Chapter 14

Mendel and the Gene Idea

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Drawing from the Deck of Genes

- What genetic principles account for the passing of traits from parents to offspring?
- 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

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Fig. 14-1

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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

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Mendel's Experimental, Quantitative Approach

- Advantages of pea plants for genetic study:
  - There are many varieties with distinct heritable features, or **characters** (such as flower color); character variants (such as purple or white flowers) are called **traits**
  - Mating of plants can be controlled
  - Each pea plant has sperm-producing organs (stamens) and egg-producing organs (carpels)
  - Cross-pollination (fertilization between different plants) can be achieved by dusting one plant with pollen from another

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Fig. 14-2

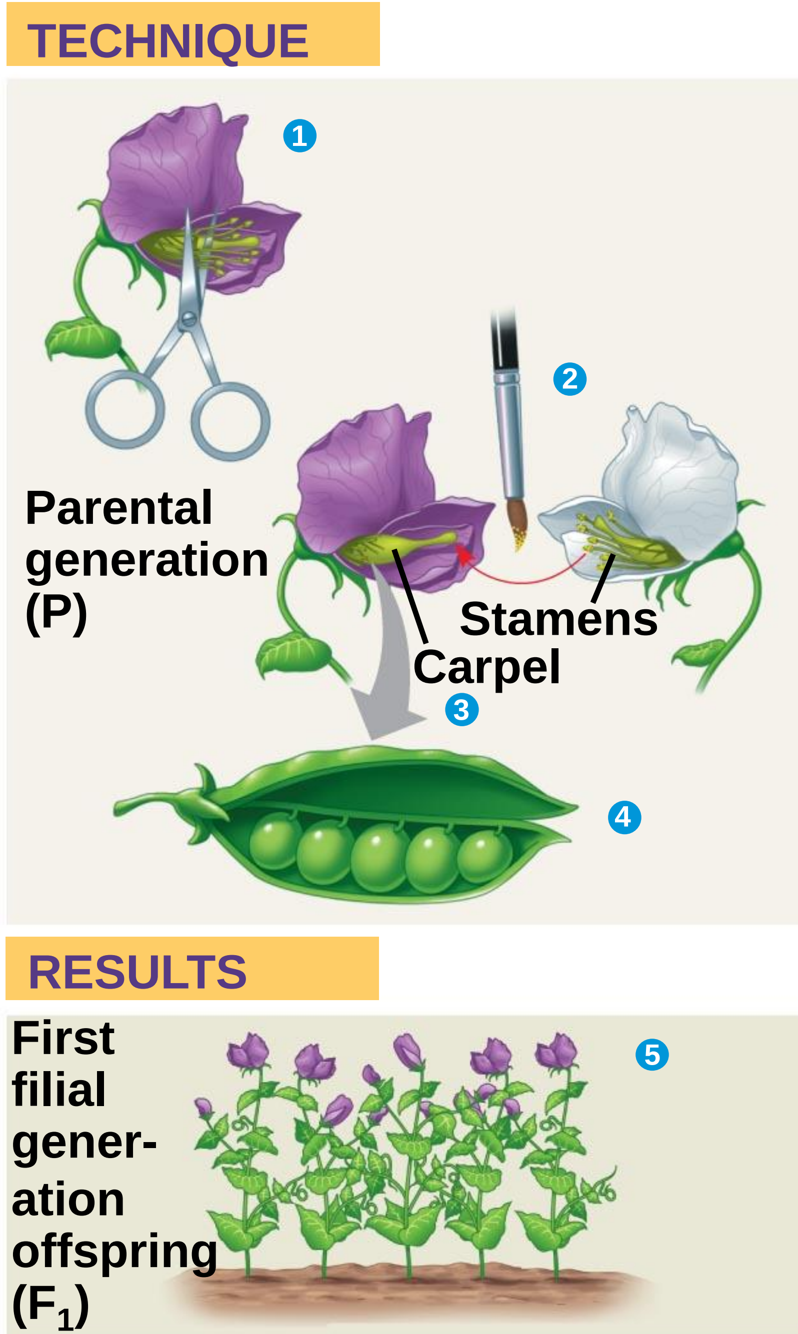

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Fig. 14-2a

TECHNIQUE

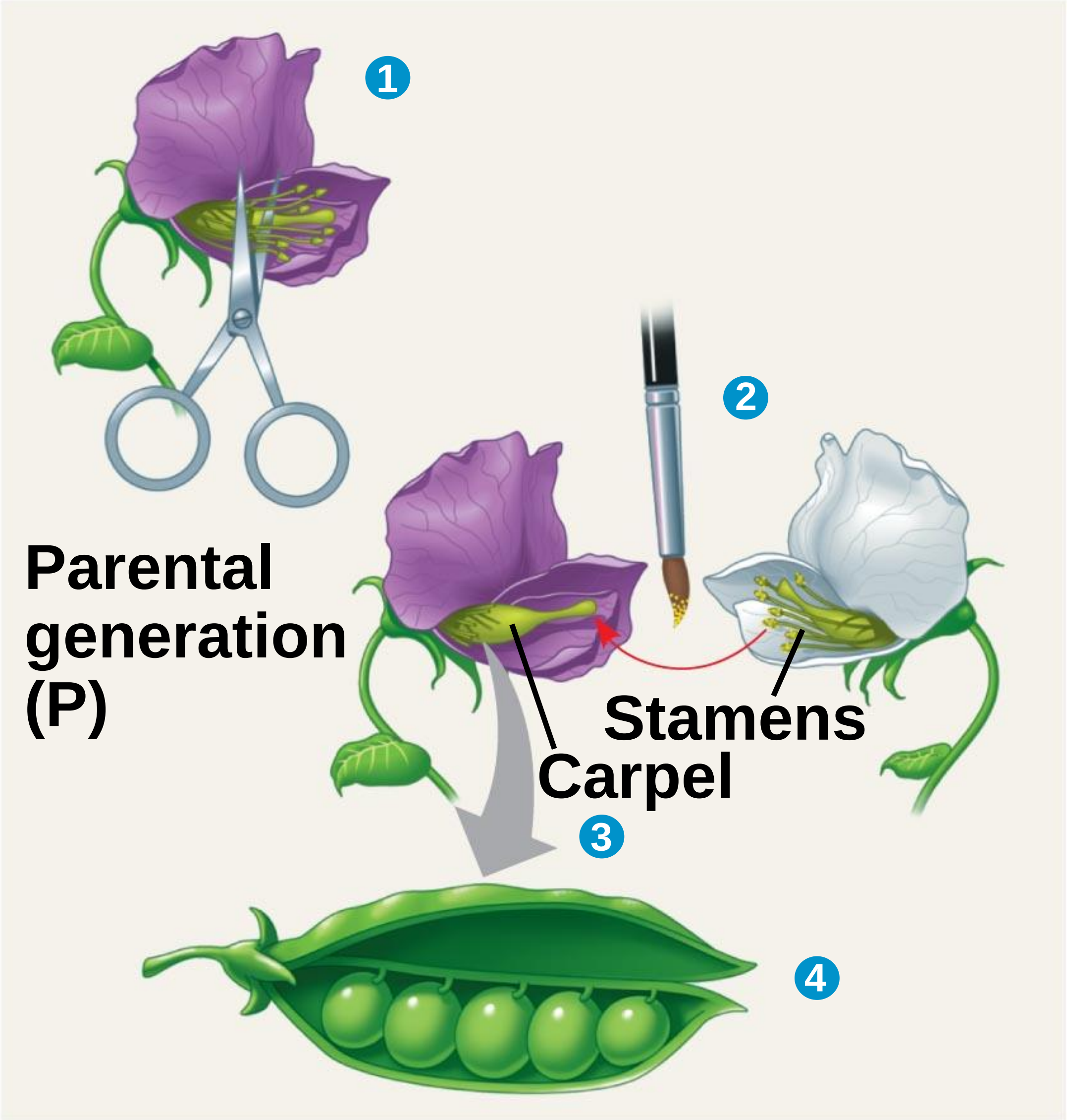

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Fig. 14-2b

RESULTS

First filial gener-ation offspring (F_1)

