Chapter 14

Mendel and the Gene Idea

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

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)**

- 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

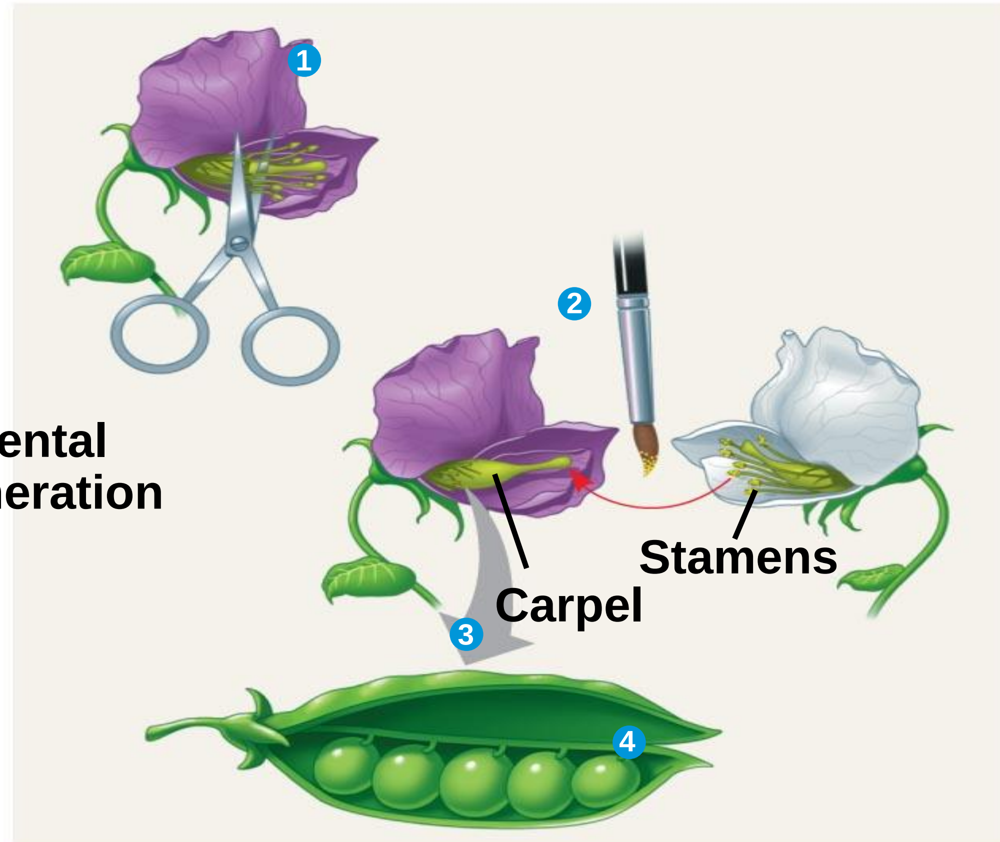
- **Mendel discovered the basic principles of heredity by breeding garden peas in carefully planned experiments**

Fig. 14-2

Crossing pea plants

TECHNIQUE

Parental generation (P)



RESULTS

First filial generation offspring (F_1)

- **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.***

- 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_1 generation**
- When **F_1 individuals self-pollinate**, the

  F_2 generation is produced

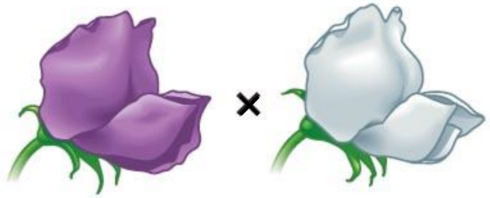
Mendel' first law: The Law of Segregation

- 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

Fig. 14-3-1

EXPERIMENT

P Generation (true-breeding parents)



