Genetics

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Topic 8: Modification of Mendelian Ratios

Incomplete Dominance

- This inheritance pattern occurs when the heterozygote produces an intermediate phenotype between the two homozygotes.
- **Example 1: the four-o'clock plant (Mirabilis jalapa) ➔** C^RC^R ➔ red flowers

  C^RC^W ➔ pink flowers

  C^WC^W ➔ white flowers
- **Example:** the **HYPP** (**H**yperkalamic **P**eriodic **P**aralysis) in horses. The allele causing the syndrome is partially dominant over the normal allele. Homozygous individuals for the disease allele have more severe syndrome than the heterozygotes.

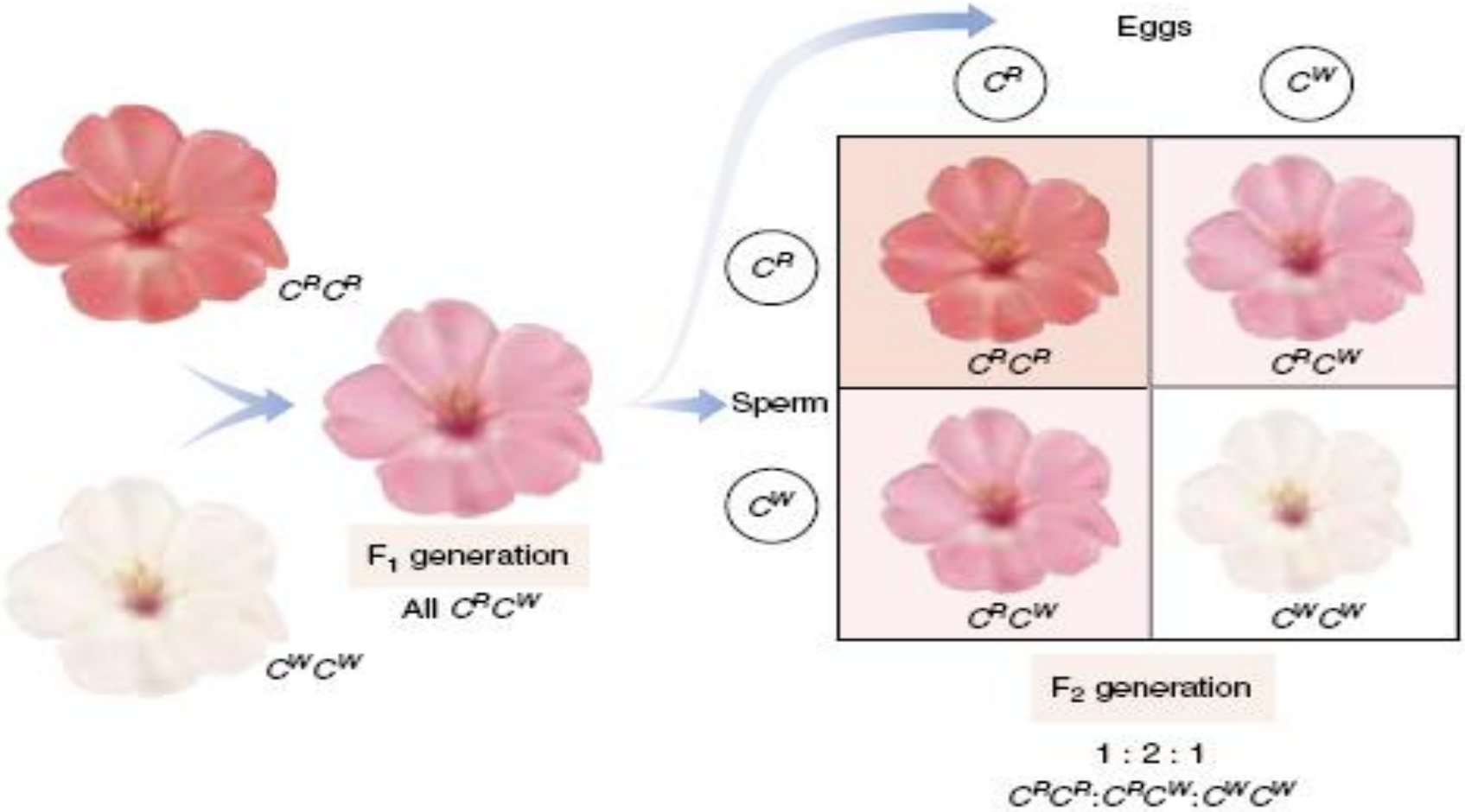


FIGURE 13.18
Incomplete dominance. In a cross between a red-flowered Japanese four o'clock, genotype C^RC^R, and a white-flowered one (C^WC^W), neither allele is dominant. The heterozygous progeny have pink flowers and the genotype C^RC^W. If two of these heterozygotes are crossed, the phenotypes of their progeny occur in a ratio of 1:2:1 (red:pink:white).

Multiple Alleles

- A gene may have more than two alleles in the population.
- **Example 1: ABO blood group system ➔**
- The gene which determines the blood type has three alleles: I^A, I^B, and i
- The i allele is recessive to both I^A, and I^B .
- *ii* ➔ **O** blood type
- $I^A I^A$, $I^A i$ ➔ **A** blood type
- $I^B I^B$, $I^B i$ ➔ **B** blood type
- $I^A I^B$ ➔ **AB** blood type (**Codominance**)
- In **codominanc**e, each allele has its own effect (both alleles are expressed ➔ each allele codes for its own product)