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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)

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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 **F_1 generation**
- When F_1 individuals self-pollinate, the **F_2 generation** is produced

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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

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Fig. 14-3-1

EXPERIMENT

P Generation (true-breeding parents)

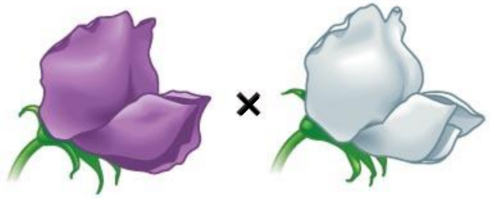

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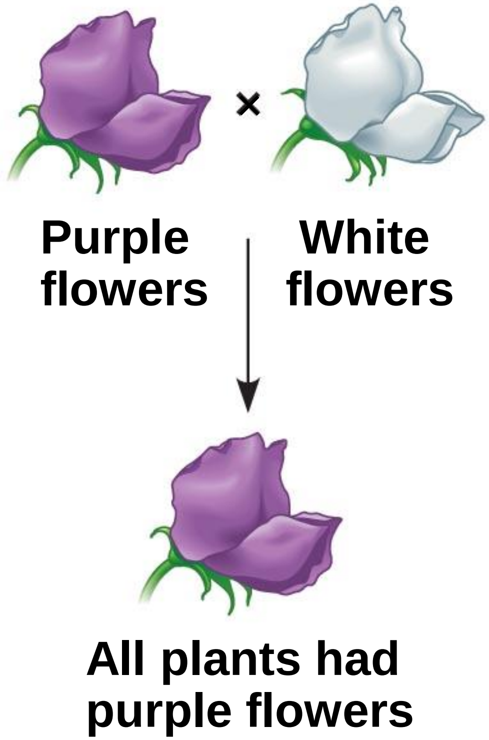
Fig. 14-3-2

EXPERIMENT

P Generation
(true-breeding parents)



F_1 Generation
(hybrids)

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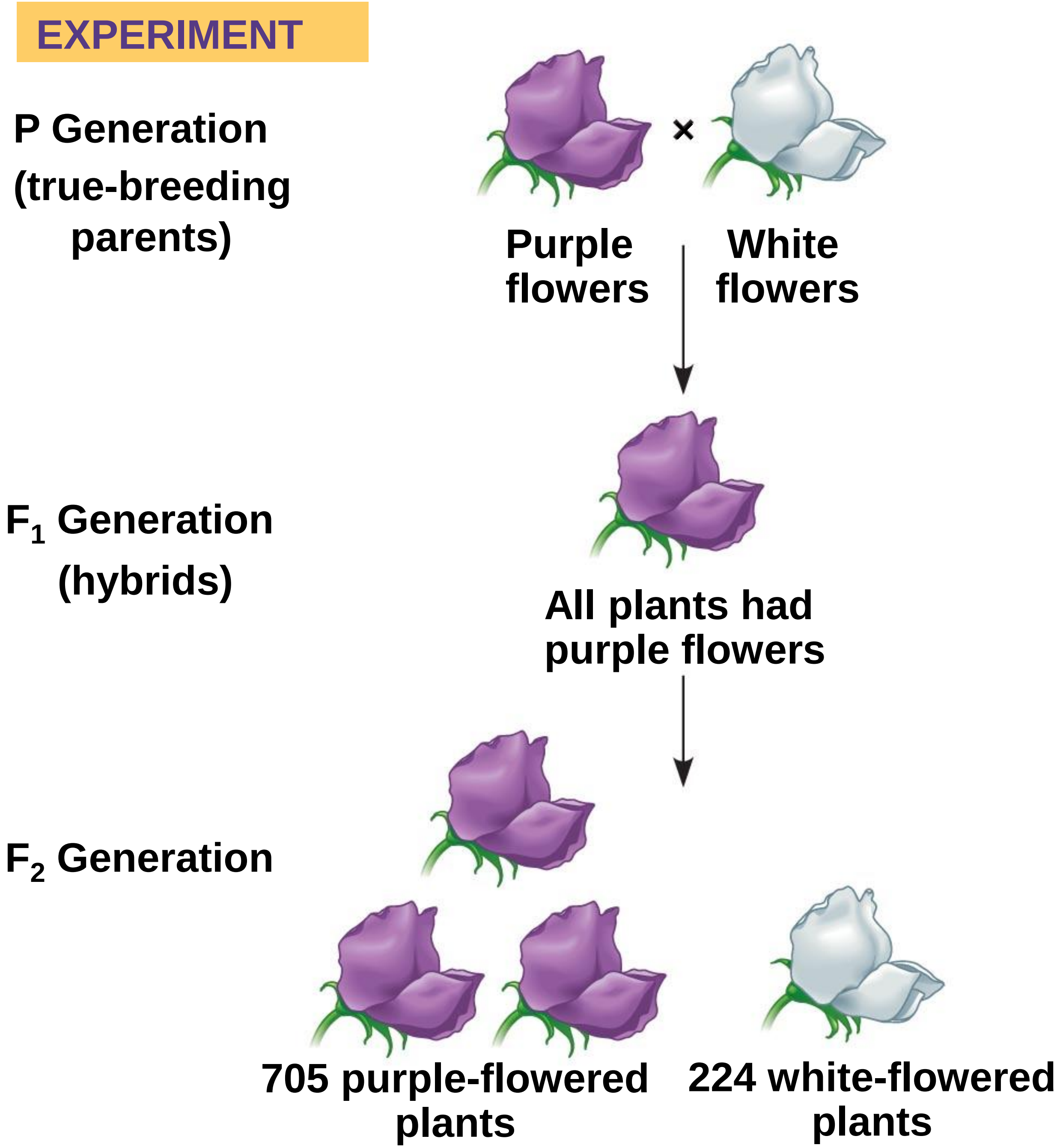
Fig. 14-3-3



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- 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
- 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

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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

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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

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- The first concept is that alternative versions of genes account for variations in inherited characters
- For example, the gene for flower color in pea plants exists in two versions, one for purple flowers and the other for white flowers
- These alternative versions of a gene are now called **alleles**
- Each gene resides at a specific locus on a specific chromosome

