominant or recessive
 - When a gene has more than two alleles
 - **When** a gene produces multiple phenotypes

Degrees of Dominance

- **Complete dominance** occurs when phenotypes of the heterozygote and dominant homozygote are identical
- In **incomplete dominance**, the phenotype of F_1 hybrids is somewhere between the phenotypes of the two parental varieties. Example: *Snapdragon flower color*

Fig. 14-10-1

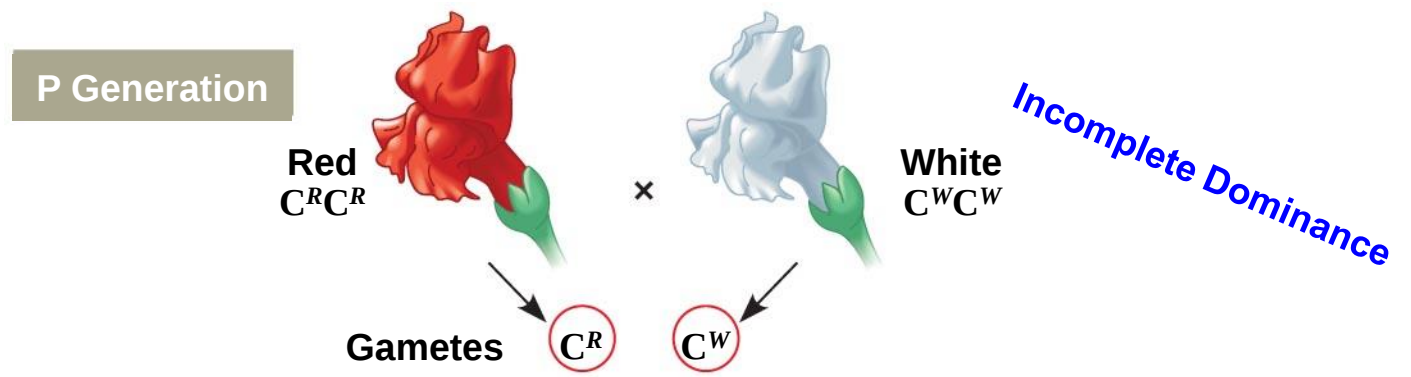
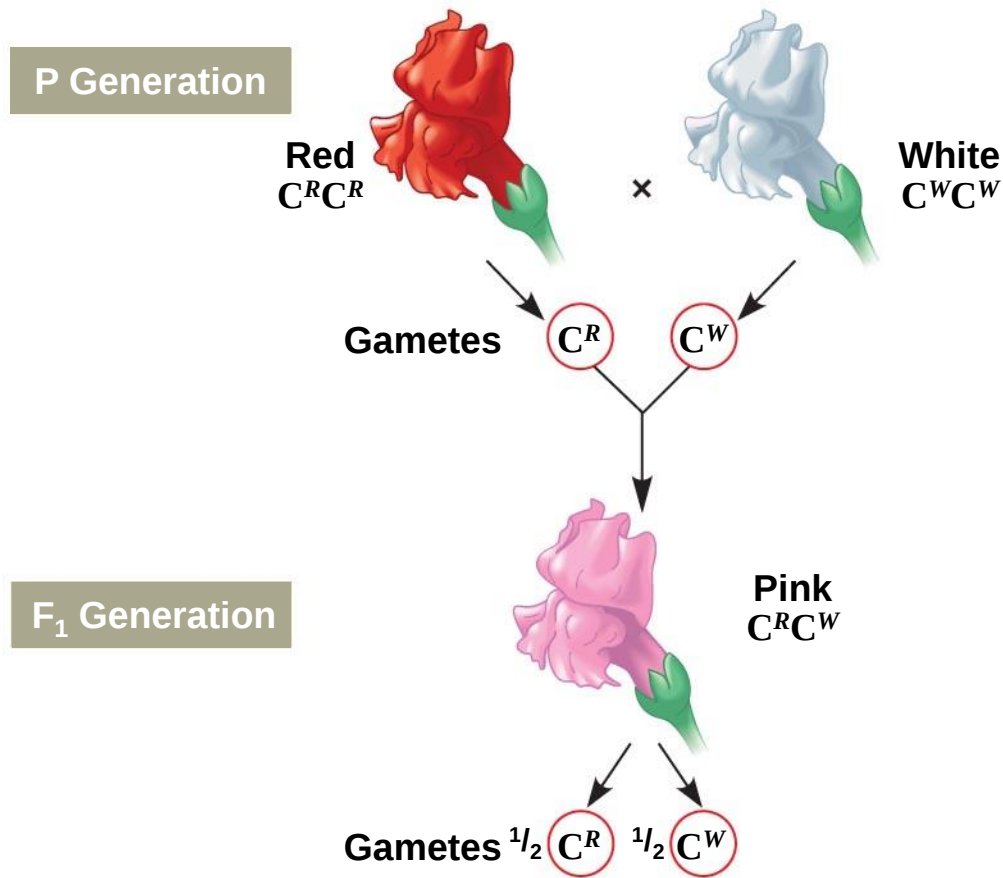


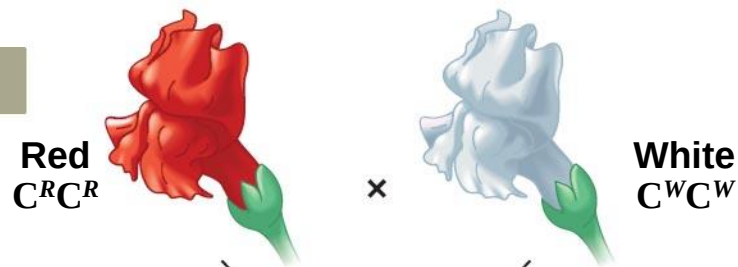
Fig. 14-10-2



**Incomplete
dominance in
snapdragon color**

Fig. 14-10-3

P Generation

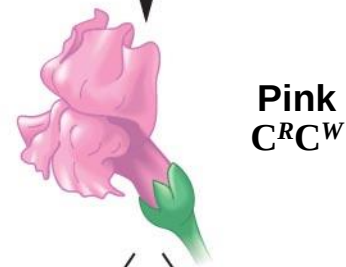


Incomplete Dominance

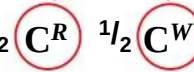
Gametes



F₁ Generation



Gametes

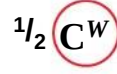
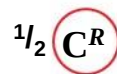


Sperm



F₂ Generation

Eggs



$\frac{1}{2} C^R$	 $C^R C^R$	 $C^R C^W$
$\frac{1}{2} C^W$	 $C^R C^W$	 $C^W C^W$

- In **codominance**, two dominant alleles affect the phenotype in **separate, distinguishable ways**.
- **Example: blood groups (A & B)**

Multiple Alleles

- Most genes exist in populations in **more than two allelic forms**
- For example, the **four phenotypes of the ABO** blood group in humans are determined by **three alleles** for the enzyme (I) that attaches A or B carbohydrates to red blood cells: **I^A , I^B , and i** .

- The enzyme encoded by the I^A allele adds the **A** carbohydrate, whereas the enzyme encoded by the I^B allele adds the **B** carbohydrate; the enzyme encoded by the i allele **adds neither**

<u>Allele</u>	<u>Carbohydrate</u>
I^A	A 
I^B	B 
i	none

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

<u>Genotype</u>	<u>Red blood cell appearance</u>	<u>Phenotype (blood group)</u>
$I^A I^A$ or $I^A i$	 antigen	A
$I^B I^B$ or $I^B i$		B
$I^A I^B$		AB
ii		O

(b) Blood group genotypes and phenotypes