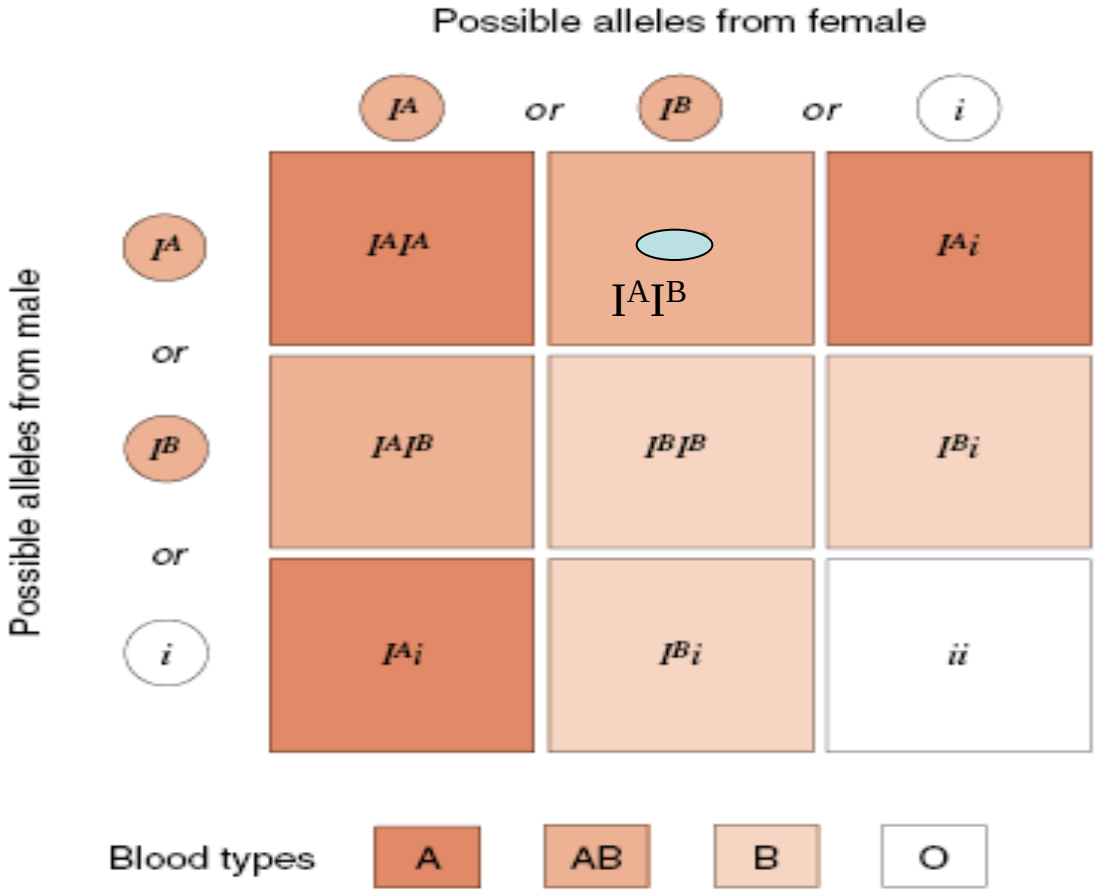


FIGURE 13.24
Multiple alleles control the ABO blood groups. Different combinations of the three *I* gene alleles result in four different blood type phenotypes: type A (either I^AI^A homozygotes or I^Ai heterozygotes), type B (either I^BI^B homozygotes or I^Bi heterozygotes), type AB (I^AI^B heterozygotes), and type O (*ii* homozygotes).

Blood type of cells	Genotype	Antibodies made by body	Reaction to added antibodies	
			Anti-A	Anti-B
A	I^AI^A or I^Ai^O	Anti-B		
B	I^BI^B or I^Bi^O	Anti-A		
AB	I^AI^B	Neither anti-A nor anti-B		
O	i^Oi^O	Both anti-A and anti-B		

Red blood cells that do not react with antibody remain evenly dispersed.

Red blood cells that react with antibody clump together (speckled appearance).

- **Example 2: coat color in rabbits ➔**
- The gene which codes for coat color has 4 different alleles:
- C, c^{ch} , c^{h}, and c
- The phenotype (coat color) of the rabbit depends on the dominant/recessive relationships among the combinations of alleles: - C is dominant to c^{ch} , c^{h}, and c

  - c^{ch} is recessive to C but dominant to c^{h}, and c

  - c^{h} is recessive to C and c^{ch} but dominant to c

  - c is recessive to C, c^{ch}, and c^{h}
- Agouti (full coat color): CC, Cc^{ch}, Cc^{h}, Cc
- Chinchilla: $c^{ch}c^{ch}$, $c^{ch}c^{h}$, $c^{ch}c$
- Himalayan pattern of coat color: $c^{h}c^{h}$, $c^{h}c$
- Albino: cc

- The Himalayan pattern of coat color is an example of a **temperature-sensitive** allele.

- The allele encodes a pigment-producing protein that functions only at low temperatures.

- Because of this, the dark fur is produced only in the cooler regions of the body including the tail, tips of the nose, ears, and paws.

Agouti

Chinchilla

Himalayan

Albino