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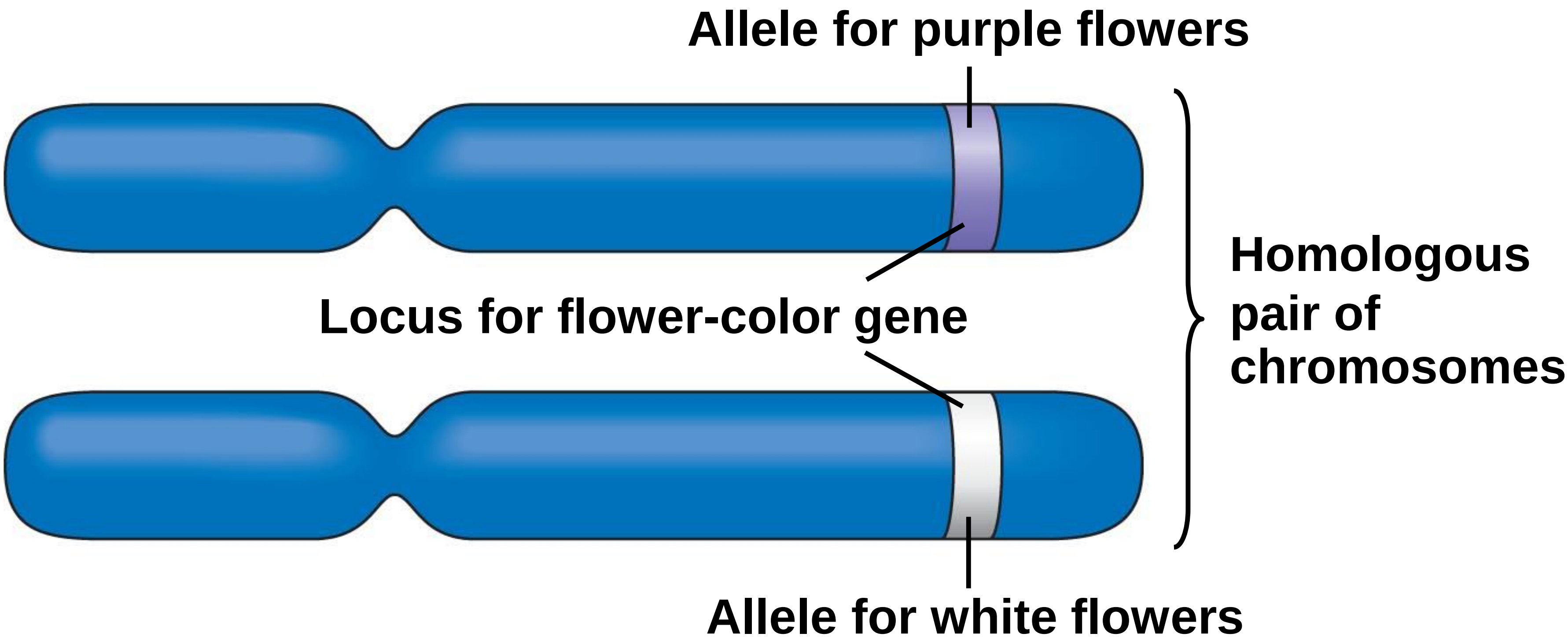
Fig. 14-4



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- The second concept is that for each character an organism inherits two alleles, one from each parent

- Mendel made this deduction without knowing about the role of chromosomes

- The two alleles at a locus on a chromosome may be identical, as in the true-breeding plants of Mendel’s P generation

- Alternatively, the two alleles at a locus may differ, as in the F_1 hybrids

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- The third concept is that if the two alleles at a locus differ, then one (the **dominant allele**) determines the organism's appearance, and the other (the **recessive allele**) has no noticeable effect on appearance
- In the flower-color example, the F_1 plants had purple flowers because the allele for that trait is dominant

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- The fourth concept, now known as the **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

- This segregation of alleles corresponds to the distribution of homologous chromosomes to different gametes in meiosis

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- 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

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Fig. 14-5-1

P Generation

Appearance:	**Purple flowers**	**White flowers**
Genetic makeup:	***PP***	***pp***
Gametes:	***P***	***p***