Purple flowers

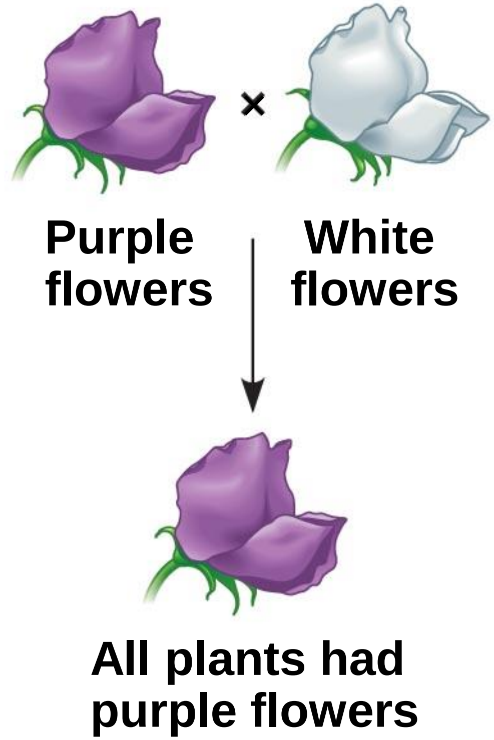
White flowers

Fig. 14-3-2

EXPERIMENT

P Generation

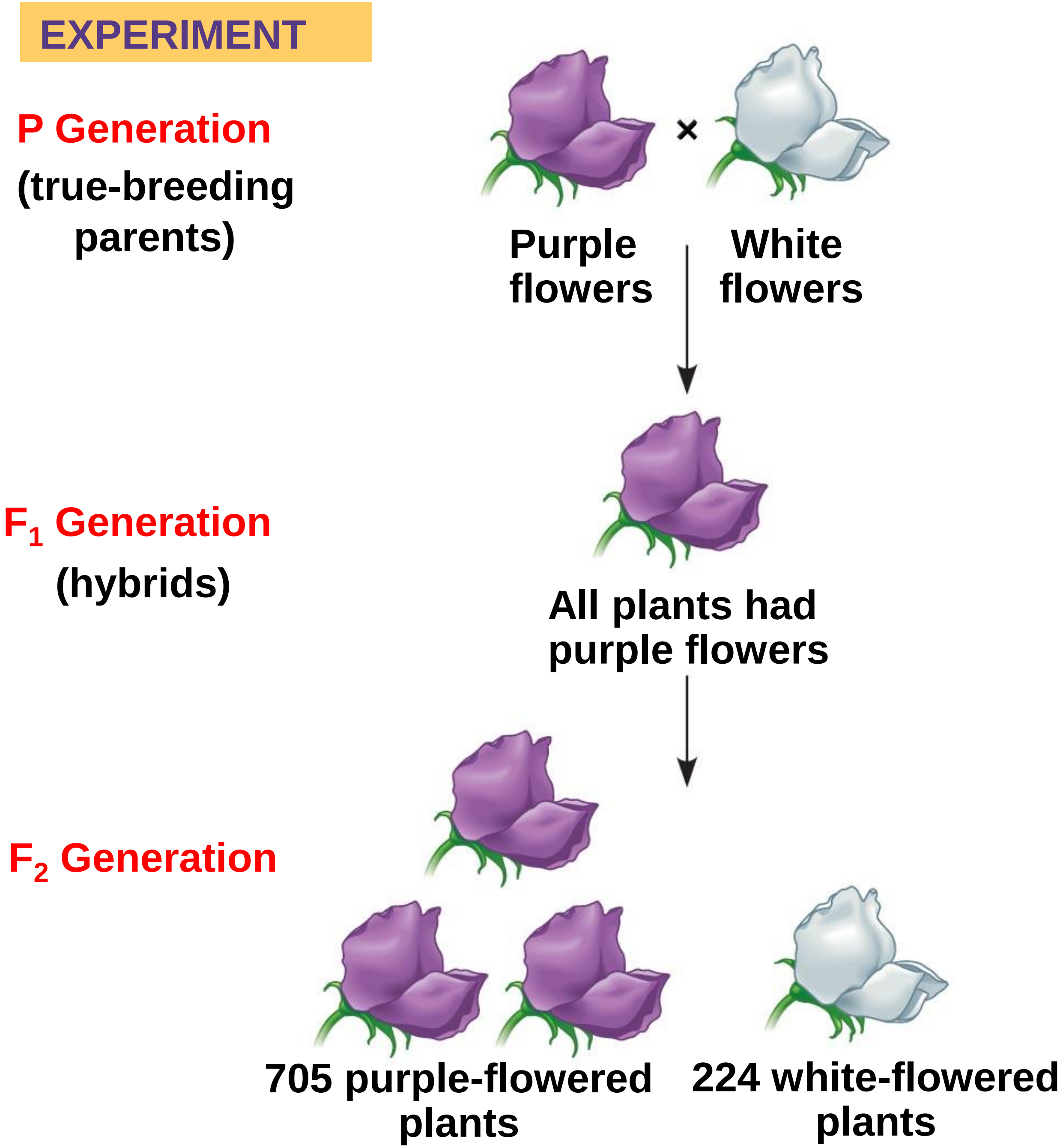
(true-breeding parents)



F_1 Generation

(hybrids)

Fig. 14-3-3


EXPERIMENT
P Generation
(true-breeding parents)
Purple flowers
×
White flowers
F$_1$ Generation
(hybrids)
All plants had purple flowers
F$_2$ Generation
705 purple-flowered plants
224 white-flowered plants