Overdominance

- It is a form of dominance (interaction between alleles on the same locus) such that the heterozygous genotype displays characteristics more beneficial than the homozygous genotypes. Another term for overdominance is "**heterozygote advantage**".
- For example the heterozygote may be larger, disease resistant or better able to withstand harsh environmental conditions.

- Example: the allele causing sickle-cell anemia confers resistance to malaria in the heterozygotes: $Hb^{A}Hb^{A}$ and $Hb^{S}Hb^{S}$ are less resistant to malaria than $Hb^{A}Hb^{S}$ individuals.

- Heterosis or hybrid vigor which results when crossing two different breeds of animals or two plant varieties may result from overdominance at one or more loci.

Incomplete penetrance

- Dominant genes are expected to influence the outcome of trait when they are present in heterozygotes. Occasionally, this may not occur.
- **Example:** **polydactyly** in humans is caused by a **dominant gene**.

- The trait causes the affected individual to have additional fingers and or toes.
- A single copy of this allele is sufficient to cause this condition. But sometimes, individuals carry the dominant allele but do not exhibit the trait. This phenoenon is called **incomplete penetrance**.

Sex-influenced inheritance

- The term sex-influenced inheritance refers to the phenomenon in which an allele is dominant in one sex but recessive in the other sex. Therefore, sex influence is a phenomenon in heterozygotes.
- **Example: baldness in humans** (autosomal trait)
- Baldness is a pattern characterised by loss of hair in men on the top and the front of the head but not on the sides.
- This is not X-linked character because bald fathers can pass their trait to their sons.