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Fig. 14-5-2

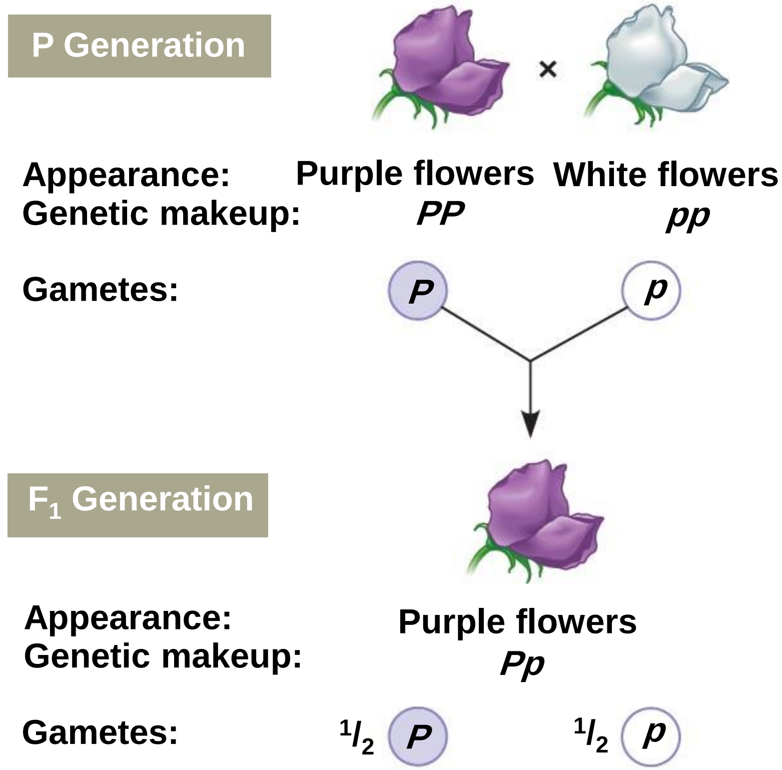

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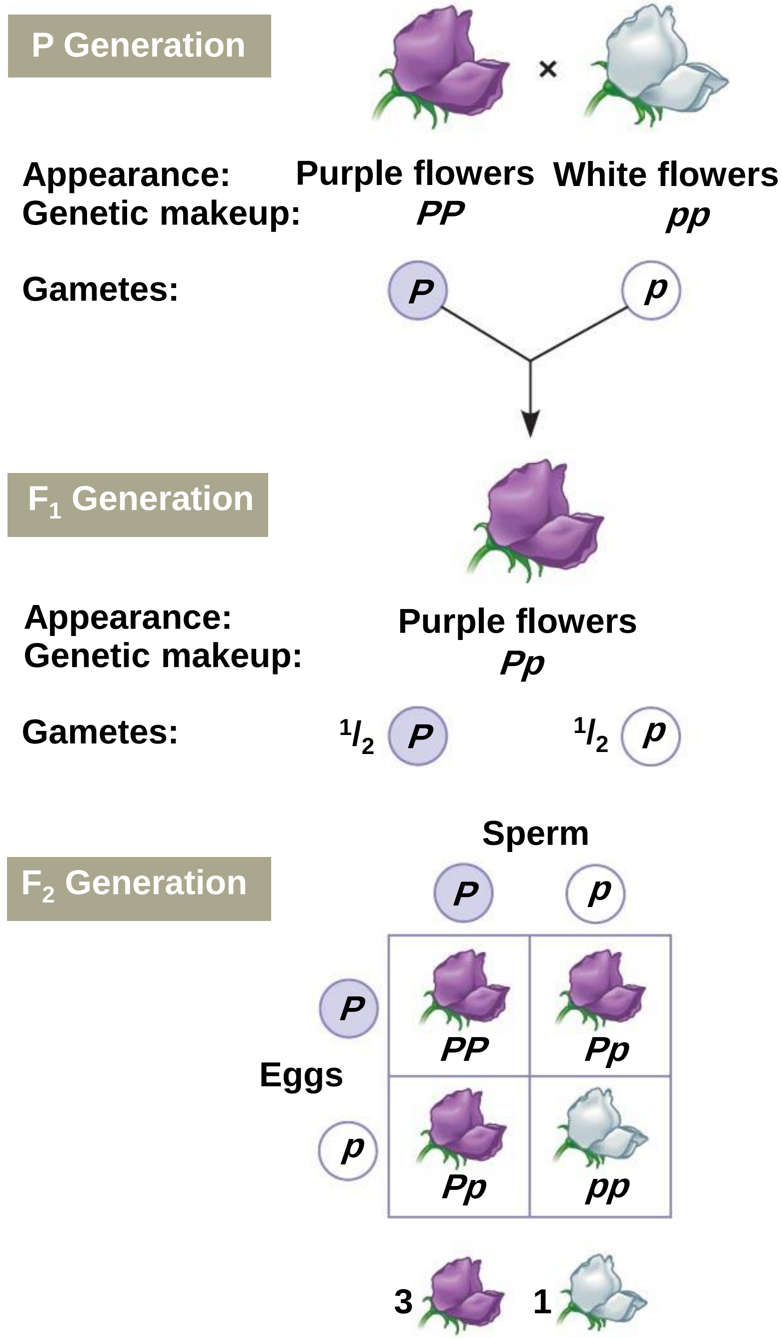
Fig. 14-5-3



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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
- Unlike homozygotes, heterozygotes are not true-breeding

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- Because of the different effects of dominant and recessive alleles, an organism's traits do not always reveal its genetic composition
- Therefore, we distinguish between an organism's **phenotype**, or physical appearance, and its **genotype**, or genetic makeup
- In the example of flower color in pea plants, *PP* and *Pp* plants have the same phenotype (purple) but different genotypes

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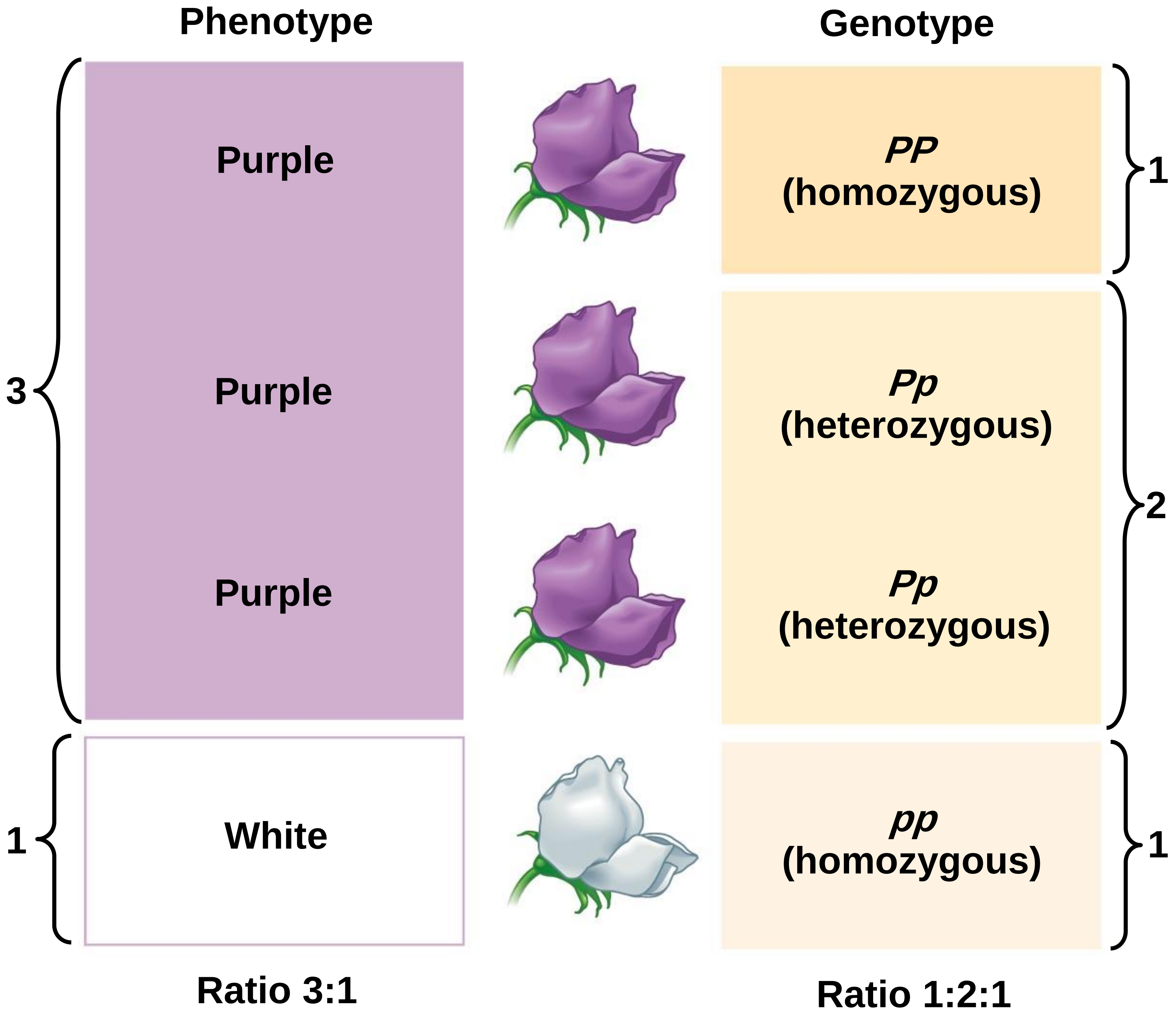
Fig. 14-6



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The Testcross

- How can we tell the genotype of an individual with 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