- **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

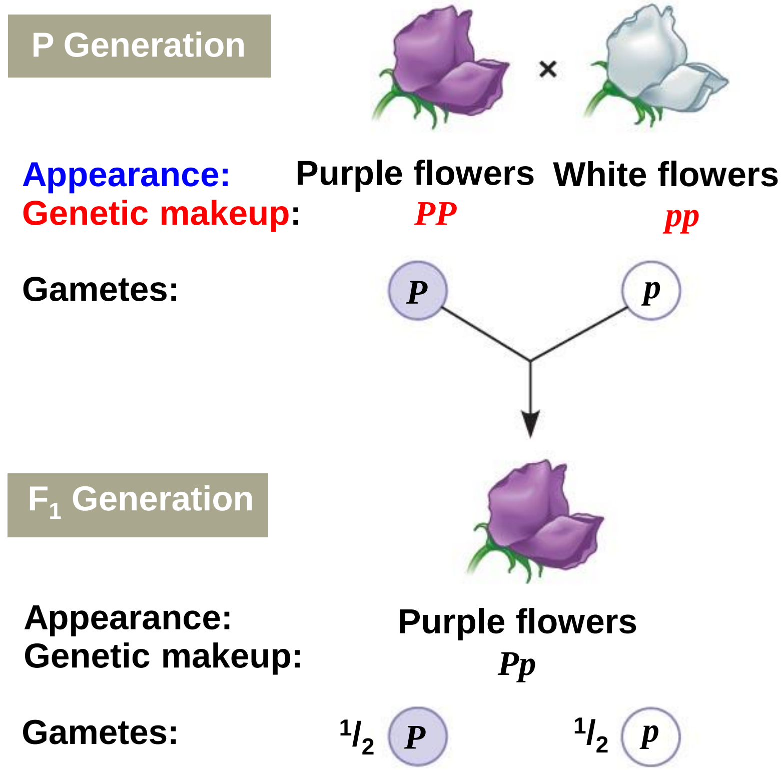
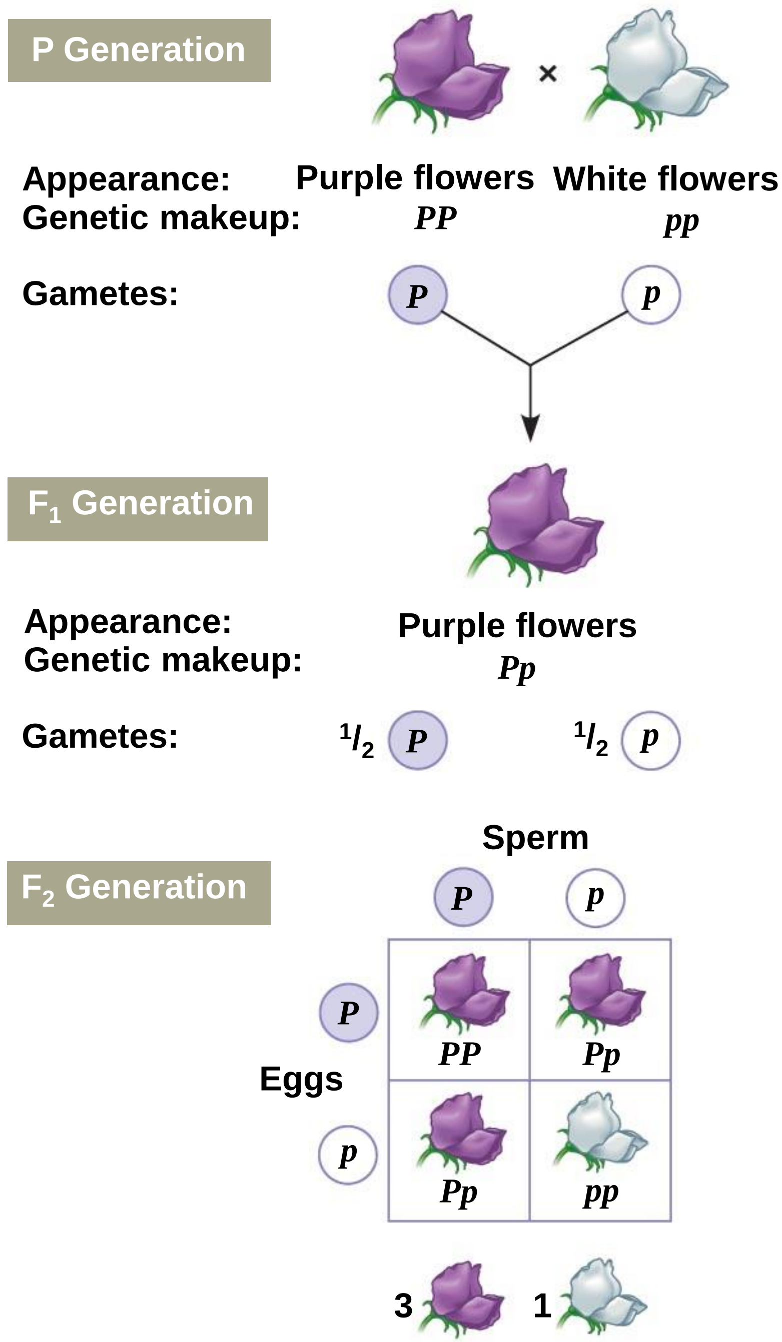