	Phenotype	
Genotype	**Males**	**Females**
BB	Bald	Bald
Bb	Bald	Nonbald
bb	Nonbald	Nonbald

Women who are homozygous for the baldness allele will develop the trait, but it is usually characterized by a significant thinning of the hair that occurs relatively late in life.

Sex-limited inheritance

- Sex-limited traits **are those that are expressed only in one sex.**
- In humans: breast development is limited to females while beard growth is limited to males.
- In animals milk production is limited to females.
- The expression of genes is regulated by sex hormones.
- For sex-influenced and sex-limited traits, the genes are located on autosomal chromosomes (not on the sex chromosomes).

Example on sex-limited traits: hen and cock feathering in domestic fowl

- **Hen feathering** is controlled by a **dominant** allele that is expressed in both males and females
- **Cock feathering** is a **recessive** allele that is expressed only in males.

Genotype	Phenotype	
	Female	**Male**
HH	Hen-feathered	Hen-feathered
Hh	Hen-feathered	Hen-feathered
hh	Hen-feathered	Cock-feathered

Sex-linked inheritance

- The genes are located on the sex chromosomes.
- **Example:** in Drosophila red-eye color allele (wild-type) is dominant over the white-eye color allele (mutant-type).

Red-eye allele: w^+, White-eye allele: w

Cross A:

P1: (white-eyed males: X^wY) x (red-eyed females X^{w+} X^{w+})

F1: ½ ($X^{w+}Y$) ➔ all males are red-eyed

½ ($X^{w+}X^w$) ➔ all females are red-eyed

($X^{w+}Y$) x ($X^{w+}X^w$)

F2: ¼ X^{w+} X^{w+} , ¼ $X^{w+}X^w$ ➔ All females are red-eyed

¼ ($X^{w+}Y$) , ¼ (X^wY) ➔ Half the males are red-eyed and half are white eyed

Phenotypic ratio: 3 red : 1 white

Cross B:

P1: (red-eyed males $X^{w+}Y$) x (white-eyed females X^wX^w)

F1: ½ ($X^{w+}X^w$) ➔ all females are red-eyed

½ (X^wY) ➔ all males are white-eyed

(X^wY) x ($X^{w+}X^w$)

F2: ¼ ($X^{w+}X^w$) ➔ red-eyed females

¼ (X^wX^w) ➔ white-eyed females

¼ ($X^{w+}Y$) ➔ red-eyed males

¼ (X^wY) ➔ white-eyed males

Phenotypic ratio in F2: 1 Red : 1 White

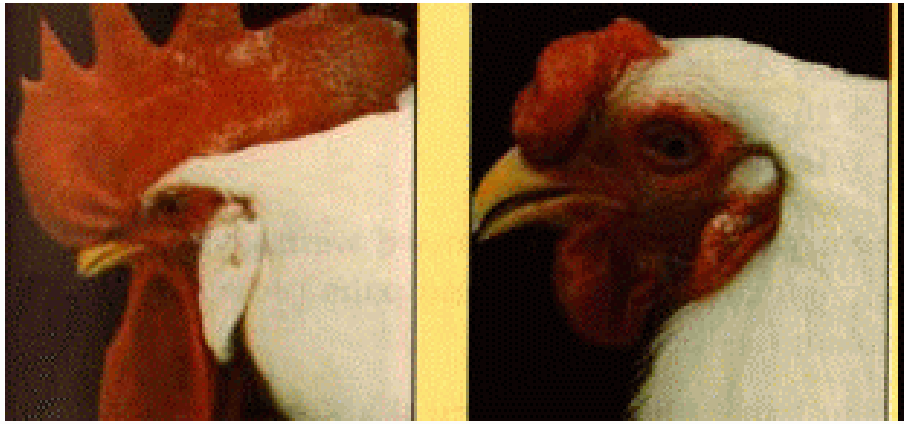
Gene Interaction

(two or more genes affecting the same character)

- Here we are concerned with a single character only affected by two or more genes.
- The phenotypes produced depend on the interaction between the alleles on the different genes affecting the character.
- Lets consider some examples on the case when two genes affect the same trait.