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Fig. 14-7

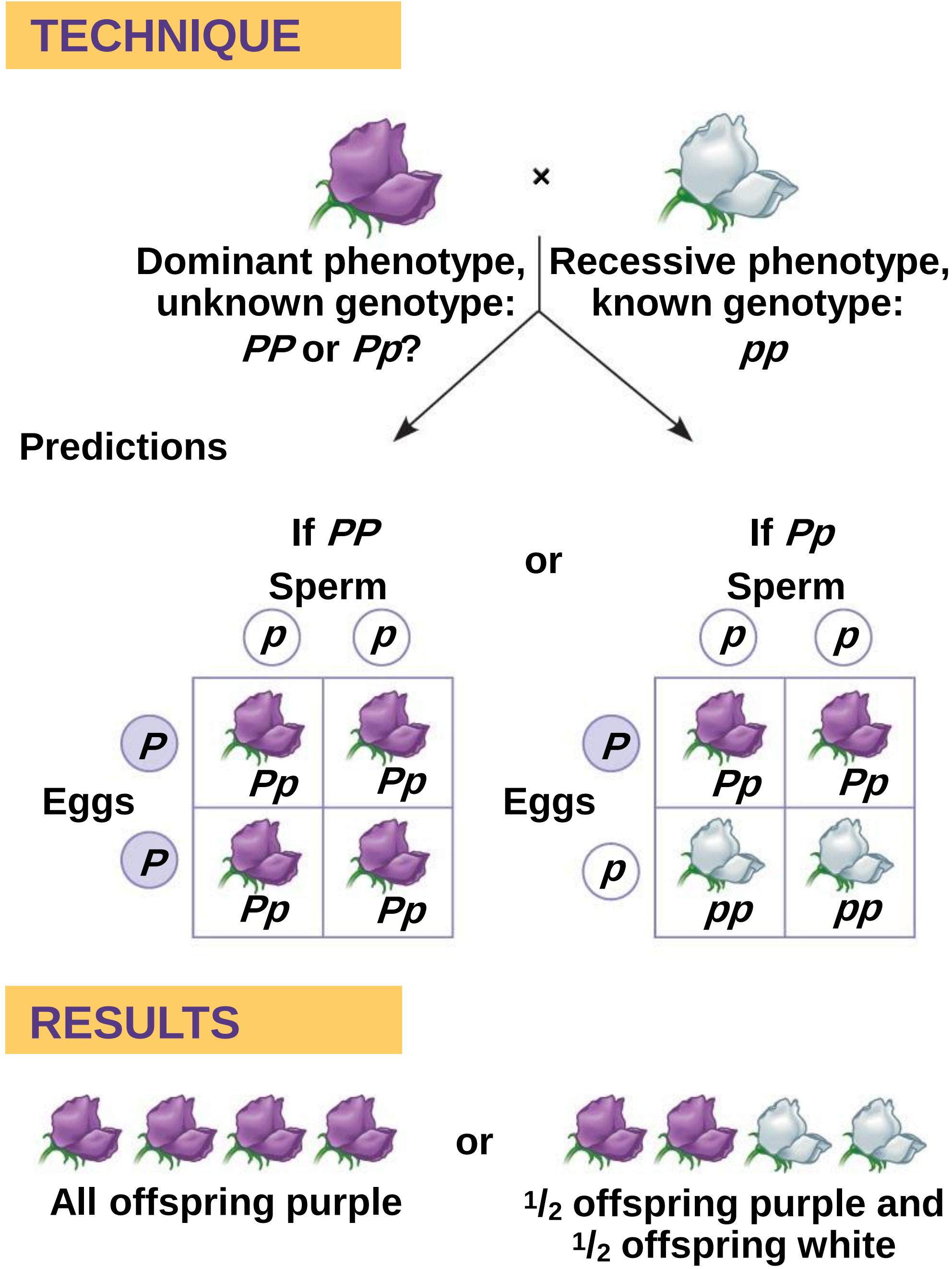

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Fig. 14-7a

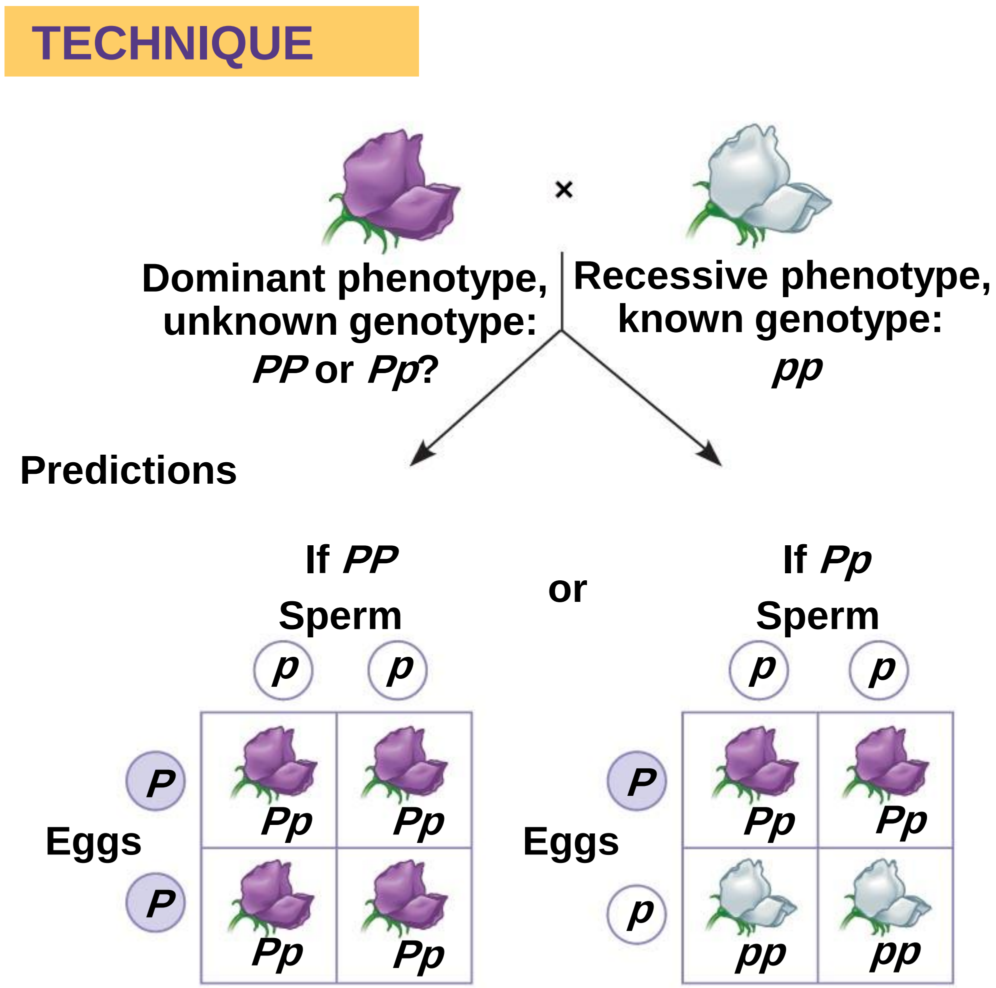

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Fig. 14-7b

RESULTS

All offspring purple

or

$^1/_2$ offspring purple and $^1/_2$ offspring white

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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*

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- 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