P Generation
×
Appearance:
Genetic makeup:
Purple flowers
PP
White flowers
pp
Gametes:
P
p
F1 Generation
Appearance:
Genetic makeup:
Purple flowers
Pp
Gametes:
1/2
P
1/2
p

Fig. 14-5-3

Mendel's law of segregation

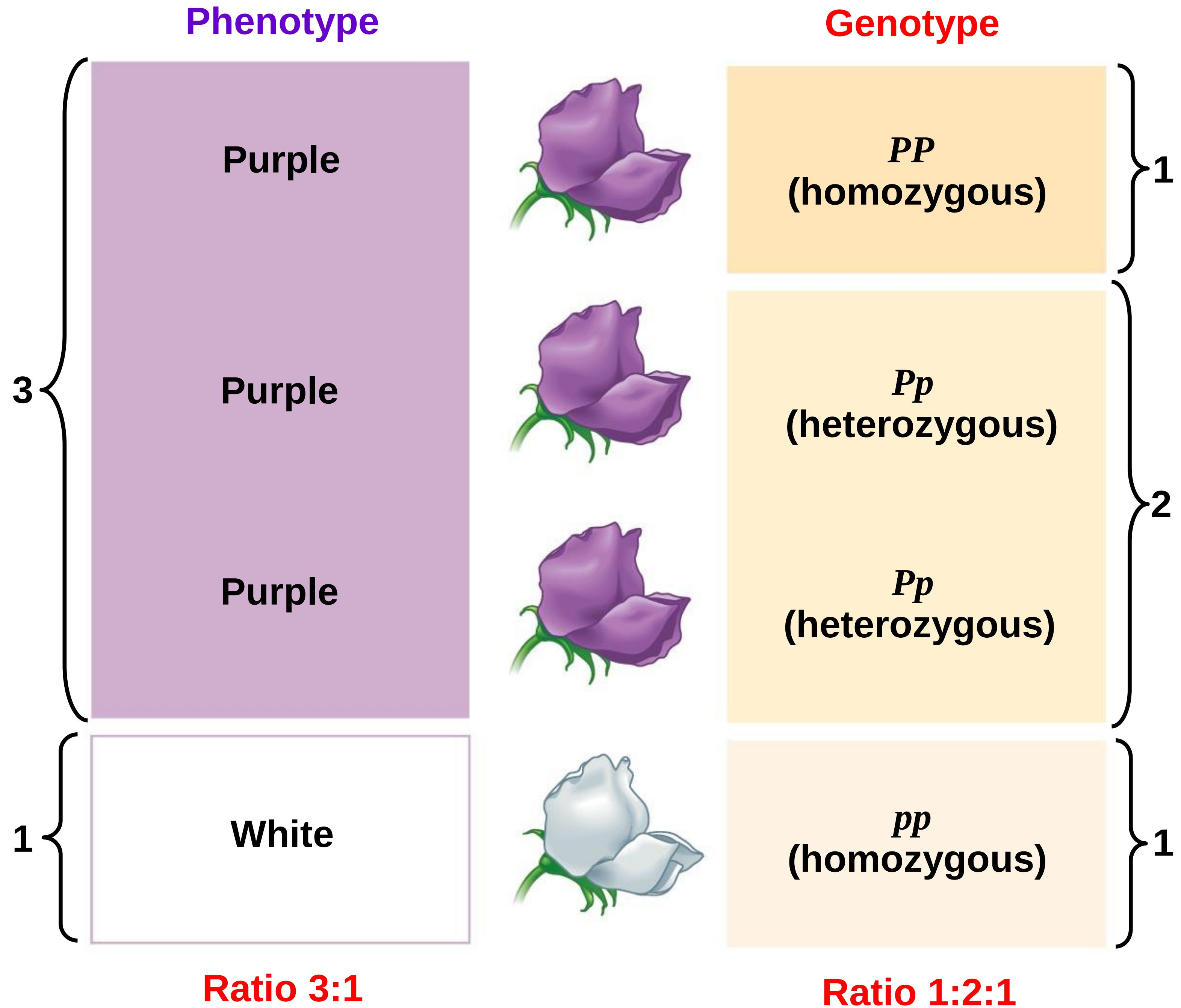


Useful Genetic Vocabulary