Example 1: comb shape inheritance in chicken

Rose **Pea**



Single **Walnut**

R (Rose comb) is dominant to r
P (Pea comb) is dominant to p
R and P are codominant (walnut comb)
rrpp produces single comb

RRpp **rrPP**

Parental Cross Rose Comb (Wyandotte) x Pea Comb (Brahama)

(Both parents were pure lines.)

↓

F1 Result All Walnut Combs **RrPp**

(This is a new phenotype not previously seen.)

↓

F2 Result 9 Walnut : 3 Rose : 3 Pea : 1 Single

Phenotypes	**Genotypes**	**Frequency**
Walnut	*R_P_*	9/16
Rose	*R_pp*	3/16
Pea	*rrP_*	3/16
Single	*rrpp*	1/16

RrPp x RrPp

↓

	RP	*Rp*	*rP*	*rp*
RP	***RRPP*** ***Walnut***	***RRPp*** ***Walnut***	***RrPP*** ***Walnut***	***RrPp*** ***Walnut***
Rp	***RRPp*** ***Walnut***	***RRpp*** ***Rose***	***RrPp*** ***Walnut***	***Rrpp*** ***Rose***
rP	***RrPP*** ***Walnut***	***RrPp*** ***Walnut***	***rrPP*** ***Pea***	***rrPp*** ***Pea***
rp	***RrPp*** ***Walnut***	***Rrpp*** ***Rose***	***rrPp*** ***Pea***	***rrpp*** ***Single***

Example2: coat color in Labrador dogs:

- **Labrador dogs** have three colors (**black**, **chocolate** and **yellow**) determined by genes at two loci:

  B locus

  E locus

- B_E_ ➔ black (BBEE, BBEe, BbEE, BbEe)
- bbE_ ➔ chocolate (bbEE, bbEe)
- _ _ ee ➔ yellow (BBee, Bbee, bbee)

- Only yellow dogs breed true (if two yellow dogs are mated, they produce only yellow dogs)

ee

No dark pigment in fur

Yellow Lab

eebb

Yellow fur, brown nose, lips, eye rims

*eeB_*

Yellow fur, black nose, lips, eye rims

*E_*

Dark pigment in fur

E_bb

Chocolate Lab

Brown fur, nose, lips, eye rims

*E_B_*

Black Lab

Black fur, nose, lips, eye rims

FIGURE 13.21
The effect of epistatic interactions on coat color in dogs. The coat color seen in Labrador retrievers is an example of the interaction of two genes, each with two alleles. The *E* gene determines if the pigment will be deposited in the fur, and the *B* gene determines how dark the pigment will be.

AbEe x AbEe

↓

9 black, 3 choclate, and 4 yellow

	BE	*Be*	*bE*	*be*
BE	***BBEE*** ***Black***	***BBEe*** ***Black***	***BbEE*** ***Black***	***BbEe*** ***Black***
Be	***BBEe*** ***Black***	***BBee*** ***yellow***	***BbEe*** ***Black***	***Bbee*** ***Yellow***
bE	***BbEE*** ***Black***	***BbEe*** ***Black***	***bbEE*** ***Chocolate***	***bbEe*** ***Chocolate***
be	***BbEe*** ***Black***	***Bbee*** ***Yellow***	***bbEe*** ***Chocolate***	***bbee*** ***Yellow***

- **Example 3: grain color in some corn varieties:**
- Some commercial varieties exhibit a purple pigment called **anthocyanin** in their seed coats, while others do not.
- The pigment anthocyanin is the product of a two-step biochemical pathway:

$$\text{Starting molecule (Colorless)} \xrightarrow{\text{Enzyme 1}} \text{Intermediate (Colorless)} \xrightarrow{\text{Enzyme 2}} \text{Anthocyanin (Purple)}$$

To produce pigment, a plant must possess at least one functional copy of each enzyme gene. The dominant alleles encode functional enzymes, but the recessive alleles encode nonfunctional enzymes.