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Fig. 14-8

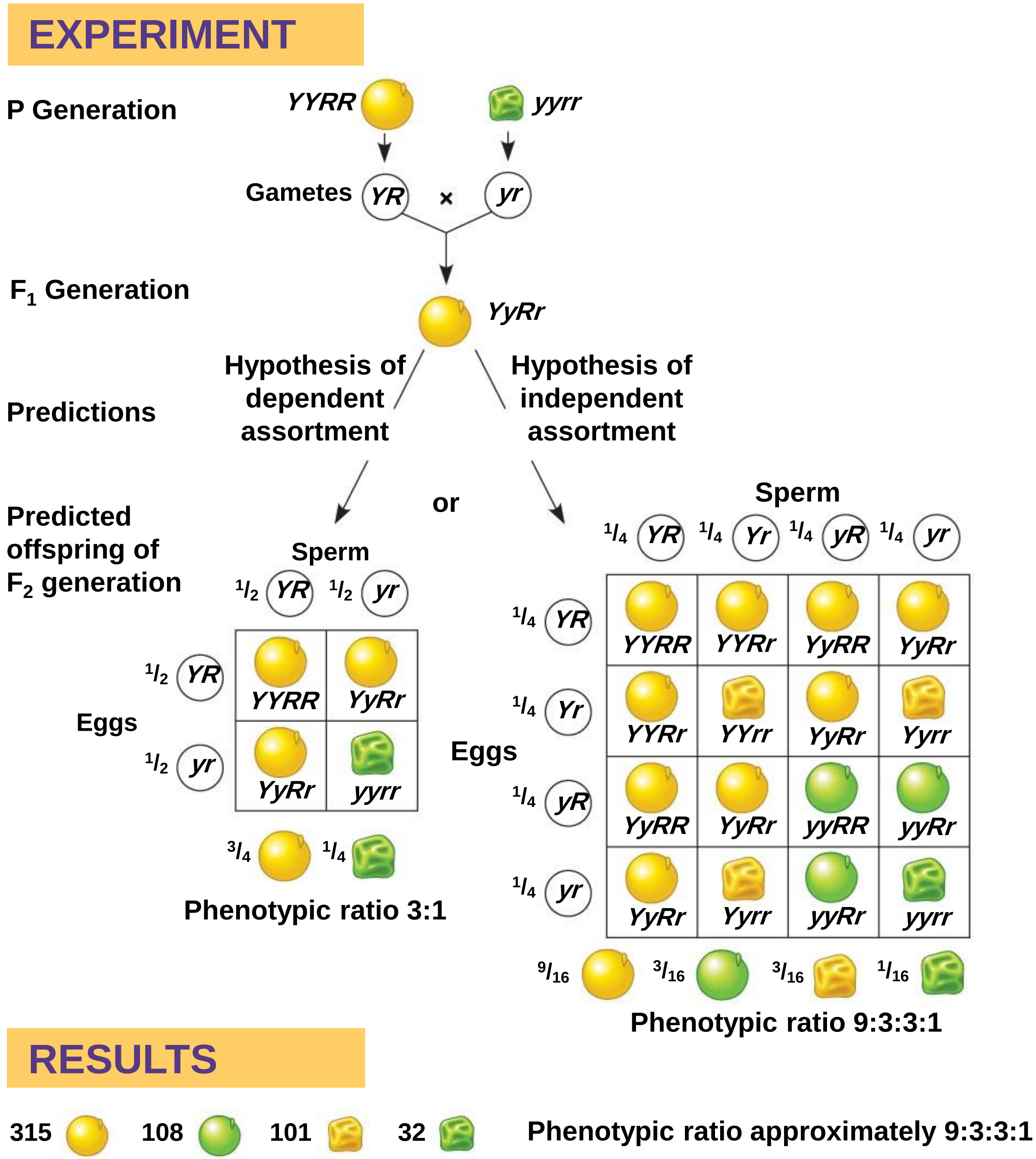

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Fig. 14-8a

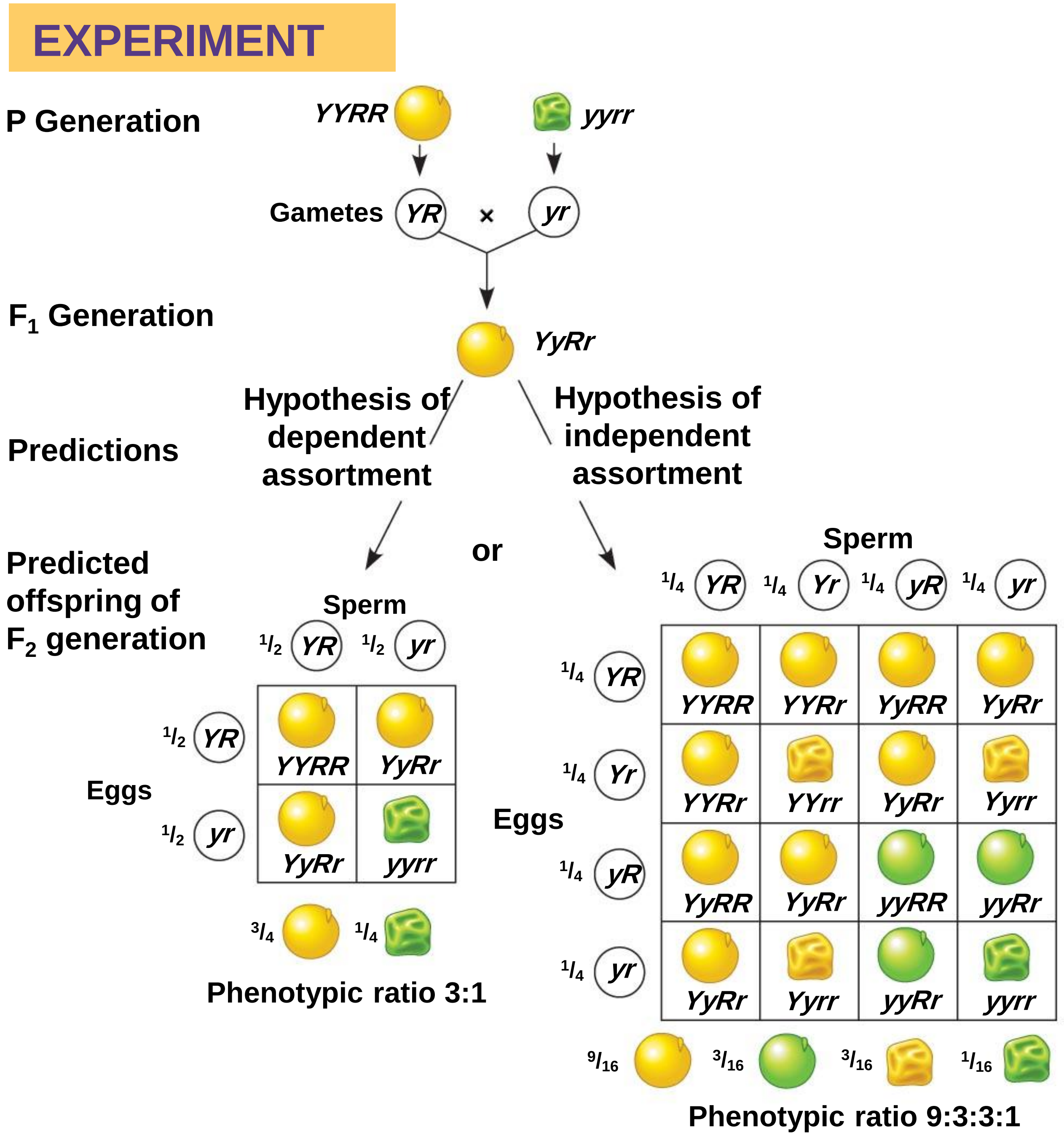

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Fig. 14-8b

RESULTS

315  108  101  32 

Phenotypic ratio approximately 9:3:3:1

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- 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 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