- **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**

- **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

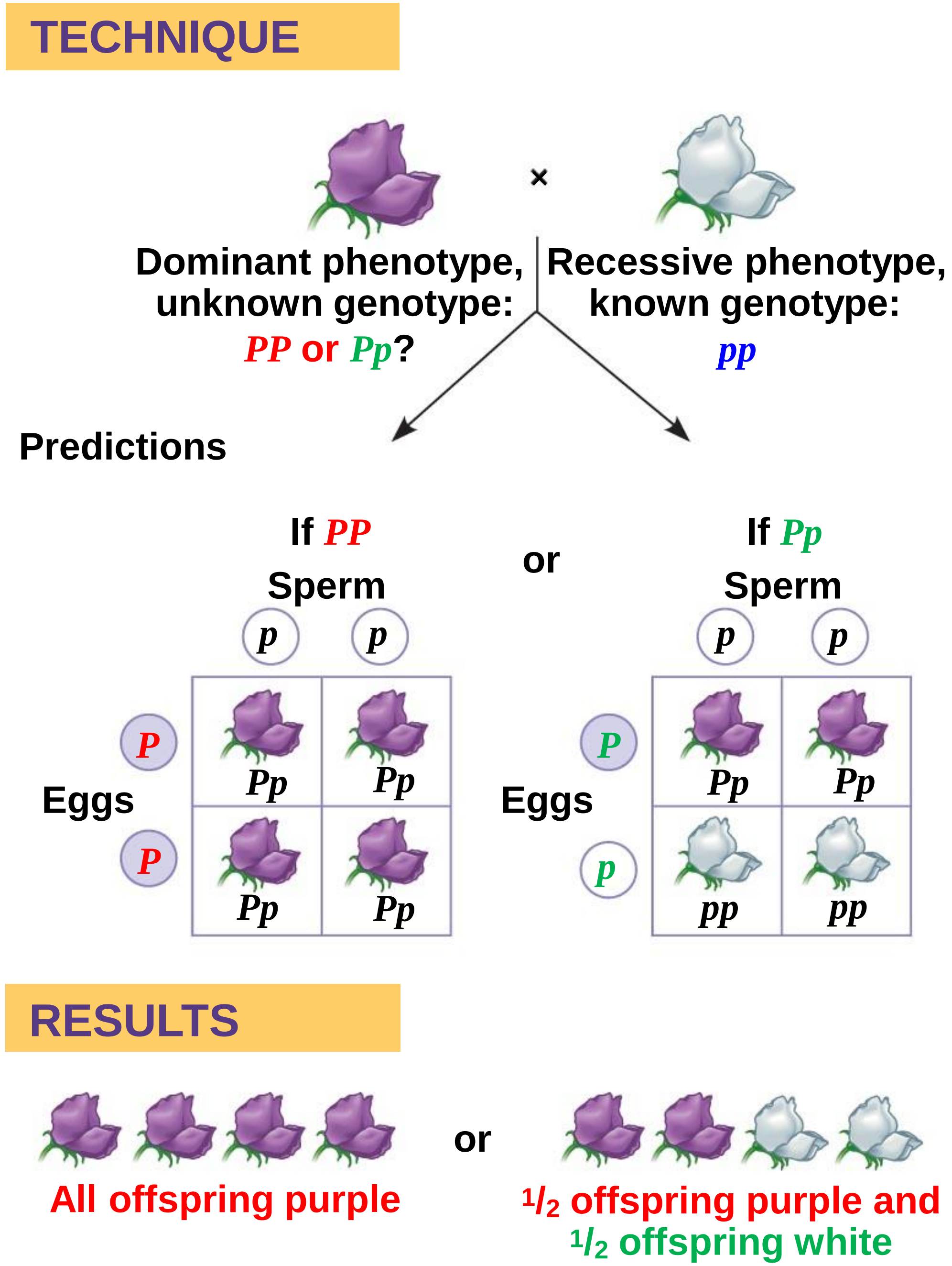

Phenotype
Genotype
Purple
PP
(homozygous)
1
Purple
Pp
(heterozygous)
3
2
Purple
Pp
(heterozygous)
1
White
pp
(homozygous)
1
Ratio 3:1
Ratio 1:2:1