A cross by Emmerson, 1918

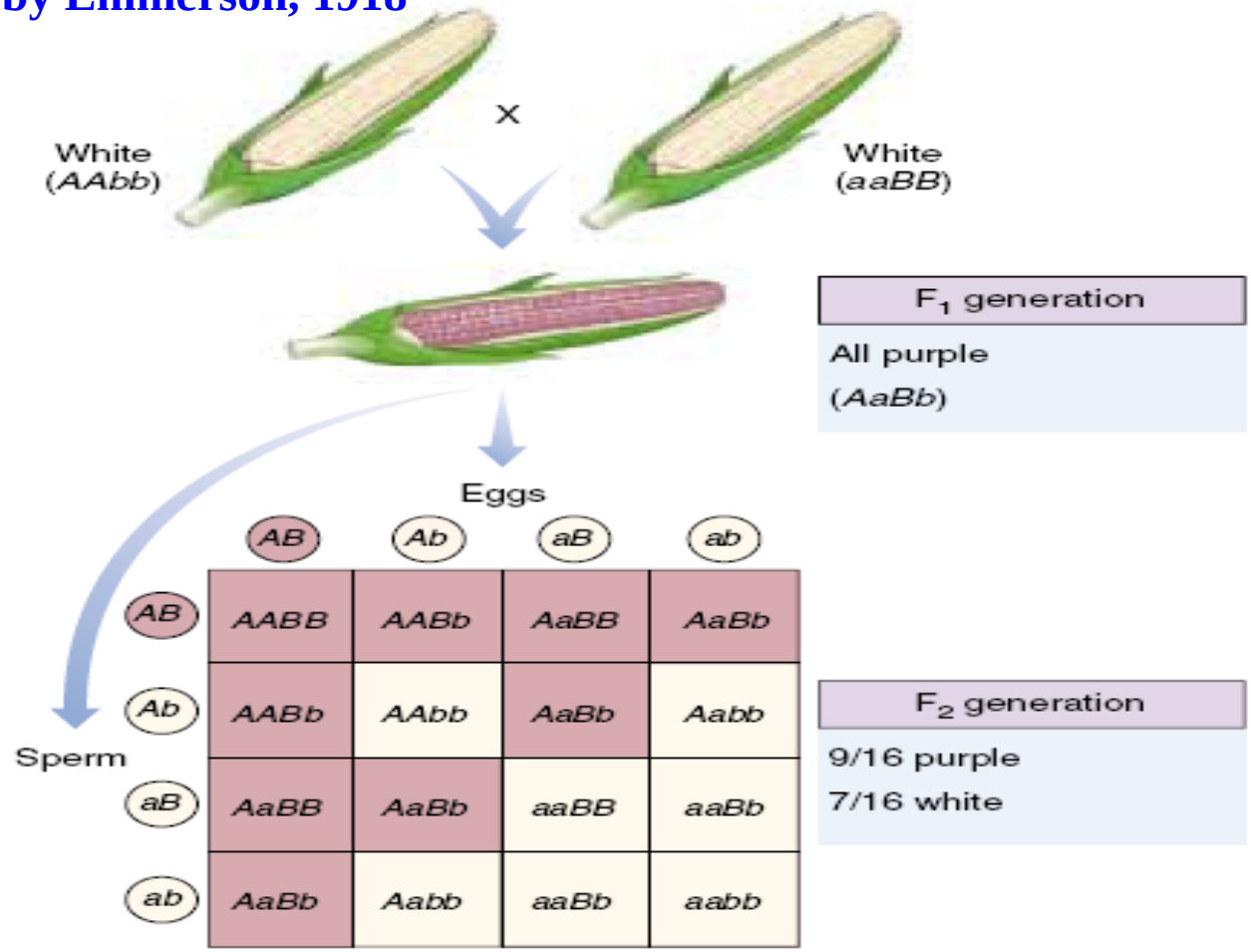


FIGURE 13.20
How epistasis affects grain color. The purple pigment found in some varieties of corn is the product of a two-step biochemical pathway. Unless both enzymes are active (the plant has a dominant allele for each of the two genes, *A* and *B*), no pigment is expressed.