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Concept 14.2: The laws of probability govern Mendelian inheritance

- Mendel's laws of segregation and independent assortment reflect the rules of probability
- When tossing a coin, the outcome of one toss has no impact on the outcome of the next toss
- In the same way, the alleles of one gene segregate into gametes independently of another gene's alleles

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The Multiplication and Addition Rules Applied to Monohybrid Crosses

- The multiplication rule states that the probability that two or more independent events will occur together is the product of their individual probabilities
- Probability in an F_1 monohybrid cross can be determined using the multiplication rule
- Segregation in a heterozygous plant is like flipping a coin: Each gamete has a ½ chance of carrying the dominant allele and a ½ chance of carrying the recessive allele

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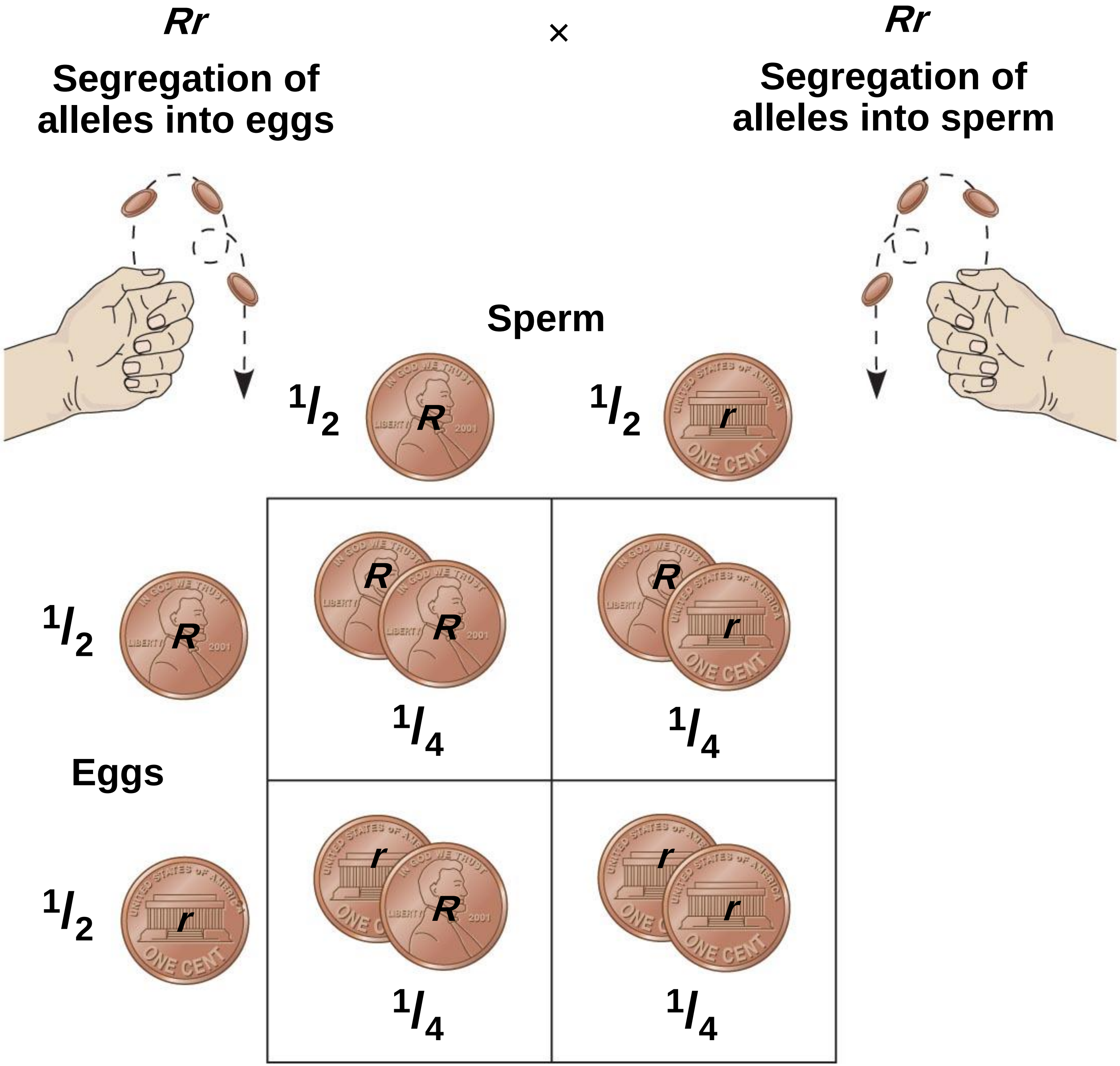
Fig. 14-9



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- The rule of addition states that the probability that any one of two or more exclusive events will occur is calculated by adding together their individual probabilities
- The rule of addition can be used to figure out the probability that an F_2 plant from a monohybrid cross will be heterozygous rather than homozygous

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Solving Complex Genetics Problems with the Rules of Probability

- We can apply the multiplication and addition rules to predict the outcome of crosses involving multiple characters
- A dihybrid or other multicharacter cross is equivalent to two or more independent monohybrid crosses occurring simultaneously
- In calculating the chances for various genotypes, each character is considered separately, and then the individual probabilities are multiplied together

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Fig. 14-UN1

ppyyRr	$\frac{1}{4}$ (probability of *pp*) $\times$ $\frac{1}{2}$ (*yy*) $\times$ $\frac{1}{2}$ (*Rr*)	$= \frac{1}{16}$
ppYyrr	$\frac{1}{4} \times \frac{1}{2} \times \frac{1}{2}$	$= \frac{1}{16}$
Ppyyrr	$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$	$= \frac{2}{16}$
PPyyrr	$\frac{1}{4} \times \frac{1}{2} \times \frac{1}{2}$	$= \frac{1}{16}$
ppyyrr	$\frac{1}{4} \times \frac{1}{2} \times \frac{1}{2}$	$= \frac{1}{16}$
Chance of *at least two* recessive traits		$= \frac{6}{16}$ **or** $\frac{3}{8}$

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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

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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