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**

Fig. 14-7


TECHNIQUE
×
Dominant phenotype, unknown genotype:
PP or Pp?
Recessive phenotype, known genotype:
pp
Predictions
If PP
Sperm
p
p
Eggs
P
P
Pp
Pp
Pp
Pp
or
If Pp
Sperm
p
p
Eggs
P
p
Pp
Pp
pp
pp
RESULTS
All offspring purple
or
1/2 offspring purple and
1/2 offspring white

Mendel's second law: 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***

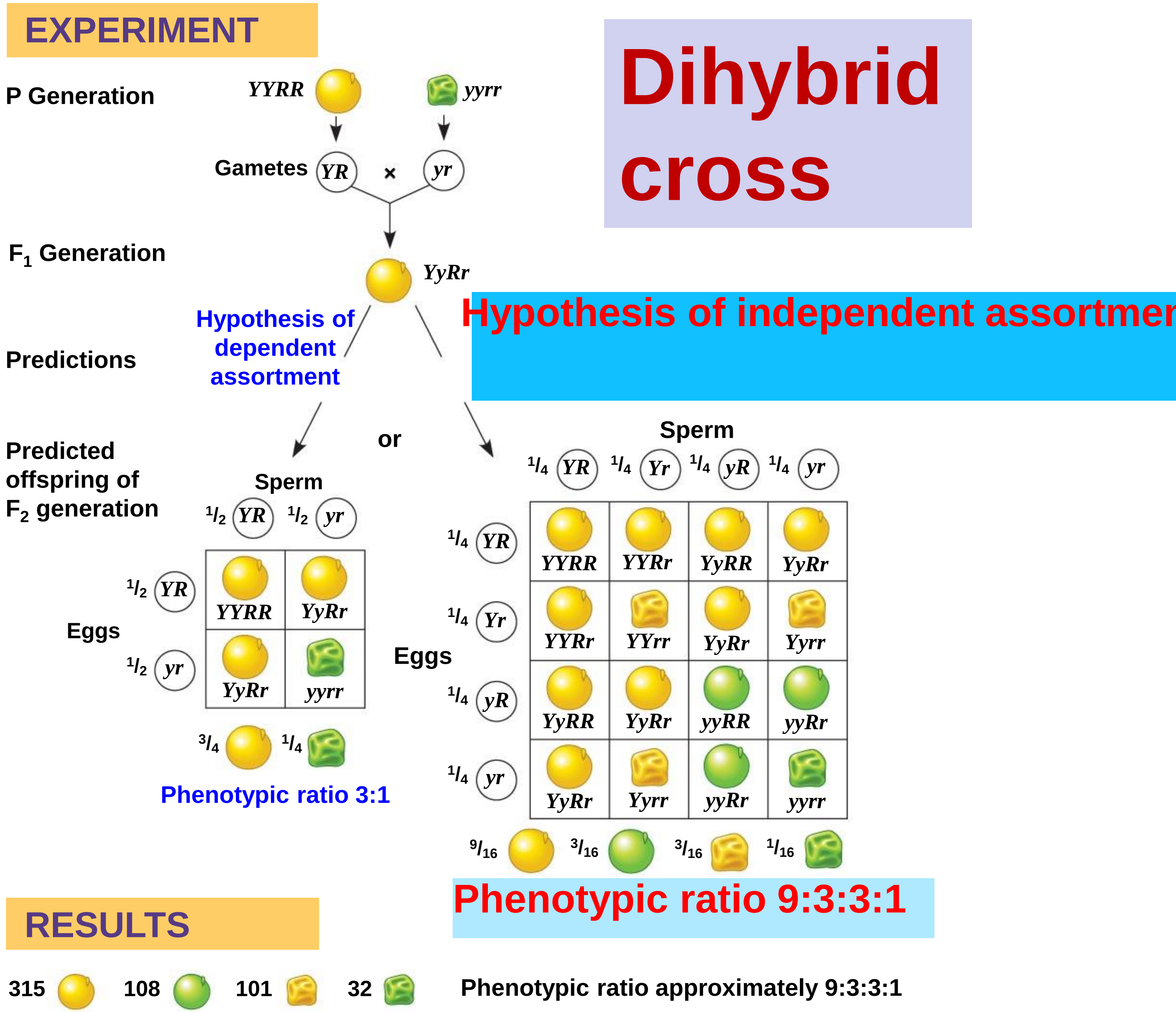
- **Mendel identified his second law of inheritance by following two characters at the same time**