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

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Fig. 14-10-1

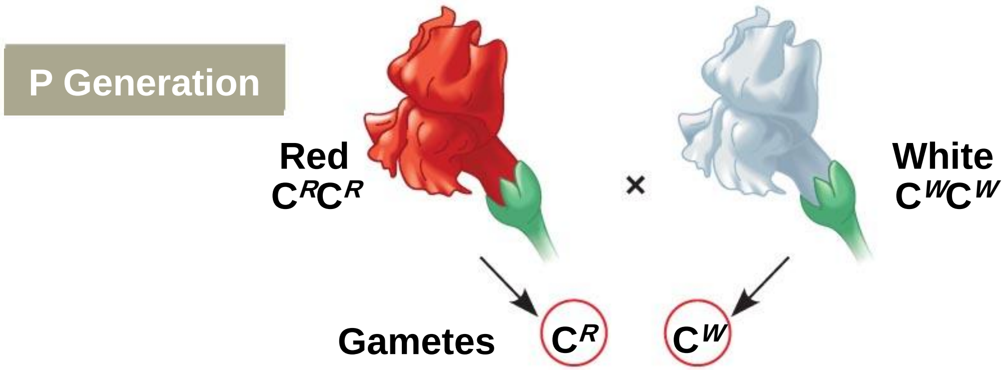

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Fig. 14-10-2

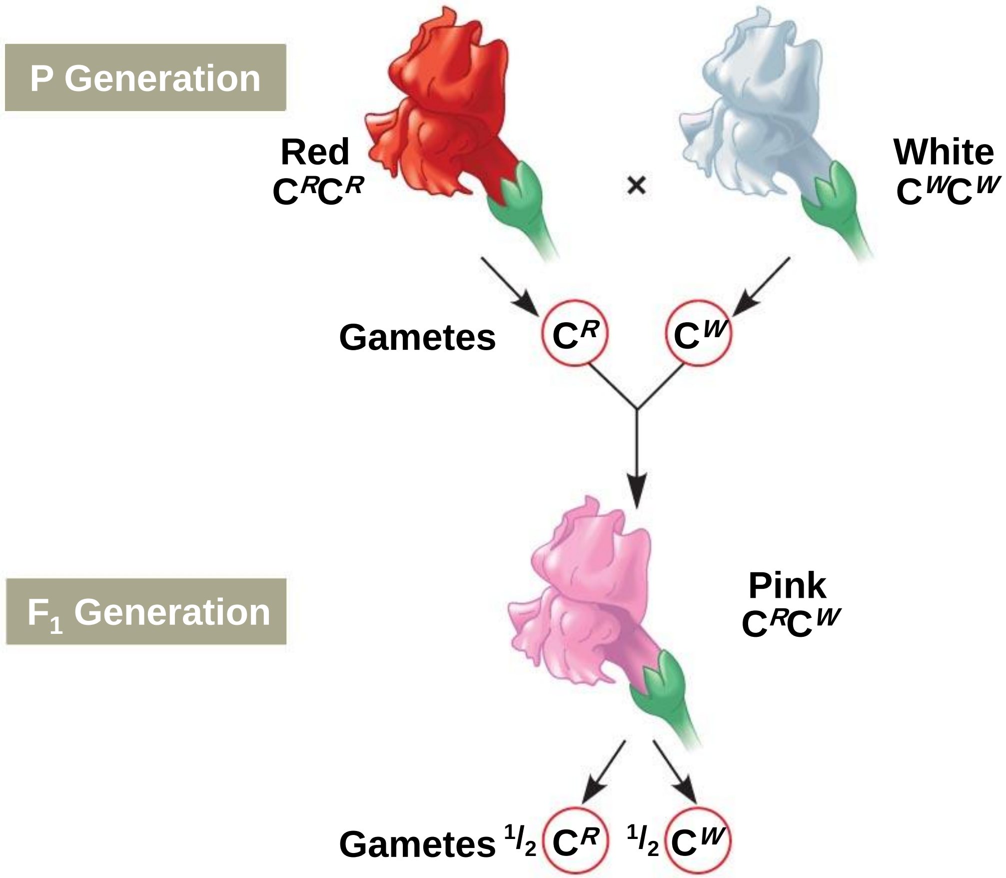

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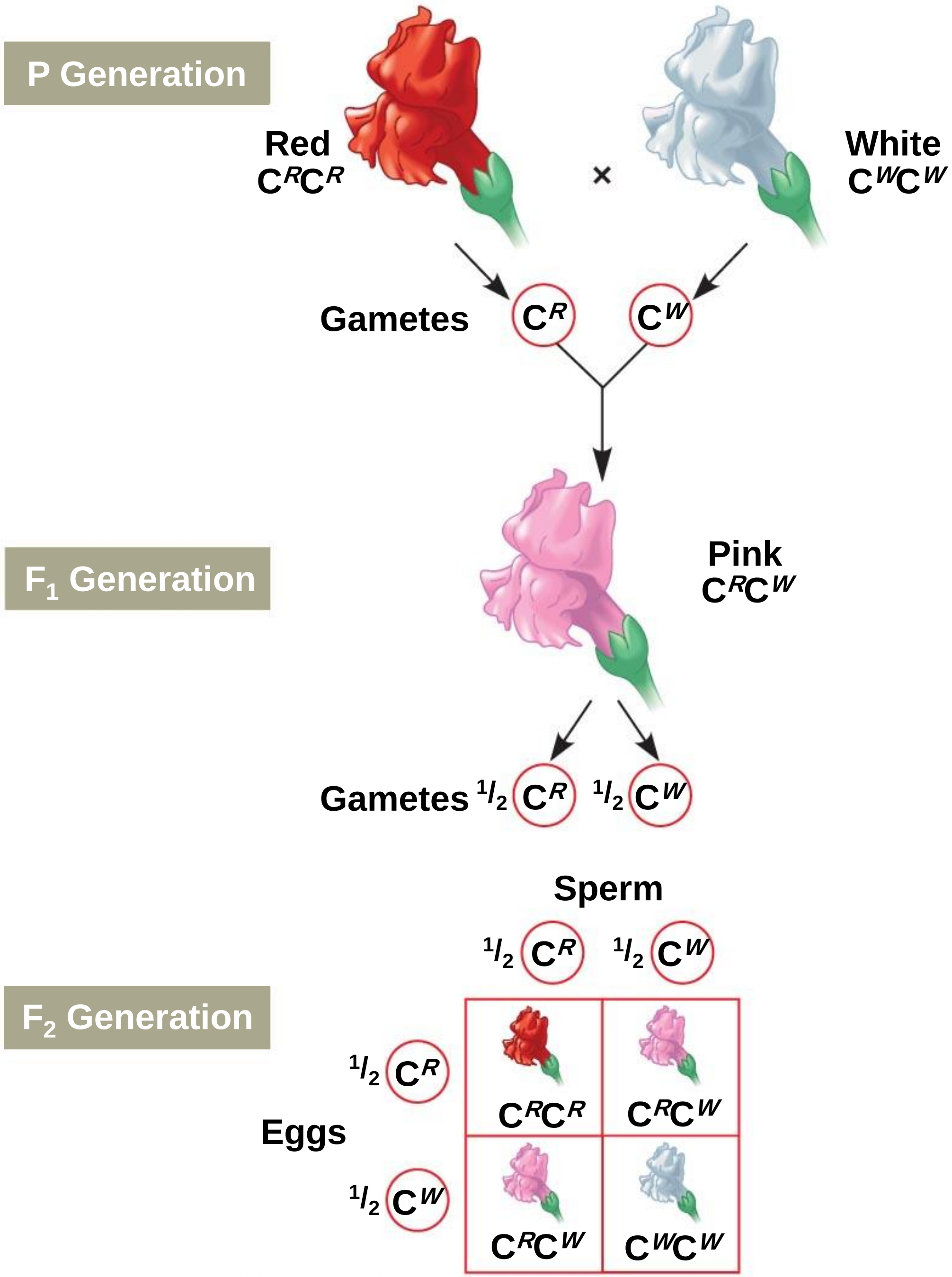
Fig. 14-10-3



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