- **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***

Fig. 14-8

Dihybrid cross



- 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

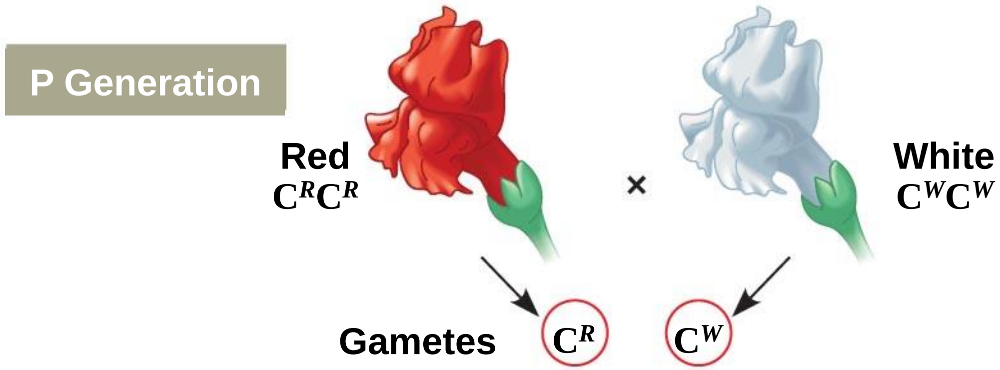
- **Inheritance of characters by a single gene may deviate from simple Mendelian patterns in the following situations:**
  - **When alleles are not completely dominant or recessive**
  - **When a gene has more than two alleles**
  - **When a gene produces multiple phenotypes**

Degrees of Dominance

- **Complete dominance** occurs when phenotypes of the heterozygote and dominant homozygote are identical

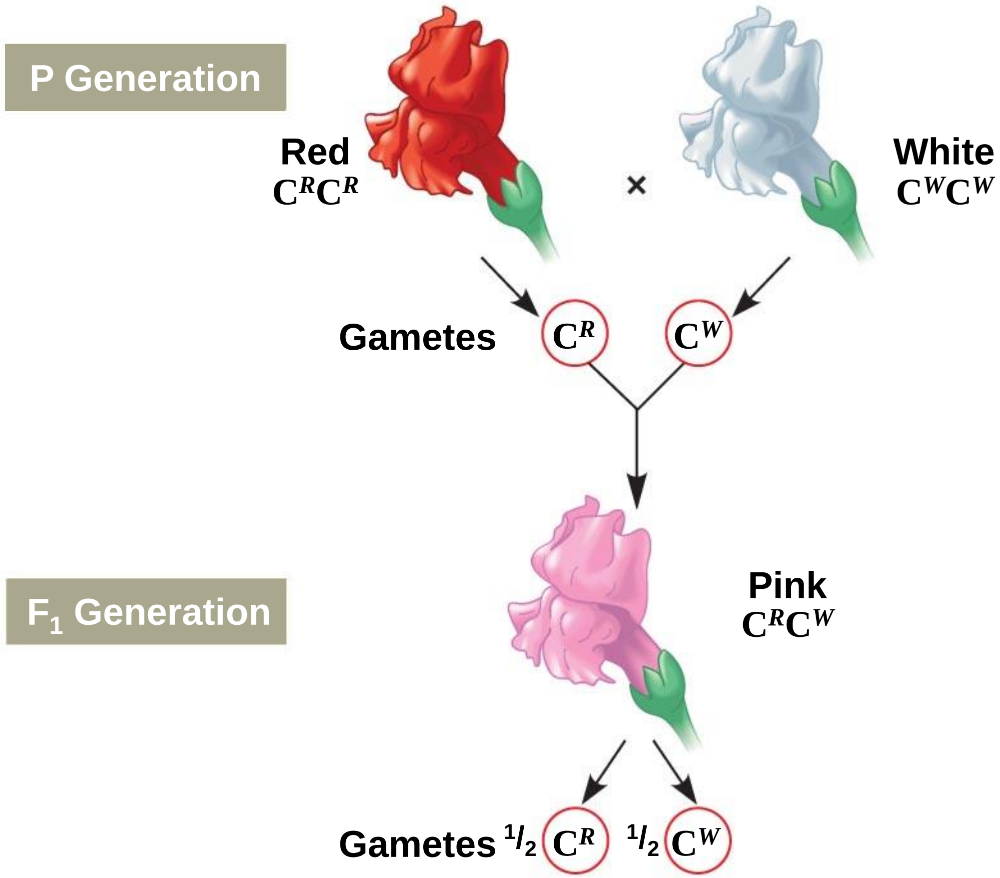
- In **incomplete dominance**, the phenotype of F_1 hybrids is somewhere between the phenotypes of the two parental varieties. Example: ***Snapdragon flower color***

Fig. 14-10-1



Incomplete Dominance

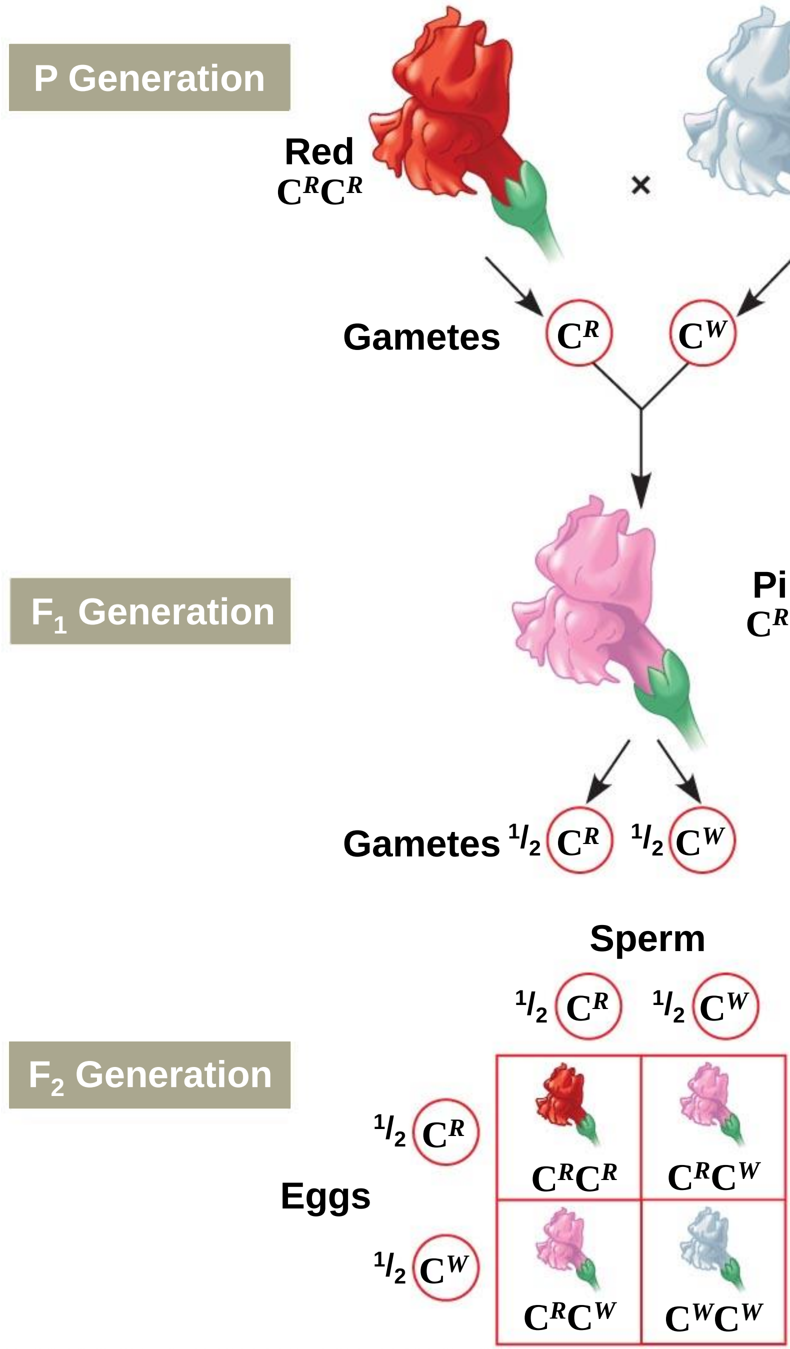
Fig. 14-10-2



Incomplete dominance in snapdragon color

Fig. 14-10-3

Incomplete Dominance



- In **codominance, two dominant alleles affect the phenotype in separate, distinguishable ways.**

- **Example: blood groups (A & B)**

Multiple Alleles

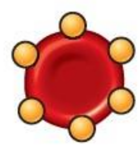
- Most genes exist in populations in more than two allelic forms
- For example, the four phenotypes of the ABO blood group in humans are determined by three alleles for the enzyme (I) that attaches A or B carbohydrates to red blood cells: I^A, I^B, and i.

- **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**

Fig. 14-11

Allele	Carbohydrate
I^A	A 
I^B	B 
i	none

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

Genotype	Red blood cell appearance	Phenotype (blood group)
I^AI^A or I^Ai		A
I^BI^B or I^Bi		B
I^AI^B		AB
ii		O

antigen

(b) Blood group genotypes and phenotypes